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Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam (WP0485)

Right Bank Canal Design Sub-Report






January 2021

Department of Water and Sanitation
Directorate: Options Analysis

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM

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DEPARTMENT OF WATER AND SANITATION

Directorate: Options Analysis

Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam

RIGHT BANK CANAL DESIGN SUB-REPORT

January 2021

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Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam

Reports produced as part of this project are indicated below.

Bold type indicates this report.

Report Index	Report Number	Report Title
1		Inception Report
2	P WMA 09/E10/00/0417/2	Capacity Building & Training Year 1
3	P WMA 09/E10/00/0417/3	Capacity Building & Training Year 2
4	P WMA 09/E10/00/0417/4	Water Requirements Assessment
5	P WMA 09/E10/00/0417/5	Distribution of Additional Available Water
6		Existing Infrastructure and Current Agricultural Development Sub-Report
7	P WMA 09/E10/00/0417/6	Existing Conveyance Infrastructure and Irrigated Land
8		Suitable Agricultural Areas and Land Ownership Report
9		Evaluation of Development Options Sub-Report
10	P WMA 09/E10/00/0417/10	Suitable Areas for Agricultural Development
11		**Right Bank Canal Design Sub-Report**
12		Conceptual Design Sub-Report
13		Environmental Screening Sub-Report
14		Jan Dissels and Ebenhaeser Schemes Design Sub-Report
15	P WMA 09/E10/00/0417/13	Feasibility Design
16	P WMA 09/E10/00/0417/7	Topographical Surveys
17	P WMA 09/E10/00/0417/8	Geotechnical Investigations
18	P WMA 09/E10/00/0417/9	Soil Survey
19		Financial Viability of Irrigation Farming Sub-Report
20	P WMA 09/E10/00/0417/11	Agricultural Production and Farm Development
21		Right Bank Canal Cost Analysis Sub-Report
22		Socio-Economic Impact Analysis Sub-Report
23	P WMA 09/E10/00/0417/12	Socio-Economic Impact Analysis
24	P WMA 09/E10/00/0417/14	Record of Implementation Decisions Report
25	P WMA 09/E10/00/0417/1	Main Report
26	P WMA 09/E10/00/0417/15	Historically Disadvantaged Farmers Report

Concise Description of the Content of Study Reports

Report Index	Report Number	Report Title and Description of Content
1		Inception The report forms part of the contract and stipulates the scope of work for the study, the contract amount and the contract period. It contains a detailed description of tasks and methodology, a study programme, human resource schedule, budget and deliverables. The Capacity Building and Training Plan has been included.
2	P WMA 09/E10/00/0417/2	Capacity Building & Training Year 1 Describes the range of capacity building and training activities planned for the study, and the activities undertaken during the first year of the study, including field-based training, training workshop 1 and mentorship of DWS interns through secondment.
3	P WMA 09/E10/00/0417/3	Capacity Building & Training Year 2 Describes the range of capacity building and training activities planned for the study, and the activities undertaken during the second year of the study, including field-based training, training workshop 2 and mentorship of DWS interns through secondment.
4	P WMA 09/E10/00/0417/4	Water Requirements Assessment Provides an analysis of the existing water use and current water allocations in the study area, and addresses ecological water requirements, water use for irrigated agriculture and projections for future use, current domestic and industrial water use and projections for future use, water use for hydropower and water losses in the water supply system.
5	P WMA 09/E10/00/0417/5	Distribution of Additional Available Water Confirms the volume of additional water available for development, after water has been reserved for the current water uses, as well as making recommendations on how the additional yield should be distributed among water use sectors and water users.
6		Existing Infrastructure and Current Agricultural Development Sub-Report Provides an overview of the extent and general condition of the current bulk water storage and conveyance infrastructure. This report also provides an overview of the locality and extent of the existing agricultural areas determined by reviewing Geographic Information System (GIS) data obtained from various sources.
7	P WMA 09/E10/00/0417/6	Existing Conveyance Infrastructure and Irrigated Land An update of the Sub-Report, providing a refinement of the current agricultural water requirements following evaluation of the current crop types, an assessment of the desirability of diverting releases for downstream irrigators via the Clanwilliam Canal and Jan Dissels River, to meet the summer ecological flows in the lower Jan Dissels River, and presents an Implementation Action Plan with costs.

Report Index	Report Number	Report Title and Description of Content
8		Suitable Agricultural Areas and Land Ownership Sub-Report Description of the collection of information and the preparation undertaken for the analysis of options, which includes a summary of existing irrigated areas and water use, cadastral information, land ownership, environmental sensitivity, soils suitability, water quality considerations and constraints, and the initiation of the process to identify additional areas suitable for irrigation.
9		Evaluation of Development Options Sub-Report Describes the salient features, costs and impacts of identified potential irrigation development options for new irrigation development in the lower Olifants River. This provides the background and an introduction to the discussions at the Options Screening Workshop held in December 2018.
10	P WMA 09/E10/00/0417/10	Suitable Areas for Agricultural Development Describes the supporting information, process followed and the salient features, costs and impacts of identified potential irrigation development options for new irrigation development in the lower Olifants River. Recommends the preferred options to be evaluated at feasibility level.
11		Right Bank Canal Feasibility Design Sub-Report Describes the Design Criteria Memorandum, based on best practice in engineering and complying with recognised codes and standards. Description of route alignments and salient features of the new Right Bank canal. Feasibility-level design of bulk infrastructure, including evaluation of capacities, hydraulic conditions, canal design, surface flow considerations, canal structures, power supply and access roads. Operational considerations and recommendations.
12		Conceptual Design Sub-Report Describes the scheme layouts at a conceptual level and infrastructure components to be designed, alternatives to consider or sub-options, and affected land and infrastructure, as well as the updated recommended schemes for new irrigation development.
13		Environmental Screening Sub-Report Describes and illustrates the opportunities and constraints, and potential ecological risks/impacts and recommendations for the short-listed bulk infrastructure development options at reconnaissance level. Describes relevant legislation that applies to the proposed irrigation developments.

Report Index	Report Number	Report Title and Description of Content
14		Jan Dissels and Ebenhaeser Schemes Feasibility Design Sub-Report Describes the Design Criteria Memorandum, based on best practice in engineering and complying with recognised codes and standards. Description of route alignments and salient features of the Jan Dissels and Ebenhaeser schemes. Feasibility-level design of bulk infrastructure, including evaluation of capacities, hydraulic conditions, intake structures, balancing dams and reservoirs, rising mains and gravity pipelines and trunk mains where relevant, power supply and access roads. Operational considerations and recommendations.
15	P WMA 09/E10/00/0417/13	Feasibility Design Description of the approach to and design of selected bulk infrastructure at feasibility level, with supporting plans and implementation recommendations.
16	P WMA 09/E10/00/0417/7	Topographical Surveys Describes the contour surveys for the proposed identified bulk infrastructure conveyance routes and development areas, the surveying approach, inputs and accuracy, as well as providing the survey information.
17	P WMA 09/E10/00/0417/8	Geotechnical Investigations Presents the findings of geotechnical investigations of the various identified sites, as well as the approach followed, field investigations and testing, laboratory testing, interpretation of findings and geotechnical recommendations.
18	P WMA 09/E10/00/0417/9	Soil Survey Describes the soil types, soil suitability and amelioration measures of the additional area covering about 10 300 ha of land lying between 60 to 100 m above river level, between the upper inundation of the raised Clanwilliam Dam and Klawer.
19		Financial Viability of Irrigation Farming Sub-Report Describes the findings of an evaluation of the financial viability of pre-identified crop-mixes, within study sub-regions, and advises on the desirability of specific crops to be grown in these sub-regions. It includes an evaluation of the financial viability of existing irrigation farming or expanding irrigation farming, as well as the identification of factors that may be obstructive for new entrants from historically disadvantaged communities.
20	P WMA 09/E10/00/0417/11	Agricultural Production and Farm Development This report will focus on policy, institutional arrangements, available legal and administrative mechanisms as well as the proposed classes of water users and the needs of each. This would include identifying opportunities for emerging farmers, including grant and other types of Government and private support, and a recommendation on the various options and opportunities that exist to ensure that land reform and water allocation reform will take place through the project implementation.

Report Index	Report Number	Report Title and Description of Content
21		Right Bank Canal Cost Analysis Sub-Report Provides an economic modelling approach to quantify the risk of the failure of the existing main canal and the determination of the economic viability of the construction of the new right bank canal to reduce the risk of water supply failure.
22		Socio-Economic Impact Analysis Sub-Report Describes the socio-economic impact analysis undertaken for the implementation of the new irrigation development schemes, for both the construction and operational phases. This includes a description of the social and economic contributions, the return on capital investment, as well as the findings of a fiscal impact analysis.
23	P WMA 09/E10/00/0417/12	Socio-Economic Impact Analysis Synthesis of agricultural economic and socio-economic analyses undertaken, providing an integrated description of agricultural production and farm development and socio-economic impact analysis, as well as the analysis of the right bank canal costs and benefits.
24	P WMA 09/E10/00/0417/14	Record of Implementation Decisions Describes the scope of the project, the specific configuration of the schemes to be implemented, the required implementation timelines, required institutional arrangements and the required environmental and other approval requirements and mitigation measures, to ensure that the project is ready for implementation.
25	P WMA 09/E10/00/0417/1	Main Report Provides a synthesis of approaches, results and findings from the supporting study tasks and interpretation thereof, culminating in the study recommendations. Provides information in support of the project funding motivation to be provided to National Treasury.
26	P WMA 09/E10/00/0417/15	Historically Disadvantaged Farmers Report Describes the activities undertaken by an independent consultant to evaluate existing HDI Farmers policies and legislative context, identify, map and analyse prospective HDI farmers and potential land for new irrigation, as well as propose a mechanism for the identification and screening of HDI farmers.

Executive Summary

Introduction

This report describes the feasibility level design of the Right Bank Canal Scheme. The Right Bank Canal Scheme offers a solution to ensure a more secure future supply for new as well as existing irrigators, by replacing the existing main canal on the left bank of the Olifants River with a new Right Bank Canal. This will address the poor state of the existing canals, especially the main (Trawal) section, which poses a high risk of disruption and potential shortfall in supply to the lower Olifants River irrigators and other users, and ultimately the prosperity of the region.

Proposed Right Bank Canal Scheme

An options analysis of initial conceptual design options was undertaken and described in the *Conceptual Design sub-report*. The proposed Right Bank Canal Scheme will use the existing outlet works from the Bulshoek Weir, cross the Olifants River 3 km further downstream, and continue along the right bank of the Olifants River up to 'Verdeling', where the canal splits into a left bank and a right bank distribution canal. The scheme consists of the following components:

- The existing intake works to the canal system, i.e. outlet works at the Bulshoek Weir.
- Upgrading of a portion of the existing Left Bank Canal to accommodate the design flow.
- A new syphon and pipe bridge across the Olifants River.
- A new Right Bank Canal from the syphon crossing the Olifants River to the existing syphon at Verdeling.
- A combination of two concrete culvert syphons and a short canal reach to cross the Doring River.
- Modifications to the existing syphon outlet at Verdeling to increase the head of the syphon.

This Right Bank Canal will supply the proposed four significant new irrigation areas in the Trawal region, which can potentially be considered for the development of a Government Water Scheme (GWS).

Feasibility Design

Design Capacity

The Right Bank Canal Scheme will be designed to convey a total design flow of 11.40 m^3/s.

Canal Design

It is anticipated that the existing outlet structure at Bulshoek Weir does not require modification to release the peak design flow of 11.40 m^3/s into the proposed Right Bank Canal. The water level immediately downstream of the five sluice gates is controlled by the gates themselves which is approximately 61.0 metres above mean sea level (masl). This level was used as the starting level for the scheme downstream.

The proposed routing of the canal is north, north-west from Bulshoek Weir to the existing syphon at Verdeling. The vertical alignment of the canal was designed with a constant slope of 1:5 000 to convey the design flow, with syphons at locations where the required slope cannot be sustained. The design of the canal is optimised (for construction cost) by undertaking a cut/fill balance for the earthworks of the canal, based on the optimum horizontal and vertical alignments.

The canal was designed to be constructed with a cross-sectional cut and fill balance as close to zero as possible. As the invert level of the canal follows a gradual slope, naturally there will be some stretches where the canal will be either mostly in cut or in fill. At the fill stretches and culverts will be placed along the vertical alignment of the canal. This allowed for the drainage of the upstream catchments that would be cut off from their natural drainage paths if the canal were to follow the contours at watercourse crossings.

A trapezoidal canal cross-section is proposed for the entire route. Two types of cross-sections were used based on side slope and bottom width:

- Canal type T1 is a wider section with flatter side slopes and a design flow depth of 1.945 m, proposed for the flatter, more open topography found in the lower Olifants River valley. Type T1 is recommended from about chainage 6.41 km In Reach 1 up to the end of Reach 3 at Verdeling.
- Canal type T2 is a narrower section with steeper side slopes and a design flow depth of 1.824 m, minimising the total section width. This section is proposed for the steeper, more extreme topography found in the relatively upper valley of the Olifants River just downstream of the Bulshoek Weir. Type T2 is recommended for the upgrading of the existing Left Bank Canal up to a chainage of 3.05 km, and then again on the right bank from chainage 3.35 km to about 6.41 km.

Due to different hydraulics, the freeboard also differs for each canal type. The greater of the values from the following two scenarios was used as the canal freeboard to avoid any risk of overtopping due to velocity and curve wave action at bends in the canal:

- A 20% overload + velocity wave action (Current DWS practice), and
- Normal loading velocity wave action + curve wave action (SANRAL Drainage Manual).

The main objective of providing a concrete lining in a water supply canal is to limit seepage losses. Concrete was selected as the material for the lining of the canal and construction joints between slabs should be sealed. A canal lining thickness of 150 mm and mesh reinforcement of Y10 at 200 mm (Mesh ref. 617) is proposed. It is recommended that the lining design be optimised during the detailed design phase of the project.

Underdrains should be installed along the full length of the canal to avoid floatation of the canal panels caused by buoyancy forces. The canal will also affect normal drainage paths of percolated rain and irrigation water, which will build up below the canal lining if not effectively drained.

Embankment cross-drainage culverts were allowed for to account for the catchments that will be created by the new canal. In order to convey the 1:20 year peak runoff from the North Eastern ridge, a series of culvert pipes ranging from 600 mm diameter to 1 050 mm diameter would need to be placed along the canal route at low points. This amounts to 73 culvert crossings. A berm would be needed on the upper side of the embankment to convey the runoff to the relevant culvert crossing.

The route of the canal achieves a cut-fill balance over several reaches, indicating that very limited mass haul will be needed. Where fill is needed under the canal, the material can be obtained by the cut material in adjacent canal reaches.

Flow measurement is incorporated into the design of the canal to improve the water management of the system. Crump weirs are recommended for all flow measurement. A minimum of four flow measurement locations are recommended for the canal:

1. Directly downstream of the Bulshoek Weir where the existing Parshall Flume needs to be replaced;
2. On the left bank, downstream of the inlet to the pipe bridge syphon to measure flow to existing farms on the left bank, using the existing Left Bank Canal;
3. On the new Right Bank Canal, directly downstream of the outlet of the pipe bridge syphon; and
4. On the new Right Bank Canal, directly upstream of the existing Verdeling syphon inlet.

Long weir rejects are proposed at all syphon inlets. These rejects will be placed on the wall of the canal directly upstream of these inlets.

A 4.0 m wide canal service road next to the canal is proposed. This road will link to existing roads at locations where the canal crosses these roads. It is envisaged that the service road will be used as the access road during the construction of the canal.

New off-takes from the canal will be required to supply the irrigation blocks of the proposed development options, such as the possible new GWS in the Trawal area. The off-takes will either be supplied under gravity or via a pump system due to the topography of the irrigation areas.

The proposed canal alignment will affect existing infrastructure, such as crossing of the existing R363 road at various places and private farms/property.

Syphons

Syphons are required in two sections along the new Right Bank Canal route:

1. Syphon 1 (S1) crosses the Olifants River, approximately 3 km downstream of the Bulshoek Weir;
2. Syphon 2A (S2A) crosses the Doring River; and
3. Syphon 2B (S2B) avoids a steep, sandy hillside.

Syphon 1 is a 300 m long DN2400 mm circular steel pipe. It will cross the Olifants River with a pipe bridge, similar to the existing syphon bridge at Verdeling.

Syphon 2A is a 1 270 m long rectangular reinforced concrete culvert (2.8 m wide x 2.4 m high) and Syphon 2B is an 840 m long rectangular reinforced concrete culvert (2.8 m wide x 2.4 m high). These syphons will be buried underground.

Existing Verdeling Syphon

The proposed right bank conveyance system needs to tie in with the existing 2.0 m diameter syphon (650 m long) at Verdeling. This syphon currently operates by conveying flow from the Left Bank Canal, across the Olifants River to the outlet on the right bank. The flow in the syphon must be reversed for the new canal. The peak design flow for the reversed Verdeling Syphon is calculated as 4.02 m^3/s. The right bank outlet will be altered to become an inlet with gates to continue servicing the existing downstream right bank distribution canal. As the current syphon has a physical level difference of approximately 0.96 m to accommodate the design flow from left bank to right bank, the height of the proposed new inlet must be increased by 0.96 m plus the design head difference to reverse the flow.

Cost Estimate

The estimated 2020 capital cost of the proposed scheme is R 1 833 million, including VAT, professional fees and contingencies.

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Acronyms

CBA	Critical biodiversity area
DEFF	Department of Environment, Forestry and Fisheries
DEM	Digital elevation model
DMR	Department of Mineral Resources
DTM	Digital terrain model
DWAF	(Previous) Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental impact assessment
GIS	Geographical information system
GWS	Government water scheme
HDPE	High density polyethylene
IRR	Internal Rate of Return
LiDAR	Light Detection and Ranging
LORGWS	Lower Olifants River Government Water Scheme
LORWUA	Lower Olifants River Water User Association
WCDoA	Western Cape Department of Agriculture (Provincial)
WUA	Water User Association

1 Introduction

1.1 Study Objectives

The objective of the *Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam (WP0485)* is to provide recommendations on the bulk conveyance infrastructure options (new developments/upgrading/rehabilitation) required for the equitable distribution of the existing and additional water from the raised Clanwilliam Dam, after investigation of:

- The existing water allocation and projections for the supply area;
- New areas for agricultural development;
- Options for the required conveyance infrastructure; and
- Appropriate farming models and cost of irrigation water.

1.2 Purpose of this Sub-Report

This sub-report describes the design parameters, assumptions and feasibility design of the infrastructure associated with the proposed Right Bank Canal Scheme. This will form a Chapter of the Feasibility Design Report.

1.3 Background to the Project

The Clanwilliam Dam is situated in the Olifants River near the town of Clanwilliam in the Olifants/Doorn River Catchment Management Area in the Western Cape. The dam requires remedial work for dam safety reasons, which offers the opportunity to increase the yield at the same time by raising the dam wall and thereby enlarging the storage capacity. Water use in the region is predominantly for irrigated agriculture. **Figure 1.1** shows the study area and provides an overview of the existing conveyance infrastructure discussed in this report.

A feasibility study was completed in 2008, which concluded that the raising of Clanwilliam Dam and further associated agricultural development is economically viable and socially desirable. The feasibility study recommended the raising of the full supply level of the existing Clanwilliam Dam by 13 m, to augment the water supply to the existing scheduled irrigation area, towns and industrial users, as well as to provide additional water for new irrigation areas to establish historically-disadvantaged farmers, and to supply other local water users.

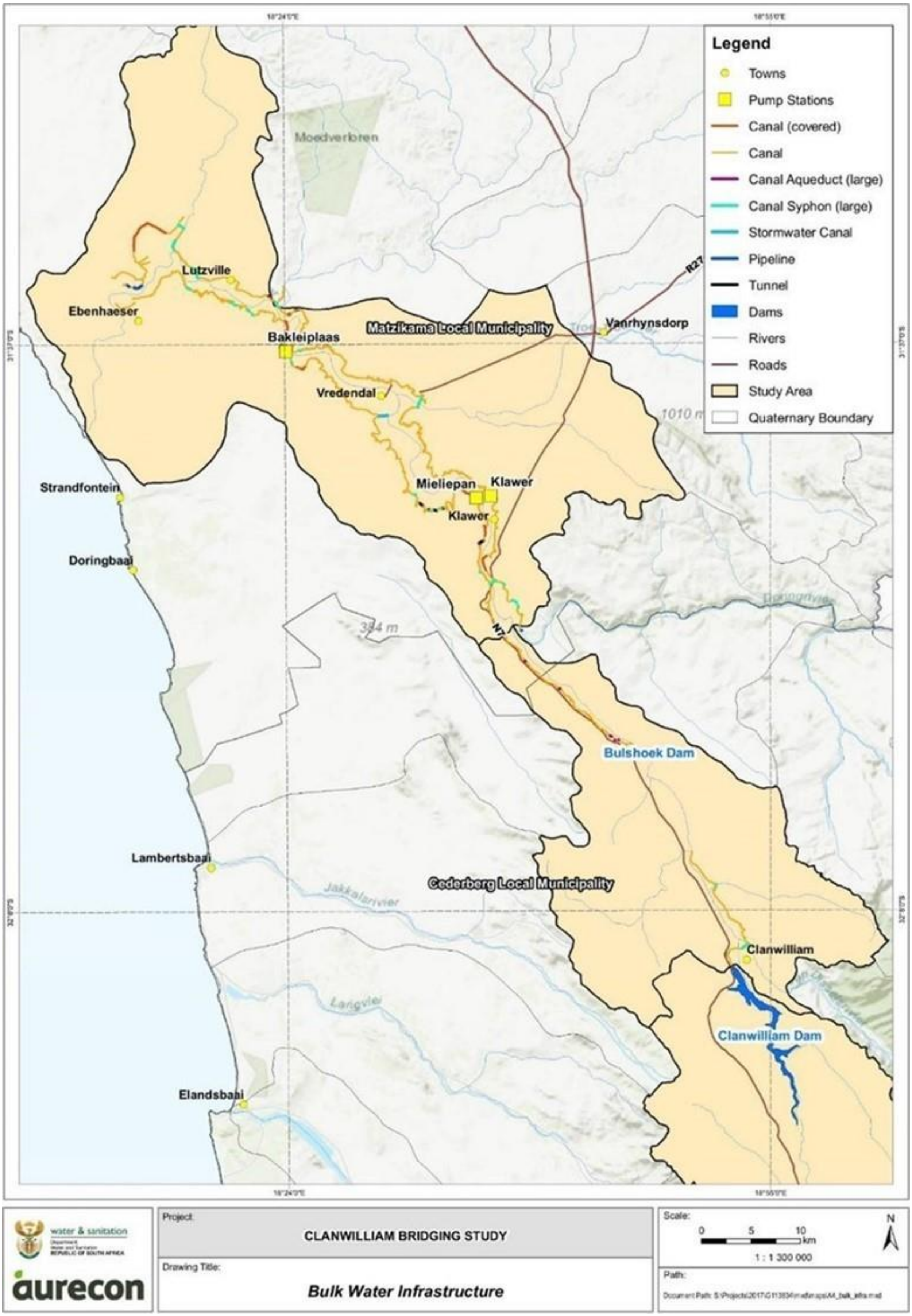

Figure 1.1: Study Area and Bulk Water Infrastructure

The environmental authorisation for the raising of Clanwilliam Dam is effective from February 2010 and the project was approved by the then Minister of Water and Environmental Affairs as a Government Water Works in August 2010. The implementation of this project is currently in the construction stage, which commenced in October 2018, after a significant delay.

The Clanwilliam Dam Raising Feasibility Study Report titled '*Irrigation Development and Water Distribution Options'* provided reconnaissance-level information on the potential areas for new irrigation development and some water distribution options. The water distribution options and associated bulk water infrastructure have been determined at a higher level of confidence during this Bridging Study and are described in the *Conceptual Design Sub-Report*.

One of the bulk water infrastructure options recommended for feasibility design is the Right Bank Canal Scheme, which involves replacing the existing main canal from the Bulshoek Weir with a new canal of increased capacity on the right bank of the Olifants River.

1.4 Right Bank Canal Scheme

Several major breaks have been experienced along the Bulshoek / Lower Olifants Canal due to ageing infrastructure. After more than 80 years of usage, the concrete lining of the existing canal has become frail and prone to damage, which results in canal breaks occurring frequently. The largest break happened in January 2015 with a repair cost of R11.5 million (2015 prices), and which cost the agriculture sector an estimated R100 million. The most recent canal failure on 30 December 2019 resulted in water loss of approximately 144 000 m^3 and a repair cost of R500 000, see **Figure 1.2**. The Lower Olifants River Water User Association (LORWUA) reported that it spends approximately R4.2 million per annum on normal maintenance with its own teams, and contracts out approximately R5.8 million per annum on more serious repairs.

Figure 1.2: Failure of the Lower Olifants Canal along the main (Trawal) section

It is evident that the poor state of the existing canals, especially the main (Trawal) section, poses a high risk of disruption and potential shortfall in water supply to the Lower Olifants River irrigators and other users, which includes towns in the area. Water is the driving force supporting the prosperity of the region. Therefore, the Right Bank Canal Scheme is being investigated as a means to ensure a secured future water supply to sustain existing development in the region, as well as to supply new irrigators. The Right Bank Canal Scheme is designed to replace the existing main canal with a new canal on the right bank of the Olifants River, which will have an increased capacity to also supply new downstream irrigation development and other future uses. It will transport water from the existing Bulshoek Weir to the existing 2.0 m diameter syphon at Verdeling.

Several options were compared and evaluated for the different components of the Right Bank Canal Scheme (refer to the *Conceptual Design sub-report* of this study). The proposed scheme is shown in **Figure 1.3** and consists of the following:

- Upgrading of the Left Bank Canal for approximately 3.05 km;
- A 2.4 m diameter syphon crossing the Olifants River on a pipe bridge (300 m long);
- A new reach of trapezoidal canal on the right bank (approximately 18.56 km long);
- Two rectangular in-situ concrete syphons and a short reach of canal (1 270 m, 840 m and 680 m long respectively);
- Another long reach of new trapezoidal canal (approximately 8.85 km long);
- Upgrades to the existing syphon outlet at Verdeling to act as an inlet (chainage 33.55 km).

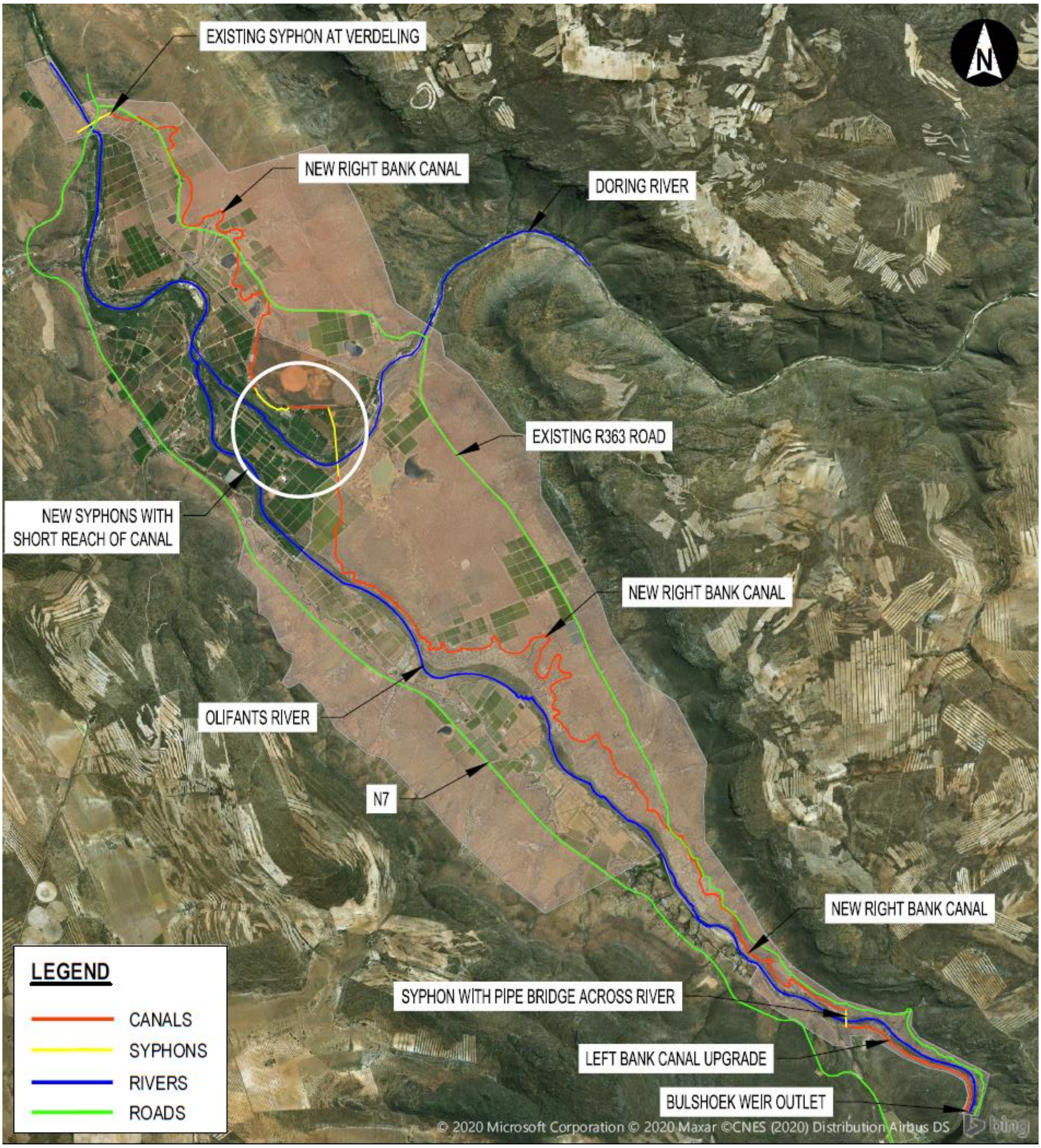

Figure 1.3: Overall layout of the Right Bank Canal Scheme

1.5 Content of this Report

The various chapters in this report and their content are briefly described hereunder.

Chapter 1: Introduction (this Chapter)

Introduces and provides background to the project and the bulk water infrastructure option that was investigated.

Chapter 2: Survey Data

Describes the topographical survey undertaken.

Chapter 3: Geotechnical Investigation

Describes the geotechnical and materials investigations undertaken to date.

Chapter 4: Environmental Screening

Describes the environmental screening of the Right Bank Canal scheme.

Chapter 5: Canal Design

Provides details of the canal routing, the hydraulic parameters used in the design, the hydraulic calculations, and preliminary canal sizing and cross-sectional design.

Chapter 6: Syphons

Provides details of the hydraulic parameters used in the design, the hydraulic calculations, and choice of pipe materials.

Chapter 7: Existing Verdeling Syphon

Provides detail of proposed changes to the existing Verdeling Syphon to allow reverse flow from the new Right Bank Canal.

Chapter 8: Quantities and Cost Estimate

Provides a high-level summary and cost estimate of the various components of the proposed Right Bank Canal scheme.

Chapter 9: Legislative Considerations and Authorisations

Briefly identifies the various legislative considerations required for implementation of the conveyance infrastructure and the status of each process.

Chapter 10: Conclusions

Summarises the findings from this report.

Chapter 11: Recommendations

Provides a list of recommendations for the Right Bank Canal Scheme.

2 Survey Data

A topographical survey was completed by Southern Mapping for the proposed project area from Clanwilliam Dam to Ebenhaeser (11 030 ha) in January 2020. The results are reported in the survey report *Topographical Survey Report* (Report No. P WMA 09/E10/00/0417/7). Supplementary topographical survey data was provided in July 2020.

The topographical survey was carried out using an aircraft mounted Light Detection and Ranging (LiDAR) system that scanned the ground below, resulting in a dense Digital Terrain Modelling (DTM) of the ground surface and objects above the ground. Accurate topographical information in the form of digital terrain modelling data, high quality orthophotos and line mapping of salient features for the feasibility study were provided. **Figure 2.1** shows the survey area for the proposed Right Bank Canal and the Trawal Government Water Scheme (GWS).

The following deliverables were submitted in electronic format:

- CAD design files in Microstation DGN, DWG and DXF format showing:
    i. Orthophoto tiles and LiDAR point block layout.
    ii. The surveyed project area with property boundaries.
    iii. Contours at 0.5 m, 1.0 m and 2.0 m intervals.
- Digital Terrain Model (DTM) containing all the survey points (X, Y and Z co-ordinates), complete with descriptions of the acronyms used in ASCII and ESRI Grid format files.
- Ortho-rectified aerial images in ECW format with an 8 cm pixel resolution.
- Composite Image in ECW format at 0.5 m.
- 1.0 m Raster Digital Elevation Model (DEM).
- 1.0 m Elevation Grid.
- Google Earth Overlay in KMZ format at 0.5 m.
- Full LiDAR points in LAS1.4 format.
- The list of survey controls installed by the surveyor as part of the survey, with their coordinates and levels.
- Report on the control survey including the coordinated lists of the photo control stations established and employed, existing survey beacons and new survey beacons established.

The available survey data is considered sufficient to undertake the feasibility, preliminary and detailed designs of the proposed infrastructure. It is, however, recommended that a ground centreline survey be done along the final chosen canal centreline, prior to construction commencing. This will serve as a final check on the canal's vertical alignment.

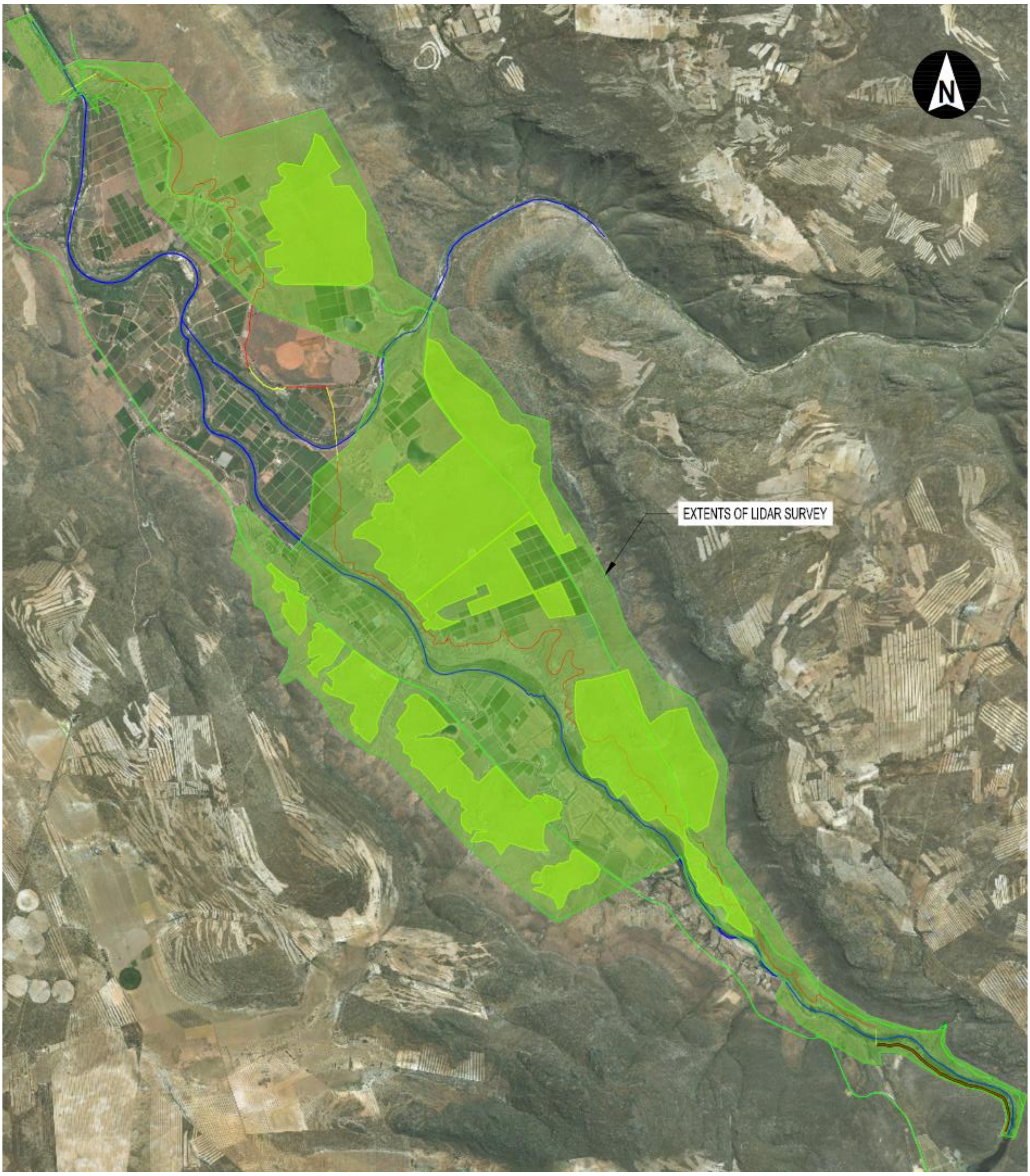

Figure 2.1: Survey area for the Right Bank Canal and Trawal GWS

3 Geotechnical Investigation

3.1 Overview

Geotechnical investigations for the preliminary conveyance infrastructure routes were conducted. The geotechnical investigations comprised:

- A desk study and a reconnaissance visit;
- A test pitting exercise;
- Field testing;
- A laboratory testing programme; and
- Analysis and interpretation of the findings, culminating in reporting.

The following sections are extracts from the *Geotechnical Investigations Report Vol II: Right Bank Canal Scheme* (Report No. P WMA 09E10/00/0417/8).

3.2 Geology

The Right Bank Canal Scheme is located in an area underlain by rocks of the Cape Supergroup, primarily sandstone and quartzitic sandstone. A variety of younger soils overlie the bedrock. The area is located within the Cape Fold Belt, and the strata are characterised by folding and faulting.

The project area is located to the north of elevated seismicity. The Peak Ground Acceleration (PGA) associated with the area is roughly 0.05 g, with a 10% probability of being exceeded in a 50-year period. It is considered a non-seismic activity zone and as such, no specific seismic design requirements, other than normal structural design requirements, are required.

3.3 Geotechnical Considerations

The engineering geological / geotechnical implications and considerations for each of the respective components of the Right Bank Canal scheme are discussed below.

3.3.1 Upgrading of the First 3 km of the Existing Left Bank Canal

3.3.1.1 Geological Profile

The geological profile for the initial 1 900 m of the canal route comprises bedrock of bedded, very hard rock quartzitic sandstone from surface.

For the section between Chainages 1 900 m and approximately 3 050 m, similar bedrock is expected. The bedrock however occurs beneath a cover of colluvial talus material that typically comprises a coarse fraction of gravels, cobbles and boulders in a matrix of sandy gravel or silty sand. The overburden might also comprise patch accumulations of aeolian sand. Although bedrock is expected at shallow depths, the actual depths are not confirmed as the test pits refused on boulders, at depths varying between 0.35 m and 1.0 m.

3.3.1.2 Water Table

None of the excavated test pits intersected groundwater. While it may reasonably be deduced that shallow groundwater will therefore not be encountered, it is pertinent that excavations for the upgrading will be immediately adjacent to the current canal, which is known to be in a poor condition. The possibility of leakage from the current canal, to the extent of causing locally saturated conditions therefore cannot be excluded. If encountered, such localised saturated areas would hold implications in terms of the stability of excavations (see below).

3.3.1.3 Excavation Considerations

The hard rock / very hard rock quartzitic sandstone bedrock can be considered to represent 'hard excavations' in terms of SANS 1200D, i.e. where blasting would be required.

Between Chainages 1 900 m and say 3 050 m, where an upper horizon of colluvial material or patchy aeolian sands might be expected, these upper horizons may be considered 'soft excavation' after SANS 1200D, and these upper horizons might be excavated without ripping or blasting. Note that very large boulders / tabular slabs of rock might be encountered where some form of rock fracture might be necessary before the fragments are of a manageable size for mechanical removal.

3.3.1.4 Slope Stability

Excavations for the upgrade of this initial section of Left Bank Canal will basically encounter two typical profiles, as described above.

For the initial 1 900 m long section from Bulshoek Weir, excavations will primarily be within rock. To date, no detailed discontinuity measurements have been taken, and no kinematic analysis carried out. On the basis of observations during the site walk-over, the rock mass structure is dominated by the shallow-dipping bedding planes. Sub-vertical joints are also expected. The rock mass might be characterised as blocky, although the larger blocks might also be tabular. Stability of these blasted faces will be controlled by the geological structure.

While the sandstone beds on their own are not expected to be likely to slide into the excavation, the bedding planes in conjunction with the other joint sets might produce unstable rock blocks and wedges. All excavations would have to be inspected regularly by a competent geotechnical person and assessed in terms of potential risks of instability.

Where the bedrock occurs beneath the cover of colluvial material or aeolian sands, excavations within these upper horizons would need to be battered to safe angles or shored. The presence of cobbles and boulders is a further consideration; removal of these from the cut faces can result in further destabilisation and ravelling of cut faces.

3.3.2 The New Right Bank Canal

This section describes the proposed new canal which will be constructed on the right bank of the Olifants River, i.e. excluding the initial portion (upgrading of the Left Bank Canal) discussed above.

3.3.2.1 Geological Profile

The test pit profiles and surface observations were used to sub-divide the canal routing into zones of similar geological profiles. The materials encountered are of varied origin, and the following material types are identified:

- Sands of aeolian origin;
- Alluvial soils in the rivers;
- Colluvial sand;
- Colluvial (talus) deposits comprising gravels, cobbles and boulders in a sand matrix;
- Terrace gravels, comprising variable proportions of sand, gravels and cobbles, with a sandy matrix;
- Pedogenic materials that comprise variable sand and gravel soils, which are cemented to varying degrees, from calcretised sand to hardpan;
- Residual soils derived from the weathering of the shales or siltstones; and
- Bedrock, either quartzitic sandstone, shale or siltstone.

For each of the zones, a generalised ground profile was developed as described in the *Right Bank Canal Geotechnical Investigations Report*.

3.3.2.2 Water Table

None of the test pits encountered any seepage, or a shallow water table. It is also pertinent that these investigations were carried out in the winter months, which comprise the wet season. The implication is that the conditions recorded represent the shallowest water table that might be experienced in a normal year.

There is a possibility that longer-term water tables might occur below the pedogenic horizons commonly intersected at depth, and thus cannot be excluded at this stage.

3.3.2.3 Excavation Considerations

For the purpose of this discussion regarding excavations, the geological profile to a depth of 3.0 m is considered relevant.

Although the soils are variable in terms of origin as well as the soil types, these upper soil horizons in general would be classified as 'soft excavation' after SANS 1200 D. As a rule, however, refusal was typically recorded at reasonably shallow depths, across the variety of soil types encountered. Reasons for refusal are varied, and would either be shallow bedrock, or large boulders, or very dense pedogenic horizons, including hardpan ferricrete or calcrete. Excavation below these depths of TLB refusal can be considered to comprise 'hard' excavation and might require blasting for efficient removal. It is possible that heavy ripping might be successful, which would be considered as 'intermediate' excavation according to SANS 1200 D, but for the sake of being conservative the excavation is considered as 'hard'.

With almost all test pits recording refusal from depths as shallow as 0.3 m to say 2.0 m, the implication is that 'hard' excavations will be experienced for almost the entire length of the canal on the right flank; at least in the deeper portions of the canal excavations.

3.3.2.4 Slope Stability

Sidewall instability was a common feature of the test pits. These unstable conditions serve to highlight the potential risks of slope instabilities that will be associated with the upper soil horizons during excavations.

Regular inspection of cut faces by a competent geotechnical person will be essential during construction.

3.3.3 Road Crossings

The preferred alignment of the Right Bank Canal requires that the canal crosses the R363 road several times. The expected geological profiles of the road crossings are provided in the *Right Bank Canal Geotechnical Investigations Report*.

It is too early for firm decisions to be taken regarding the favoured construction method for these road crossings. Pipe-jacking would be an option but, considering the low traffic levels on the R363, it is likely that a cut-and-cover option would be optimal.

Comments regarding excavation considerations, as well as groundwater, are as above.

In terms of slope stability, the excavated faces for construction of the crossings would be considered temporary slopes. The upper portion of these excavations will be within soils where the excavated faces would be susceptible to ravelling and spalling. These faces must be cut to safe angles, and / or shored. Such temporary cuts would ideally be aimed to be near-vertical / very steep to minimise the excavation footprint, but this will not be possible without shoring, and / or other stabilisation.

3.3.4 Olifants River Crossing (Syphon 1)

3.3.4.1 Geological Profile

The topography at the position of the Olifants River Crossing is asymmetrical; the left flank is characterised by steep, near-vertical cliffs and outcrop of quartzitic sandstone bedrock while the right flank is moderately steep, and is characterised by talus deposits of sand and gravels / cobbles, and boulders that overlie the quartzitic sandstone bedrock. The rockhead is expected to be quite variable, and in places is seen to outcrop on surface.

Within the river section, alluvial deposits of sand as well as boulders occur, but these are patchy and in some areas outcrop of very hard rock quartzitic sandstone is evident.

3.3.4.2 Founding Conditions

Bedrock of hard rock quartzitic sandstone is characteristically found at shallow depths; on the left flank the bedrock outcrops on surface, while scattered outcrop occurs both in the river section as well as on the right flank, although variable deposits of colluvial talus deposits overlie the bedrock. The generally shallow bedrock holds implications for founding, and also for the decision regarding the favoured means of crossing the river.

For the preferred syphon option of a pipe bridge, the detailed layout still needs to be confirmed, specifically the number of piers, but the shallow quartzitic sandstone bedrock would generally be considered a good founding stratum in terms of bearing capacity. Assuming hard rock is encountered at or near-surface, foundation excavations would be shallow, i.e. deep founding solutions such as piling will not be necessary.

It is pertinent that these quartzitic sandstones are bedded lithologies, and there remains a possibility that hard rock strata are underlain by, or interbedded with weathered, soft rock strata.

3.3.4.3 Excavation Considerations

Within the hard rock quartzitic sandstone bedrock, all excavations may be considered to comprise 'hard excavations', after SANS 1200 D, i.e. blasting would be required. At the same time, it is pertinent that excavation within the bedrock is expected to be negligible, i.e. founding will likely be on the upper bedrock surface, although minor trimming of the rockhead might be necessary if very irregular. Such localised trimming is likely to be achieved by means of jackhammers or an excavator-mounted rockpecker, rather than blasting.

Note that founding on the rockhead assumes that the rock mass is not characterised by interbedded weak strata. If this is the case, deeper excavations within the rock mass will be necessary.

The colluvial and alluvial overburden can be considered as 'soft excavation' after SANS 1200 D.

3.3.4.4 Slope Stability

As far as the bridge footings and abutments are concerned, only shallow excavations would be required where the rock is at or near surface. In such cases, there would not be concerns regarding the stability of excavated faces.

Should locally thick deposits of alluvial or colluvial soils be encountered above the bedrock, excavations in these materials would have to be cut back to safe angles, and / or shored.

The near-vertical cliffs on the left flank deserve mention. To date, no detailed consideration of the geological structure has been carried out for these cliffs. The location of the bridge abutment with respect to the cliff, and the cliff edge in particular, would be pertinent in terms of the additional loading surcharge that would be introduced, and the impact, if anything, on the global stability of the cliff.

3.3.4.5 Groundwater

Shallow groundwater is not expected on the flanks, i.e. it is not expected to influence construction of the respective abutments. Should the layout include piers within the river section then provision must be made for encountering water. Coffer dams would be necessary as well as provision for pumping of seepage water.

3.3.5 Doring River Crossing (Syphon 2A)

At the time of the site investigation, the Doring River was initially in flood and high water levels persisted. Access within the river section was therefore difficult and test pitting was only partially achieved. As a result, a full understanding of the sub-surface conditions has not been achieved, and this is dealt with below.

3.3.5.1 Geological Profile

The test pit revealed alluvial sand with a coarse fraction of cobbles and boulders with a minimum thickness of 1.5 m. The test pit was terminated at this depth due to collapse of the sidewalls, but it is expected that the alluvial deposits are considerably thicker than 1.5 m.

To date, investigations have been limited and the deeper conditions are uncertain.

3.3.5.2 Founding Conditions

For the proposed syphon type, the excavation considerations and grading analysis of the deep alluvial soils is important, more so than the bearing capacity.

3.3.5.3 Excavation Considerations

The alluvial sands will classify as ‘soft excavations’ in accordance with SANS 1200 D. The profile will also include variable amounts of cobbles / boulders, and selected excavation methods must be able to deal with the coarser fraction.

3.3.5.4 Slope Stability

Excavations within the river section, within saturated sands, will be prone to collapse. This was borne out by the single test pit, which exhibited failure of the sidewalls.

All excavations will therefore require support, such as shoring. It is doubtful that battering back to safe angles will be practical, as these slopes would of necessity be very flat, and would be subject to continual collapse.

No decisions have yet been taken regarding the favoured method of construction, but consideration of the stabilisation of excavations, and lateral support requirements, are some of the implications of a decision on the favoured construction methodology.

3.3.5.5 Groundwater

This river crossing will, by definition, be within the active river channel and appropriate measures to deal with high flows and even flooding would be required. It is also recognised that the Doring River is not perennial, and surface flow is typically not encountered in the dry summer months. Importantly it is not assumed that sub-surface flow is not occurring, and at any time of the year appropriate measures to deal with water inflow are required.

3.3.6 Extended Doring River Syphon (Syphon 2B)

Downstream of the Doring River crossing, a section of the new Right Bank Canal is aligned along a steep section where it is envisaged that a syphon will be required.

3.3.6.1 Geological Conditions

The geological conditions are judged as being highly variable but equally important. The steep topography prevented TLB access and only a single test pit could be excavated at the downstream end of the envisaged syphon.

3.3.6.2 Excavation Considerations

Conditions are noted to be highly variable, and it follows that these materials will also vary in terms of excavation considerations. The soils may be considered to represent ‘soft excavation’.

Shale bedrock is expected at an approximate depth of 2.0 m, and comprises very soft to soft rock, but is still assessed as ‘hard excavation’. At the northern end of this section, TLB refusal was recorded as shallow as 0.3 m on calcified sand. In both instances it is possible that excavation will be achievable with heavy ripping, but at this stage it is assessed as being ‘hard excavation’.

3.3.6.3 Slope Stability

The current excavated face, largely within residual clayey silt, is cut at an approximate angle of 30°. No indications of major instability were evident, but it is noted that minor spalling and ravelling of this cut face does occur, based on the accumulated material at the toe of the cut face.

Depending on the selected construction methodology, consideration will have to be given to the stability of both temporary cut faces, as well as the permanent slopes.

3.3.6.4 Groundwater

This steep section is elevated above the floodplain, thus shallow groundwater is not expected.

3.4 Conclusions and Recommendations

Conditions for the two river crossings could not be investigated in sufficient detail. Follow-up geotechnical investigations at the respective Olifants and Doring river crossings are currently being planned.

Rotary core drilling is recommended at the Olifants River bridge pier / abutment positions in order to confirm the founding conditions. Even where scattered outcrop of quartzitic sandstone is present, there is a possibility within this stratified, bedded rock mass that weak horizons occur at depth. Rotary core drilling is essential to confirm the geological profile within the foundations’ ‘bulb of influence’. An understanding of the geological structure is essential for the assessment of the stability of the abutment foundation. Discontinuity data must be collected, together with a detailed description of the founding rock mass, for a full understanding of the kinematics.

Further investigation, comprising rotary core drilling is required at the Doring River crossing to confirm the geological conditions within the river section, as well as the extended syphon on the steep section where test pits could also not be excavated.

Geophysical traverses might be considered as a precursor to the drilling of boreholes. Initially this will allow rapid appraisal of the expected sub-surface bedrock profile, and identify target areas for the borehole locations. After drilling it would allow for interpretation and extrapolation of the borehole information.

Ground investigations are typically phased, as is the project itself, and a single round of investigations will not necessarily meet all the requirements for detailed design into the construction phase. Thus, any subsequent refinements to the Right Bank Canal Scheme during the detailed design phase might require additional geotechnical information. This will depend on the details of these refinements and the level of available information in the affected areas.

4 Environmental Screening

An environmental screening of the proposed development areas and activities was conducted as part of the Bridging Study, to determine the best ecological options and to minimise impacts on the natural environment. The findings of this screening, relevant to the Right Bank Canal scheme, are reported in the *Environmental Screening Sub-Report* (Report No. P WMA 09/E10/00/0417/8). The relevant conclusions from this report are listed below:

- The upgrading of the existing Left Bank Canal should consider limiting vegetation clearance, since the site is located partly within a Critical Biodiversity Area (CPA), the Rondeberg Oord Private Nature Reserve and an endangered vegetation type.
- The proposed works should be subject to further on-site specialist assessments by a freshwater and botanical specialist to determine the best environmental options within the sensitive areas and especially the watercourses.
- The work to be undertaken as part of the Left Bank Canal upgrade, syphons through the Olifants and Doring rivers, construction of the Right Bank Canal and any other associated infrastructure would require a Basic Assessment to obtain authorisation from the Department of Environment, Forestry and Fisheries (DEFF).
- If borrow pits are proposed, an application for authorisation should also be submitted to the Department of Mineral Resources (DMR) for mining activities.
- The proposed infrastructure would also require heritage authorisation in terms of Section 38 (a) and (c) of the National Heritage Resources Act (NHRA).
- A water use authorisation in terms of Section 21 (a), (c) and (i) of the NWA is required.

5 Canal Design

The proposed new Main Canal starts on the left bank at the Bulshoek Weir for approximately 3 km before crossing to the right bank and connects to the existing syphon at Verdeling. Design of the Right Bank Canal is based on DWS' (1980) *Guidelines for the Design of Canals and Related Structures*.

5.1 Water Requirements and Design Capacity

The existing canals supplying the Lower Olifants River Government Water Scheme (LORGWS) cannot currently provide the full allocations to irrigators because of the restrictive canal capacities. This constraint is in addition to the typical annual restrictions due to the current limiting storage of Clanwilliam Dam and sometimes drought conditions. Rebuilding the main canal with adequate flow capacity on the right bank will only solve this problem for existing irrigators up to 'Verdeling', where the canal splits. The situation will in the future incrementally be improved further, should more canal sections be replaced or improved.

The capacity of the Right Bank Canal should be designed considering the following aspects:

- Current flow capacity of the main canal, providing existing irrigators;
- An increased flow capacity for existing irrigators, to alleviate the bottleneck caused by the existing flow capacities of canal sections, taking a long-term view of incremental betterment / replacement of the existing canal sections;
- Future non-irrigation flows;
- Flow requirement for new irrigation downstream of Bulshoek Weir; and
- Adequate freeboard.

5.1.1 Current Bulshoek Main Canal flow capacity

According to LORWUA, the current capacity of the main canal is 26 000 m^3/h (7.222 m^3/s).

The current irrigated area, which receives scheduled water allocations from the Clanwilliam Dam via the LORWUA canal system, is 9 517 ha. If irrigators obtain their full scheduled allocation of 12 200 $m^3/ha/a$, this equates to total scheduled water allocations of approximately 116 million m^3/a (average flow of 3.682 m^3/s). With an average peak factor of 2.13 (refer **Section 5.1.3**), the canal is required to convey a peak flow of 7.842 m^3/s.

5.1.2 Increased flow capacity for existing irrigators and other uses

An increased flow capacity for existing irrigators is required to alleviate the bottleneck caused by the existing restrictive flow capacities of canal sections, when taking a long-term view of incremental betterment / replacement of these existing canal sections. This will enable existing irrigators to increase the use of their current allocations, in line with the increased assurance of supply, following the raising of the Clanwilliam Dam. The benefit will initially only extend to 'Verdeling', once the Right Bank Canal has been constructed, but can be realised further downstream if the flow capacity of the remainder of the canal sections are progressively increased.

Following the raising of Clanwilliam Dam, existing irrigators will have an increased assurance of supply. Up to 20.35 million m^3/a (25% of 81.4 million m^3/a) may be used by existing irrigators. This equates to an increased flow of 0.645 m^3/s, which is an 8.9% increase in current maximum flow. With the increased assurance of supply, it is expected that irrigation flows to existing irrigators will increase. Farmers may plant more permanent crops, and winter flows are also expected to increase. Such additional flows can be used by increasingly making use of spare canal capacity, which is already very limited, and then additionally as sections of canal infrastructure are upgraded.

The canal will be required to accommodate the peak flow during the summer months. An average peak factor (for January) for the irrigation development areas downstream of the Bulshoek Weir of 2.13 was applied to the average flow of 0.645 m^3/s to give a peak flow of 1.374 m^3/s, for improving the supply to existing irrigators. Adding this improved assurance of supply of 1.374 m^3/s to the existing canal capacity of 7.222 m^3/s means that a total flow of 8.596 m^3/s will be required to supply existing irrigators in future.

An increased canal flow capacity will also allow for future growth in water requirements from urban and municipal use and large industries, such as mines. An additional 1.1% increase in current maximum flow capacity of 0.079 m^3/s has been assumed to provide for this growth in water requirements.

These increased flow capacities required for improved assurance of supply to existing irrigators and other users is shown in **Table 5.1**.

Table 5.1: Water requirements for improved assurance of supply

Improved assurance of supply to existing irrigators	
Additional allocation for improved assurance of existing irrigators (million m^3/a)	20.35
Additional flow and losses for improved assurance of existing irrigators (m^3/s) [equivalent to 8.9% increase in existing canal capacity]	0.645
Average peak factor (January)	2.13
Increase of Peak flow (m^3/s)	**1.374**
1.1% increase for future non-irrigation flows (m^3/s)	**0.079**

5.1.3 Flow requirement for additional irrigation downstream of Bulshoek Weir

Current identified preferred new irrigation development schemes and their associated water requirements and losses are as shown in **Table 5.2**.

Table 5.2: Water requirements and losses of preferred development options

Sub-area	Water allocations (Mm^3/a)	Conveyance losses (Mm^3/a)	River losses (Mm^3/a)	Water allocations and losses (Mm^3/a)
Zone 2 - Olifants River Catchment upstream of and including Bulshoek Weir	17.95	0.00	0.64	18.59
Sub-total (above Bulshoek)	***17.95***	***0.00***	***0.64***	***18.59***
Zone 4 - Olifants River Below Bulshoek Weir to Trawal (post-Right Bank Canal)	22.31	2.02	1.62	25.95
Zone 5 - Olifants River from Klawer to Coast (post-Right Bank Canal)	13.59	2.26	0.68	16.51
Sub-total (Below Bulshoek)	***35.90***	***4.28***	***2.30***	***42.46***
Total	**53.84**	**4.27**	**2.94**	**61.05**

The total available water for additional allocation for new irrigation from a raised Clanwilliam Dam is 61.05 million m^3/a (75% of 81.4 million m^3/a). The preferred new irrigation schemes were selected such that their combined water requirements plus losses equates to the total available additional water. However, it has become apparent that irrigation is sometimes developed in soil that is marginal or not recommended for irrigation. While the total area (hectares) of the preferred irrigation areas are a good indication of the location and extent of new irrigation, it is likely that actual development will differ to some extent.

The proposed new irrigation development areas downstream of Bulshoek Weir (i.e. Zone 4 and Zone 5) require a total allowance of 42.46 million m^3/a.

The design capacity of the new proposed Right Bank Canal should be sufficient to firstly convey the potential water allocation, as well as account for canal conveyance losses. Furthermore, the design flow of the new canal should allow for peak flows. A peak factor of 2.17 and 2.09 was used for Zone 4 and Zone 5 respectively. These peak factors were determined by a Bridging Study sub-committee, consisting of DWS, Western Cape Department of Agriculture (WCDoA), Aurecon and Agrifusion, who derived the crop water requirements for each zone/sub-area. The design flow component for additional irrigation is **2.723 m^3/s** and is calculated as shown in **Table 5.3**.

Table 5.3: Design flows for additional irrigation

Sub-Area	Water allocation (Mm^3/a)	Canal losses (Mm^3/a)	Water allocation & losses (Mm^3/a)	Ave flow (m^3/s)	Peak factor (Jan)	Peak / design flow (m^3/s)
Zone 4	22.31	2.02	24.33	0.771	2.17	1.674
Zone 5	13.58	2.26	15.83	0.502	2.09	1.049
Total	**35.89**	**4.27**	**40.16**	**1.273**		**2.723**

5.1.4 Total design flow

The total peak design flow for the proposed Right Bank Canal at the outlet of the Bulshoek Weir is **11.40 m^3/s**, and is calculated as shown in **Table 5.4**. The various components of the Right Bank Canal Scheme will thus be sized for this design flow.

Table 5.4: Right Bank Canal peak design flows

Flow component	Flow (m^3/s)
Current irrigation	7.222
Improved assurance of supply to existing irrigators	1.374
Future non-irrigation flows	0.079
Additional irrigation	2.723
Total peak design capacity	**11.398**

5.2 Scheme Overview and Components

An initial conceptual design assessment of alternatives for supplying water from Bulshoek Weir considered several options. The options included refurbishing the existing canal, constructing a new canal on the right bank from Bulshoek Weir to 'Verdeling', and several combinations of syphons and outlets. The proposed scheme would be required to serve the identified new irrigation areas of Trawal, Zypherfontein 1 and 2, and Melkboom, as shown in **Figure 5.1**. Note that the red line on the map indicates a very early indicative location of a new Right Bank Canal route and is not the most feasible route. The recommended route, based on the feasibility design, is shown in **Figure 5.2**.

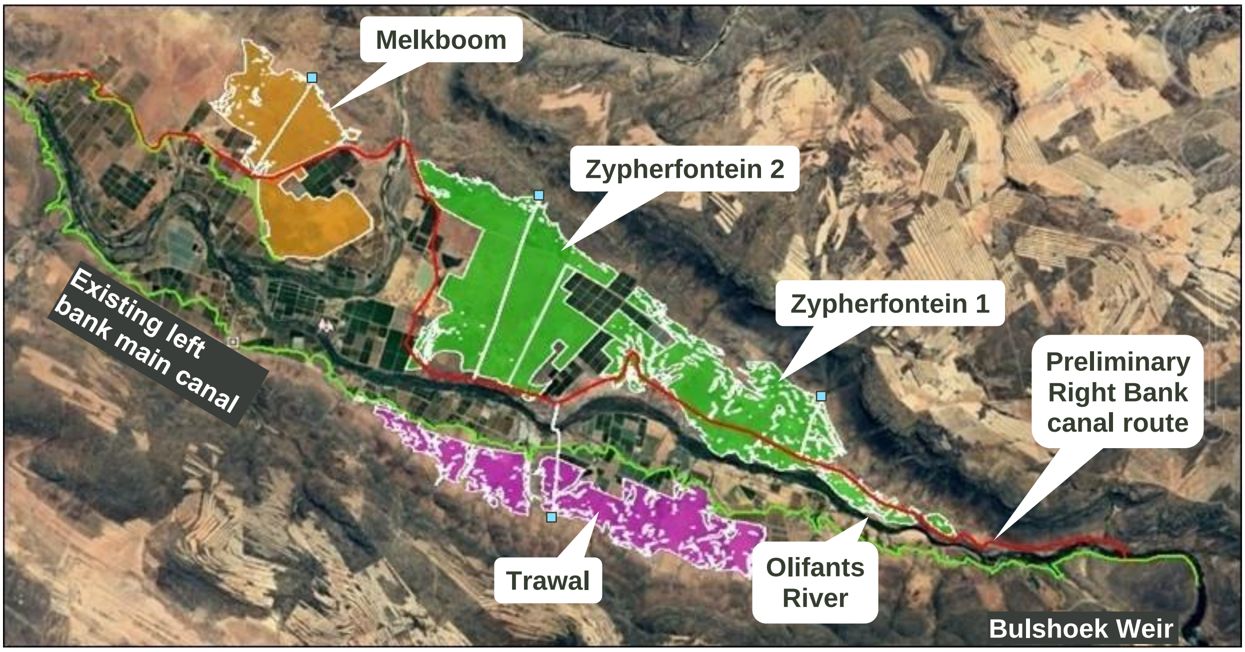

Figure 5.1: New irrigation schemes between Bulshoek Weir and Verdeling Syphon

The following challenges regarding sections of the canal were noted:

- A number of reaches of the proposed canal would be located where the topography is steep, and hard rock is present at a very shallow depth, which significantly increases the cost of the proposed canal.
- There are a few sections of the proposed canal route which would require the relocation of portions of the R363 road on the right bank of the Olifants River.
- The structural strength of the existing syphon at 'Verdeling' may be problematic, if the pressure on the syphon increased and it is greater than the design pressure.
- It was proposed, in the short-term to medium-term, that the existing main canal (Trawal section) on the left bank continues to supply the existing and proposed additional left bank irrigation areas upstream of 'Verdeling' at Trawal. This is more economical than to serve such irrigators from the proposed Right Bank Canal. In the long-term the complete phasing out of the left bank main canal may be a possibility.

Following the preliminary reconnaissance assessment and initial desktop analysis of the canal route, possible sub-options for each of the canal components were also considered and were investigated further during a site visit. An options analysis was conducted to confirm the preferred route for the conveyance (refer to the *Conceptual Design Sub-report*). The proposed Right Bank Canal Scheme involves the following components to convey water from the Bulshoek Weir to the existing syphon at Verdeling:

- The existing intake works to the canal system, i.e. outlet works at the Bulshoek Weir.
- Upgrading of a portion of the existing Left Bank Canal to accommodate the design flow.
- A new syphon and pipe bridge across the Olifants River.
- A new Right Bank Canal from the syphon to the current outlet of the existing syphon at Verdeling.
- A combination of two concrete culvert syphons and short canal reach to cross the Doring River.
- Modifications to the existing syphon outlet at Verdeling to increase the head of the syphon.

The description of the various sub-components of the Right Bank Canal Scheme are given in **Table 5.5** and depicted in **Figure 5.2**.

Table 5.5: Right Bank Canal Scheme sub-components

Outlet Works
Existing outlet works at 0.00 km
Canal (Section 5 of Sub-report)
Upgrade existing Left Bank Canal (3.05 km long reach from 0.00 km to 3.05 km)
New Right Bank Canal Reach 1 (18.56 km long reach from 3.35 km to 21.91 km)
New Right Bank Canal Reach 2 (0.68 km long reach from 23.18 km to 23.86 km)
New Right Bank Canal Reach 3* (8.85 km long reach from 24.70 km to 33.55 km)
Syphon 1 (Section 6 of Sub-report)
New steel pipe syphon with pipe bridge (300 m long from 3.05 km to 3.35 km)
Syphon 2 (Section 6 of Sub-report)
Syphon 2A – new concrete box conduit (1.27 km long from 21.91 km to 23.19 km)
Syphon 2B – new concrete box conduit (840 m long from 23.86 km to 24.70 km)
Existing Syphon (Section 7 of Sub-report)
Existing steel syphon at Verdeling at 33.55 km

* Existing Doring River canal section replaced by new Right Bank Canal

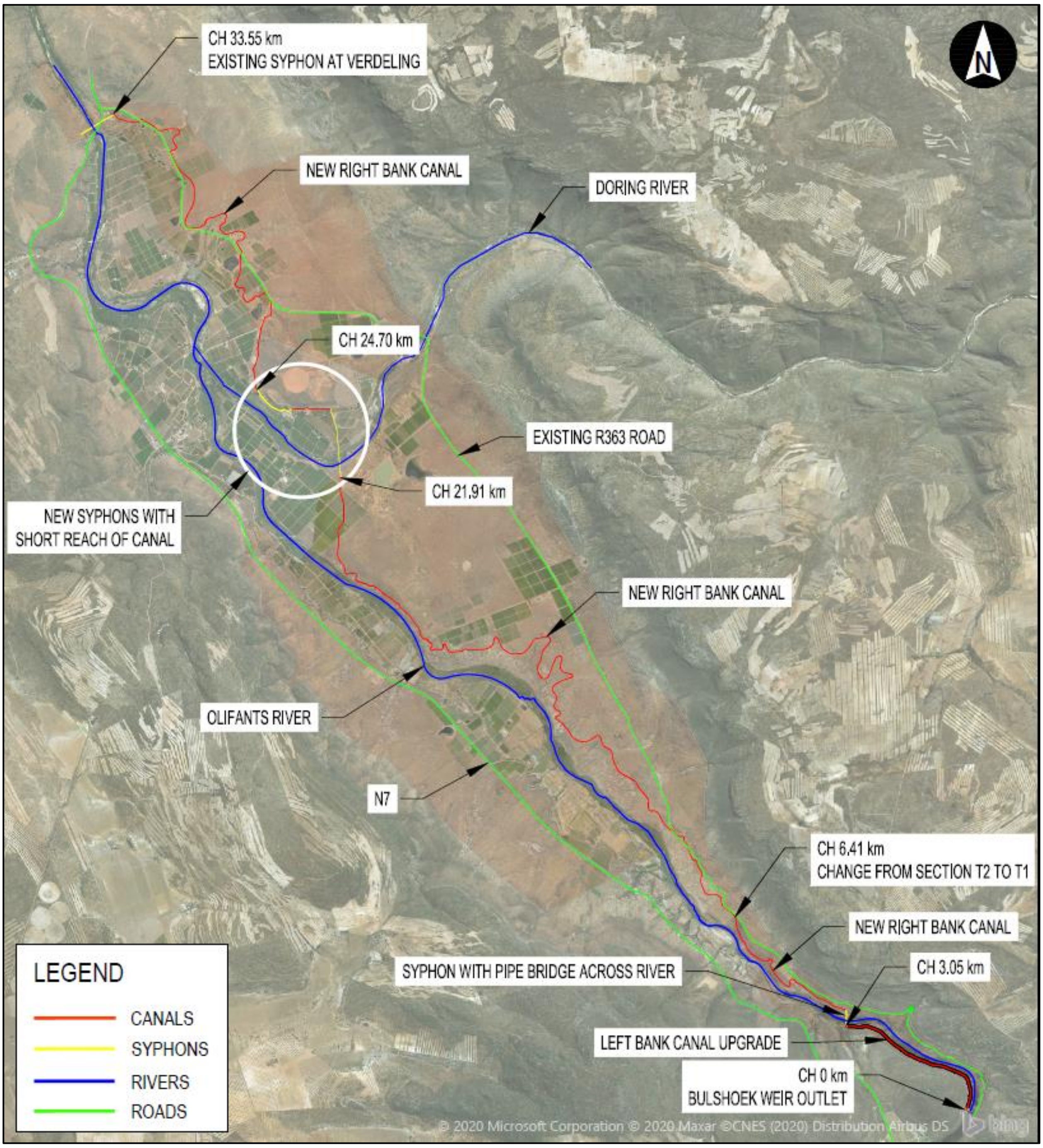

Figure 5.2: Right Bank overall scheme layout

5.3 Canal Routing, Hydraulics and Design

The routing of the canal is north, north-west from Bulshoek Weir to the existing syphon at Verdeling. Refer to Drawing No. 113838-0000-DRG-CC-0001 in **Appendix A** for the detailed routing and **Figure 5.3** and **Figure 5.4** below for a view of the typical terrain of the proposed canal route.

Figure 5.3: Typical topography looking upstream from the right bank of the Olifants River (at approx. ch. 3.0 km)

Figure 5.4: Typical topography looking upstream from the right bank of the Olifants River (at approx. ch. 17.0 km)

The vertical alignment of the canal requires a constant gradient to convey the design flow, with syphons at locations where the required slope cannot be sustained. The design of the canal is optimised (for cost of construction) by undertaking a cut/fill balance for the earthworks of the canal, based on the optimum horizontal and vertical alignments.

The alignment was defined using the topographical survey undertaken for the project and a design slope of 1:5 000. The canal was designed to be constructed with a cross-sectional cut and fill balance as close to zero as possible. As the invert level of the canal follows a gradual slope, naturally there will be some stretches where the canal will be either mostly in cut or in fill. At the fill stretches, culverts will be placed along the vertical alignment of the canal. This allowed for the drainage of the upstream catchments that would be cut off from the natural drainage paths if the canal were to follow the contours at watercourse crossings. Either box or pipe culverts will be provided at these embankment crossings. The basic sizing of the culverts and of cross drainage are described in **Section 5.3.8** of the report.

5.3.1 Bulshoek Weir Outlet Works and Available Hydraulic Energy

The Bulshoek Weir (**Figure 5.5**) was constructed in 1924. No details of the actual founding conditions were recorded at the time. The weir has a history of leakage through the rock foundation. A new mass concrete apron was constructed from 2003 to 2005 and detailed records of the exposed bedrock were captured. Due to its age and the condition of the weir, it would be risky to blast in the vicinity of the weir to construct a new outlet to serve the proposed Right Bank Canal.

The sluice gates used to control the flow into the existing main canal appear to be in good condition. It is unlikely to be feasible to increase the water level in the canal immediately downstream of the outlet works for the following reasons:

- The level of the outlet works relative to the canal provides access to storage in Bulshoek Weir. This is necessary to balance releases from Clanwilliam Dam, and to utilise runoff from the Jan Dissels River and other tributaries downstream of Clanwilliam Dam.
- The level of the intake works relative to the canal is dictated by the existing outlets of this historical structure and it is very unlikely that these levels can be changed.

The existing outlet works (**Figure 5.6**) has five sluice gates (**Figure 5.7**), each estimated to be 1.5 m wide and 2.0 m high. The total width of the outlet works is approximately 17.5 m. The LORWUA advised that the maximum capacity of the canal is 26 000 m^3/h (i.e. 7.222 m^3/s). Assuming an orifice opening height of 0.284 m with all five sluice gates open and a difference in water level height of 3.6 m (upstream water level at dam full supply level and downstream water level at full canal depth including freeboard), the existing outlet structure will have a flow of 11.5 m^3/s. Based on this calculation, it appears that the existing outlet structure does not need to be modified to release the peak design flow of 11.4 m^3/s into the proposed Right Bank Canal. The water level immediately downstream of the five sluice gates is controlled by the gates themselves and is approximately 61.0 masl. This level was used as the starting level for the design.

Figure 5.5: Concrete masonry Bulshoek Weir

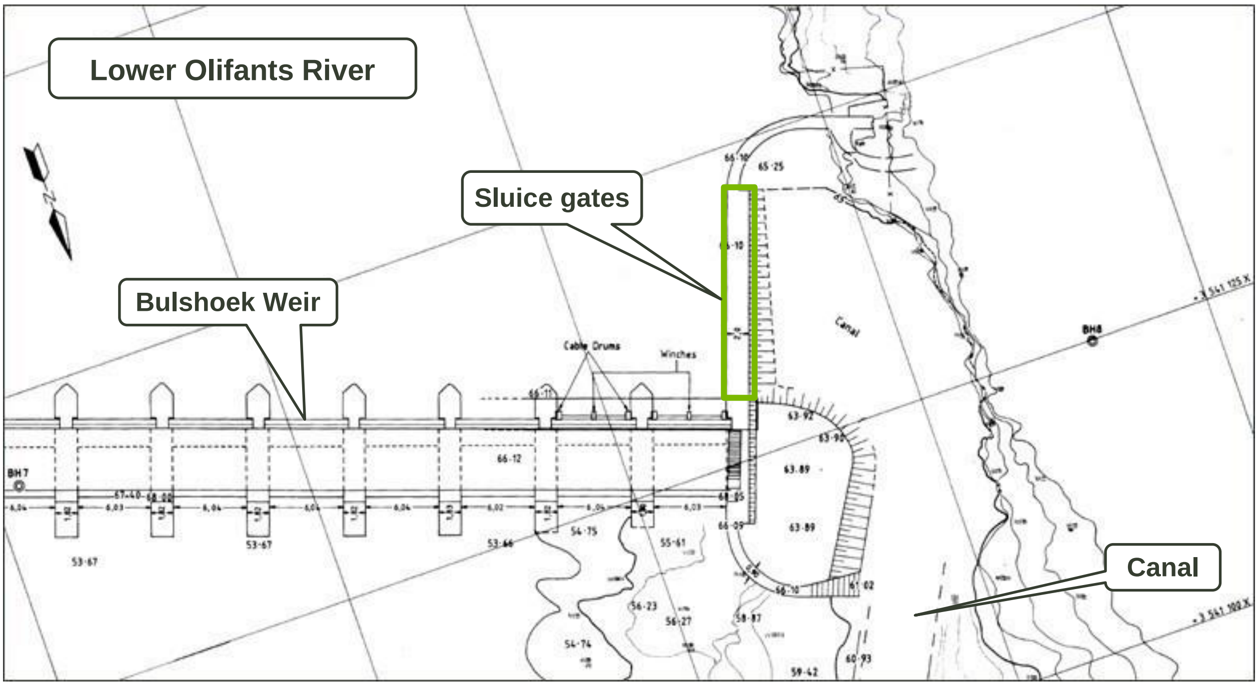

Figure 5.6: Plan view of Bulshoek Weir showing existing outlet structure

Figure 5.7: Bulshoek Weir outlet structure sluice gates

It is important to note that the Bulshoek Weir is a national monument. For the betterment works project previously undertaken on the dam structure, it was a requirement that the aesthetics of the Bulshoek Weir not be affected. It is assumed that a similar restriction will be applied to any construction works affecting the weir as it currently stands and operates.

5.3.2 Vertical Alignment

The hydraulic gradient of the open channel is dictated by the canal slope. A slope of 1:1 000 to 1:5 000 is typical for medium to large irrigation canals (Chadwick et al., 2013).

The slope between the upstream water surface elevation (61.0 masl) at the start of the existing canal, at the outlet of the Bulshoek Weir, and the existing Verdeling Syphon is 1:5000, which has been used for the hydraulic design of the Right Bank Canal. This slope is fairly flat and requires a relatively large canal cross-section and relatively low flow velocities. It can be expected that the canal will require more frequent maintenance as the low velocities will result in suspended solids being deposited. However, the lower velocities may improve the effective life of the canal lining and joint seals.

5.3.3 Horizontal Alignment

Canals generally need to follow contours to achieve the required slope but should be aligned for optimal economy. This is done by optimising and balancing the cut and fill volumes of excavated material. The water carrying section of the canal profile should preferably be in cut and the excess material should be used for the access road and side drains. The geology and soil materials play an important role in the optimisation.

In addition to the material factors, canal construction plant has an influence on the minimum allowable radius of the canal alignment. The radius should be larger than 60 m, but 80 m is recommended by the DWS for machine-lined canals. For hand-lined canals, the radii should be greater than three times the top width of the canal.

Instead of following the contours, syphons can be introduced to shorten the canal length over valleys. A typical value of syphon length to canal length of 1:4 proves to be economical (SWADE, 2015).

Similar to syphons, deep cuttings through hills can be used to shorten the canal length. In general, an aspect ratio of 1:8 proves to be economical (SWADE, 2015).

As shown earlier in **Figure 5.2**, for the first 3 km the horizontal alignment of the proposed new main canal will follow the current horizontal alignment of the existing Left Bank Canal. The existing canal would however need to be upgraded to ensure that it can accommodate the increased capacity required for the additional irrigation and other users. The canal would maintain its trapezoidal cross-section, but would be widened for the additional flow, and its lining must be rehabilitated to reduce the likelihood of future canal breaks.

After approximately 3.05 km, the main canal will cross the Olifants River by means of a pipe bridge and follow the contours of the right bank. The topography is still quite steep, and a deeper and narrower trapezoidal canal section will be used.

After about 6.41 km the valley opens up and is flatter, and more favourable terrain becomes prevalent. The main canal will then follow the natural contours. The alignment crosses the Doring River at approximately 21.91 km with a syphon, followed by a short reach of canal and another short syphon to avoid a steep sandy hill. From approximately 24.70 km to the Verdeling Syphon at 33.55 km, the canal again follows the natural contours of the land. The canal reaches are shown in **Figure 5.2** and **Table 5.6**Table 5.6 provides a summary of the canal reaches and their chainage.

Table 5.6: Summary of canal reaches and chainage

Reach	From Chainage (km)	To Chainage (km)
Left Bank Upgrade	0.00	3.05
Right Bank Reach 1	3.35	21.91
Right Bank Reach 2	23.18	23.86
Right Bank Reach 3	24.70	33.55

5.3.4 Canal Hydraulics and Cross-section

Normal flow conditions in the canal are calculated using the Manning formula. The Manning formula provides a hydraulic relationship between velocity, bed slope and hydraulic radius. For an initial concrete surface finish, a Manning n-value friction factor of 0.014 has been found to be generally acceptable. A value of 0.015 gives satisfactory results to account for natural deterioration with time. A Manning n-value of 0.015 was used as the design value for the canal.

A parabolic cross-section is the optimum cross-section as it yields the smallest cross-sectional area and perimeter. This cross-section shape is usually limited to depths not exceeding 2.0 m as construction becomes difficult. The trapezoidal section is closest to that of a parabola and easy to construct. Therefore, the trapezoidal section was chosen.

Optimisation of the canal profile needs to take into account the best hydraulic section, cost of lining and excavation, as well as the best cut and fill balance. The natural cross fall slope will also limit the total width of the canal corridor (including allowance for service roads and storm water). In steep natural cross fall slopes, a narrower cross-section is needed, sometimes even a rectangular section.

It is normal practice to attempt a cut and fill balance in a canal profile taking into consideration the cross fall slope of the natural ground. Where possible, the water carrying portion of the canal must be in cut. The cut-and-fill balance is usually achieved with a road on the downslope of the canal.

The width of the roadway is dictated by the vehicle size and traffic. This road will predominantly be used for inspection and maintenance purposes. Storm water drains on the upslope side are vital to prevent the ingress of storm water into the canal and are included in the canal profile.

For the entire canal route, a trapezoidal cross-section is proposed to convey the design flow. It should be noted that the bottom slope of the canal stays fixed at 1:5000. This trapezoidal canal was divided into two types of cross-section based mainly on side slope and bottom width. Because of this, the two types of cross-section have different hydraulic characteristics. Due to different hydraulics, the freeboard also differs for each canal type. Refer to **Figure 5.8** and **Table 5.7** for the differences between the two types of trapezoidal canals recommended. A drawing of the canal cross-section is included in **Appendix A** (Drawing No. 113838-1000-DRG-CC-0001). The differences between the two types of canal are summarised as follows:

- Canal type T1 is a shallower section with flatter side slopes, proposed for the flatter, more open topography found in the lower Olifants River valley. Type T1 is recommended from about chainage 6.41 km in Reach 1 up to the end of Reach 3 at Verdeling.
- Canal type T2 is a deeper section with steeper side slopes, minimising the total section width. This section is proposed for the steeper, more extreme topography found in the relatively upper valley of the Olifants River just downstream of the Bulshoek Weir. Type T2 is recommended for the upgrading of the existing Left Bank Canal up to chainage 3.05 km, and then again on the right bank from chainage 3.35 km to about 6.41 km.

Geological conditions along the route on the right bank are expected to be variable. Generally, the landscape is characterised by more gently sloping topography. Geological profiles are expected to predominantly comprise sandy soils, which may vary to comprise gravelly sands in places. Hard rock might also be encountered, especially at deeper excavations.

In terms of excavation conditions, and referring to **Section 3** (excavation considerations of the new Right Bank Canal), hard rock may be expected anywhere between 0.3 m and 2.0 m depth, or deeper, according to the refusal of the test pits, but more precise tests need to be conducted to confirm this. Furthermore, the test pits' side wall instability showed that caution should be taken in the shallow unstable soil conditions. Regular inspection of the cut faces by a competent geotechnical person and other stabilisation measures, such as shoring of temporary excavations, benching, or other support measures, would be required during excavation.

The slopes adjacent to the Left Bank Canal are generally characterised by scattered outcrop of hard rock quartzitic sandstone. It can be assumed that excavation to widen the Left Bank Canal will therefore require heavy ripping or even blasting, i.e. 'hard excavation'. A key consideration for blasting adjacent to the already-weak Left Bank Canal is the risk of damaging these canals. Great care will have to be exercised in blasting close to this canal. As with blasting for the new Right Bank Canal, consideration would also have to be given to the stability of these blasted rock faces.

Table 5.7: Canal sections - design parameters*

Parameter	Symbol (refer to Figure 5.8)	Type T1	Type T2
Canal Shape		Trapezoidal	Trapezoidal
Canal Slope		1:5 000	1:5 000
Bottom width (m)	b	2.8	5.0
Side slope (1V:xH)	x	1:1.5	1:0.5
Top flow width (m)	B1	8.64	6.82
Top canal width	B2	9.91	7.22
Flow depth (m)	y	1.945	1.824
Flow velocity (m/s)		1.025	1.057
Froude number		0.288	0.269
Freeboard (m)		0.423	0.396
Total depth (m)	D	2.370	2.220
Fill slope (1V:S_{FILL})	S_{FILL}	1:1.5	1:1
Cut slope (1V:S_{CUT})	S_{CUT}	1:1.5	1:1
Roadway width (m)	W_{ROAD}	4.0	1.5 (no road)

* *Dependent on geotechnical findings*

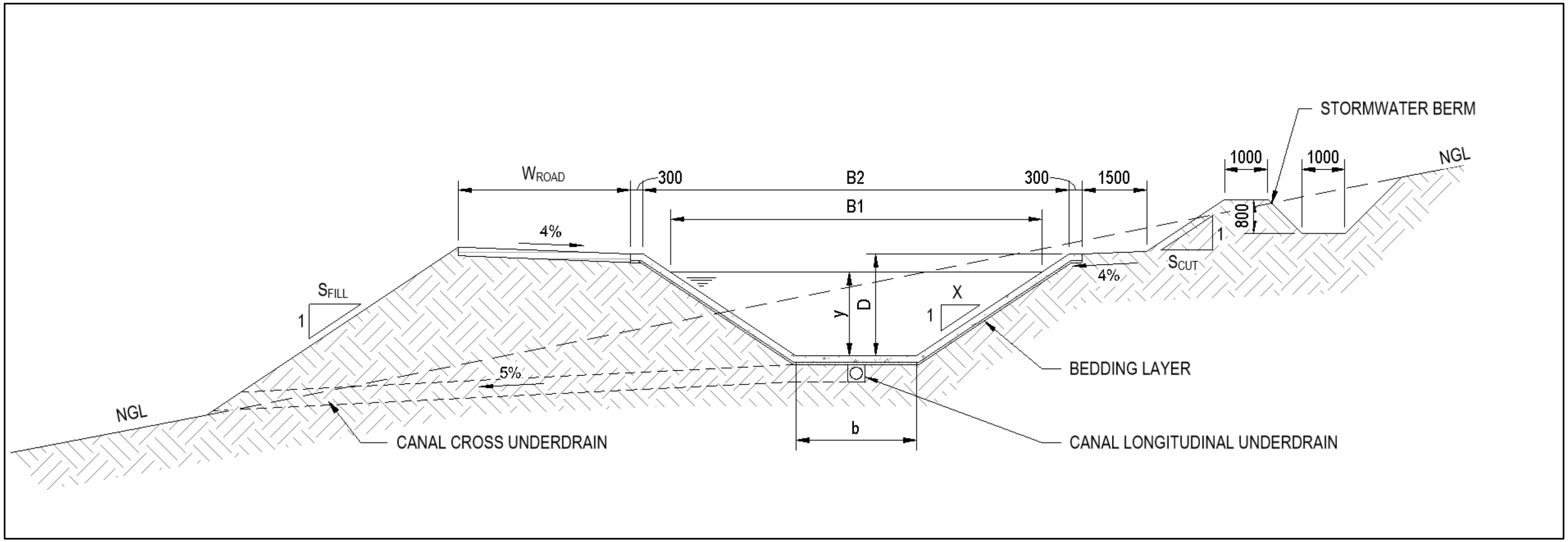

Figure 5.8: Trapezoidal canal cross-section (Types T1 and T2)

5.3.5 Canal Freeboard

Freeboard is provided in canals to allow for possible runoff from the roadway, accommodation of waves or periodic operational overloading in times of unusual heavy irrigation demands.

There are several freeboard equations and the following has been investigated:

- A 20% overload + velocity wave action (current DWS practice);
- Normal loading velocity wave action + curve wave action (SANRAL Drainage Manual).

With each canal cross-section, the greater of these two values was used as the canal freeboard to avoid any risk of overtopping due to velocity and curve wave action at bends in the canal. Due to the larger freeboard value being used, a 20% overload could be allowed for short periods of time.

5.3.6 Canal Lining

The main objective of providing a concrete lining in a water supply canal is to limit seepage losses. Concrete was selected as the material for the lining of the canal and construction joints in the lining should be sealed.

Forces acting on canal linings are caused by:

- An uneven settlement of the supporting soil;
- Expansive clays underlying and surrounding the canal;
- Shrinkage of the concrete during hydration; and
- Hydrostatic pressure behind the lining due to a high groundwater table and empty or partly empty conditions in the canal.

Canal linings should be designed to accommodate these forces. Recommendations from DWS are as follows:

- For up to 0.5 m in lining depth, use 60 mm thick concrete lining;
- For 0.5 m to 1.5 m in lining depth, use 75 mm thick concrete lining;
- For greater than 1.5 m in lining depth, use 100 mm thick concrete lining.

The design water depth in the new Right Bank Canal will range from 1.82 m to 2.00 m.

As South Africa currently lacks an approved standard for water retaining structures, the design parameters adopted for canals were dictated by BS EN 1992-3:2006, and are as follows:

- Minimum cover to reinforcement is 40 mm to water contact areas and 50 mm to soil contact areas.

- Concrete strength: 35 MPa.
- Increase in temperature due to hydration (T1): 25°C.
- For joint spacing < 4.5 m use minimum reinforcement of 2/3 x ρ_{crit}: in combination with T1.
- Maximum crack thickness: 0.2 mm.

Based on these criteria a lining thickness of 150 mm and mesh reinforcement of Y10 at 200 mm (Mesh ref. 617) is recommended. Construction joints should be spaced at 3.0 m, contraction joints at 9.0 m and expansion joints at 27 m. A wood float finish will be satisfactory.

Polymer coal-tar (hot-pour) type joint sealant should be used with an IR hardness value between 5 and 15. An expanded polyethylene (10 mm thick) strip should first be installed at the exposed concrete side faces of the first casting before the intermediate slabs are cast. The top 30 mm should then be reamed and filled with the polymer coal-tar (hot-pour) sealant. This type of joint will be watertight and will allow for expansion and contraction.

Interlocking of panels is recommended. Dowel bars of size R16 should be installed at 300 c/c across the joints. The bars should be sleeved on one side and cast into the concrete at the other to allow for axial movement at the joints.

5.3.7 Typical Canal Underdrainage

Longitudinal underdrainage should be installed along the full length of the canal to avoid floatation of the canal panels caused by buoyancy forces. The canal will also affect normal drainage paths of percolated rain and irrigation water, which will build up below the canal lining if not effectively drained.

The proposed single longitudinal underdrain will consist of a 300 mm deep by 300 mm wide boxed drain, lined with 3.4 mm thick (Bidim type) geofabric filled with 19 mm aggregate, with the geofabric overlapped at the top. The longitudinal drain will run along the centreline of the canal invert for the entire length of the canal, except where the canal is in fill. Standard practice is to make use of a stone drain below the concrete lining. The drain is made up of a perforated DN200 pipe surrounded by an aggregate layer wrapped in a geotextile. The drain width is a minimum of 300 mm and the height is at least that of the pipe diameter. The perforated pipe allows the ingress of water and conveys the water to the outfall. The perforations must be smaller than the smallest sized aggregate. The geotextile layer prevents the ingress of soil to prevent blockages of the subsurface drainage leading to lining failure.

Cross drains must be provided regularly, typically every 200 m. The spacing thereof must be optimised during the detail design phase. These cross drains typically consist of a DN200 mm pipe with a slope of at least 1% downhill away from the cut side to daylight on the fill side. These pipes should either be connected to the longitudinal drainage pipes with tee pieces or be placed end to end, wrapped in 3.4 mm thick (Bidim type) geofabric, as shown in **Figure 5.9** and **Figure 5.10**.

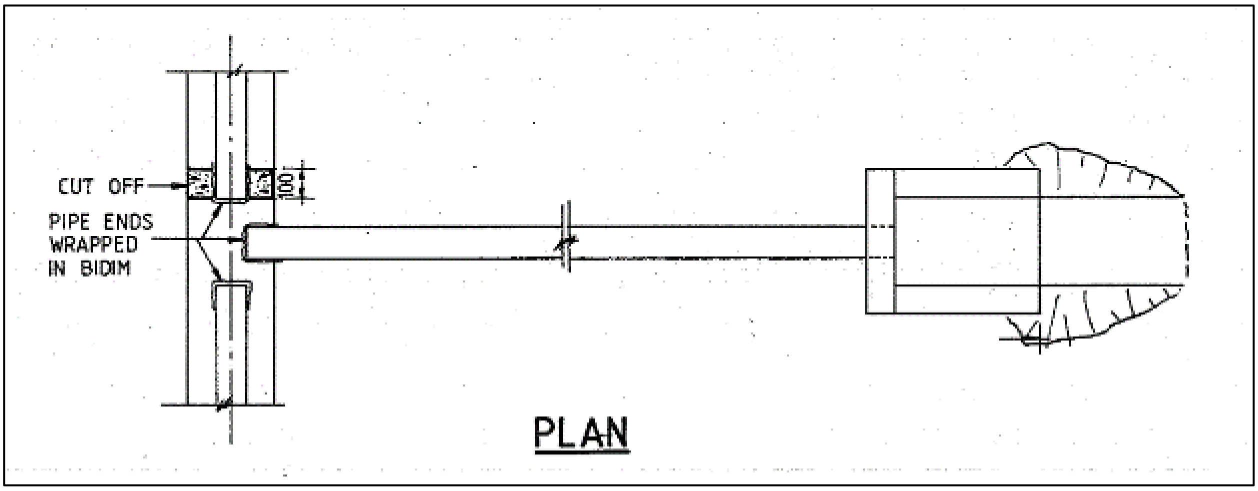

Figure 5.9: Typical longitudinal and cross underdrain connection

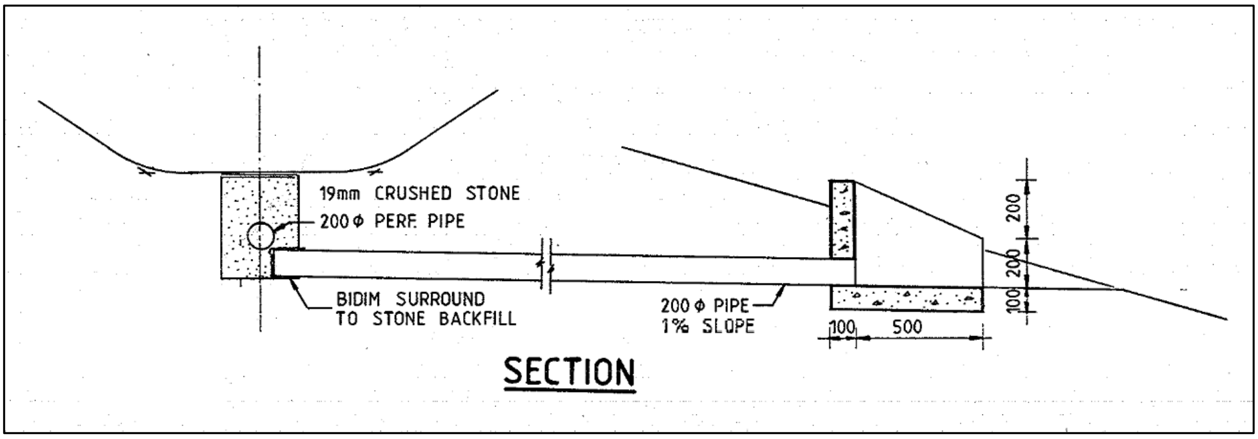

Figure 5.10: Typical section through cross underdrainage

Maintenance of the canal needs to be done regularly, and the canal will need to be drained in order to do this. The subsurface drainage needs to drain subsurface water away effectively to prevent lining failure. The aggregate drain will convey the water slowly and unevenly compared to a pipe. Therefore, a stone drain with a perforated pipe, with solid wall pipes to daylight at positions where the canal is in fill will be more effective. The water will be directed away and consequently the pressure will be relieved.

The underdrainage should be analysed in more detail during the detailed design phase of the project. The solution listed above is a typical solution for lined canals.

5.3.8 Storm Water Cross-Drainage Culverts

The new canal will inevitably create catchments for storm water on natural slopes or when crossing natural drainage lines. In this case the catchments will be on the right side of the canal. To account for this, a storm water drain shall be constructed. In the case where the canal is in cut, this drain shall be located where the cut day lights to the natural ground level. In the case where the canal is in fill, the drain shall be placed at the bottom of the fill. See **Figure 5.8** in **Section 5.3.4** for the location of this storm water drain. The drain shall be trapezoidal in shape, with a bottom width of 1 000 mm and a depth of 1 000 mm. The side slopes shall be 1:1 and sufficiently protected from erosion by means of either a concrete lining or drop structures, depending on the slope and flow characteristics.

In order to convey the 1:20 year peak runoff from the north eastern ridge, a series of culvert pipes ranging from 600 mm diameter to 1 050 mm diameter would need to be placed along the canal route at low points. This amounts to 73 culvert crossings. All culvert pipes would need to be encased in concrete below the canal with at least 200 mm clearance around the pipes.

To avoid differential settlement of the canal at these encased pipes, a 150 mm layer of soft board between the concrete casing and the canal bedding is recommended.

5.3.9 Overhaul and Limited Haul

A cut-fill balance is important for the economy of the canal. It is not always possible to achieve a balance due to the topography of the natural ground together with other design parameters. When a cut-fill balance cannot be achieved, material needs to be imported where there is more fill than cut, or spoiled where there is more cut than fill. The locations where the material is imported from or spilled are called borrow pits and spoil areas respectively.

The route of the canal achieves a cut-fill balance over several reaches, indicating that there will be very limited mass haul needed. Where fill is needed under the canal, the material can be obtained by the cut material in adjacent canal reaches.

5.3.10 Flow Measurement

Flow measurement should be incorporated into the design of the canal to improve the water management of the system. All flow measuring structures should be Crump Weirs.

A minimum of four flow measurement locations are recommended for the canal:

1. Directly downstream of the Bulshoek Weir where the existing Parshall Flume must be replaced by a Crump Weir;

2. On the existing Left Bank Canal, downstream of the inlet to the pipe bridge syphon, to measure flow to existing farms on the left bank;
3. On the new Right Bank Canal, directly downstream of the pipe bridge syphon; and
4. On the new Right Bank Canal, directly upstream of the existing Verdeling syphon inlet.

If practical, it would be optional to place more measuring stations along the route to verify usage.

Flow measurement will also aid in the detection and management of losses in the canal. Ideally flow measurement structures should be provided at each of the new canal off-takes (refer to **Section 5.4**) to improve the performance monitoring of the canal and improve the water management of the system.

The use of Crump weirs for flow measurement was investigated, and is recommended, as opposed to Parshall flumes. **Figure 5.11** shows a typical Crump weir and a drawing is included in **Appendix A** (Drawing. No. 113834-1000-DRG-CC-0004). The following advantages and disadvantages were identified:

Advantages of Crump weirs:

- Easy to construct compared to the construction effort required for Parshall flumes;
- Relatively low cost when compared to Parshall flumes;
- Flow measurement is very accurate, even at low heads;
- A wide range of flow rates can be measured over a Crump weir; and
- Crump weirs can be used in conjunction with off-takes, rejects and emergency spillways without compromising the accuracy of the flow measurement.

Disadvantages of Crump weirs:

- A relatively higher head loss occurs over a Crump weir compared to a Parshall flume;
- Siltation can occur behind a Crump weir which will require cleaning during canal maintenance downtimes; and
- Drainage of the canal can be problematic with the use of Crump weirs and the use of bypass pipework or stop logs should be further investigated.

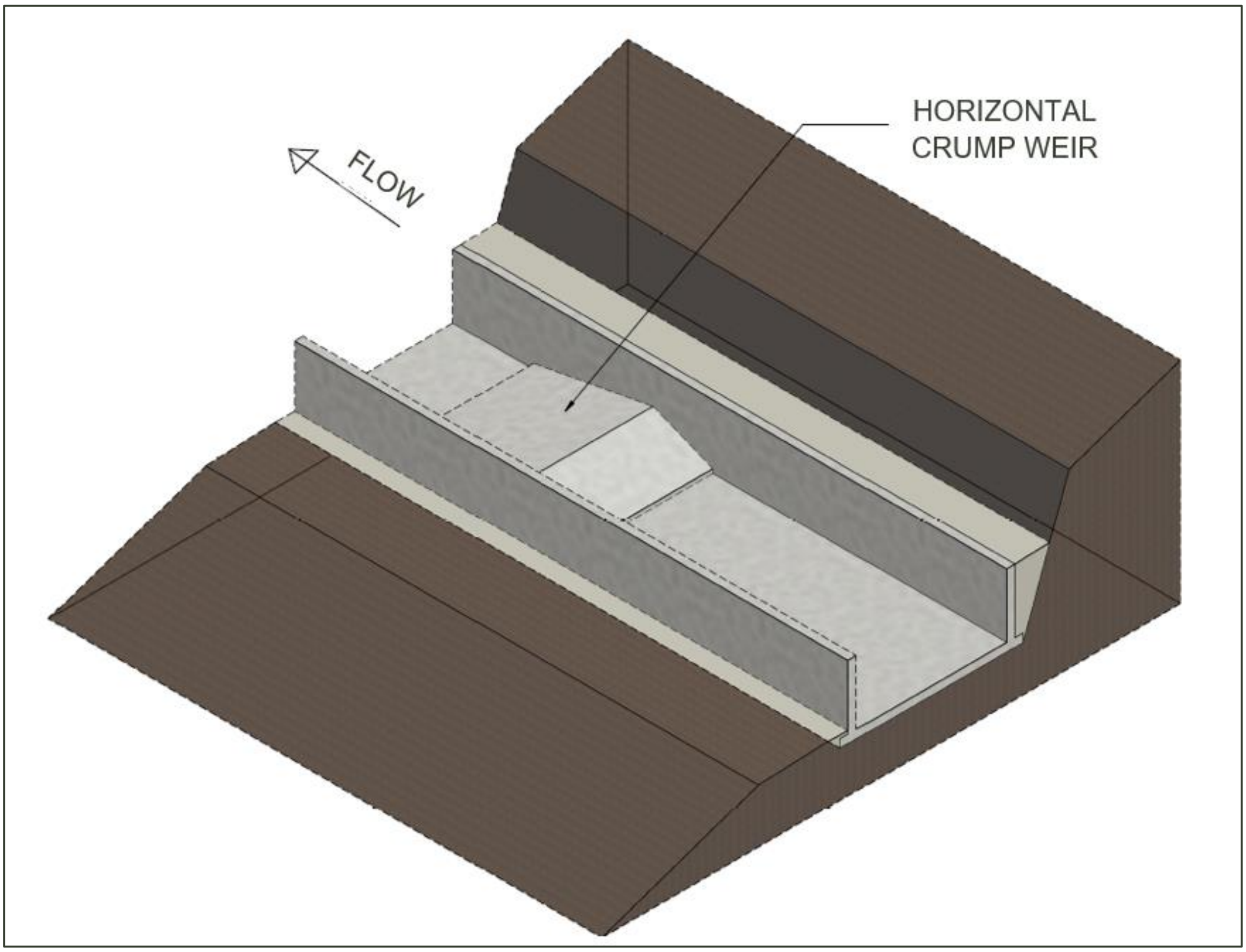

Figure 5.11: Typical Crump weir located on the Right Bank Canal

5.3.11 Rejects

Long weir rejects were investigated and proposed at all syphon inlets. These rejects will be placed on the wall of the canal directly upstream of these inlets. The length of the reject weir will be optimised so that the water level does not fluctuate too much when rejecting flow. At the same time erosion protection will be provided to safely convey the flow back to a natural water course.

5.3.12 Canal Access Road

A 4.0 m wide canal service road next to the canal is planned. This road will link to existing roads at locations where the canal crosses these roads. It is envisaged that the service road will be used as access road during the construction of the canal.

5.3.13 Special Considerations of the Left Bank Canal Upgrade

There are some other considerations that are particular to the upgrading of the Left Bank Canal (as shown in **Figure 5.12**), most notable the fact that the existing canal would be closed during construction. To overcome this, it would be necessary to pump water from the Olifants River into the existing canal downstream of the 3 km section to be upgraded.

Figure 5.12: Existing Left Bank Canal looking downstream (approx. ch. 1.2 km)

The historical weekly flows (average from 2006/07 to 2015/16) in the main section of the existing canal are shown in **Figure 5.13** (starting in the first week of October). Based on the assumption that the construction for the upgrade of the Left Bank Canal would take place only during the winter months, i.e. the low-flow period, then a flow of approximately 12 000 m^3/h (3.33 m^3/s) would need to be pumped temporarily from the Olifants River to the canal. This flow would need to be lifted by 20 m, over a distance of 75 m.

It is estimated that upgrading of the canal could be completed during the 20-week low-flow period. However, there is a potential risk of delays during construction resulting in higher costs related to temporary pumping. Based on the assumption that upgrading of the Left Bank Canal will occur over two low-flow seasons, the temporary pumping capital costs would be approximately R34 million, with an estimated R15 million operating cost. The operating cost was calculated based on the use of a diesel generator. Alternative electrical power supply sources will need to be investigated for the temporary pumping.

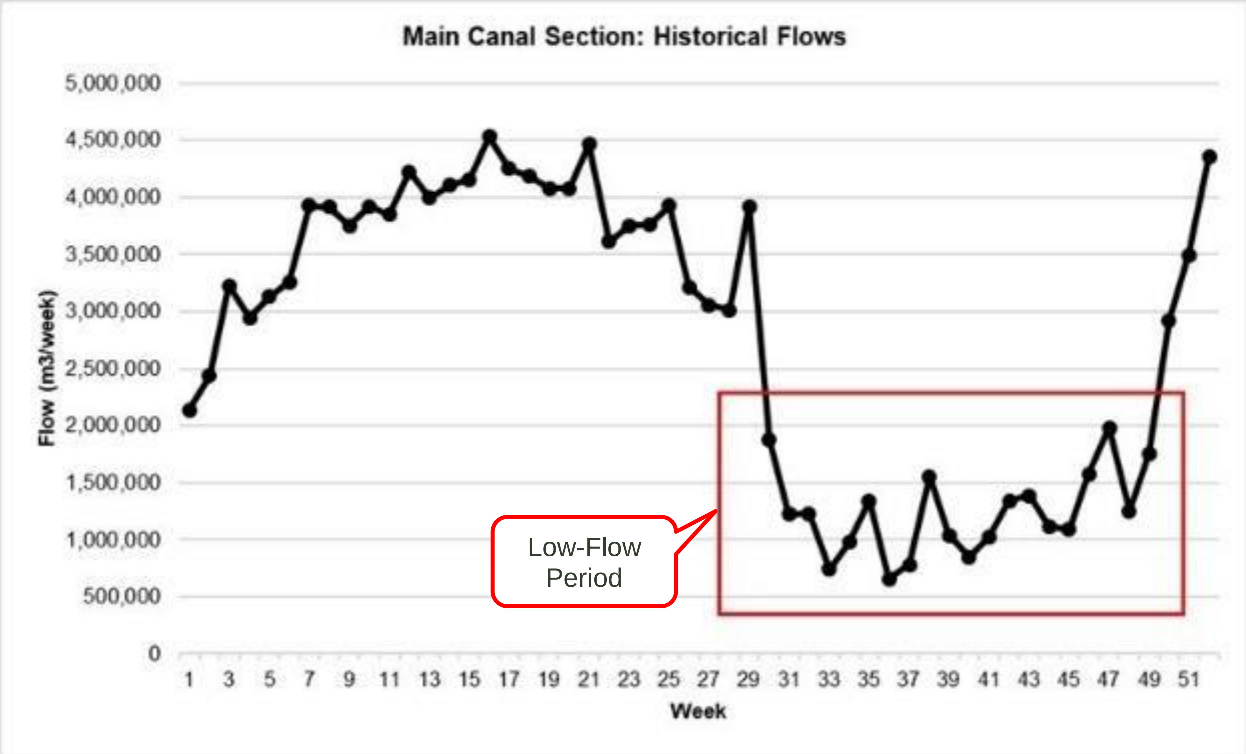

Figure 5.13: Main canal section – historical weekly flows

A further consideration is access to the left bank, but the existing access road next to the canal can be used. The road is quite bumpy and will need to be smoothed for construction.

5.4 New Canal Off-takes

New off-takes from the canal will be required to supply the irrigation blocks of the proposed development options, such as the new irrigation schemes in the Trawal area (refer to **Table 5.8**). The off-takes will either be supplied under gravity or via a pump system due to the topography of the irrigation areas.

Table 5.8: Off-take demands for new irrigation developments

Off-take	Average flow (m^3/s)	Peak flow (m^3/s)
Zypherfontein 1	0.201	0.437
Zypherfontein 2	0.186	0.355
Trawal	0.154	0.404
Melkboom	0.166	0.360

5.4.1 Gravity off-takes

The gravity off-takes comprise an intake bay protected by a galvanised screen, an off-take chamber, an outlet pipe, a flow meter and chamber downstream of the intake chamber. **Figure 5.14** provides an example of a typical off-take chamber. The off-take chambers are fitted with a sluice gate to isolate the off-take for maintenance purposes.

The level at the off-takes should be controlled to ensure a constant flow to the irrigators. A long weir is often built diagonally into the main canal just downstream of the off-take to control this level. Where the weir is too long in relation to the width of the canal, a mirrored diagonal weir is constructed and is called a 'duck bill weir'.

Duck bill weirs are proposed downstream of the off-takes to control the flow depths at the intakes of the off-take chambers. The weirs should be designed for the full design flow of the canal. The weir should be fitted with a sluice gate at the canal bed level for scouring and dewatering purposes. The dewatering sluice gate is sized to drain the canal in a required time frame. A typical layout of the proposed weirs is shown in **Figure 5.15**.

The height of the weir is sized according to the minimum head required at the off-take structure discharge. The crest length is determined by the allowable variation in the head and the flow which is to overtop the weir. The acceptable variation in head is to limit the flow variation between 95% of the required flow under adverse conditions and 105% under favourable conditions. Based on orifice flow theory, the head on the off-take opening should thus not vary by more than 20%.

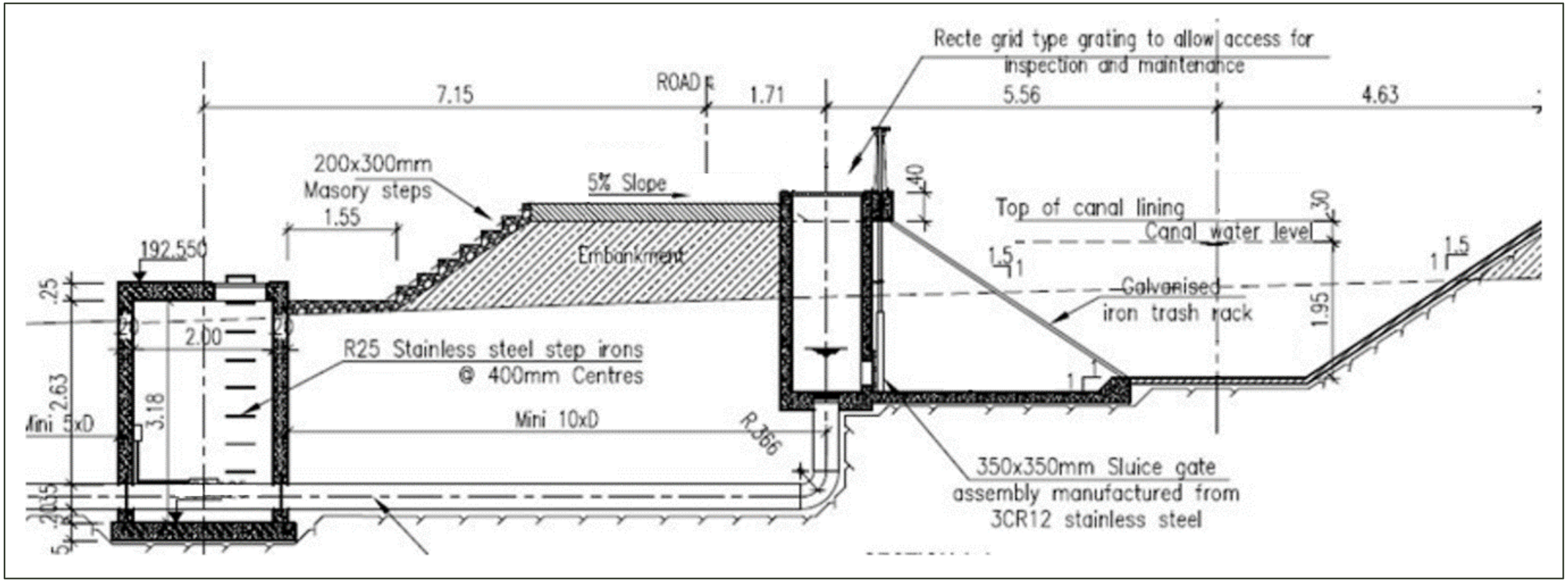

Figure 5.14: Example of typical off-take structure

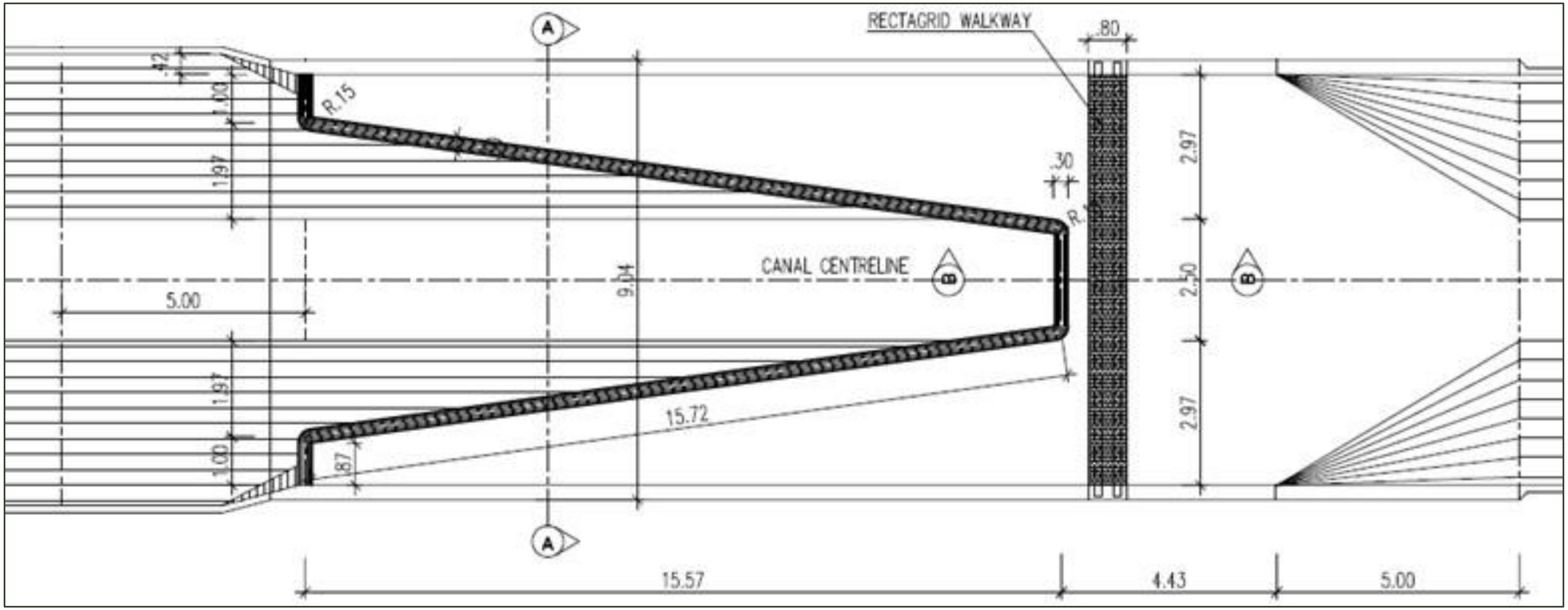

Figure 5.15: Example of a typical duckbill weir

5.4.2 Pump Station Off-takes

For the pump station off-takes, self-priming pumps with individual suction pipelines could be installed directly in the canal or in a wet well perpendicular to the canal. The sizing of the suction pipes and inlet bell mouths are determined based on the required flow rates. The required suction pipes and inlet bell diameters, the minimum submergence and distance from the inlet bells to the canal floor should be calculated based on the recommendations of the ANSI/HI standard. The suction pipelines should be sized to obtain an approximate flow velocity of 1.5 m/s and USBR bell mouths are assumed for the inlet bells.

A typical elevation and layout of a pump station design is shown in **Figure 5.16** and **Figure 5.17**. Please note that these figures are just typical pump stations and it is recommended that each self-priming pump has its own individual suction pipe with a proper off-channel intake sump.

The following are recommended for the pump stations:

- The pump stations should be formally designed and constructed pump stations for proper maintenance and security purposes.
- The pump stations should be provided with proper off-channel intake sumps that are designed to optimise the suction conditions that influence the performance and expected life of the pumps.

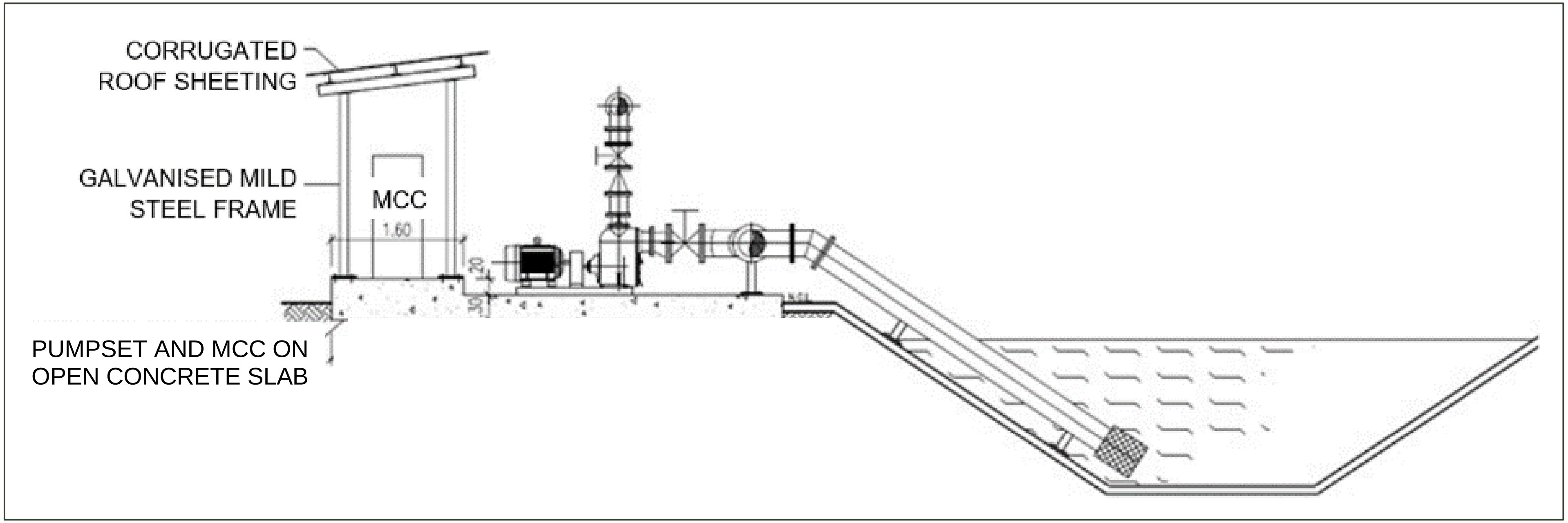

Figure 5.16: Typical pump station elevation

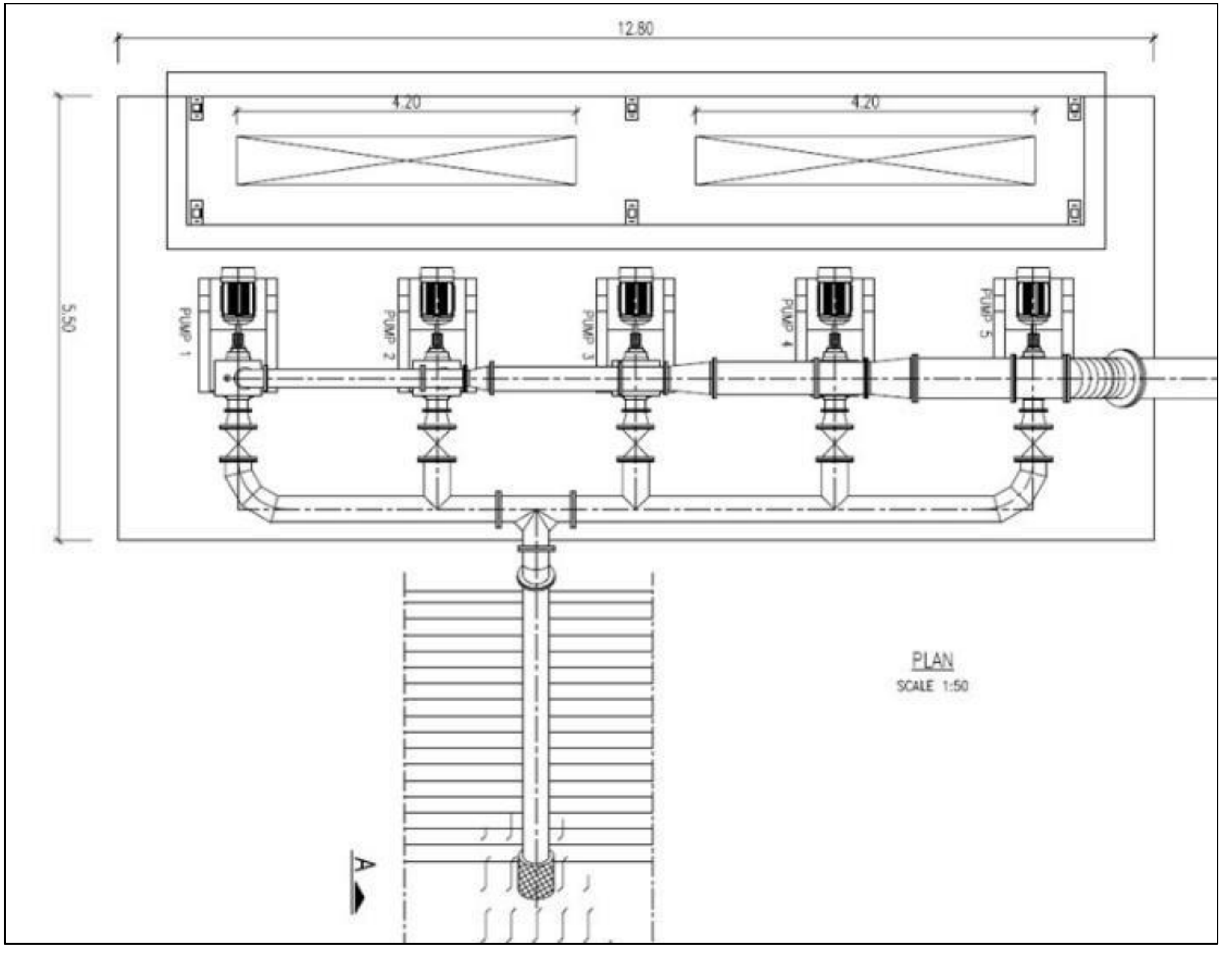

Figure 5.17: Typical pump station layout (with only a single suction pipe)

5.4.3 Flow Measurement

The flow at each off-take should be measured as part of the canal management. Flow meters should be able to measure flows accurately for the wide range of potential flows expected at the off-take. Open channel flumes and ultrasonic flow meters are recommended.

A single chord ultrasonic flow meter should be installed downstream of each off-take. The flow velocity in the pipe must be between 1.5 and 5.0 m/s to ensure accurate measurement. The most accurate measurement would be in the middle of this flow range. In addition, a straight pipe length of 10D should be allowed upstream and 5D downstream of the meter.

5.5 Existing Infrastructure Affected by Canal Alignment

Figure 5.18 shows the existing infrastructure that will be affected by the canal alignment, which includes the major components described below.

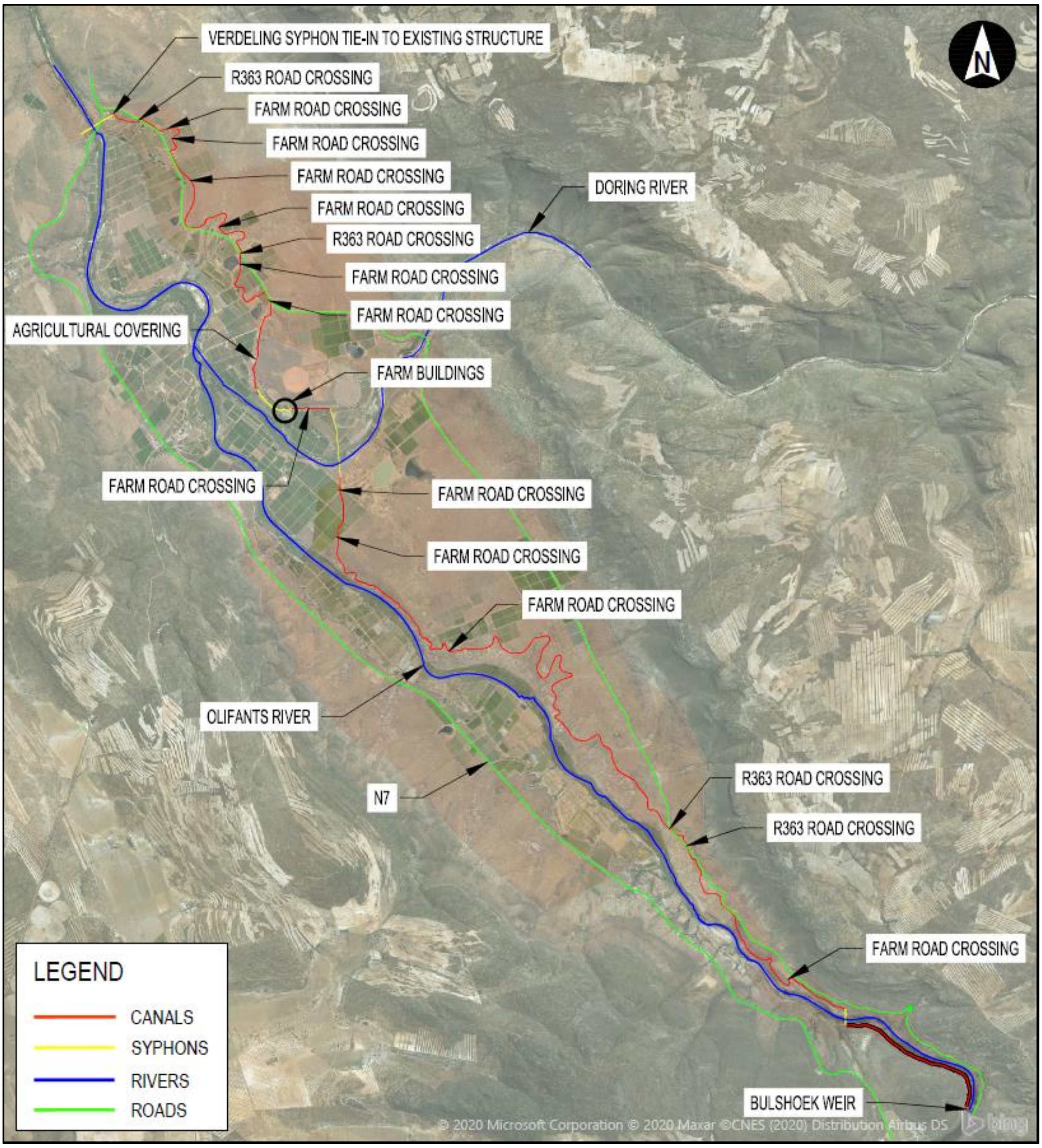

Figure 5.18: Existing infrastructure affected by the Right Bank Canal route

5.5.1 Bulshoek Weir

It is expected that DWS will be the owner of the scheme and that it will be operated by LORWUA. Thus, no issues are foreseen with additional water supply from the Bulshoek Weir.

5.5.2 Existing Left Bank Canal

Upgrading of the existing Left Bank Canal (3 km) will require the use of the existing access road during construction.

5.5.3 R363 Provincial Road and Farm Roads

The proposed Right Bank Canal will cross the existing R363 Provincial Road at various places, and the canal will be located next to the road in some sections. The R363 is owned by the Western Cape Department of Transport and Public Works. Approval will be required from the provincial roads department for construction of the road crossings and other possible construction works in the road reserve.

The proposed canal crosses the R363 a total of four (4) times and it crosses major farm roads a total of 11 times. A bridge needs to be provided at each of these crossings. A typical crossing is shown in **Figure 5.19** and the locations of the crossings in **Figure 5.18**.

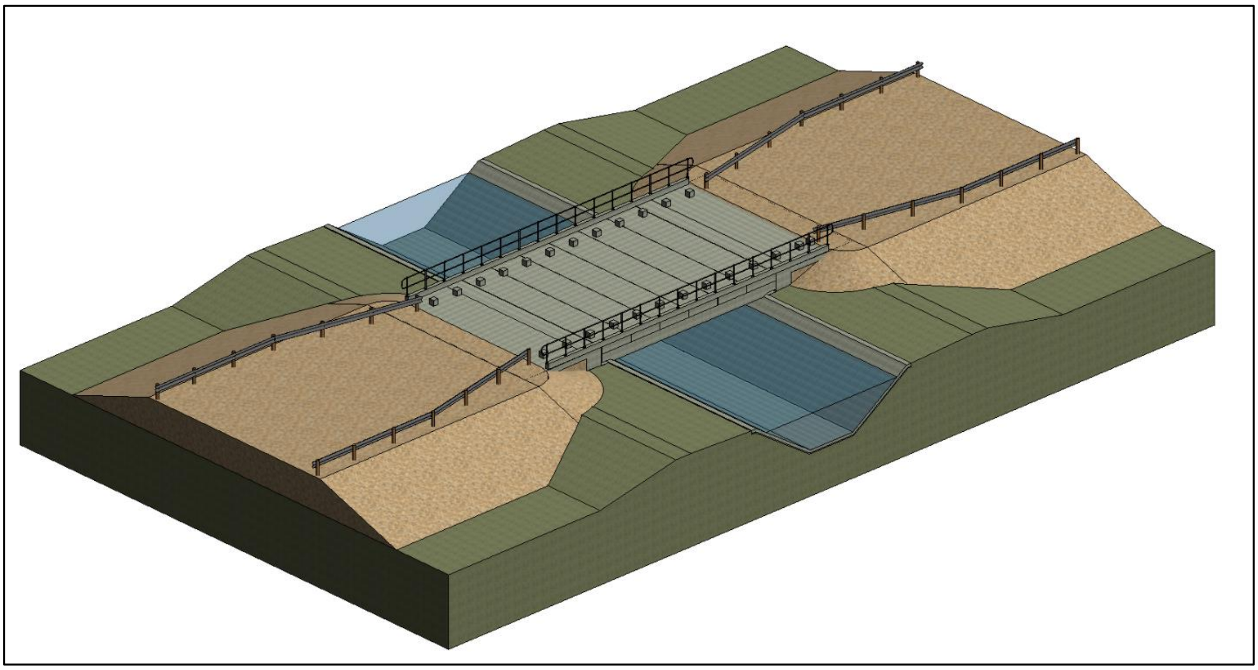

Figure 5.19: Typical basic road crossing

5.5.4 Farm Owners

The horizontal alignment for the proposed Right Bank Canal runs through privately owned farms. Land and servitudes for the canal will need to be acquired from these landowners. Compensation for the land acquired will include infrastructure affected by the project.

5.5.5 Existing Syphon at Verdeling

No issues are expected with obtaining permission from DWS and LORWUA for modifications required to the existing syphon at Verdeling to allow flow in the syphon to be reversed.

6 Syphons

Syphons are required in two sections along the new Right Bank Canal route:

1. Syphon 1 (S1) crosses the Olifants River at approximately 3.05 km downstream of the Bulshoek Weir;
2. Syphon 2A (S2A) crosses the Doring River; and
3. Syphon 2B (S2B) avoids a steep, sandy hillside shortly after the Doring River crossing.

6.1 Routing of Syphons

The routing of Syphon 1 is north, north-east from the existing main Lower Olifants River Canal on the left bank of the Olifants River to the right bank of the river. It is located between chainage 3.05 km and 3.35 km. It includes a 46 m stretch of concrete encased steel pipe, a 120 m long pipe bridge, followed by a 133 m long stretch of concrete encased steel pipe.

The routing of Syphon 2A is north, north-west and crosses the Doring River between chainage 21.91 km and 23.18 km. The syphon discharges into a short reach of canal, before Syphon 2B heads north-west from chainage 23.86 km to 24.70 km. Syphon 2A and 2B are both rectangular concrete culverts.

6.2 Design Criteria

The design of the syphons is based on the criteria in **Table 6.1:**

Table 6.1: Pipe design criteria for syphons

Description	Value
Flow formula	Darcy-Weisbach
Roughness formula	Colebrook-White
Pipe/conduit material	• X42 Steel in accordance with API5L • Reinforced concrete culvert
Coating	Fusion Bonded Medium Density Polyethylene (FBMDPE) (Sintakote or equivalent) Thickness = 120 micron
Lining	Cement Mortar Lined (CML) centrifugally spun Thickness = 120 micron

6.3 Hydraulic Design

The syphon duty is based on the canal design flow of 11.4 m³/s. The syphon diameter is dependent on the available head and flow rate. The velocity and pipe roughness in the syphon directly influence the friction losses. It was necessary to ensure that the frictional losses through the syphons were minimised as far as possible to ensure that the tie-in at Verdeling has a positive head of at least 1.0 m. A scenario considering an old syphon with maximum flow and higher friction factors (aged pipe) was investigated.

Given these design parameters, and to minimise the head loss, the syphons were designed in accordance with the design parameters listed in **Table 6.2**. Refer to **Figure 6.1** for a typical cross-section of a steel pipe and **Figure 6.2** for a typical concrete culvert installation.

The concrete culvert should be cast in-situ. Water stops should be added at all joints to ensure proper sealing against any leakage at the syphon design pressures. At the detailed design phase of the project, structural analysis should be done to confirm the detail of the culvert.

Table 6.2: Syphon design parameters

Parameter	Syphon 1	Syphon 2A	Syphon 2B
From Chainage – approx. (m)	3 050	21 910	23 860
To Chainage – approx. (m)	3 350	23 180	24 700
Elevation at start (masl)	60.40	55.65	53.87
Elevation at end (masl)	59.29	54.00	52.68
Length (m)	300	1 270	840
Type	X42 Steel pipe	Reinforced concrete culvert	Reinforced concrete culvert
Shape	Circular	Rectangular	Rectangular
Size (mm)	DN 2400	2800 x 2400 (W x H)	2800 x 2400 (W x H)
Wall thickness (mm)	16	400	400
Design friction coefficient k_s (aged pipe) (mm)	0.15	2.0	2.0
Design discharge (m³/s)	11.4	11.4	11.4
Design velocity (m/s)	2.48	1.70	1.70
Design head loss, including friction and local head losses (m)	1.11	1.65	1.19

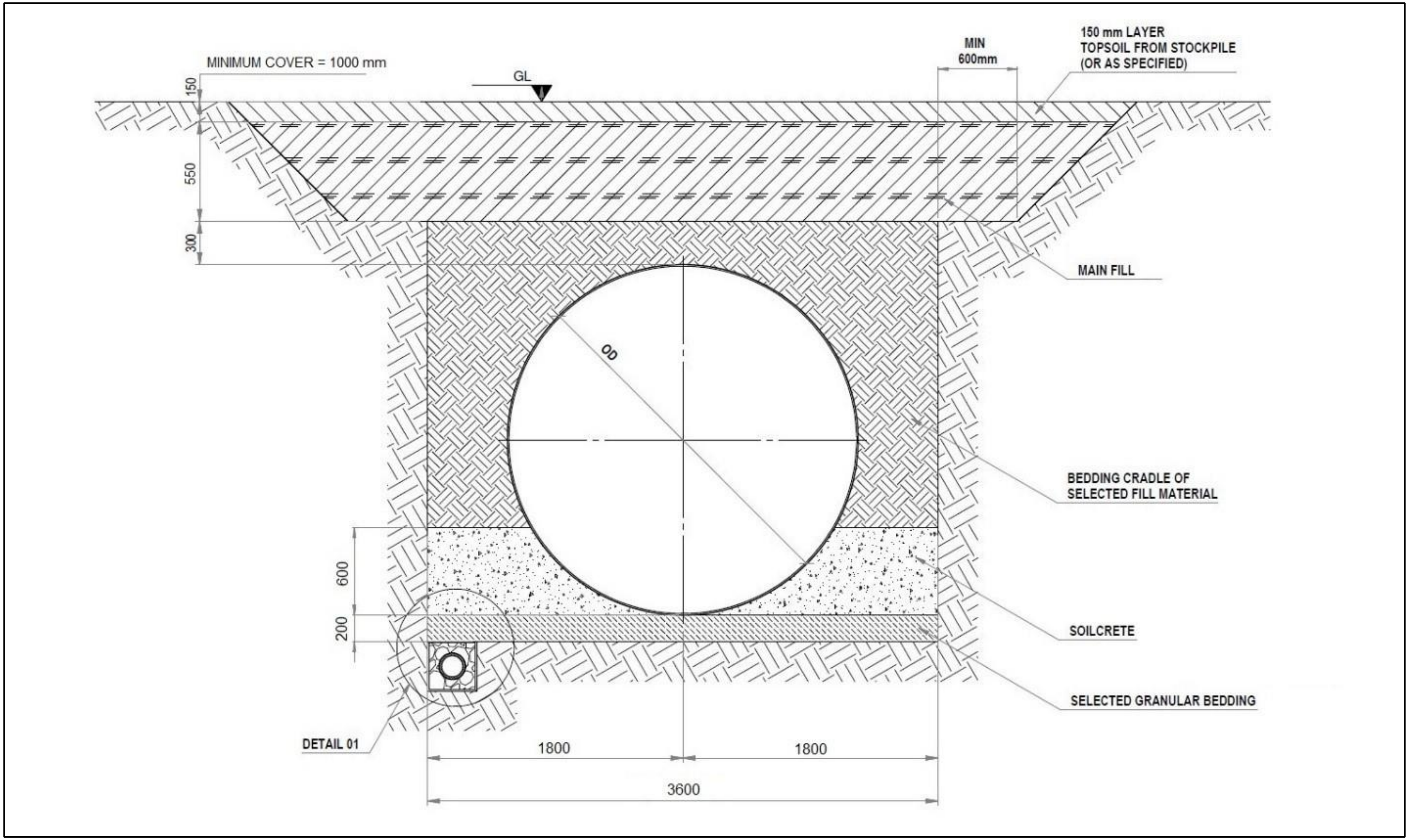

Figure 6.1: Typical cross section of Syphon 1 – underground portion of pipe installation

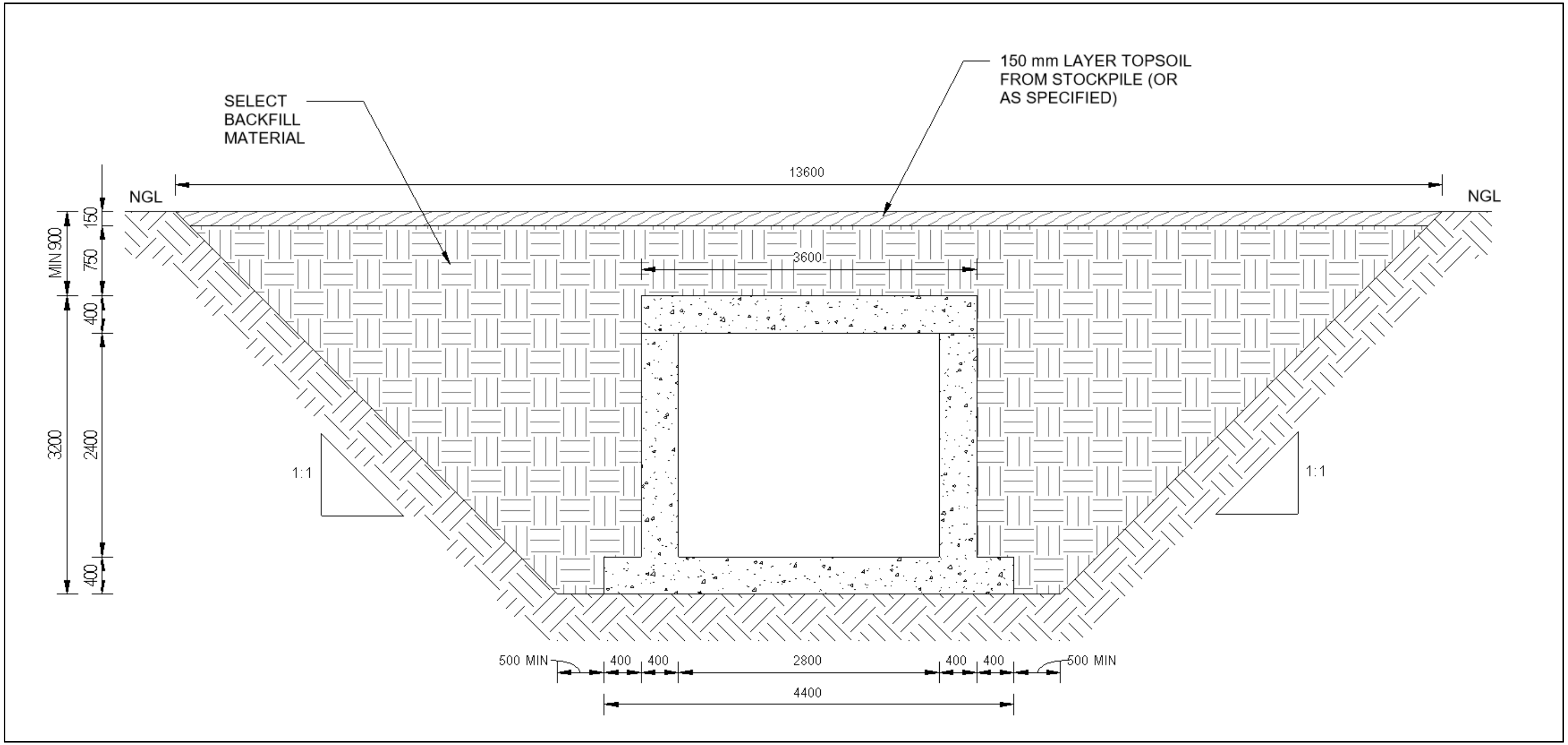

Figure 6.2: Typical cross section of Syphon 2 - rectangular portal culvert

6.4 Installations Above and Below Ground

After an options analysis was done, it was concluded that Syphon 1 should cross the Olifants River with a 120 m long pipe bridge. Up to the bridge abutments on each riverbank though, the syphon should be placed below ground. This is similar to the existing pipe bridge at Verdeling. **Figure 6.3** gives an example of a typical pipe bridge, and a drawing is included in **Appendix A** (Drawing. No. 113834-1000-DRG-CC-0010).

For above ground installations, the design of the syphon would require consideration of the following:

- Pipes supported using ring girder sections installed on concrete plinths;
- Expansion joints to be provided for thermal expansion; and
- Anchor blocks provided at all direction changes.

The options analysis also concluded that Syphon 2 should be placed below ground to allow future farming development over the syphon. The Doring River is a perennial river and it would make sense to construct the syphon below ground during the dry season. There would be no need for a pipe bridge or pipe jacking.

For below ground installations, the following considerations should be made when designing the syphon:

- A minimum cover of 1 m over the pipeline;
- The pipeline should be encased in concrete for the river crossings to protect the pipes and prevent the pipes from floating; and
- Gabions should be provided on the riverbanks to prevent erosion of the pipe trench.

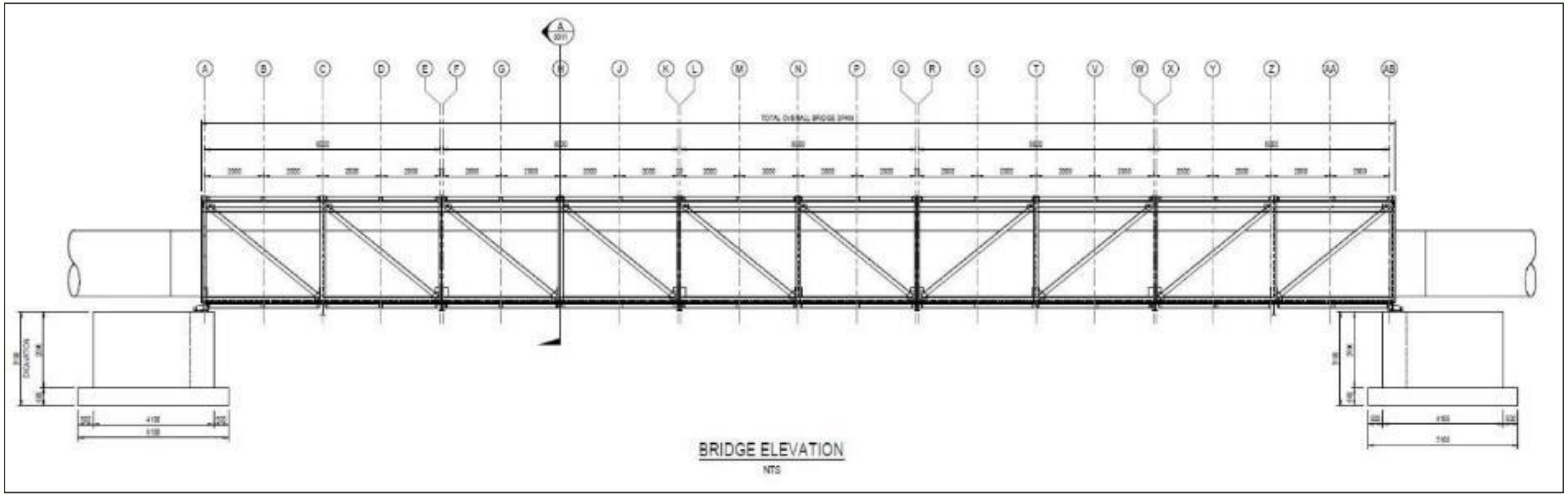

Figure 6.3: Example of typical pipe bridge

6.5 Syphon Inlet Structure

An open reinforced concrete structure is proposed for the syphon inlet. The Syphon 1 inlet on the left bank will supply flow to the Right Bank Canal, across the Olifants River, and also service the now secondary Left Bank Canal. The structure will thus have a side syphon inlet, with gates that can control the flow for either the new Right Bank Canal or the existing Left Bank Canal.

The inlet structure is to be provided with a trash rack at the entrance to screen out large floating debris and reduce possible ingress of any other foreign material into the syphon pipe. A long weir reject with erosion protection is also provided upstream of the Syphon 1 intake. Silt will be flushed out of the syphon using scour valves. A required submergence depth of 1.7 m was determined to ensure a sufficient hydraulic seal, and care should be taken to ensure that this depth is covered during detailed design. All losses through the trash rack were considered. **Figure 6.4** shows the Syphon 1 inlet while **Figure 6.5** shows the Syphon 2 inlet. A drawing of a typical syphon inlet is provided in **Appendix A** (Drawing. No. 113834-1000-DRG-CC-0006).

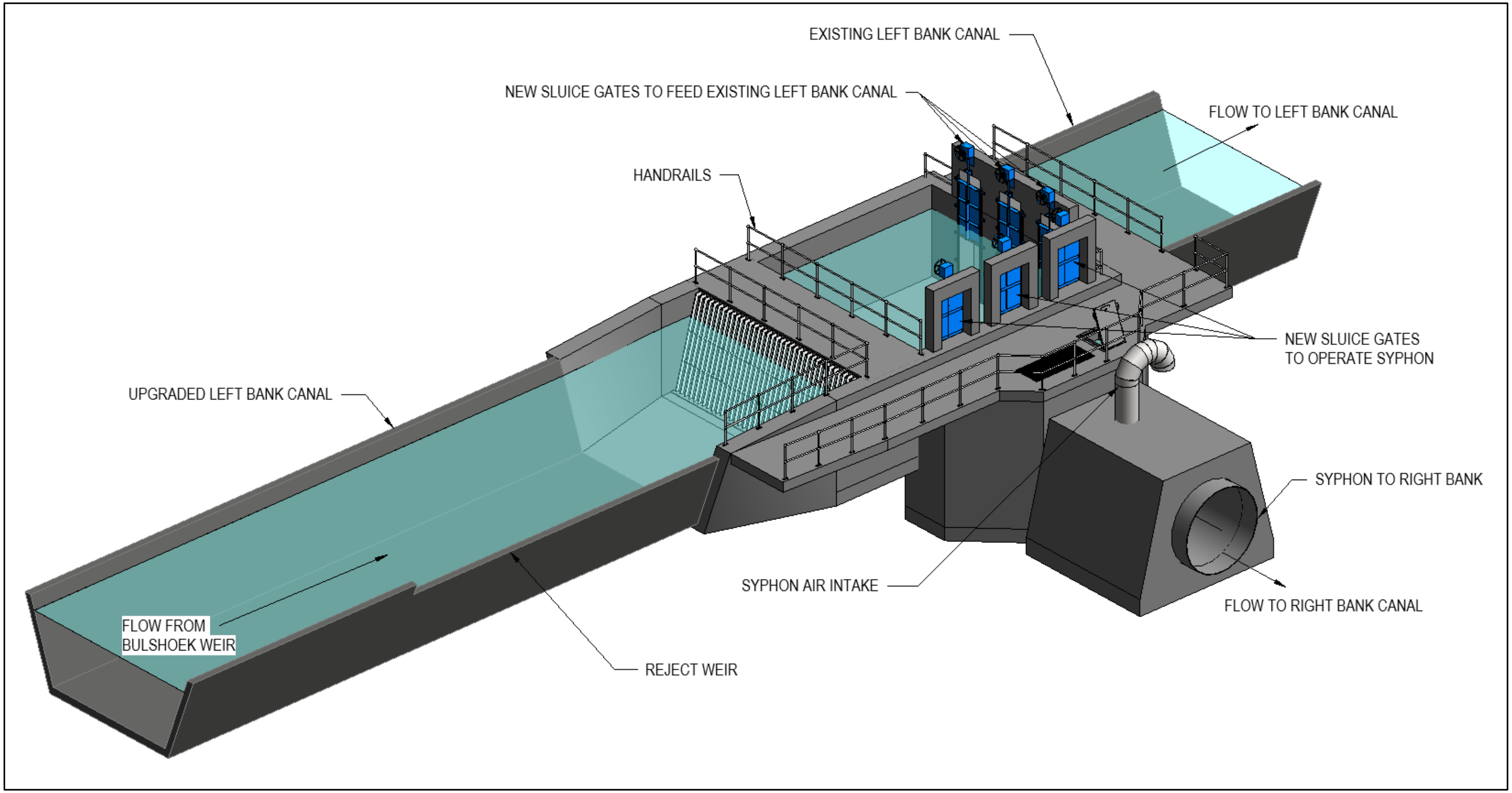

Figure 6.4: Left Bank Canal syphon inlet structure (Syphon 1)

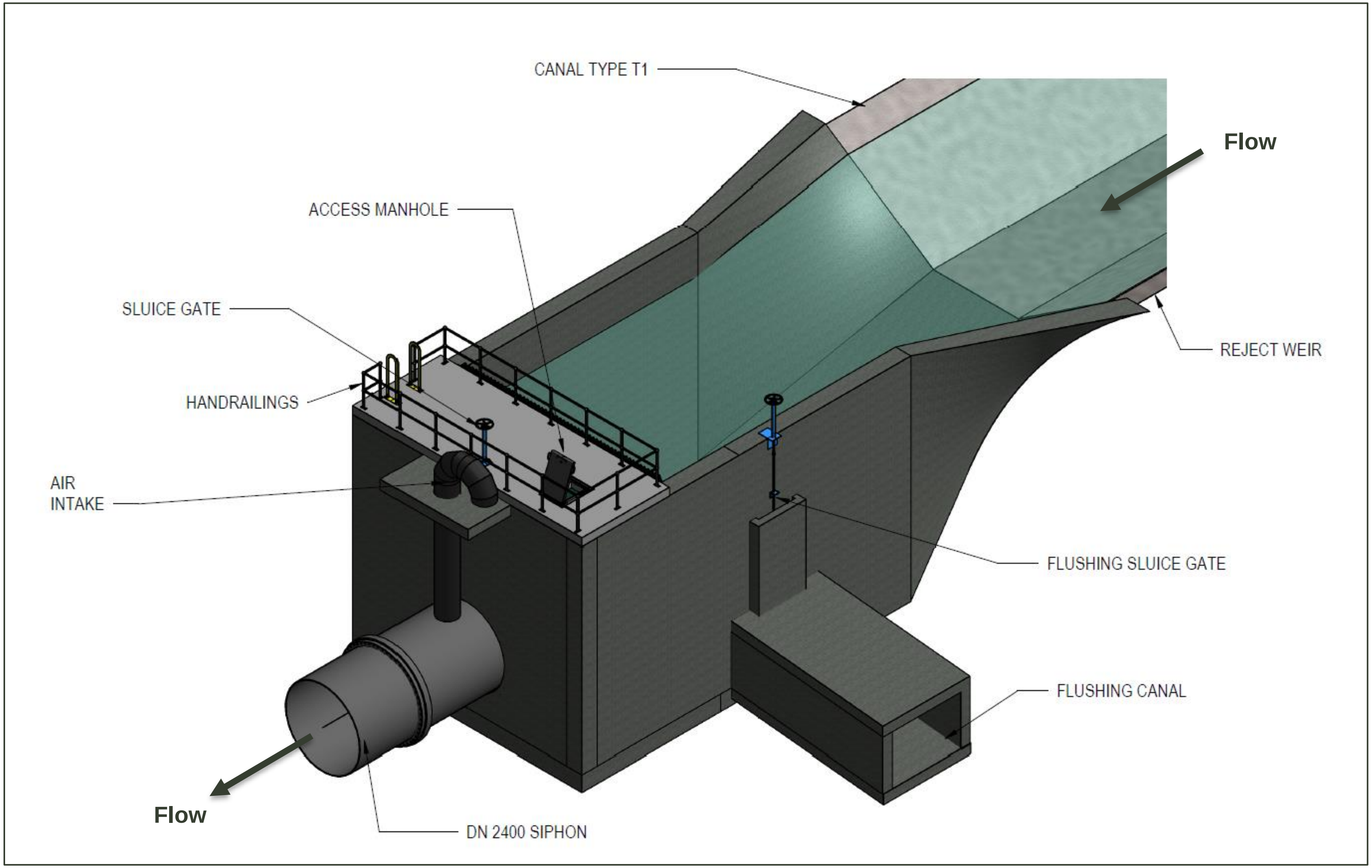

Figure 6.5: Typical inlet structure for Syphon 2

6.6 Syphon Outlet Structure

An open reinforced concrete structure is proposed for the typical syphon outlet. All three syphon outlet structures will be similar as there are no unique requirements at each outlet. **Figure 6.6** shows the typical outlet structure. A drawing of a typical syphon outlet is provided in **Appendix A** (Drawing. No. 113834-1000-DRG-CC-0007).

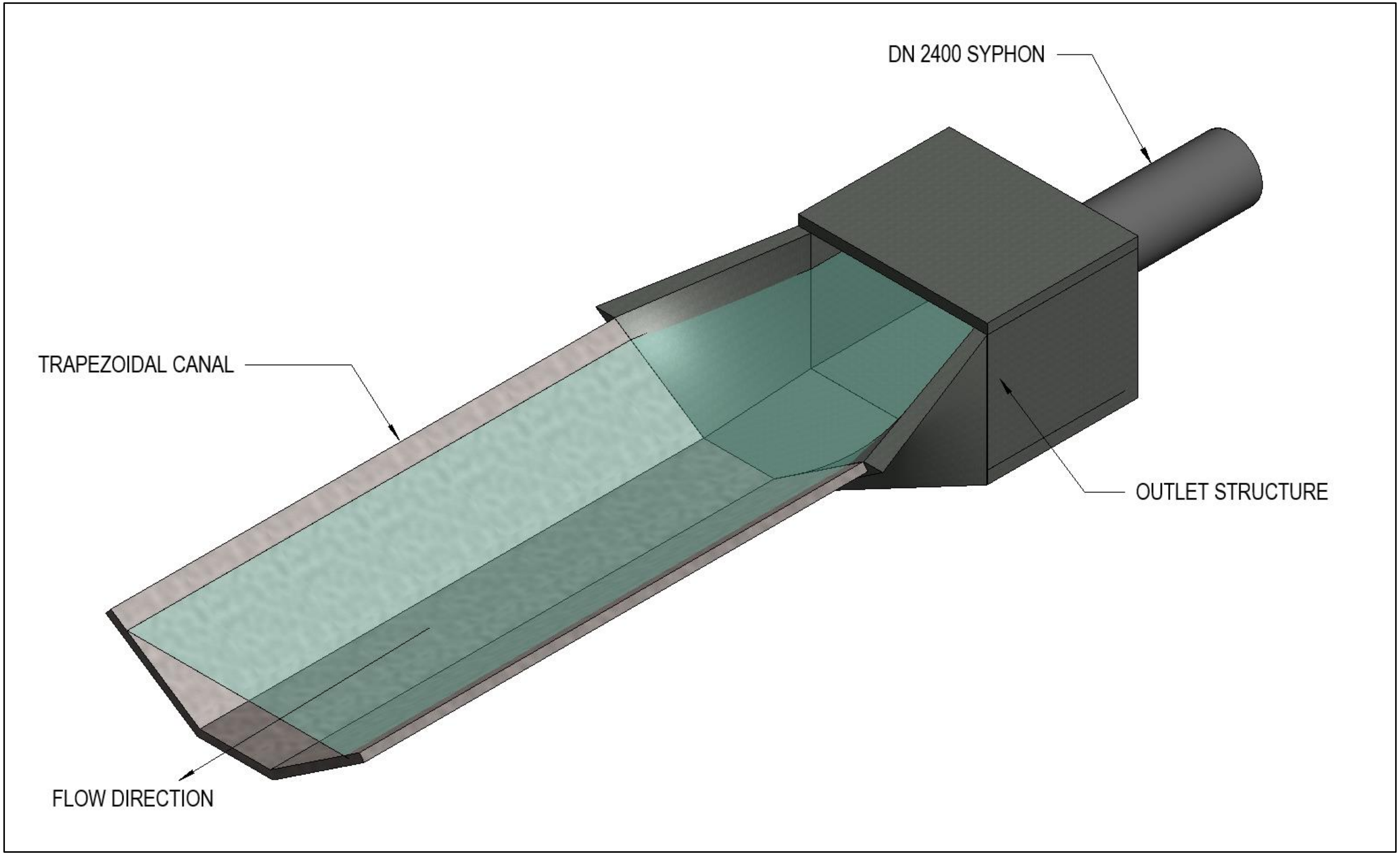

Figure 6.6: Typical syphon outlet structure

6.7 Syphon Dewatering

Allowance must be made to drain the syphons. The proposed scour installations should be designed to ensure a minimum scour velocity in the pipeline of 0.5 m/s and maximum velocity through the scour outlet not exceeding 6 m/s. A sacrificial valve will have to be added in some cases to get the velocity under the maximum scour velocity. Where necessary, scour pipework and valve diameters should be increased in order to lower friction sufficiently through the valves.

Scour valve chambers will be used to house the scour valves. Details of a typical scour chamber and mechanical arrangement are shown in **Figure 6.7**. The scour valve chamber can be optimised during the detailed design of the system.

Orifice plates should be incorporated to limit flow velocities through the valves and to prevent cavitation of the scour pipes downstream of the orifice plates. Single orifice plates will be used where the pressure is less than 30 m. Two orifice plates will be used where the pressure exceeds 30 m.

Access points should be provided on each of the syphon pipes for maintenance access. These access points will be used to drain the remaining water out of the syphon, which cannot be drained under gravity, by allowing the insertion of dewatering pumps.

The water released through the scour valves would be channelled to natural drainage channels, streams or rivers. Lined channels, to prevent erosion, will be provided to convey the water from the scour valves to the natural water courses.

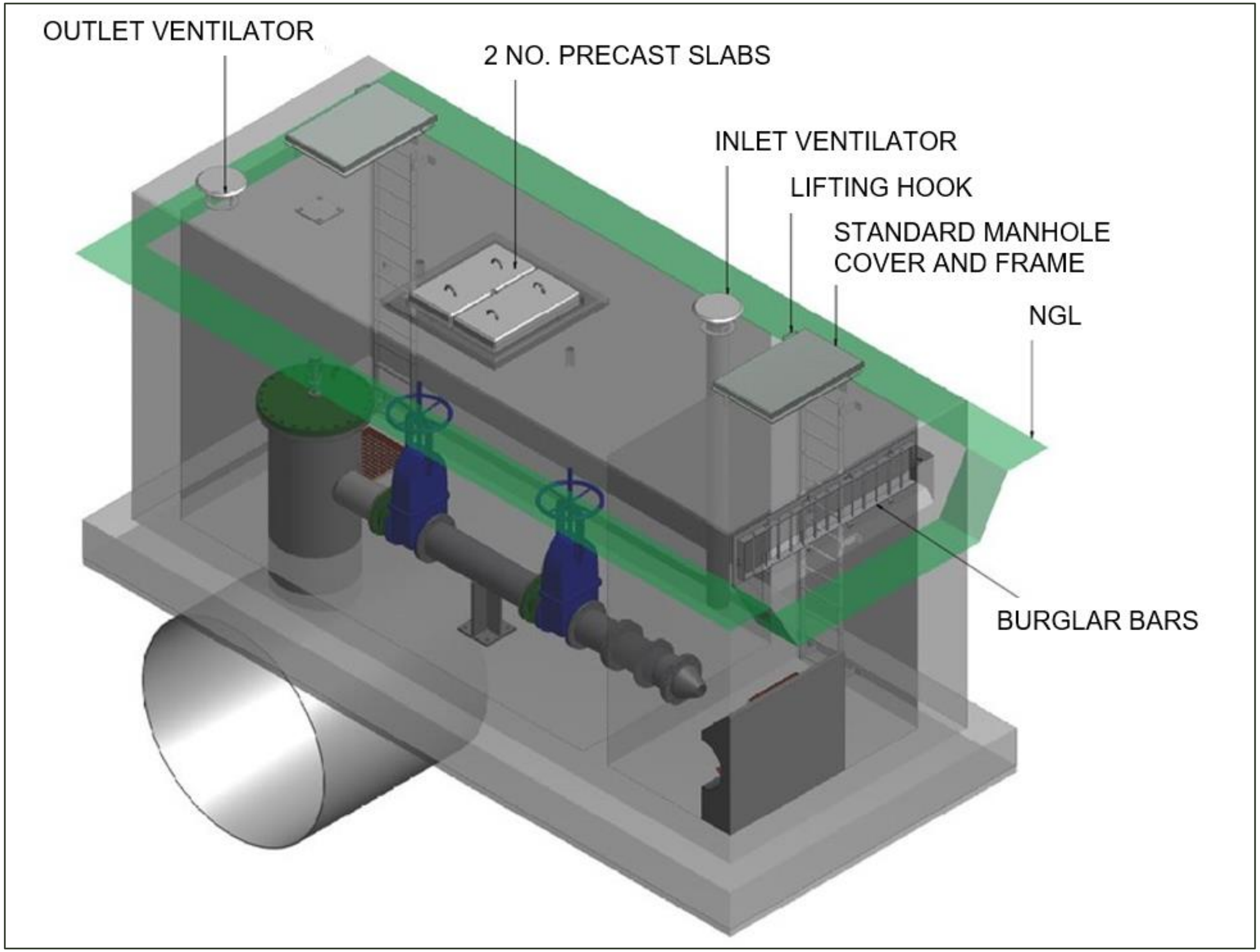

Figure 6.7: Typical scour detail for syphons

6.8 Air Valves on Syphon

Sizing and position of air valves is based on the rate at which air will be introduced or expelled from the pipeline, taking account of the following:

- Filling conditions;
- Dewatering conditions;
- Pipe rupture;
- Normal operating conditions;
- Scour points; and
- Total head.

Care should be taken to provide at least 5 m of positive head at an air valve to ensure that it closes properly. A typical air valve chamber and mechanical arrangement is shown in **Figure 6.8**.

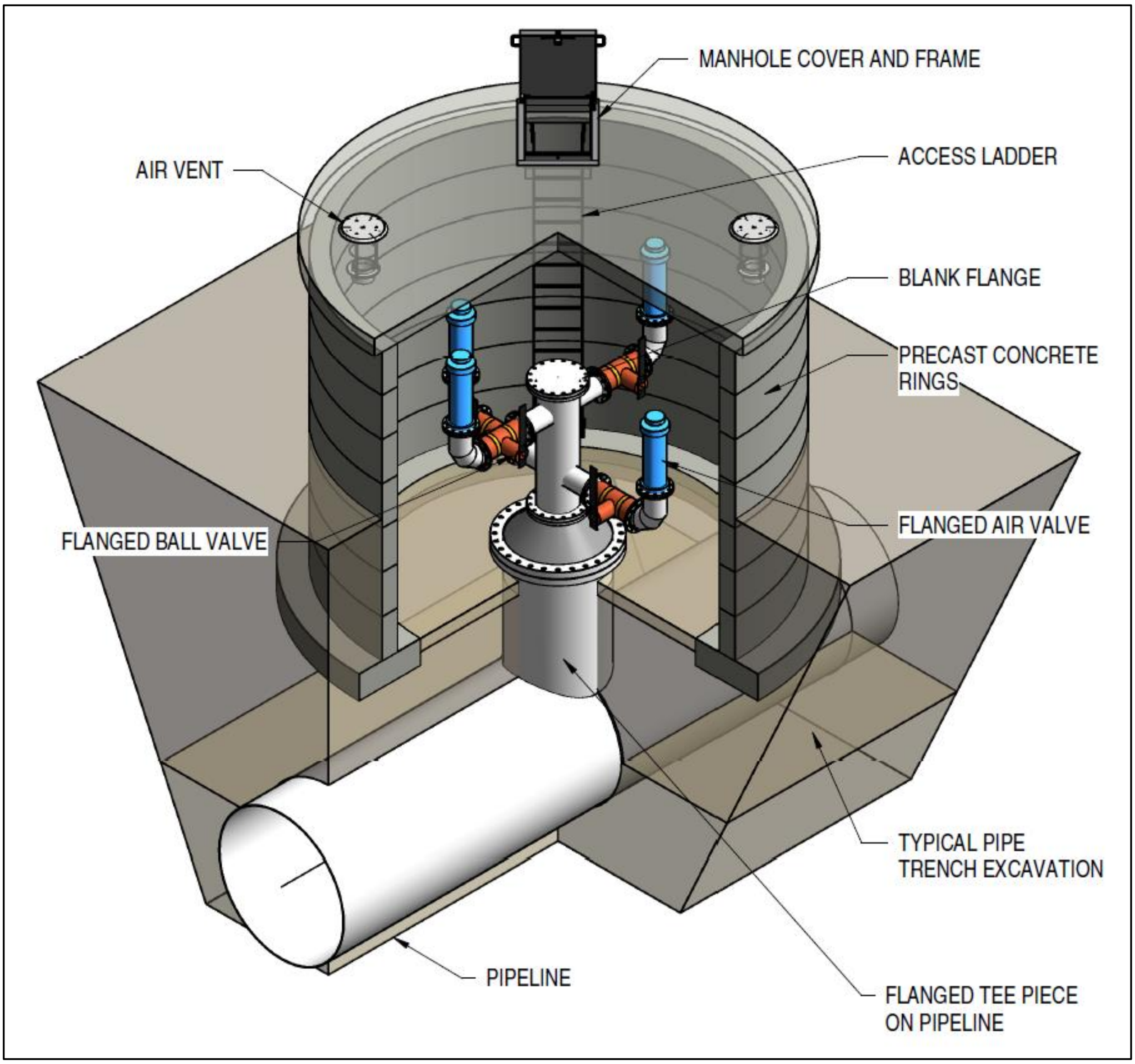

Figure 6.8: Typical air valve chamber

6.9 Operation and Maintenance

The syphon inlet is designed with two separate intake wells for the syphon pipe. These wells are to be provided with stop logs to isolate the pipe. A reject structure is provided upstream of the gates to safely discharge excess water from the system.

7 Existing Verdeling Syphon

7.1 Existing Outlet Structure and Syphon

The proposed Right Bank Canal needs to tie in with the existing syphon at Verdeling. This syphon currently operates by conveying flow from the Left Bank Canal, across the Olifants River, to the outlet and distribution canals on the right bank. At the outlet the flow divides west and south-east. The south-eastern small canal (Doring section) will be replaced by the new Right Bank Canal. **Figure 7.1** shows the existing Verdeling syphon and operation.

According to correspondence with design engineers of the syphon at Verdeling (Element Consulting Engineers), it is a DN 2000 steel pipe and approximately 650 m long. The current left bank inlet's operating level is at 50.443 masl and the right bank outlet's operation level is at 49.488 masl.

There are two contradicting estimates on the existing Verdeling Syphon's flow capacity from the left bank to the right bank:

- According to LORWUA, the current Verdeling syphon has a capacity of 9 635 m^3/hr, equating to about 2.68 m^3/s;
- According to the Element Consulting Engineers (designers and engineers on site) the syphon is a DN 2000 steel pipe, approximately 650 m long and operates at 0.6 m static head difference. Using hydraulic pipe calculations (Colebrook-White/Darcy-Weisbach), this equates to a maximum flow capacity of around 4.30 - 4.40 m^3/s (depending on the friction factors chosen); and
- According to the Southern Mapping Survey, the left bank operating water level is 50.443 masl, and the right bank outlet operating water level is 49.488 masl, giving a static head difference of 0.96 m. Using hydraulic pipe calculations (Colebrook-White/Darcy-Weisbach), this equates to a maximum flow capacity of around 5.50 m^3/s – 5.60 m^3/s (depending on the friction factors chosen).

It was concluded that the syphon therefore doesn't currently operate at its peak capacity and there should be spare head room for increased flows from the left bank to the right bank. The canal sizes are therefore a severe bottleneck in the current state.

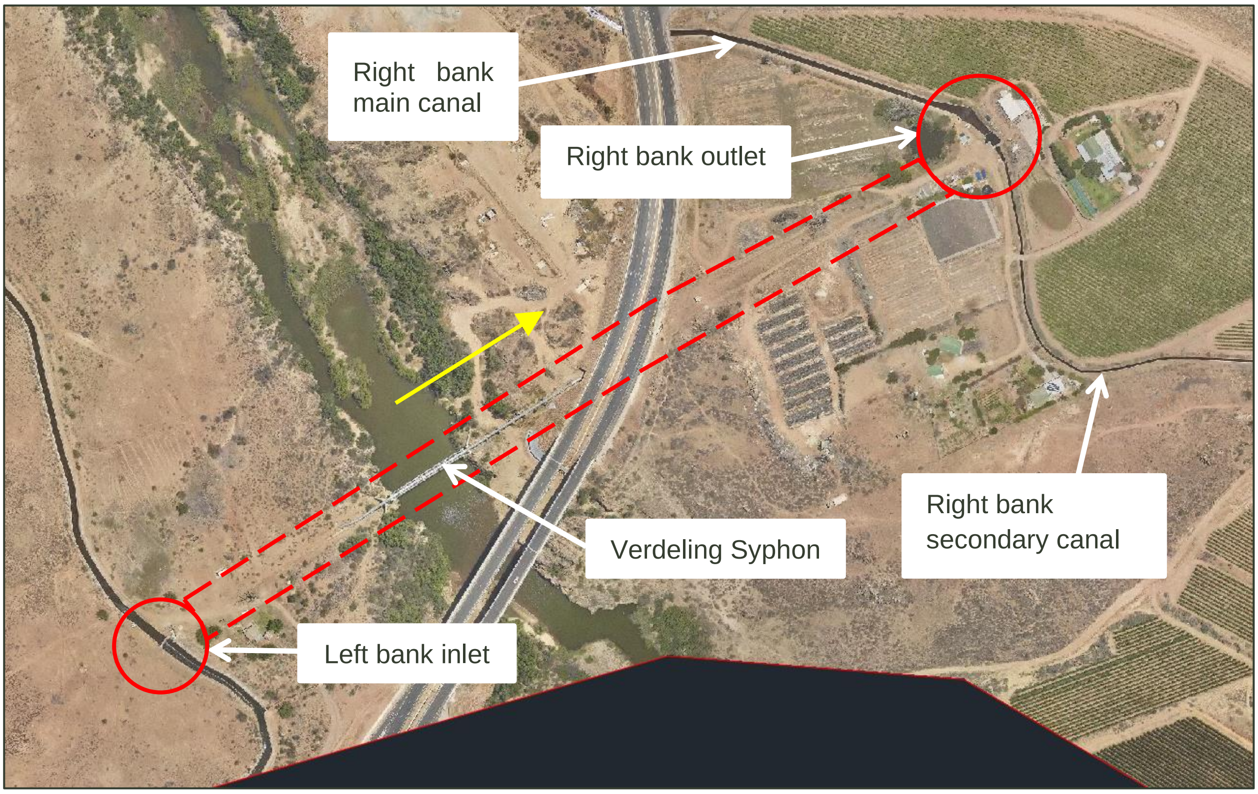

Figure 7.1: Layout and operation of existing Verdeling Syphon

7.2 Proposed Inlet Structure

For the proposed Right Bank Canal, the flow in the Verdeling syphon will be reversed. The right bank outlet will be altered to become an inlet with gates to continue servicing the existing downstream right bank distribution canal. **Figure 7.2** shows the new inlet structure and a drawing is included in **Appendix A** (Drawing. No. 113834-1000-DRG-CC-0008).

As the current syphon has a physical level difference of approximately 0.96 m to accommodate the design flow from left bank to right bank, the height of the proposed new inlet must be increased by at least the 0.96 m, plus the design head difference to reverse the flow (as discussed in **Section 7.4**). The walls of the new inlet will be placed on top of the existing structure and strengthened. Vertical sluice gates will control the flow through the syphon and to the existing right bank distribution canal. A Crump weir flow measuring station must be placed downstream of the inlet to confirm flow to the right bank distribution canal. A trash rack will be placed upstream of the inlet, as well as a reject with relevant erosion protection and a stream path back to the river.

The design water level in the new inlet structure is **51.000 masl**, and wall height (including freeboard) is 51.500 masl. Given that the current operating water level in the left bank inlet is 50.443 masl, which gives 0.557 m of positive pressure head. As evident in the hydraulic calculations shown in **Section 7.4** below, this is more than the minimum required head of 0.504 m by a factor of safety of at least 1.1. It must also be noted that the pipe roughness chosen for the hydraulic calculations is conservative, and as explained in **Section 7.3** below, the design flow is still more than the capacity of the Left Bank Canal.

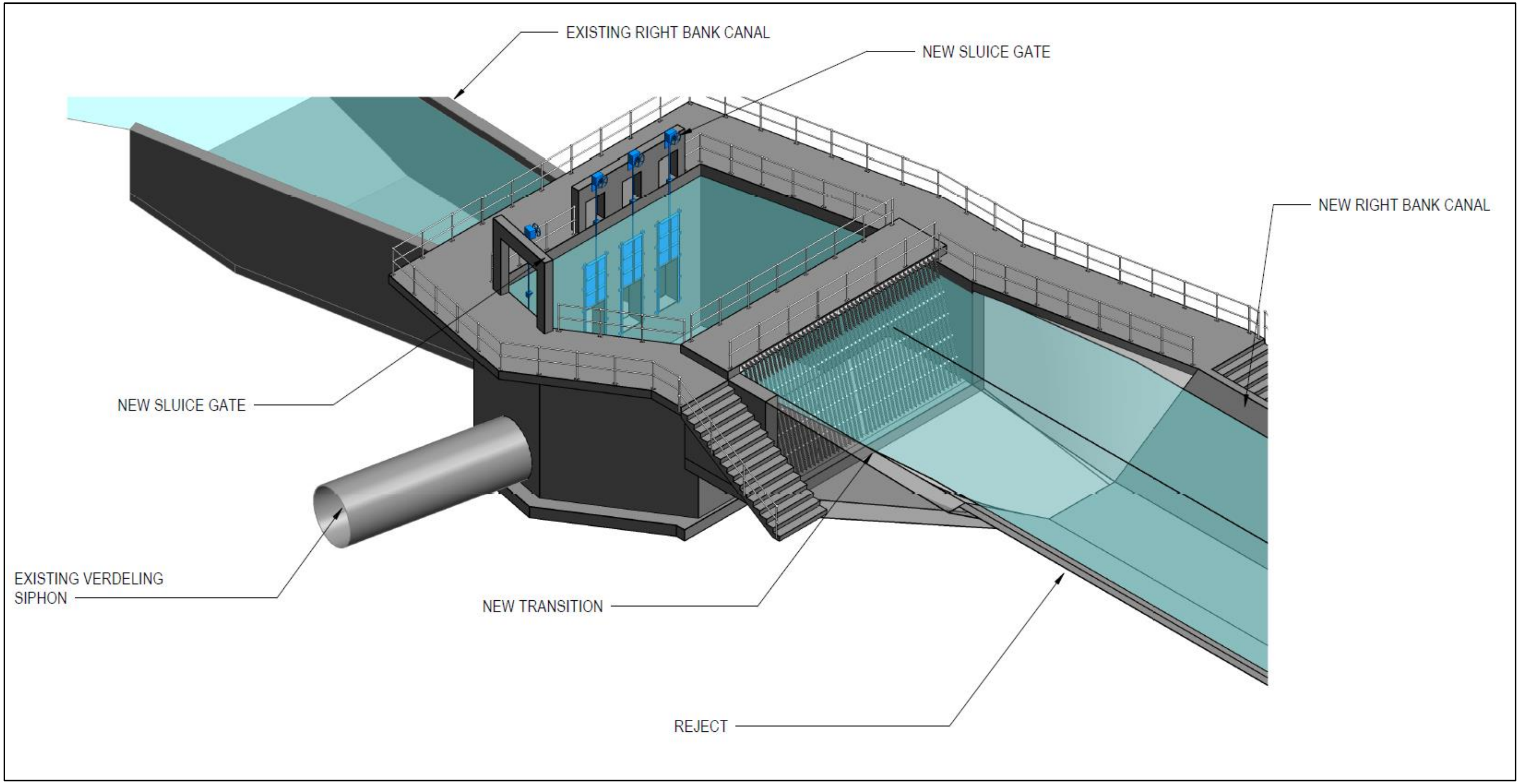

Figure 7.2: New Verdeling Syphon right bank inlet

7.3 New Syphon Design Flow Capacity

Similar to the new Right Bank Canal, the existing Verdeling syphon's new design discharge should be based on the following aspects:

- Current flow capacity of the Naauwkoes Section of the Left Bank Canal (downstream of the Verdeling syphon), providing existing irrigators;
- An increased flow capacity for existing irrigators, to alleviate the bottleneck caused by the existing flow capacities of canal sections, taking a long-term view of incremental betterment/replacement of the existing canal sections;
- Future non-irrigation flows; and
- Flow requirement for new irrigation downstream of Verdeling.

7.3.1 Current Left Bank Canal (Naauwkoes) flow capacity

According to LORWUA, the current capacity of the Left Bank Canal downstream of Verdeling (Naauwkoes section) is 9 740 m^3/h (2.706 m^3/s). As a start, the reverse flow in the Verdeling syphon must have sufficient pressure head to allow this flow.

7.3.2 Increased flow capacity for existing irrigators and other uses

An increased flow capacity for existing irrigators is required to alleviate the bottleneck caused by the existing restrictive flow capacities of canal sections, when taking a long-term view of incremental betterment / replacement of these existing canal sections. This will enable existing irrigators to increase the use of their current allocations, in line with the increased assurance of supply, following the raising of the Clanwilliam Dam. The benefit will initially only extend to 'Verdeling' once the Right Bank Canal has been constructed but can be realised further downstream if the remainder of the canal sections are progressively improved.

Following the raising of Clanwilliam Dam, existing irrigators downstream of the Bulshoek Weir will have an increased assurance of supply. Up to 20.35 million m^3/a (25% of 81.4 million m^3/a) may be used by existing irrigators, and it is assumed that this flow is divided equally after the Verdeling Syphon so that the existing left and right banks receive 10.18 million m^3/a each. This equates to an increased flow of 0.323 m^3/s.

The Naauwkoes Canal will be required to accommodate the peak flow during the summer months. An average peak factor (for January) for the irrigation development areas downstream of the Verdeling Syphon of 2.13 was applied to the average flow of 0.323 m^3/s to give a peak flow of 0.687 m^3/s for improving supply to existing irrigators. Adding this to the existing Naauwkoes canal capacity of 2.706 m^3/s means that a total flow of 3.393 m^3/s may be required to supply existing irrigators in future.

A possible increased canal flow capacity will also allow for future growth in water requirements from urban and municipal use and large industries, such as mines. An additional 10% increase in current maximum flow capacity of 0.271 m^3/s has been assumed to provide for this growth in water requirements.

These increased flow capacities required for improved assurance of supply to existing irrigators and other users is shown in **Table 7.1**.

Table 7.1: Water requirements for improved assurance of supply through the Verdeling Syphon

Improved assurance of supply to existing irrigators	
Additional allocation for improved assurance of existing irrigators (million m^3/a)	10.18
Additional flow and losses for improved assurance of existing irrigators (m^3/s)	0.323
Average peak factor (January)	2.13
Increase of Peak flow (m^3/s)	**0.687**
1.1% increase for future non-irrigation flows (m^3/s)	**0.271**

7.3.3 Flow requirement for additional irrigation downstream of Bulshoek Weir

Current identified preferred new irrigation development schemes and their associated water requirements and losses are as shown in **Table 7.2**.

Table 7.2: Water requirements and losses of development options through Verdeling Syphon

Sub-area	Water allocations (Mm^3/a)	Conveyance losses (Mm^3/a)	Water allocations and losses (Mm^3/a)
Zone 5 - Olifants River from Klawer to Coast (post-Right Bank Canal – Coastal 1 and Ebenhaeser)	4.55	0.84	**5.39**

The total available water for additional allocation for new irrigation from a raised Clanwilliam Dam is 61.05 million m^3/a (75% of 81.4 million m^3/a). For Zone 5 of the left bank, below the Verdeling Syphon, there is 5.39 million m^3/a available.

The design capacity of the reversed Verdeling Syphon should be sufficient to convey the potential water allocation, as well as account for downstream canal conveyance losses. Furthermore, the design flow of the new canal should allow for peak flows. A peak factor of 2.09 was used for Zone 5. These peak factors were determined by a Bridging Study sub-committee, consisting of DWS, WCDoA, Aurecon and Agrifusion, who derived the crop water requirements for each zone/sub-area. The design flow component for additional irrigation is calculated as shown in **Table 7.3** as **2.723 m^3/s**.

Table 7.3: Design flows for additional irrigation through Verdeling syphon

Sub-Area	Water allocation & losses (Mm^3/a)	Ave flow (m^3/s)	Peak factor (Jan)	Peak / design flow (m^3/s)
Zone 5	5.39	0.171	2.09	0.357

7.3.4 Total design flow

The total peak design flow for the reversed Verdeling Syphon is calculated as **4.02 m^3/s**, as shown in **Table 7.4**.

Table 7.4: Verdeling Syphon peak design flows

Flow component	Flow (m^3/s)
Current Left Bank Canal capacity	2.706
Improved assurance of supply to existing irrigators	0.687
Future non-irrigation flows	0.271
Additional irrigation	0.357
Total peak design capacity	**4.021**

7.4 Proposed Reversed Verdeling Syphon Hydraulics

The reversed (right bank to left bank) syphon duty is based on the above total peak design flow of 4.021 m^3/s, see **Table 7.4**. As the pipe diameter and design flow are fixed, the available head and assumed pipe roughness will equate the flow velocity. The scenario with an old syphon with maximum flow and higher friction factors (aged pipe) was investigated. An aged steel pipe roughness of 0.15 mm was assumed, and the hydraulics are shown in **Table 7.5**.

Table 7.5: Verdeling Syphon design parameters

Parameter	Reversed Verdeling Syphon
Length (m)	650
Elevation at start (masl)	51.000
Elevation at end (masl)	50.443
Type	X42 Steel pipe
Shape	Circular
Size (mm)	DN 2000
Wall thickness (mm)	14
Design friction coefficient k_s (aged pipe) (mm)	0.15
Design discharge (m^3/s)	4.021
Design velocity (m/s)	1.275
Available head difference between upstream and downstream end of syphon (m)	0.557
Design head loss, including friction and local head losses (m)	0.504

8 Cost Estimate

The basis of the cost estimate was to price each scheme element at feasibility level of evaluation by listing design items and structural volumes in South African Rands. All rates were gathered from previous South African projects from years between 2015 and 2020, and by contacting relevant manufacturers. All rates were then escalated to October 2020 values by 6% per annum for comparison. Below is a summary of all assumptions made to cost each component of the project. All bills of quantities are included in **Appendix B**. **BOQ-00 SUMMARY** in **Appendix B** includes a summary of all structures.

The following over-arching assumptions were made regarding the costing of the system:

- Excavation of soft material at R 100 /m³ and hard rock at R 530 /m³;
- Selected backfill from stockpile at R 140 /m³;
- Formwork: Gang formed at R 750 /m² and horizontal at R 1 250 /m²;
- Structural Concrete (35 MPa) at R 2 050 /m³;
- Structural Reinforcing at R 15 000 /t;
- Structural Steel (incl. delivery and erection) at R 61 840 /t; and
- New access roads at R 350 000 /km.

Preliminary and general, contingencies and professional fees were assumed as follows:

- Preliminary and General at 40% of construction cost;
- Contingencies at 25% of construction cost plus preliminary and general;
- Professional fees at 10% of construction cost plus preliminary and general plus contingencies.

8.1 Bulshoek Weir Outlet

As discussed in **Section 5.3.1**, the existing Bulshoek Weir Outlet would be used to feed the conveyance system. No changes need to be made, and the total cost was thus assumed to be zero. For completeness, **BOQ-01 BULSHOEK WEIR OUTLET** is included in **Appendix B**.

8.2 Canals

8.2.1 Left Bank Canal Upgrade

As mentioned in **Section 5**, the existing Left Bank Canal must be upgraded to accommodate the increased flow capacity. The construction cost, preliminary and general cost, contingencies and professional fees are tabulated in **Table 8.1** below. A detailed breakdown of the costs is included as **BOQ-02 CANALS - LEFT BANK UPGRADE (0.00 km - 3.05 km)** in **Appendix B**.

The following assumptions specific to the Left Bank Canal upgrade were made:

- Demolition of the existing canal at R 10 000 /m³ of concrete;
- Temporary pumping, to provide water to the scheme, capital costs of R 34 000 000 lump sum;
- Temporary pumping operating costs of R 3 000 000 /month; and
- No new access roads as the existing Left Bank Canal road can be used for access.

Table 8.1: Cost estimate - Left Bank Canal upgrade (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**144 599 200**
Preliminary & General	40%	57 839 700
Contingencies	25%	50 609 800
Professional Fees	10%	25 304 900
Total Cost (Excl. VAT)		**278 353 600**

8.2.2 Right Bank Canal Reach 1

As mentioned in **Section 5**, a new Right Bank Canal needs to be constructed in three reaches. The construction cost, preliminary and general cost, contingencies and professional fees of Reach 1 are tabulated in **Table 8.2** below. A detailed breakdown of the costs is included as **BOQ-03 CANALS - RIGHT BANK REACH 1 (3.35 km - 21.91 km)** in **Appendix B**.

The following assumptions, specific to the Right Bank Canal Reach 1 were made:

- A total of 18.6 km of new access road at R 350 000 /km; and
- A total of 12 months of maintenance of existing access roads at R 65 000 /month.

Table 8.2: Cost estimate – Right Bank Canal Reach 1 (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**351 432 200**
Preliminary & General	40%	140 572 900
Contingencies	25%	123 001 300

Description	Rate	Amount (Rand)
Professional Fees	10%	61 500 700
Total Cost (Excl. VAT)		**676 507 100**

8.2.3 Right Bank Canal Reach 2

As mentioned in **Section 5**, a new Right Bank Canal needs to be constructed in three reaches. The construction cost, preliminary and general cost, contingencies and professional fees of Reach 2 are tabulated in **Table 8.3** below. A detailed breakdown of the costs is included as **BOQ-04 CANALS - RIGHT BANK REACH 2 (23.18 km - 23.86 km)** in **Appendix B**.

The following assumptions, specific to the Right Bank Canal Reach 2 were made:

- No new access road as Reach 2 runs parallel to an existing gravel farm road; and
- A total of 12 months of maintenance of existing access roads at R 10 000 /month.

Table 8.3: Cost estimate – Right Bank Canal Reach 2 (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**12 912 200**
Preliminary & General	40%	5 164 900
Contingencies	25%	4 519 300
Professional Fees	10%	2 259 700
Total Cost (Excl. VAT)		**24 856 100**

8.2.4 Right Bank Canal Reach 3

As mentioned in **Section 5**, a new Right Bank Canal needs to be constructed in three reaches. The construction cost, preliminary and general cost, contingencies and professional fees of Reach 3 are tabulated in **Table 8.4** below. A detailed breakdown of the costs is included as **BOQ-05 CANALS - RIGHT BANK REACH 3 (24.70 km - 33.55 km)** in **Appendix B**.

The following assumptions, specific to the Right Bank Canal reach 3 were made:

- A total of 8.9 km of new access roads at R 350 000 /km; and
- A total of 12 months of maintenance of existing access roads at R 65 000 /month.

Table 8.4: Cost estimate – Right Bank Canal Reach 3 (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**136 184 600**
Preliminary & General	40%	54 473 900
Contingencies	25%	47 664 700
Professional Fees	10%	23 832 400
Total Cost (Excl. VAT)		**262 155 600**

8.3 Syphons

8.3.1 Syphon 1

As mentioned in **Section 6**, a new syphon with a pipe bridge is recommended at chainage 3.05 km to cross the Olifants River. The construction cost, preliminary and general cost, contingencies and professional fees of Syphon 1 are tabulated in **Table 8.5** below. A detailed breakdown of the costs is included as **BOQ-06 SYPHON 1 PIPEWORK AND PIPE BRIDGE (3.05 km - 3.35km)** in **Appendix B**.

The following assumptions, specific to Syphon 1 were made:

- A DN2400 steel pipe with a wall thickness of 18 mm at R 36 980 /m, excluding transport and installation;
- Transport of DN2400 steel pipe from Cape Town to Clanwilliam area – round trip of approximately 500 km at R 20 /km, equalling R 10 000 /pipe segment;
- Pipe segments of 12 m;
- Installation of DN2400 pipes at R 7 400 /m (20% of pipe cost per metre); and
- A total of 90 t of structural steel for the pipe bridge at R 61 840 /t, including transport and erection.

Table 8.5: Cost estimate – Syphon 1 with pipe bridge (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**26 259 800**
Preliminary & General	40%	10 504 000
Contingencies	25%	9 191 000
Professional Fees	10%	4 595 500
Total Cost (Excl. VAT)		**50 550 300**

8.3.2 Syphon 2A

As mentioned in **Section 6**, the syphon that crosses the Doring River needs to be split up into two syphons, Syphon 2A and 2B. Both these syphons are constructed as in-situ concrete box conduits. The construction cost, preliminary and general cost, contingencies and professional fees of Syphon 2A are tabulated in **Table 8.6** below. A detailed breakdown of the costs is included as **BOQ-07 SYPHON 2A CONCRETE CULVERT (21.91 km - 23.18 km)** in **Appendix B**.

Other than the assumptions listed in **Section 8** above, no specific assumptions were made for Syphon 2A.

Table 8.6: Cost estimate – Syphon 2A (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**62 388 900**
Preliminary & General	40%	24 955 600
Contingencies	25%	21 836 200
Professional Fees	10%	10 918 100
Total Cost (Excl. VAT)		**120 098 800**

8.3.3 Syphon 2B

As mentioned in **Section 6** and above, the syphon that crosses the Doring River needs to be split up into two syphons, Syphon 2A and 2B. Both these syphons are constructed as in-situ concrete box conduits. The construction cost, preliminary and general cost, contingencies and professional fees of Syphon 2B are tabulated in **Table 8.7** below. A detailed breakdown of the costs is included as **BOQ-08 SYPHON 2B CONCRETE CULVERT (23.86 km - 24.70 km)** in **Appendix B**.

Other than the assumptions listed in **Section 8** above, no specific assumptions were made for Syphon 2B.

Table 8.7: Cost estimate – Syphon 2B (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**40 843 400**
Preliminary & General	40%	16 337 400
Contingencies	25%	14 295 200
Professional Fees	10%	7 147 600
Total Cost (Excl. VAT)		**78 623 600**

8.4 Structures

8.4.1 Syphon 1 Inlet

The inlet to Syphon 1 is shown in more detail in **Section 6.5**. The construction cost, preliminary and general cost, contingencies and professional fees of the Syphon 1 inlet are tabulated in **Table 8.8** below. A detailed breakdown of the costs is included as **BOQ-09 SYPHON 1 INLET (at 3.05 km)** in **Appendix B**.

The following assumptions, specific to the Syphon 1 inlet were made:

- Demolition of an existing part of the Left Bank Canal at R 10 000 /m³ of concrete.

Table 8.8: Cost estimate – Syphon 1 inlet (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**3 449 600**
Preliminary & General	40%	1 379 900
Contingencies	25%	1 207 400
Professional Fees	10%	603 700
Total Cost (Excl. VAT)		**6 640 600**

8.4.2 Typical Syphon Inlet

Other syphon inlets will be a typical inlet as discussed in **Section 6.5**. The construction cost, preliminary and general cost, contingencies and professional fees of a typical syphon inlet are tabulated in **Table 8.9** below. A detailed breakdown of the costs is included as **BOQ-10 SYPHON TYPICAL INLET** in **Appendix B**.

Other than the assumptions listed in **Section 8** above, no specific assumptions were made for the typical syphon inlet.

Table 8.9: Cost estimate – Typical syphon inlet (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**2 656 200**
Preliminary & General	40%	1 062 500
Contingencies	25%	929 700
Professional Fees	10%	464 900
Total Cost (Excl. VAT)		**5 113 300**

8.4.3 Typical Syphon Outlet

All syphon outlets will be a typical outlet. The construction cost, preliminary and general cost, contingencies and professional fees of a typical syphon outlet are tabulated in **Table 8.10** below. A detailed breakdown of the costs is included as **BOQ-11 SYPHON TYPICAL OUTLET** in **Appendix B**.

Other than the assumptions listed in **Section 8** above, no specific assumptions were made for the typical syphon outlet.

Table 8.10: Cost estimate – Typical syphon outlet (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**718 500**
Preliminary & General	40%	287 400
Contingencies	25%	251 500
Professional Fees	10%	125 800
Total Cost (Excl. VAT)		**1 383 200**

8.4.4 Verdeling Syphon Tie-in Structure

As discussed in **Section 7**, the Verdeling Syphon tie-in structure (or inlet) needs special consideration, as a part of the existing outlet must be modified to allow the syphon to be used in the opposite direction. The construction cost, preliminary and general cost, contingencies and professional fees of the modified syphon inlet are tabulated in **Table 8.11** below. A detailed breakdown of the costs is included as **BOQ-12 VERDELING SYPHON TIE-IN STRUCTURE (at 33.55 km)** in **Appendix B**.

The following assumptions, specific to the Verdeling Syphon tie-in structure were made:

- Demolition of an existing part of the structure at R 10 000 /m³ of concrete.

Table 8.11: Cost estimate - Verdeling Syphon tie-in structure (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**4 458 400**
Preliminary & General	40%	1 783 400
Contingencies	25%	1 560 500
Professional Fees	10%	780 300
Total Cost (Excl. VAT)		**8 582 600**

8.4.5 Typical Road Crossing

As discussed in **Section 5.5**, the new Right Bank Canal crosses the R363 four times and other major farm roads 11 times. A similar typical road bridge will be used for these crossings of canal. The construction cost, preliminary and general cost, contingencies and professional fees of the typical road crossing are tabulated in **Table 8.12** below. A detailed breakdown of the costs is included as **BOQ-13 TYPICAL ROAD CROSSING** in **Appendix B**.

The following assumptions, specific to the typical road crossing were made:

- Fixed and unidirectional bearings with a maximum vertical load of 660 kN at R 8 900 / bearing;
- Additional foundation investigations at a lump sum of R 200 000 per crossing; and
- Access and drainage at R 100 000 per crossing.

Table 8.12: Cost estimate – Typical road crossing (October 2020 prices)

Description	Rate	Amount (Rand)
Construction Costs		**1 974 300**
Preliminary & General	40%	789 800
Contingencies	25%	691 100
Professional Fees	10%	345 600
Total Cost (Excl. VAT)		**3 800 800**

8.5 Land Acquisition

As discussed in **Section 9.1**, the new scheme crosses and intersects several privately owned parcels of land. The assumed costs associated with typical land acquisition are tabulated in **Table 8.13**. A detailed breakdown of the costs is included as **BOQ-14 LAND ACQUISITION** in **Appendix B**.

The following assumptions, specific to land acquisition were made:

- Small undeveloped irrigable areas of less than 150 ha were priced at R 28 000 /ha;
- An additional 20% land area was assumed on top of the measured area and priced at R 11 200 /ha;
- Developed areas (including crops, roads, buildings and other developed farm infrastructure) were priced at R 600 000 /ha; and
- General miscellaneous items related to land acquisition at 10% of land acquisition fees.

Table 8.13: Cost estimate – Land acquisition (October 2020 prices)

Description	Rate	Amount (Rand)
Land Acquisition Costs		**14 526 400**
General miscellaneous items related to land acquisition	10%	1 452 700
Total Cost (Excl. VAT)		**15 979 100**

8.6 Annual Operating and Maintenance Costs

Annual Operating and Maintenance (O&M) costs were based on percentages of the civil works and mechanical equipment, as shown in **Table 8.14**. An O&M cost similar to that of the Syphon 1 Inlet was assumed for the existing Bulshoek Weir Outlet. A total of **R 3 601 400** was estimated for O&M costs.

Table 8.14: Operation and Maintenance cost estimate

Description	O&M Costs for Civil Works (Rand)	O&M Costs for Mechanical Components (Rand)
Percentage Breakdown	**0.50 % of Civil Works**	**4.00% of Mechanical Components**
Bulshoek Weir Outlet	5 000	80 000
Left Bank Canal Upgrade	383 700	0
Right Bank Canal Reach 1	1 528 000	0
Right Bank Canal Reach 2	56 200	0
Right Bank Canal Reach 3	592 200	0
Syphon 1	114 200	0
Syphon 2A	271 300	0
Syphon 2B	177 600	0
Syphon 1 Inlet	5 100	79 900
Typical Syphon Inlet (2 No.)	14 800	66 800
Typical Syphon Outlet (3 No.)	9 600	0
Verdeling Syphon Tie-in Structure	12 700	54 300
Typical Road Crossing (15 No.)	127 500	22 500
Total Cost (Excl. VAT)	**3 297 900**	**303 500**

8.7 Summary

A detailed summary of all cost estimates can be found in **BOQ-00 SUMMARY** in **Appendix B**, and is shown in Table 8.15 below.

Table 8.15: Cost estimate for the proposed Right Bank Canal Scheme

Description	Bill Reference / Rate	Cost (Rand)
Outlet		**0**
Use existing Bulshoek Weir outlet	BOQ-01	0
Canals		**645 128 200**
Left Bank Upgrade (0.00 km - 3.05 km)	BOQ-02	144 599 200
Right Bank Reach 1 (3.35 km - 21.91 km)	BOQ-03	351 432 200
Right Bank Reach 2 (21.18 km - 23.86 km)	BOQ-04	12 912 200
Right Bank Reach 3 (24.70 km - 33.55 km)	BOQ-05	136 184 600
Syphon 1		**30 427 900**
Syphon 1 Inlet	BOQ-09	3 449 600
Syphon 1 Pipework and Pipe Bridge	BOQ-06	26 259 800
Syphon 1 Typical Outlet	BOQ-11	718 500
Syphon 2A		**65 763 600**
Syphon 2A Typical Inlet	BOQ-10	2 656 200
Syphon 2A Concrete Culvert	BOQ-07	62 388 900
Syphon 2A Typical Outlet	BOQ-11	718 500
Syphon 2B		**44 218 100**
Syphon 2B Typical Inlet	BOQ-10	2 656 200
Syphon 2B Concrete Culvert	BOQ-08	40 843 400
Syphon 2B Typical Outlet	BOQ-11	718 500
Verdeling Inlet		**4 458 400**

Description	Bill Reference / Rate	Cost (Rand)
Verdeling Syphon Tie-in Structure	BOQ-12	4 458 400
Typical Road Crossings		**29 614 500**
R363 Road Crossing (4 No. crossings)	BOQ-13	7 897 200
Major Farm Road Crossing (11 No. crossings)	BOQ-13	21 717 300
SUBTOTAL A		**819 610 700**
Preliminary & General (% of subtotal A)	40%	327 844 300
SUBTOTAL B		**1 147 455 000**
Contingencies (% of subtotal B)	25%	286 863 800
SUBTOTAL C		**1 434 318 800**
Professional Fees (% of subtotal C)	10%	143 431 900
Land Acquisition	BOQ-14	15 979 100
TOTAL COST (EXCL. VAT)		**1 593 729 800**
VAT	15%	239 059 500
TOTAL COST (INCL. VAT)		**1 832 789 300**

The total annual O&M costs estimated for the Civil and Mechanical Works is R 3 601 400 (excl. VAT), i.e. **R 4 141 610 (incl. VAT)**.

9 Legislative Considerations and Authorisations

9.1 Environmental Impact Assessment

Refer to **Section 4** of the report.

9.2 Water Use Licence

Refer to **Section 4** of the report.

9.3 Land Ownership

The Right Bank Canal route will traverse several farms, owned by various landowners. These landowners will need to be consulted regarding the canal route and associated infrastructure over their properties.

9.4 Wayleave

Wayleave applications will be submitted to all the relevant service authorities to (a) obtain information on the location of their existing services, (b) comment on the proposed canal alignment, and (c) to obtain their requirements that must be adhered to during construction.

This process should be undertaken during the detailed design phase of the project.

10 Conclusions

The feasibility design of the Right Bank Canal and supporting structures has concluded the following:

a) The Right Bank Canal Scheme is designed to replace the existing main canal with a new canal on the right bank of the Olifants River, transporting water from the existing Bulshoek Weir to the existing 2.0 m diameter syphon at Verdeling.

b) The *Conceptual Design Sub-report* describes the options analysis undertaken of the various components of the Right Bank Canal Scheme.

c) The canal routing, syphon types and infrastructure sizing were investigated and designed further, as described in this report. The feasibility-level design is based on a design flow rate of 11.40 m/s.

d) The total capital cost estimate for the proposed scheme is **R 1 832 789 300 (incl. VAT)**.

e) The total annual O&M costs estimated for the Civil and Mechanical Works is **R 4 141 610 (incl. VAT)**.

11 Recommendations

The following recommendations are applicable to the detailed design and construction phases of the project:

a) If the required design flow capacity is revised, the scheme routing and sizing of infrastructure should be amended during the detailed design stage.

b) A more detailed analysis and survey of the existing Bulshoek Weir Outlet should be conducted to verify the capacity. This could influence the decision to alter the current outlet.

c) The detailed design of the scheme will need to account for findings from the further planned geotechnical investigations, i.e. the geophysical evaluation and core drilling of syphon routes.

d) A ground centreline survey should be done along the final chosen canal routes, prior to construction commencing. This will serve as a final check on the canal's vertical alignment and verification of the survey data.

e) During the detailed design, the canal routes and infrastructure locations will need to be confirmed, after discussions with affected landowners and authorities. Some refinements to the routes and locations may be required due to developments subsequent to the feasibility design.

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Appendices

APPENDIX A: Drawings

RIGHT BANK CANAL GENERAL ARRANGEMENTS

SCALE 1 : 40000

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CLIENT

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B	27/01/21	FEASIBILITY STUDY - NOT FOR CONSTRUCTION	E.v.d. BERG

SCALE	SIZE
AS SHOWN	A1

DRAWN: S. DAKA

DESIGNED: G. CALITZ

CHECKED: A. CHANG

FEASIBILITY
NOT FOR CONSTRUCTION

APPROVED

PROJECT: CLANWILLIAM BRIDGING STUDY

TITLE: RIGHT BANK CANAL GENERAL LAYOUT SHEET 1 OF 1

DRAWING No.

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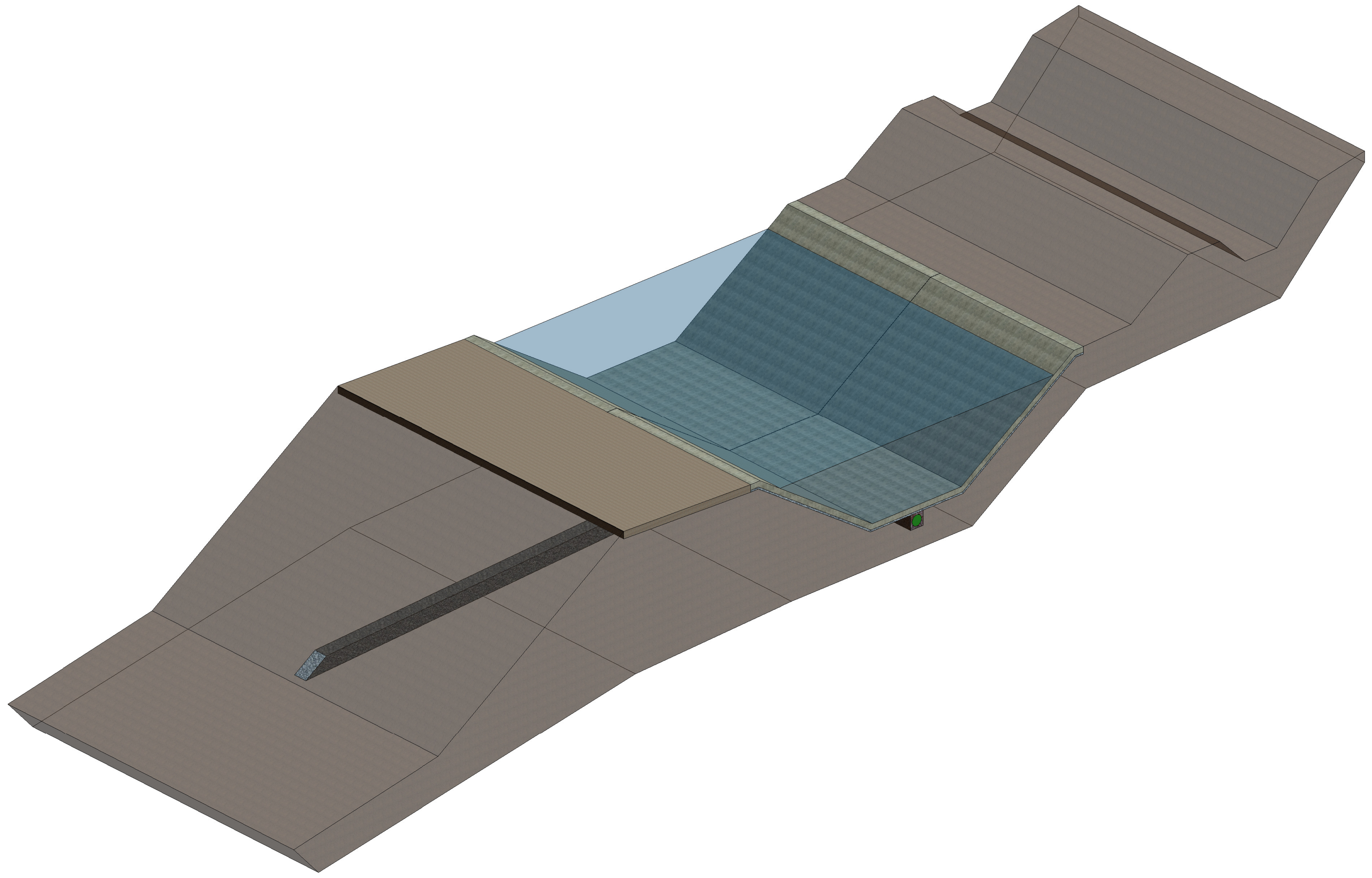

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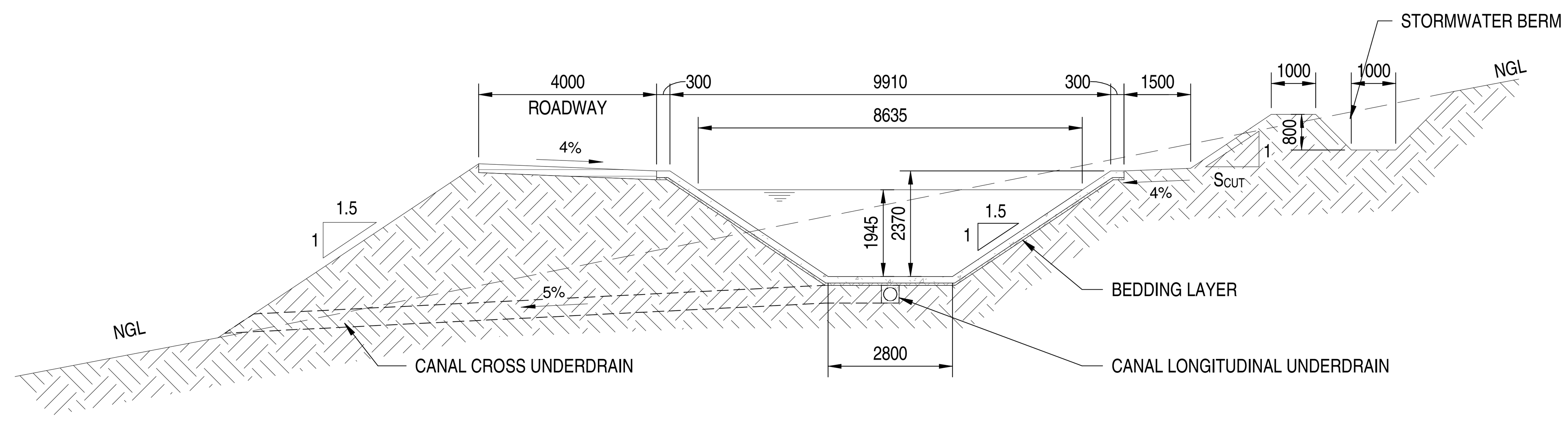

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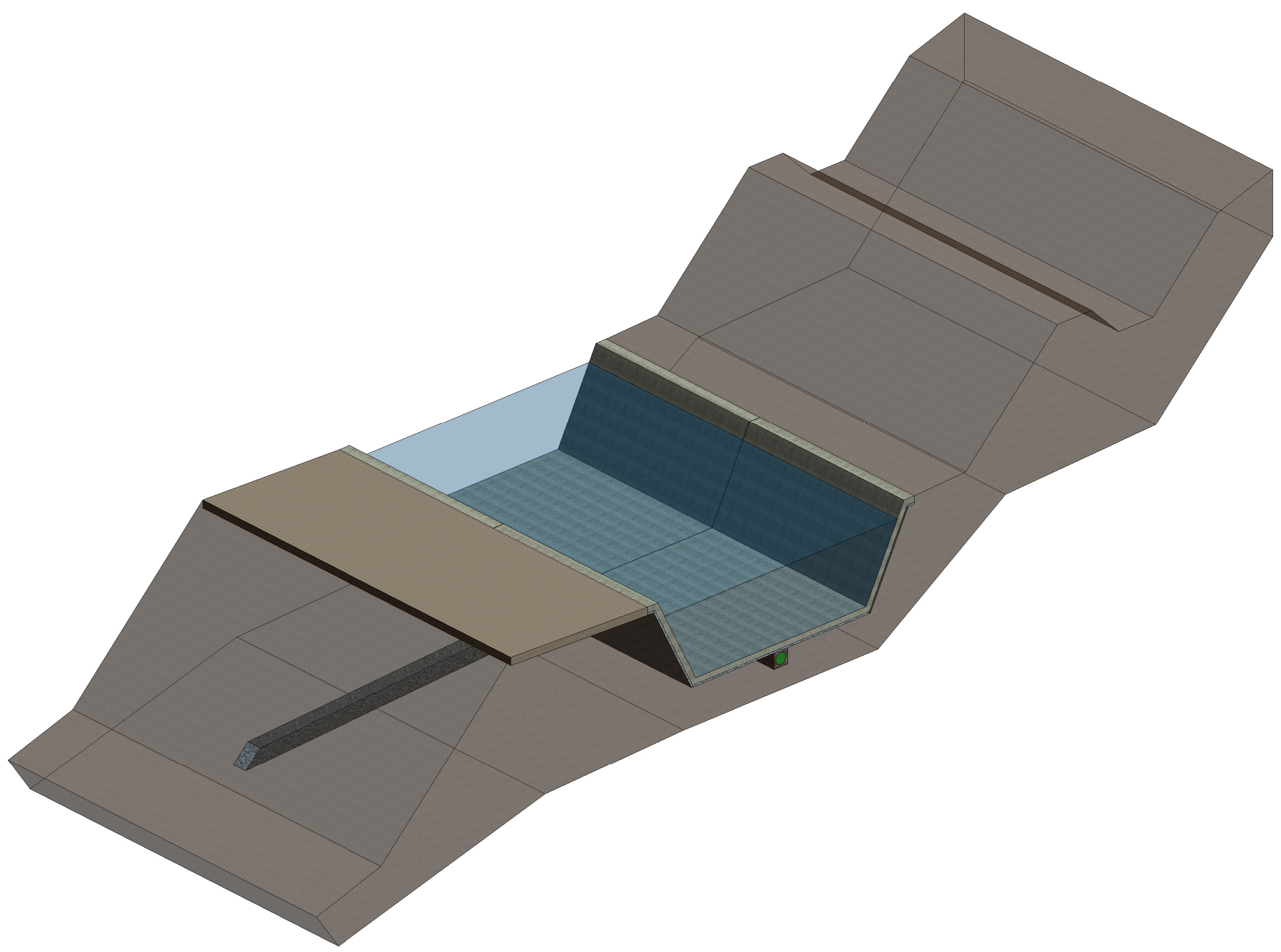

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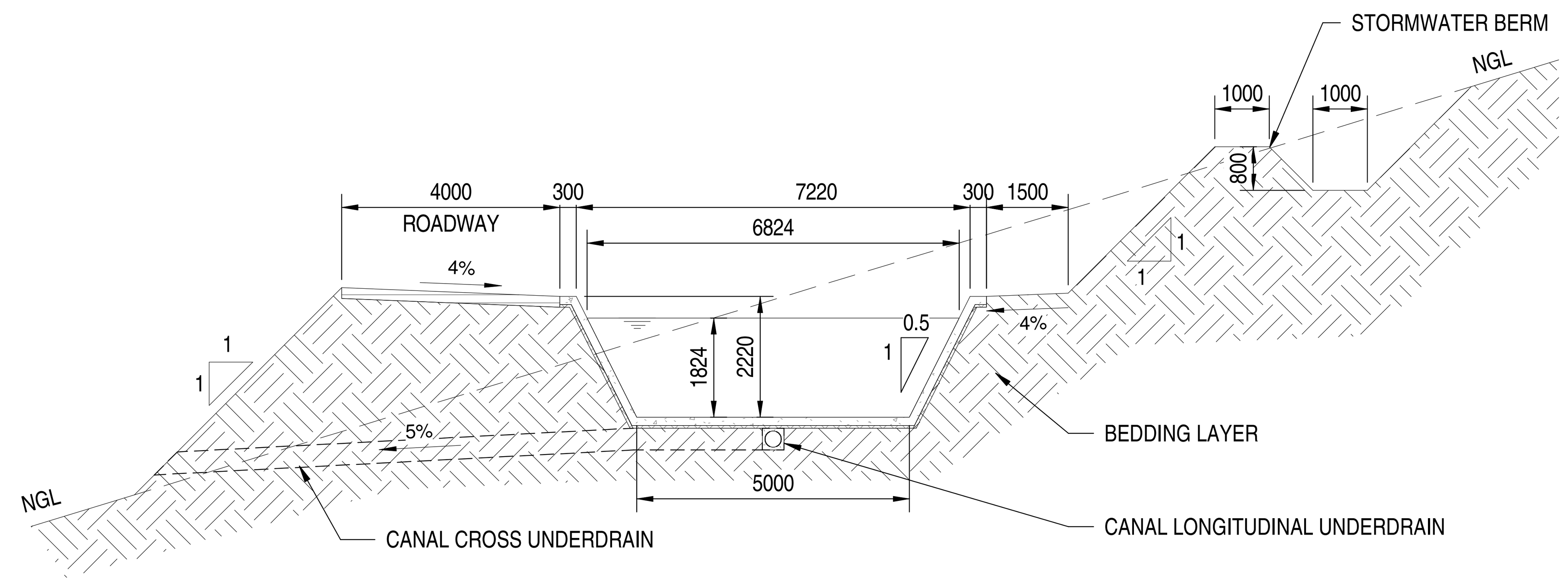

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DESIGNED: G. CALITZ
CHECKED: A. CHANG

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NOT FOR CONSTRUCTION

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DATE

PROJECT: CLANWILLIAM BRIDGING STUDY

TITLE: RIGHT BANK CANAL
TYPICAL CANAL SECTIONS
SHEET 1 OF 1

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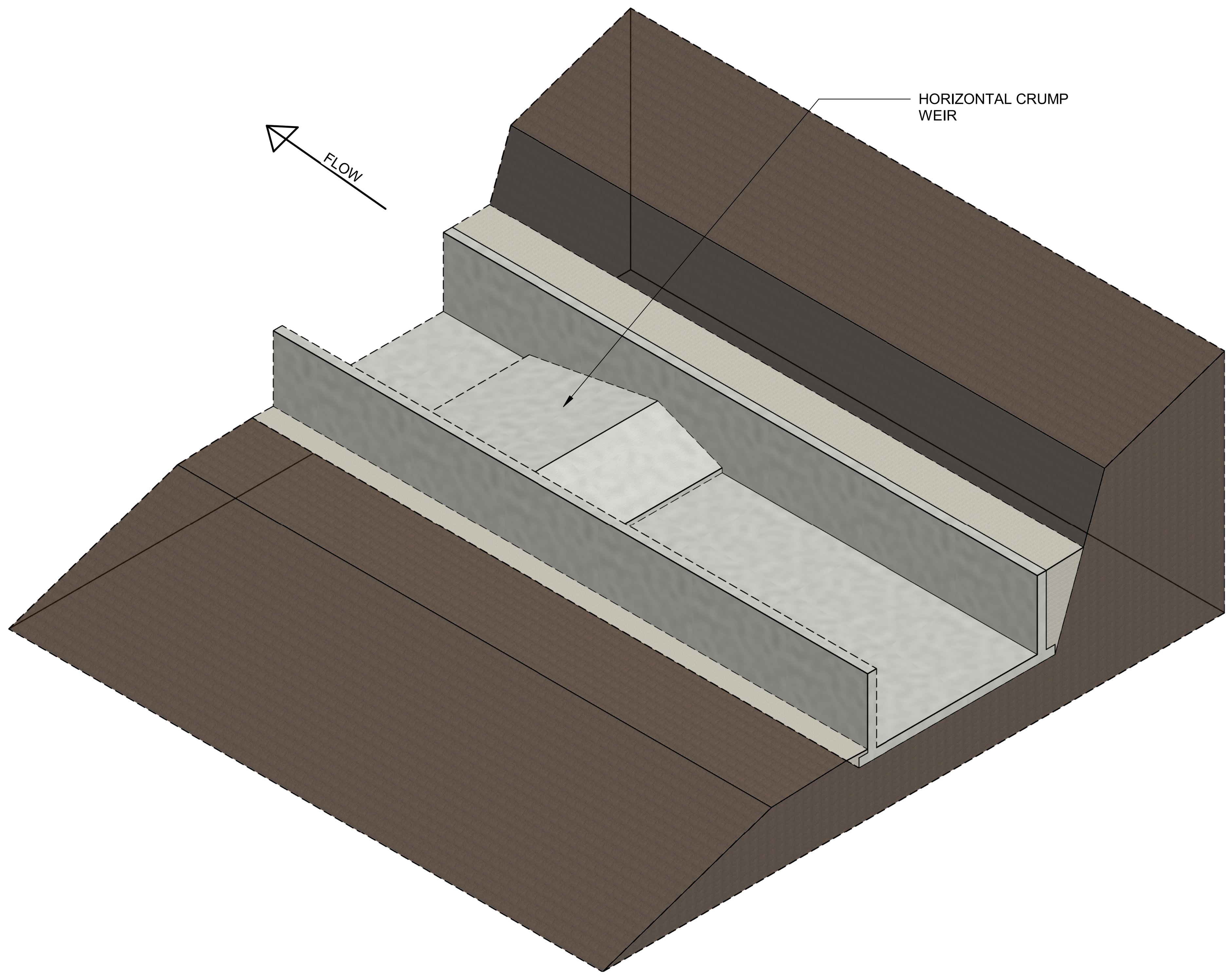

TYPICAL CRUMP WEIR 3D VIEW

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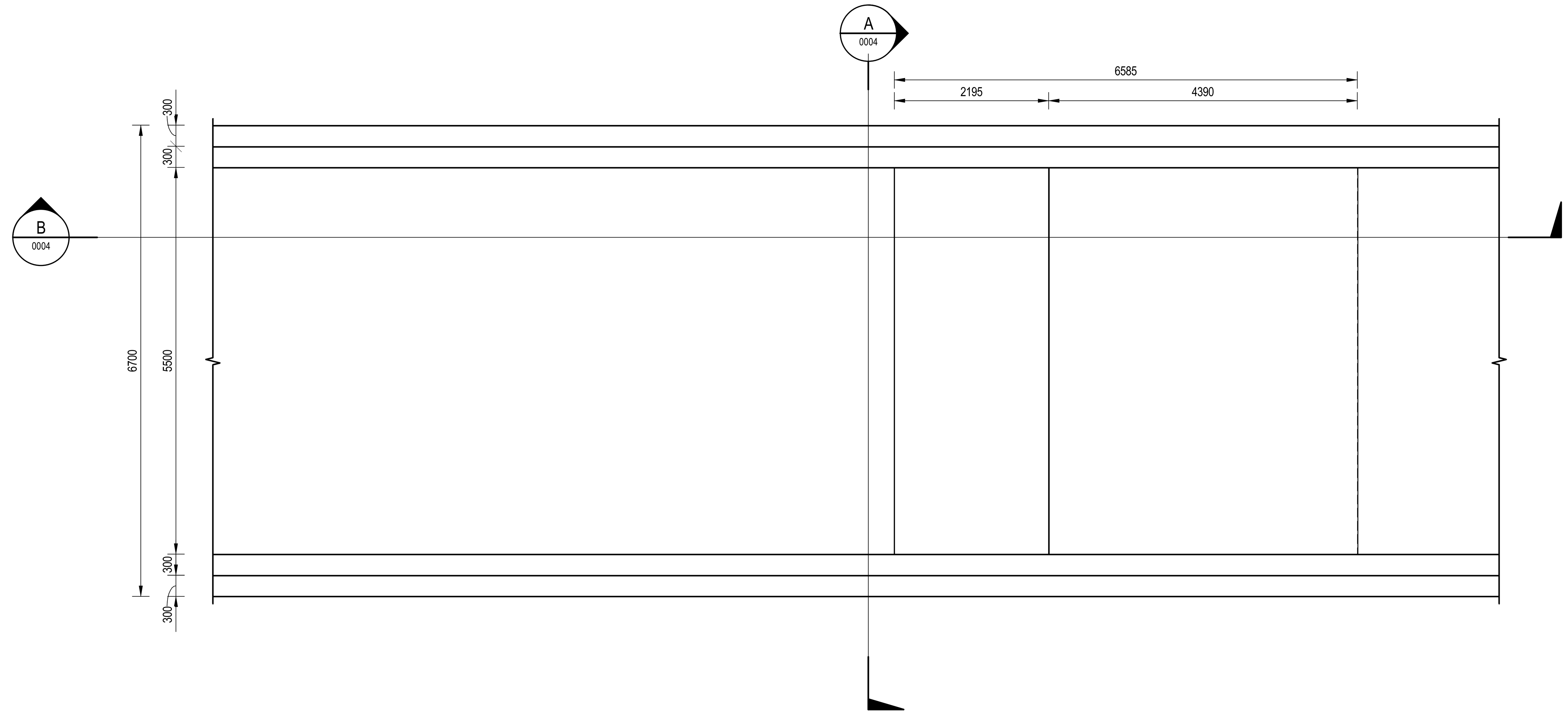

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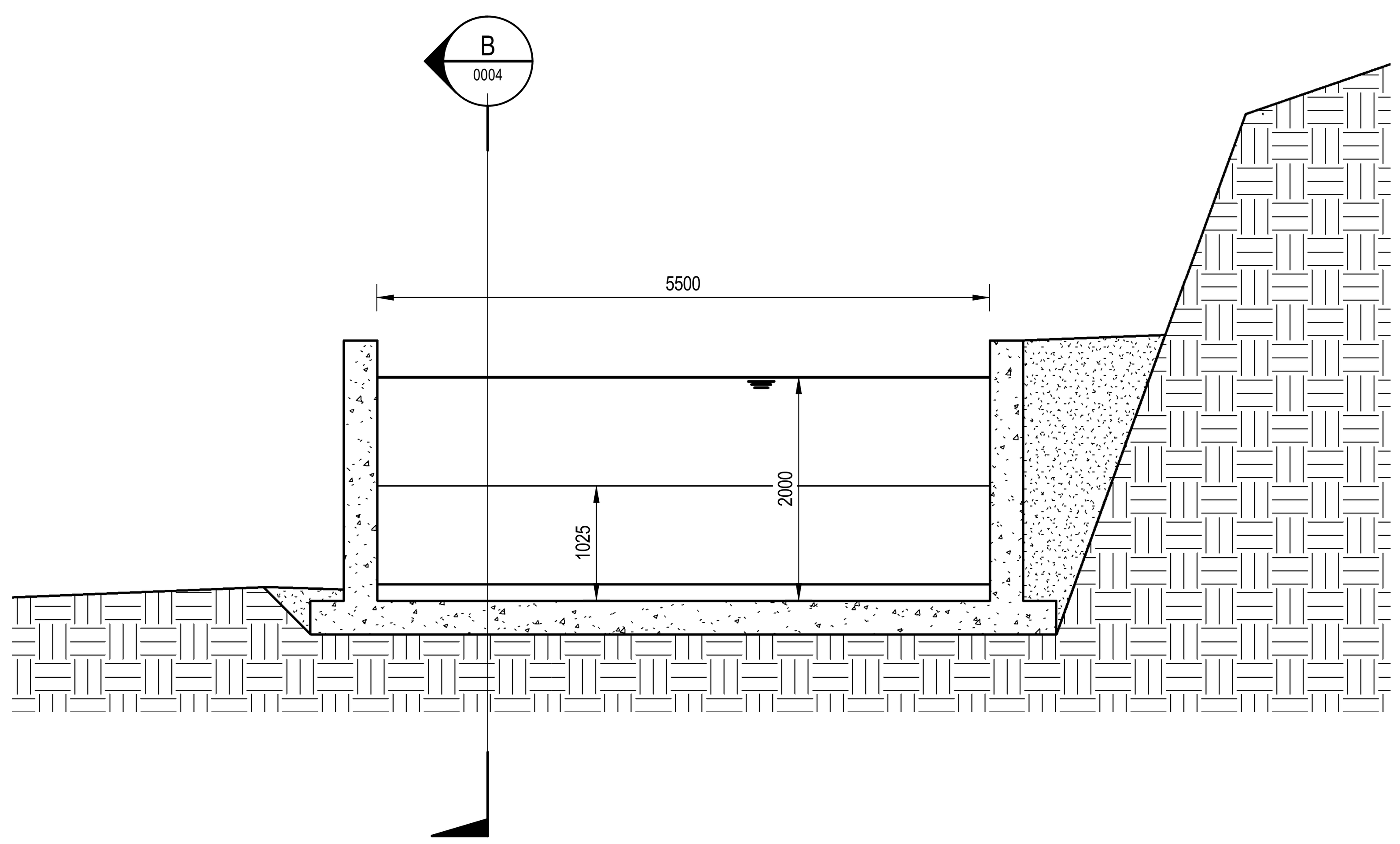

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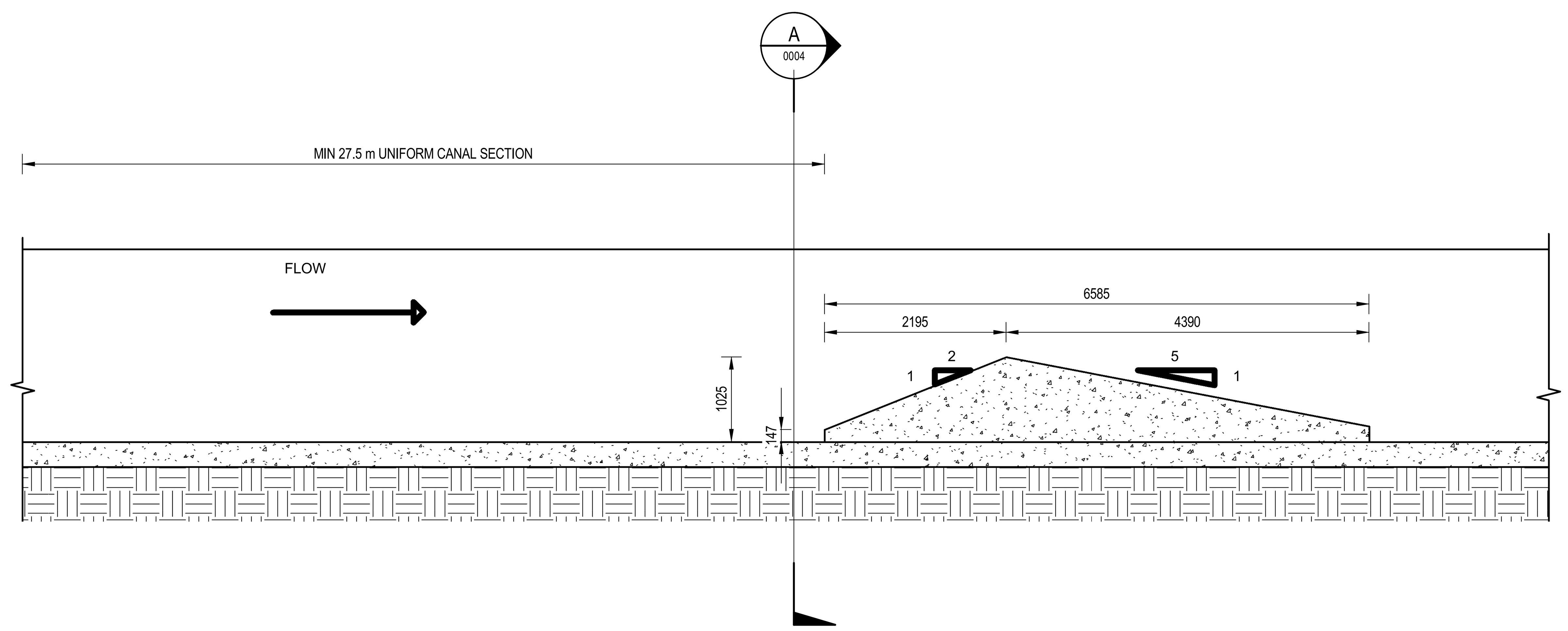

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					DRAWN: S.DAKA	
					DESIGNED: S. DAKA	
					CHECKED: A. CHANG	

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DATE

PROJECT	CLANWILLIAM BRIDGING STUDY
TITLE	RIGHT BANK CANAL TYPICAL CRUMP FLOW MEASURING WEIR SHEET 1 OF 1

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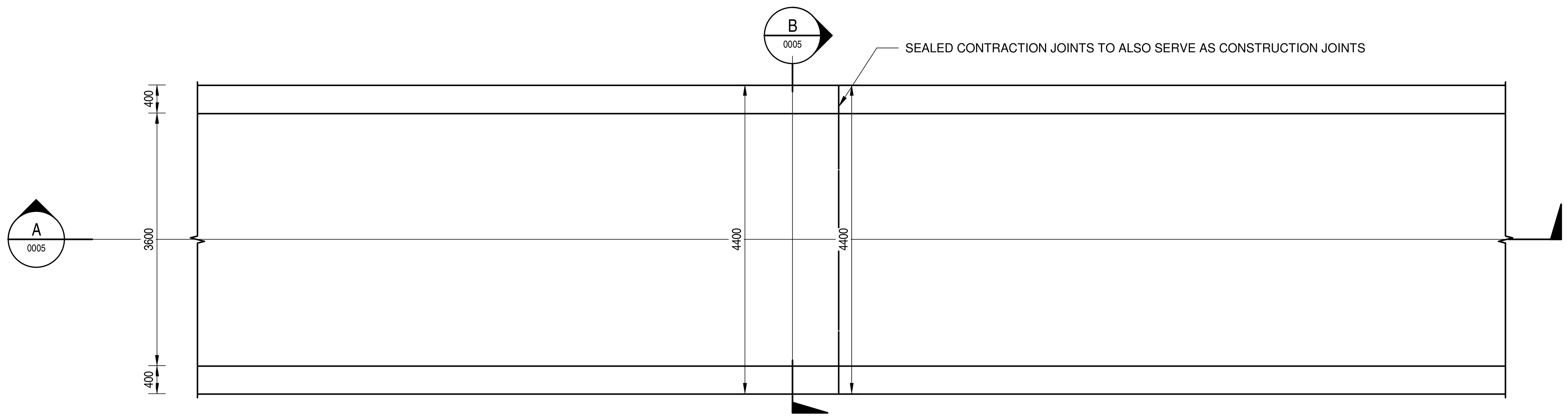

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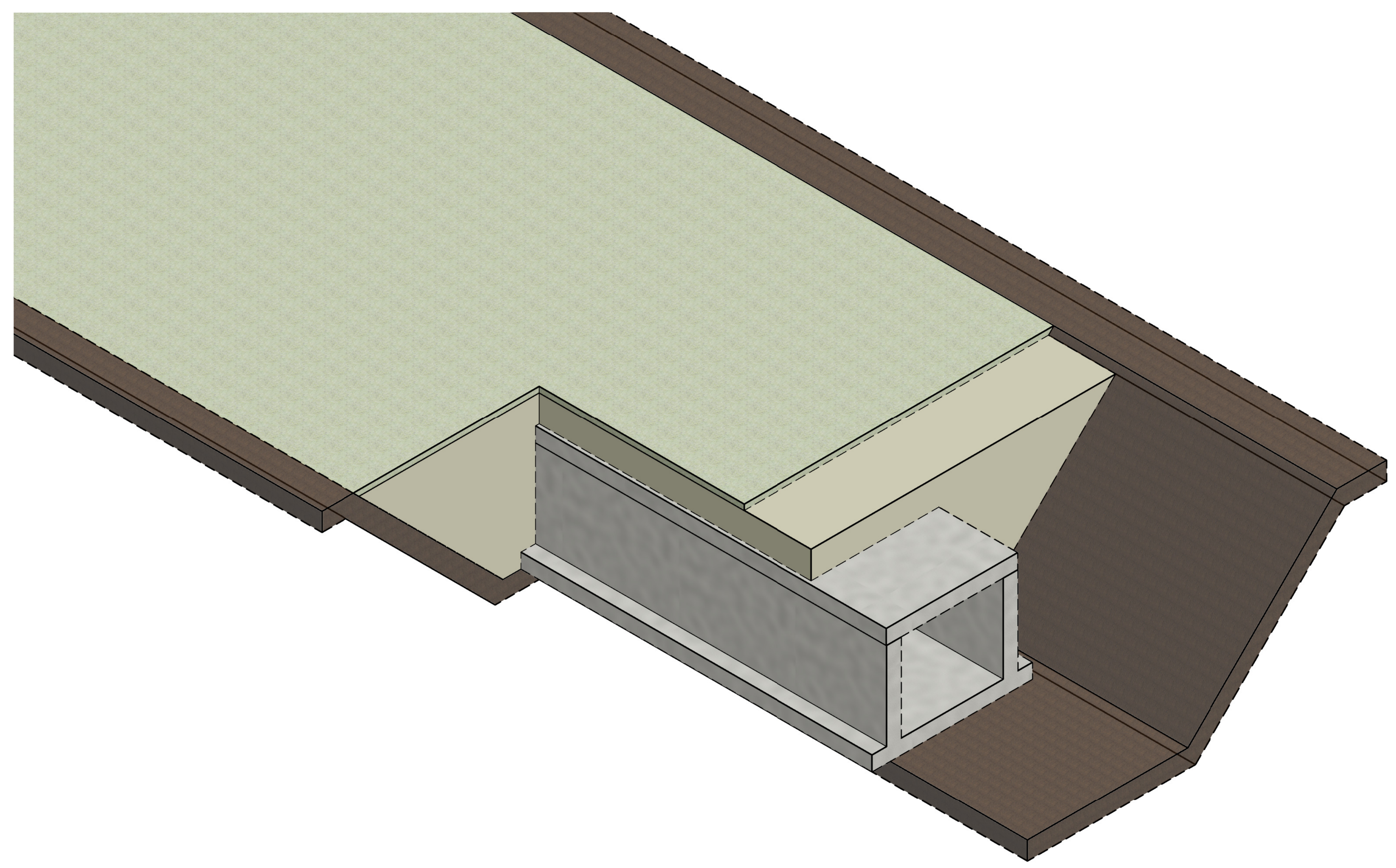

TYPICAL PORTAL CULVERT 3D VIEW

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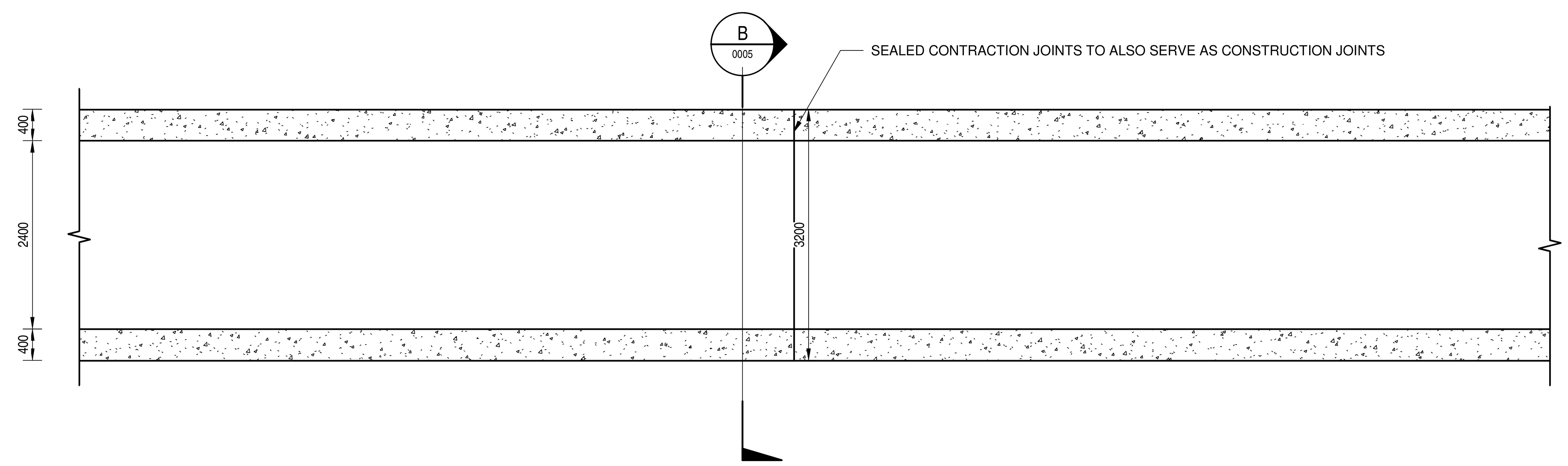

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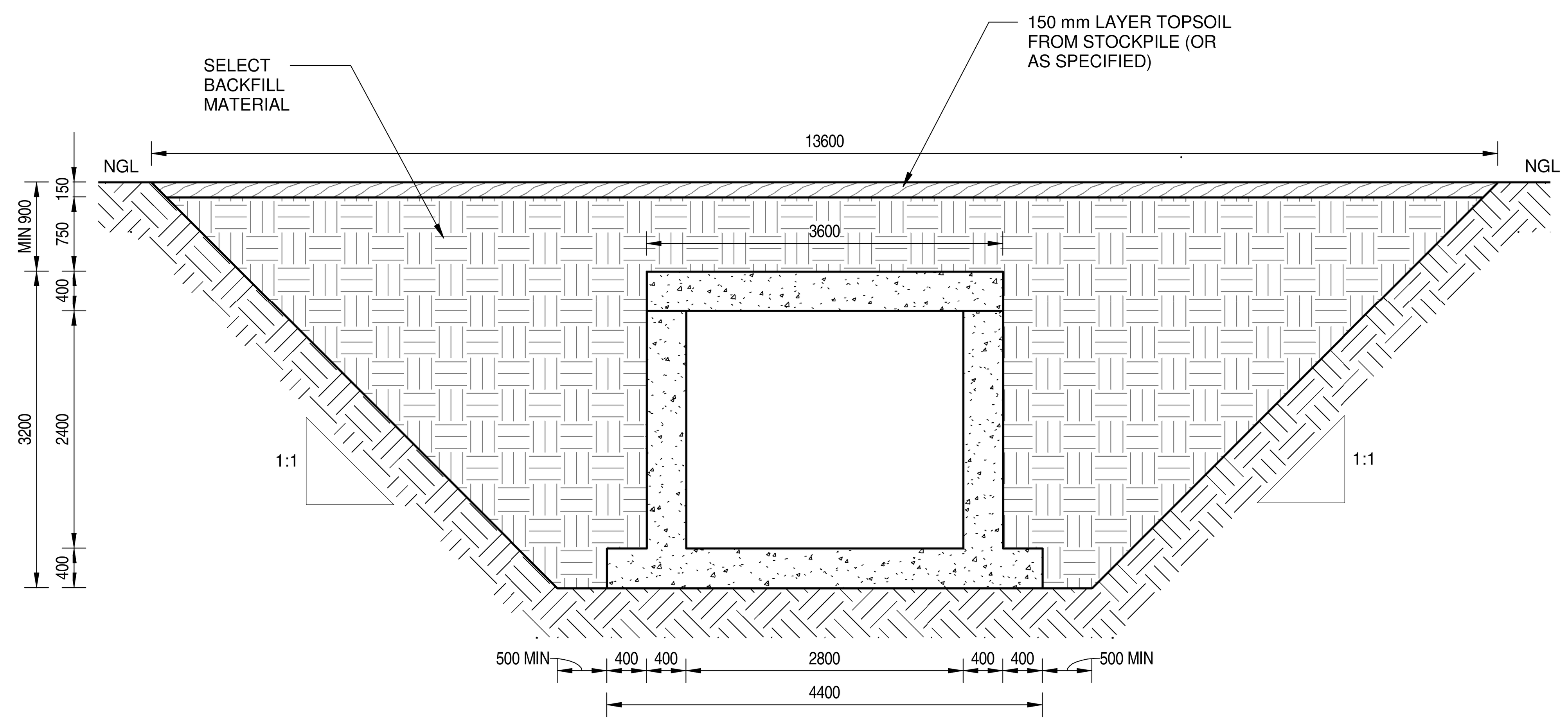

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SCALE	SIZE
AS SHOWN	A1

DRAWN: S. DAKA

DESIGNED: G. CALITZ

CHECKED: A. CHANG

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DATE

Approver

PROJECT	CLANWILLIAM BRIDGING STUDY
TITLE	RIGHT BANK CANAL TYPICAL CULVERT SYPHON SHEET 1 OF 1

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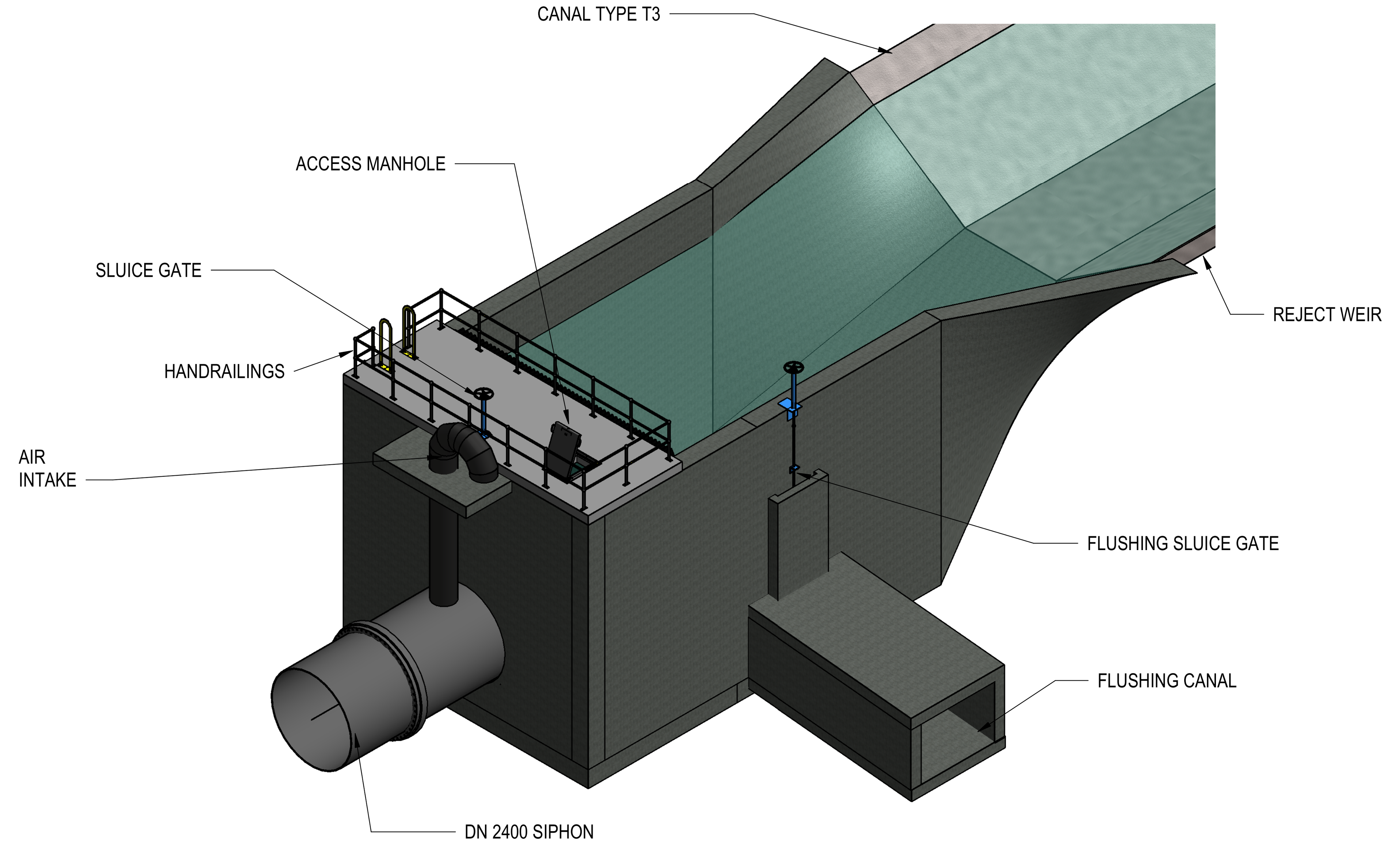

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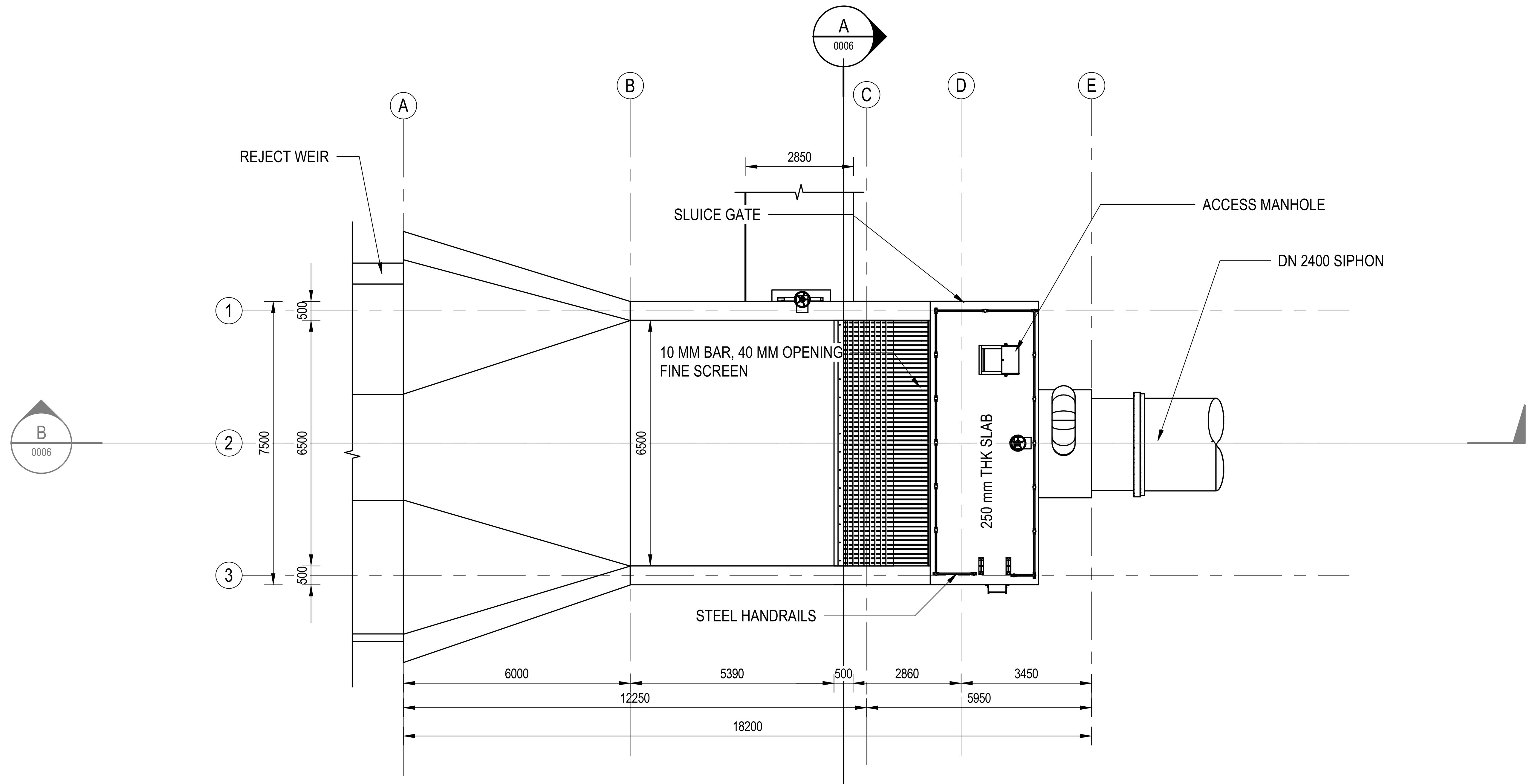

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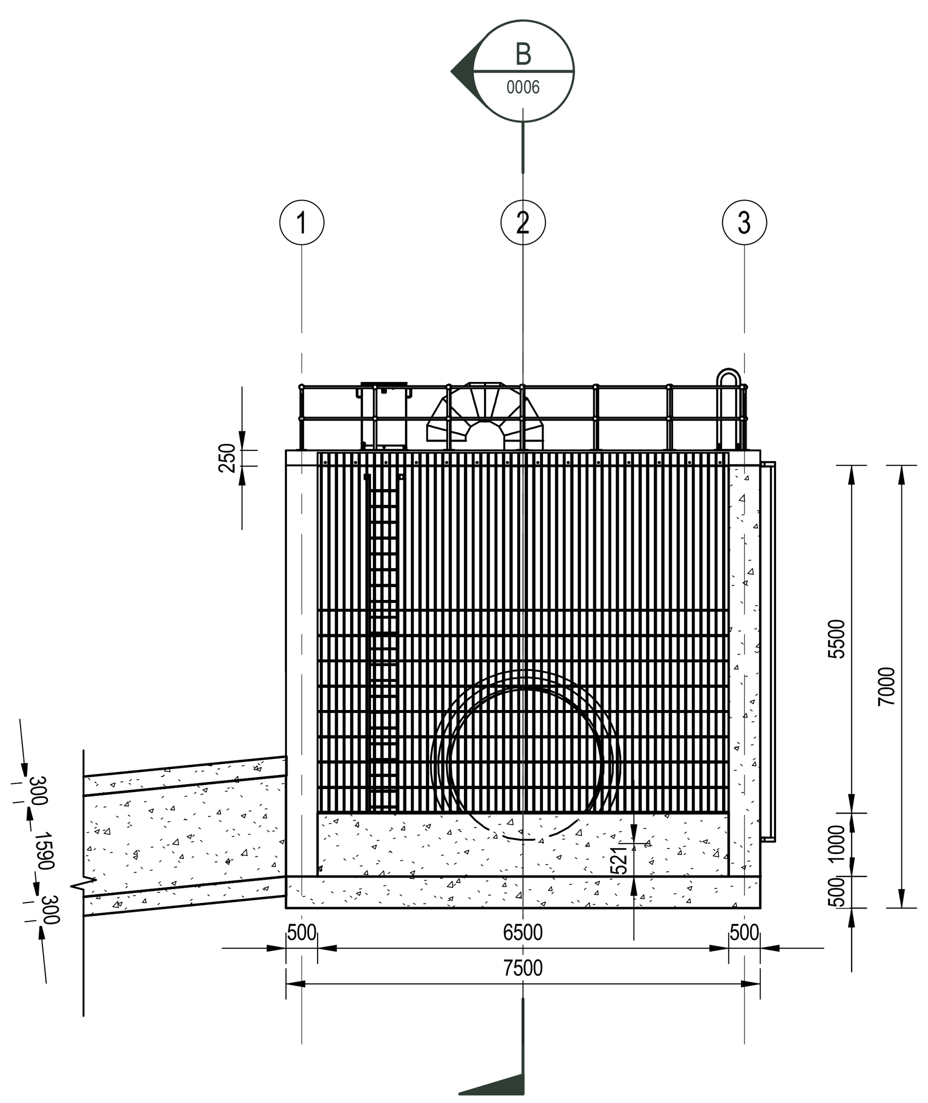

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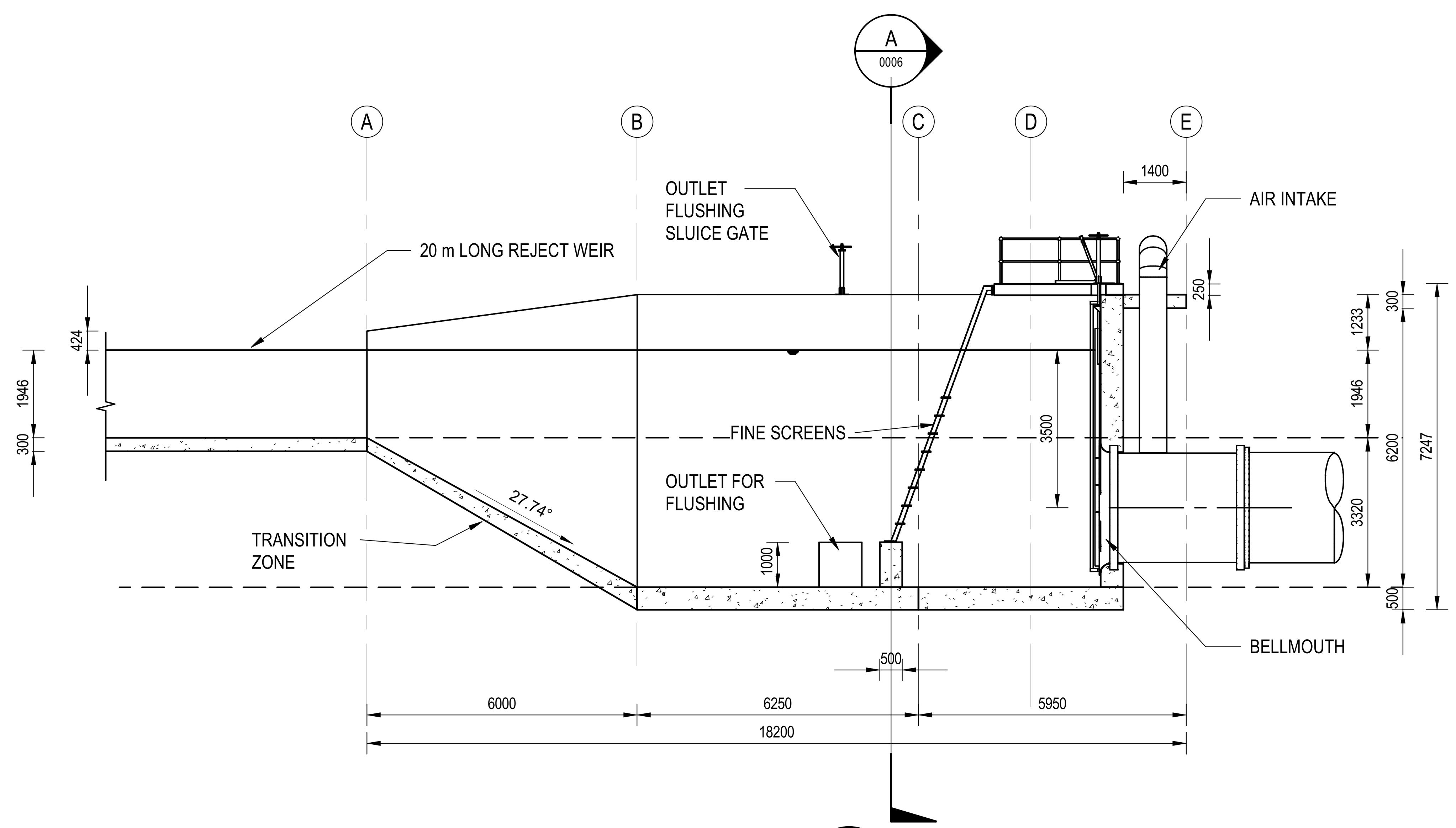


SECTION B
1 : 100
0006

CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	A	31.07.20	FEASIBILITY - NOT FOR CONSTRUCTION	E. v.d. BERG

aurecon

SCALE	SIZE
AS SHOWN	A1

DRAWN: S. DAKA
DESIGNED: G. CALITZ
CHECKED: A. CHANG

FEASIBILITY
NOT FOR CONSTRUCTION
APPROVED
DATE

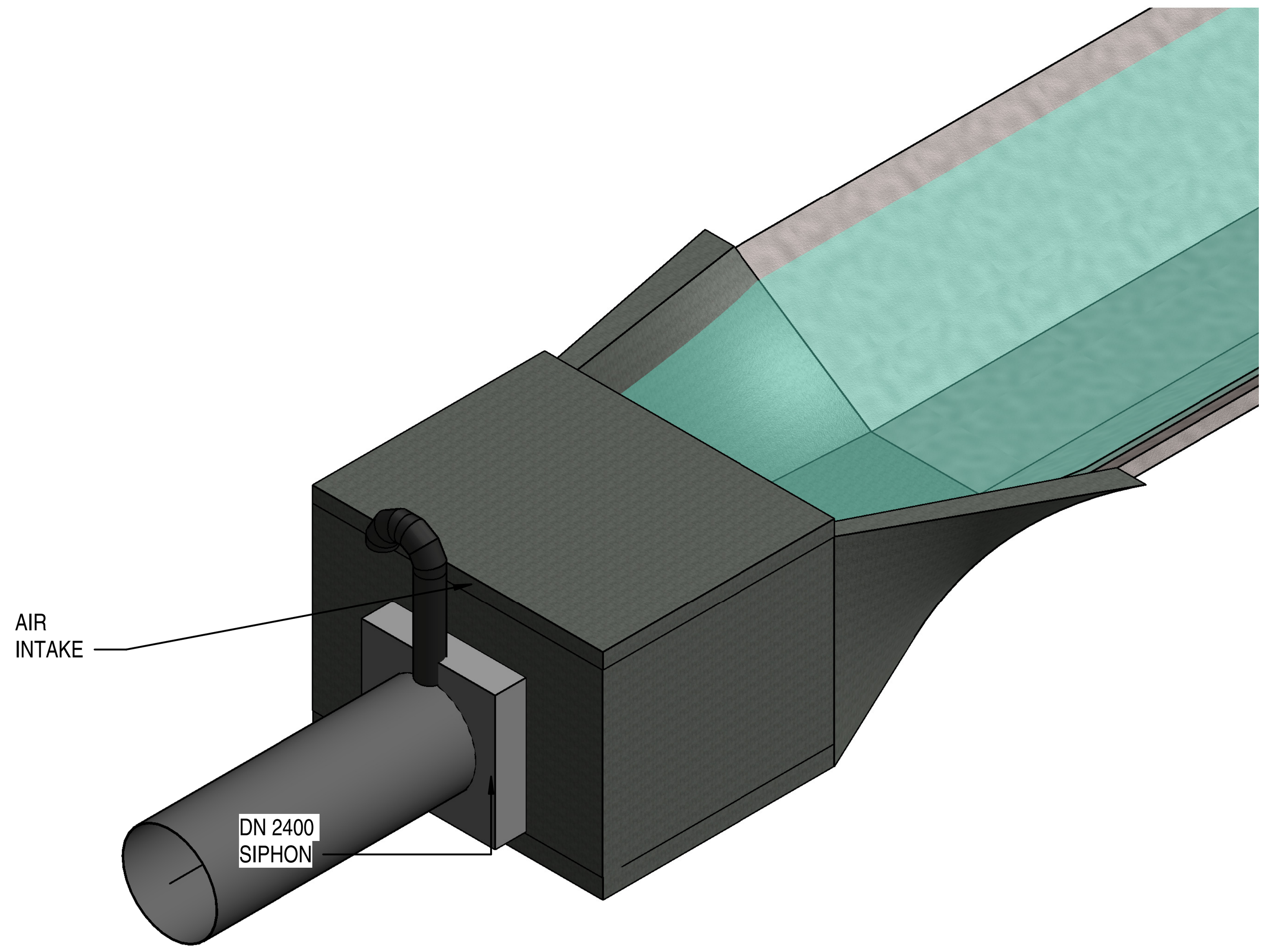
PROJECT: CLANWILLIAM BRIDGING STUDY

TITLE: RIGHT BANK CANAL TYPICAL SIPHON INLET

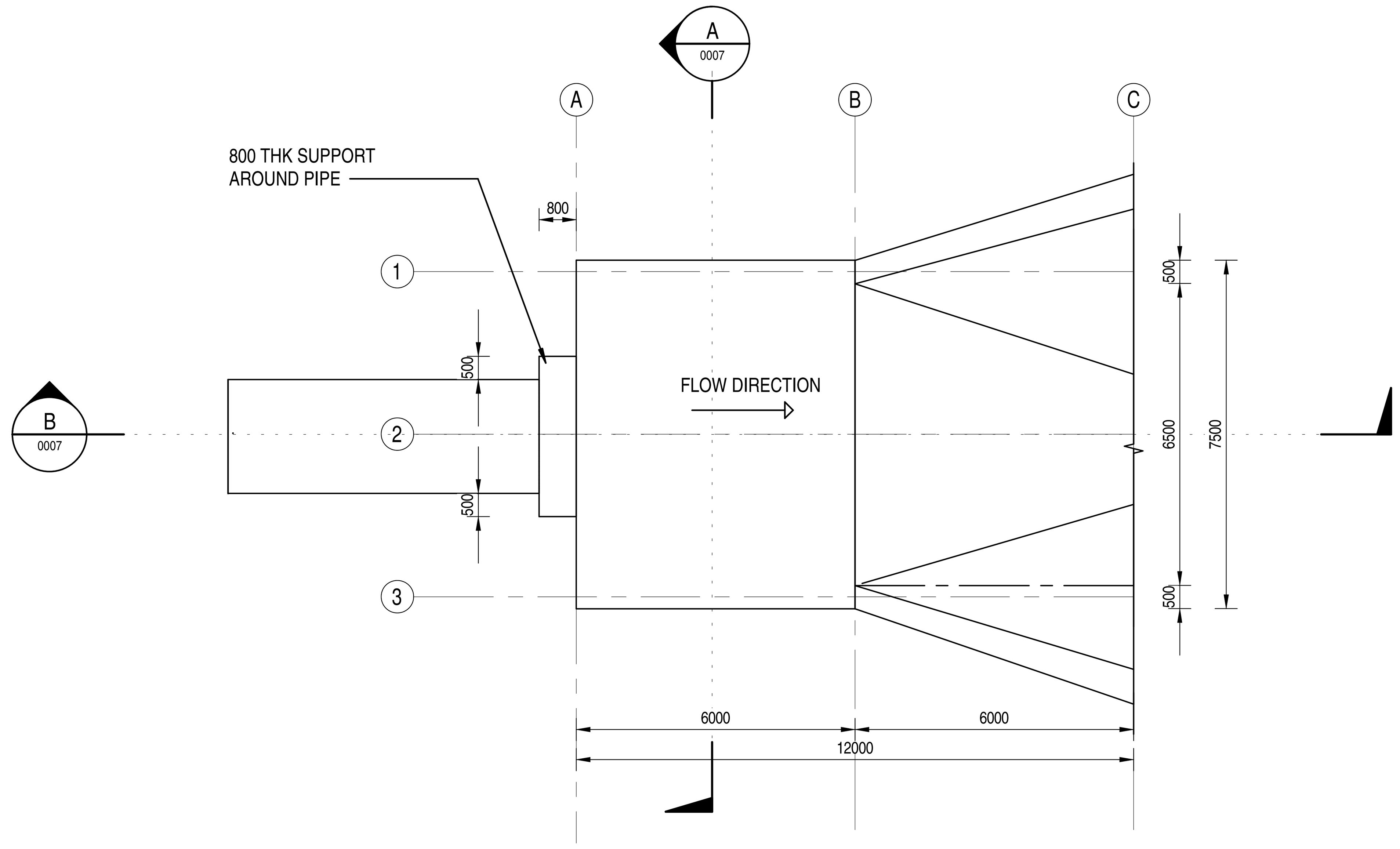
DRAWING No.

PROJECT No	WBS	TYPE	DISC	NUMBER	REV
113281	1000	DRG	CC	0006	A

Plot Date: 8/5/2020 1:12:23 AM Office: CC Filename: C:\Users\Sithembiso.Daka\Aurecon Group\Clanwilliam - General\03 Prj DEL\06 Task 7 Feasibility Options\05 RB Canal\Modelling\Revit\113834-1000-MDM-CC-0001 SIPHON INLET.rvt

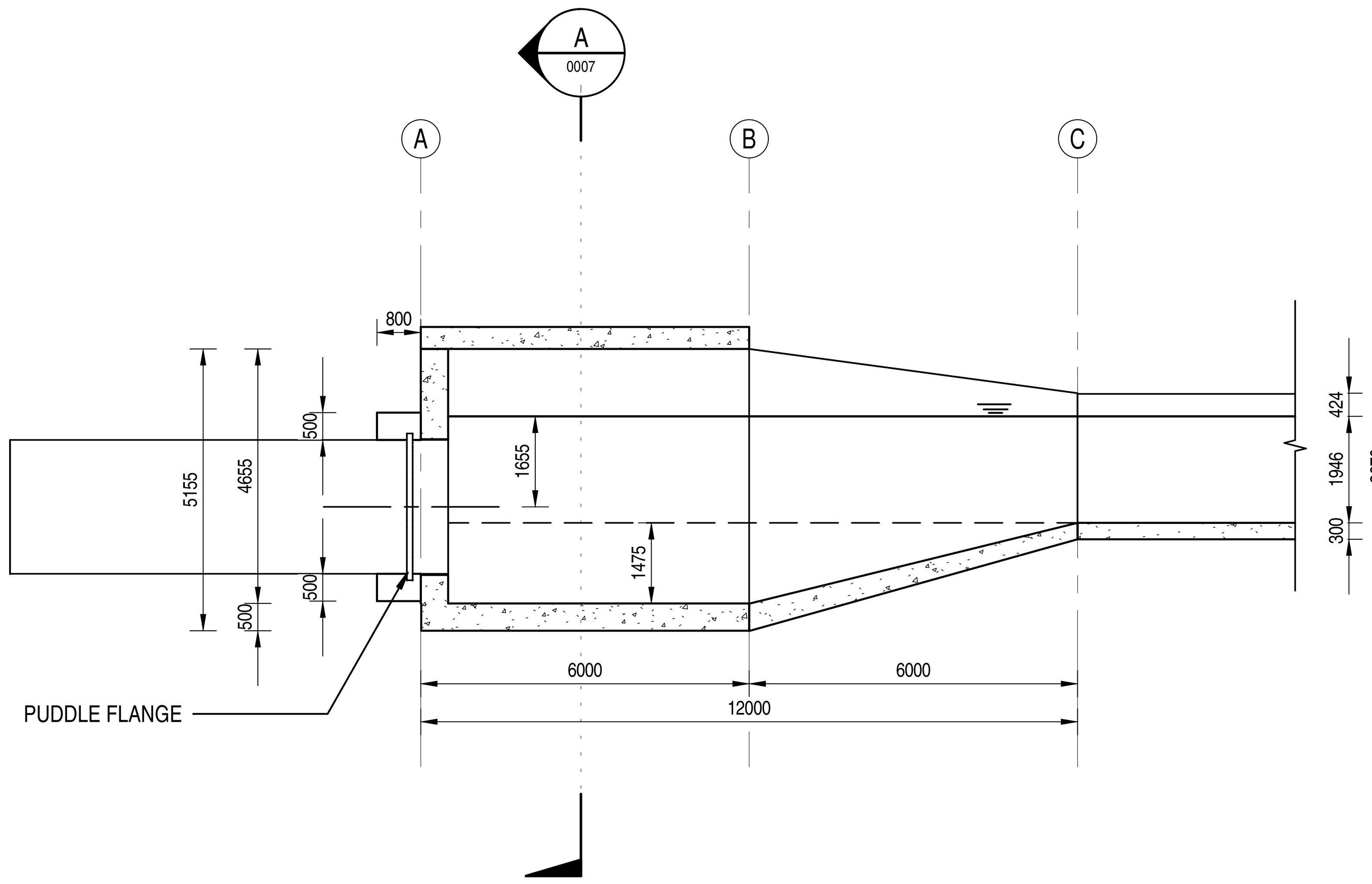


ISOMETRIC VIEW



PLAN

SCALE 1 : 100



SECTION B
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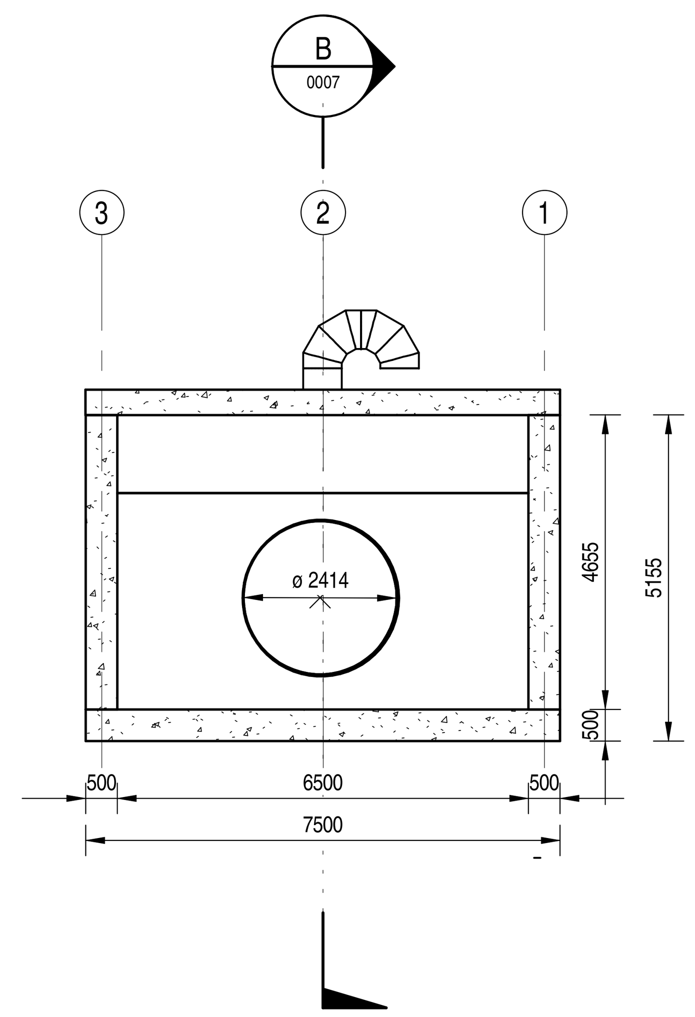


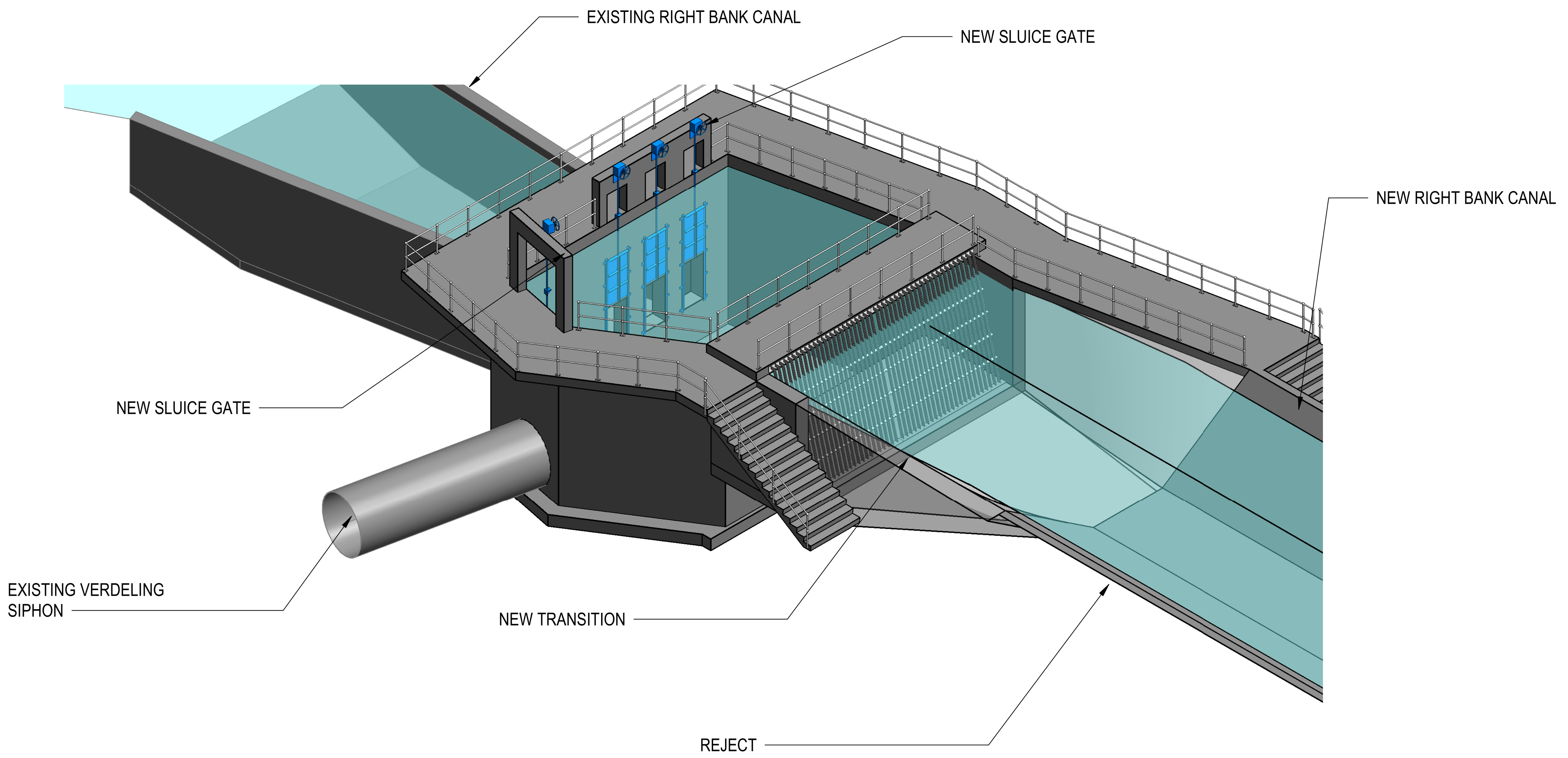
SECTION A
0007
1 : 100

aurecon

CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	A	24.04.20	FEASIBILITY - NOT FOR CONSTRUCTION	E. v.d. BERG

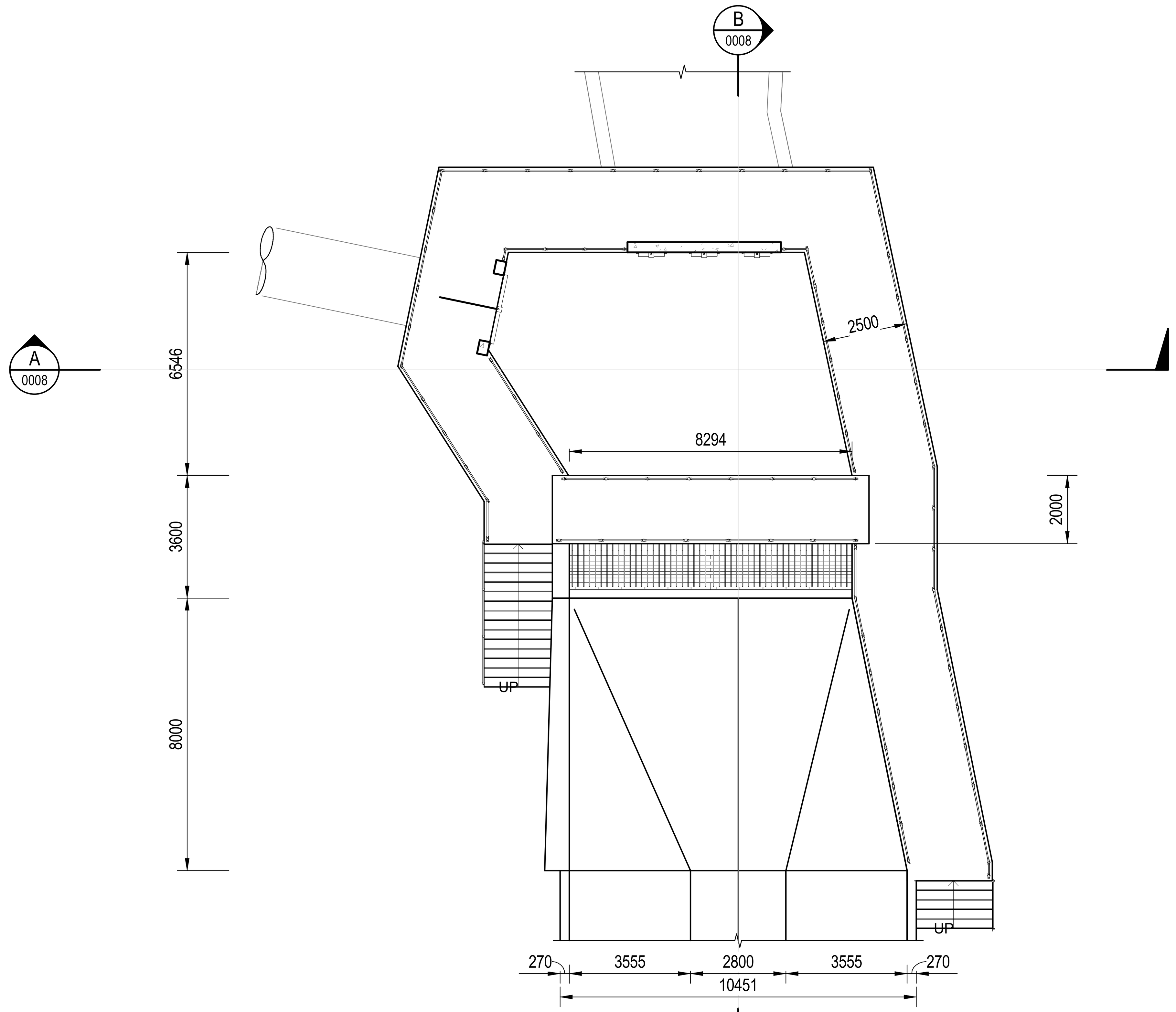
SCALE	AS SHOWN
SIZE	A1
DRAWN	S. DAKA
DESIGNED	G. CALITZ
CHECKED	A. CHANG
	FEASIBILITY NOT FOR CONSTRUCTION
APPROVED	DATE
PROJECT	CLANWILLIAM BRIDGING STUDY
TITLE	RIGHT BANK CANAL TYPICAL SIPHON OUTLET

DRAWING No.	PROJECT No	WBS	TYPE	DISC	NUMBER	REV
	113834	1000	DRG	CC	0007	A



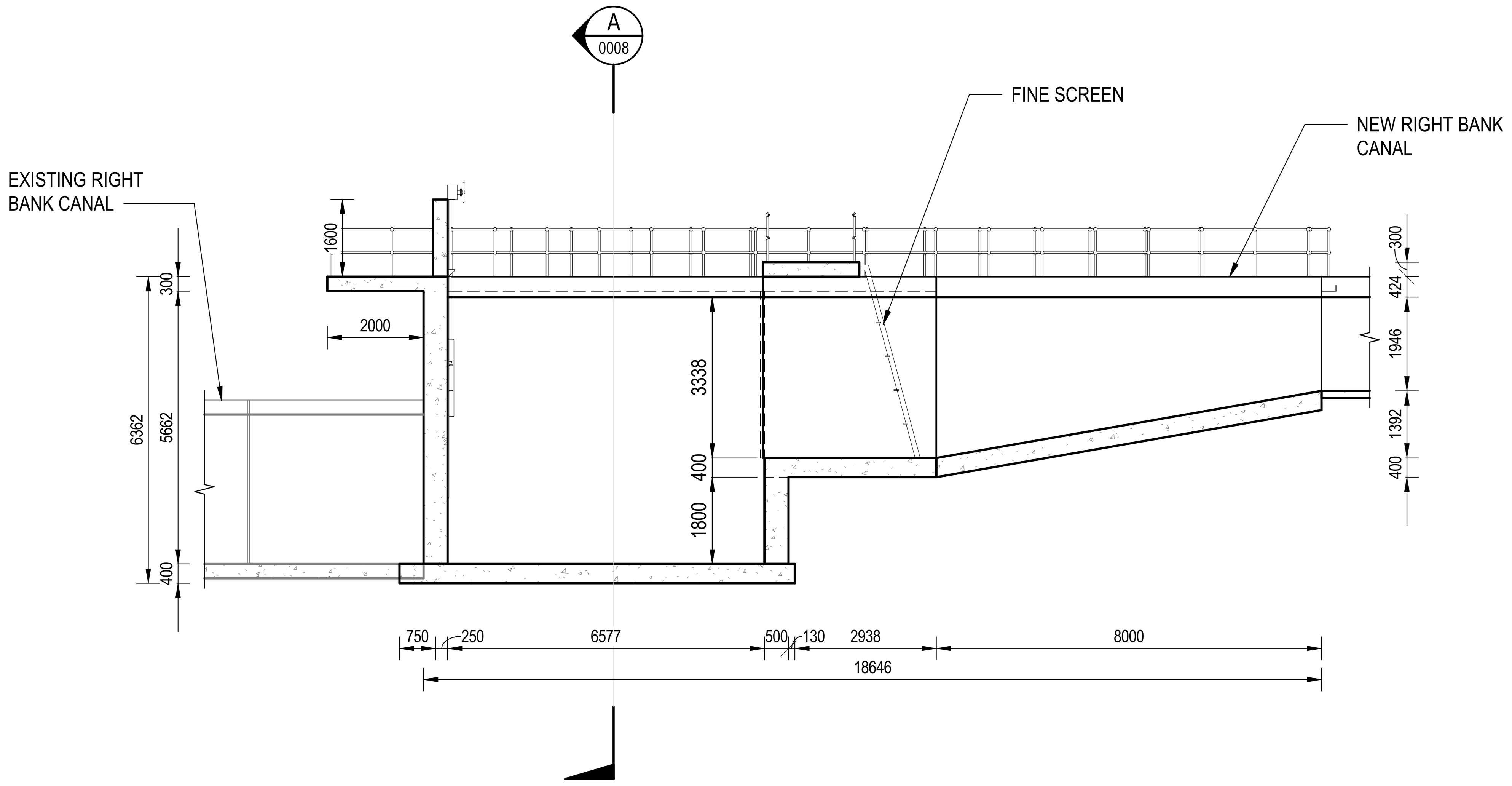
VERDELING SIPHON INLET 3D

NTS



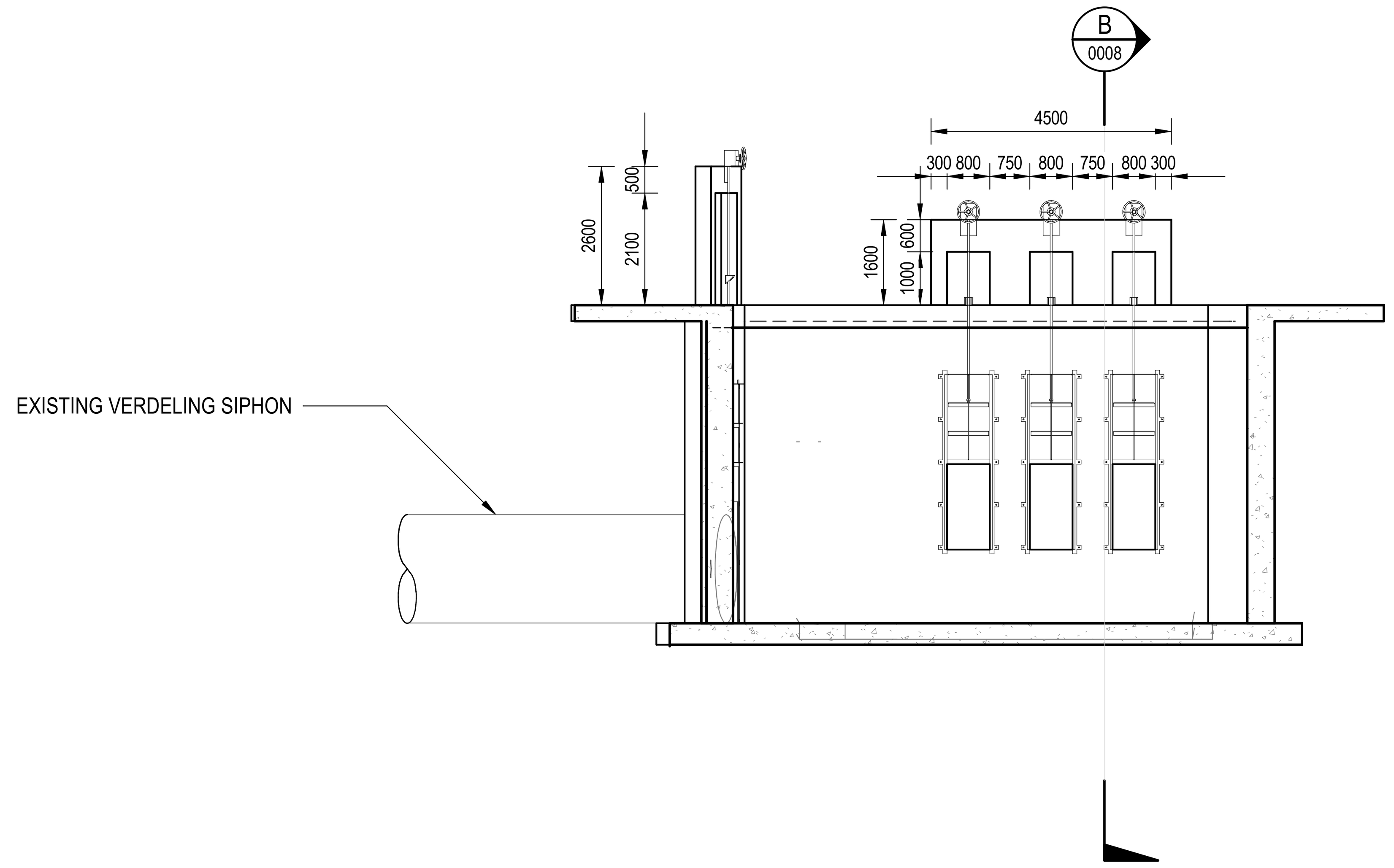
PLAN VIEW

SCALE 1 : 120



SECTION B

1 : 100 — 0008



SECTION A

1 : 100 — 0008

aurecon

CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	A	31.07.20	FEASIBILITY-NOT FOR CONSTRUCTION	E.v.d. BERG

SCALE	AS SHOWN
SIZE	A1
DRAWN	S. DAKA
DESIGNED	G. CALITZ
CHECKED	A. CHANG

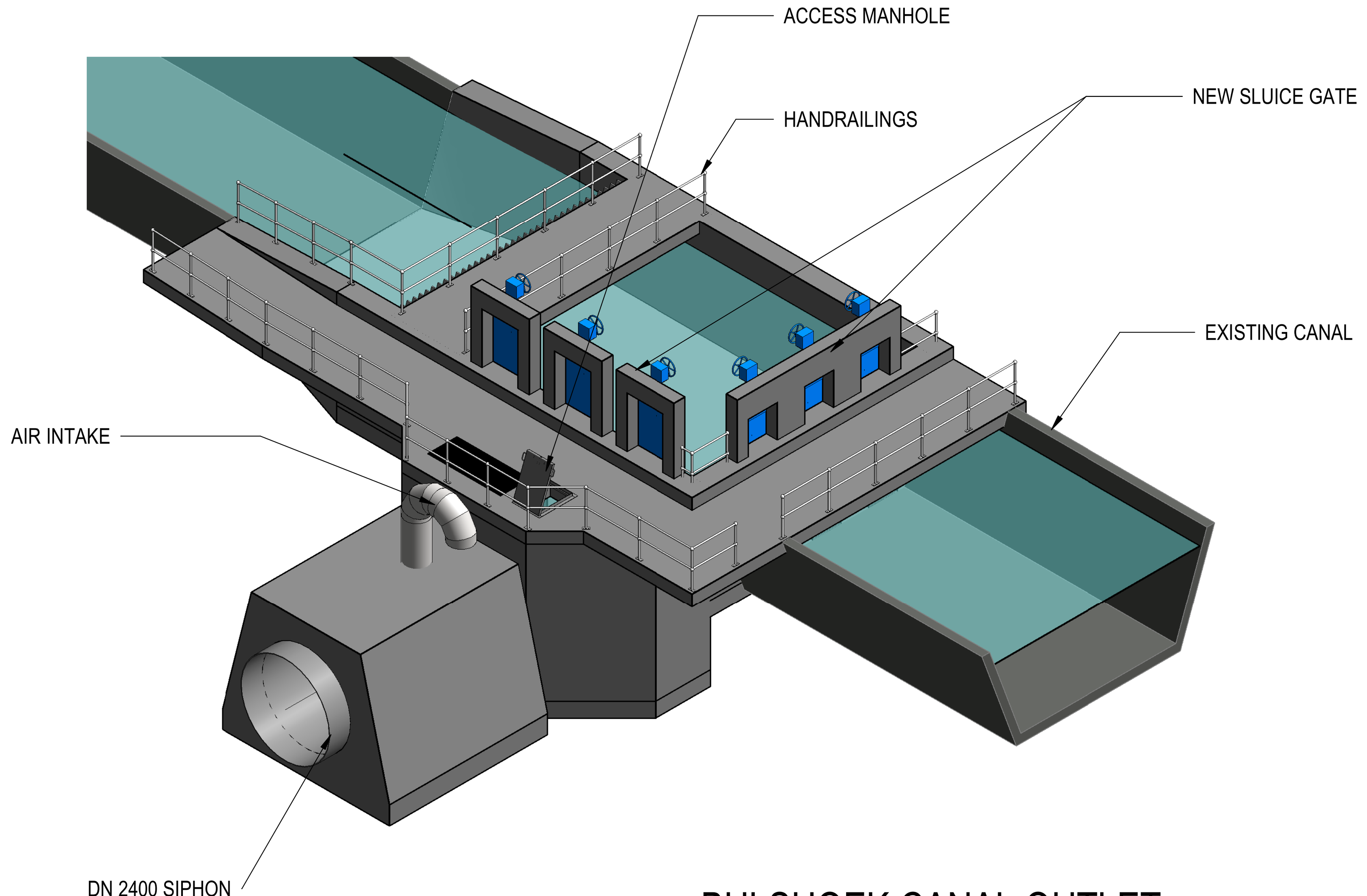
FEASIBILITY
NOT FOR CONSTRUCTION

APPROVED

DATE

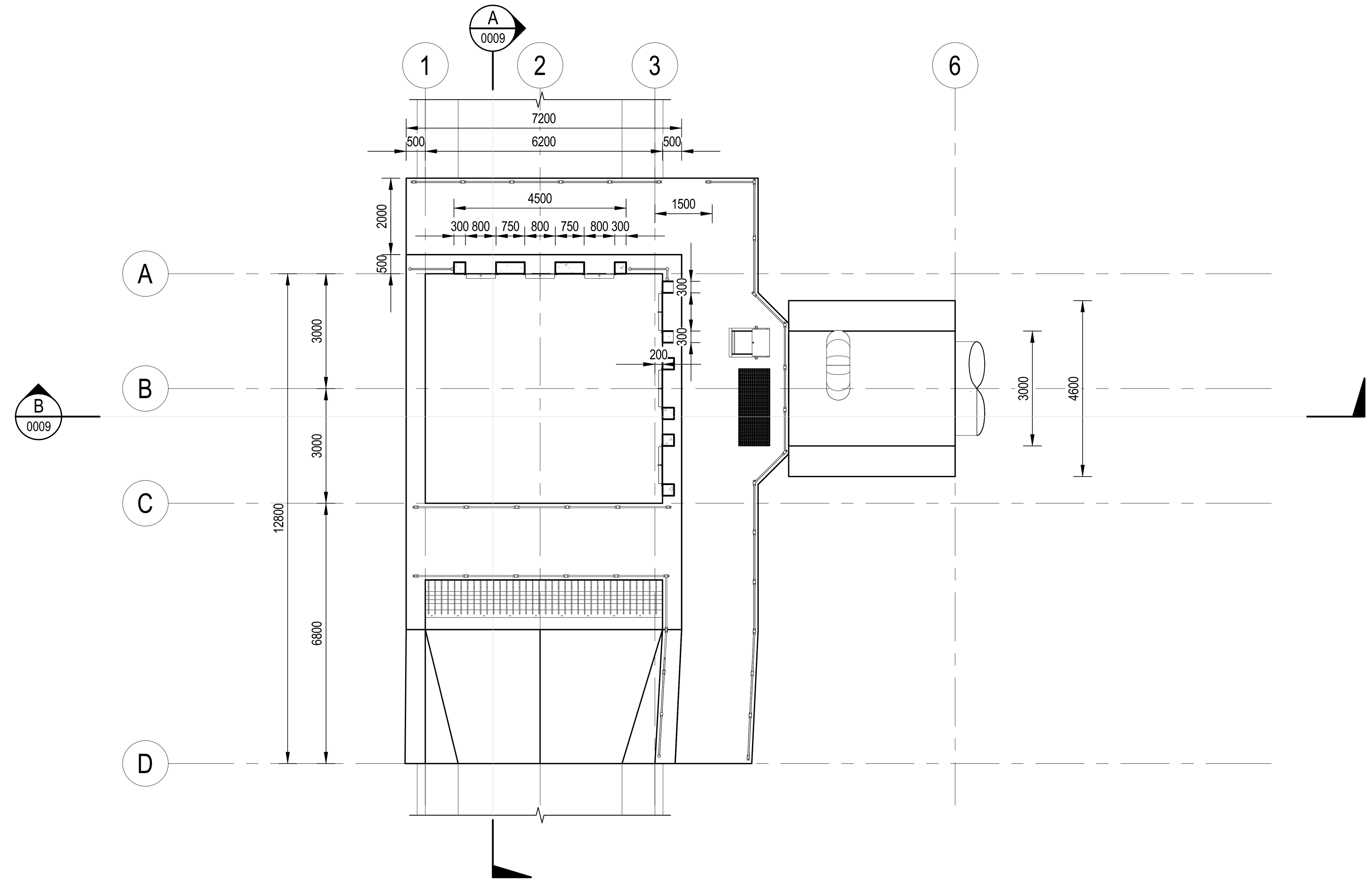
PROJECT	CLANWILLIAM BRIDGING STUDY
TITLE	RIGHT BANK CANAL VERDELING SIPHON INLET

DRAWING No.	PROJECT No	WBS	TYPE	DISC	NUMBER	REV
	113834	1000	DRG	CC	0008	A



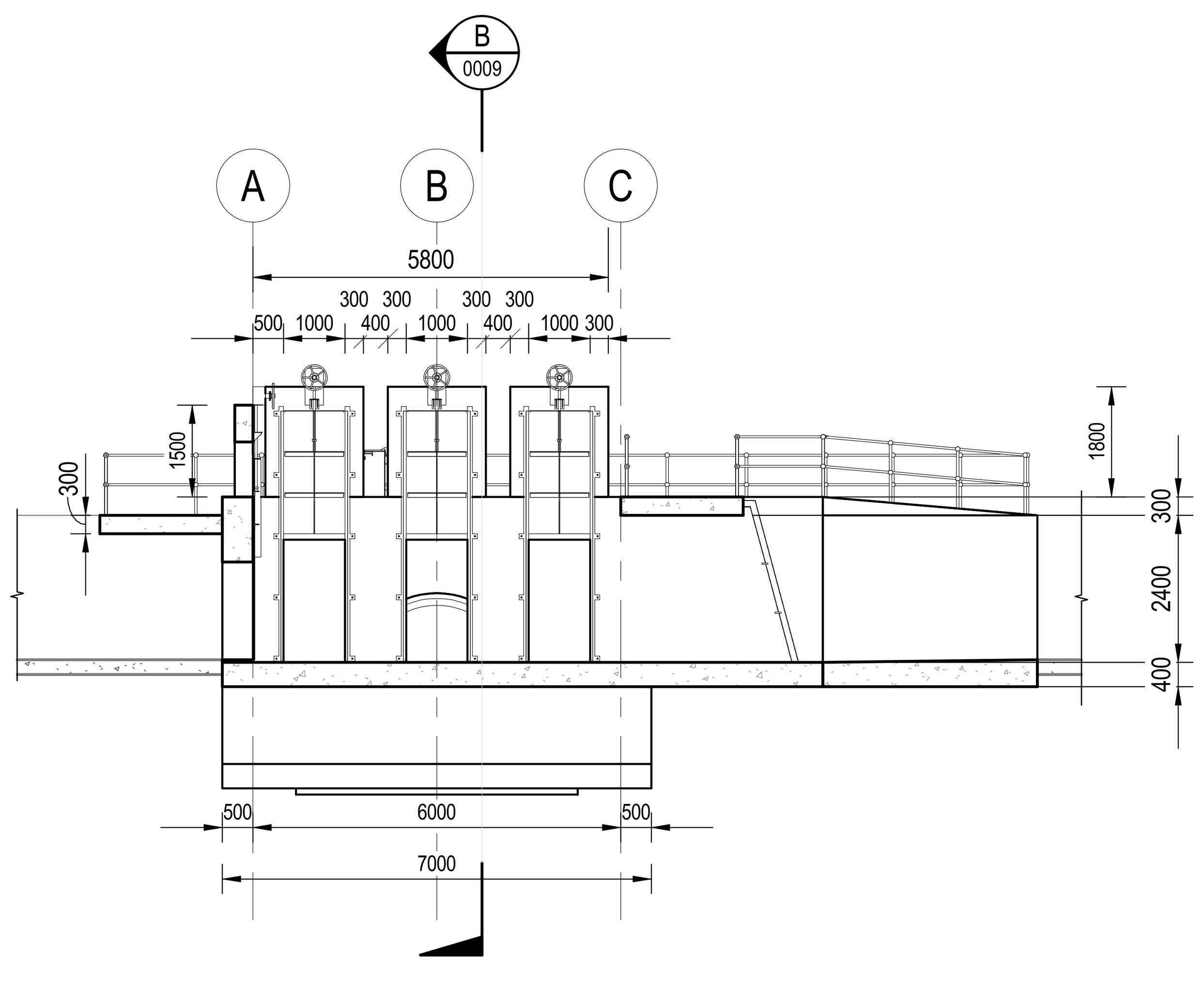
BULSHOEK CANAL OUTLET

NTS



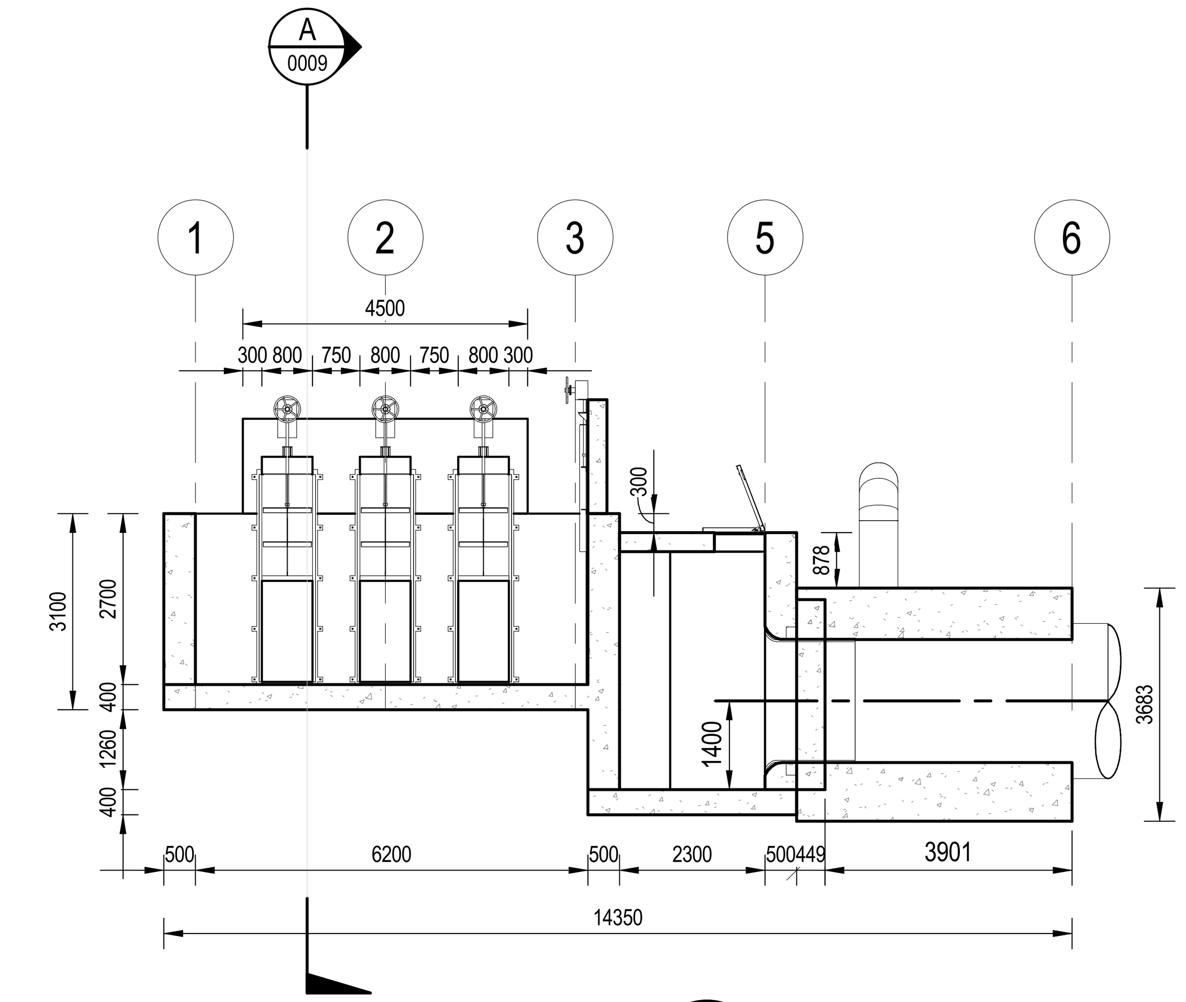
PLAN VIEW

SCALE 1 : 100



SECTION A 0009

1 : 100



SECTION B 0009

1 : 100

aurecon

CLIENT					
REV	DATE	REVISION DETAILS	APPROVED	SCALE	SIZE
A	31.07.20	FEASIBILITY- NOT FOR CONSTRUCTION	E. v.d. BERG	AS SHOWN	A1

DRAWN: S. DAKA

DESIGNED: G. CALITZ

CHECKED: A. CHANG

FEASIBILITY

NOT FOR CONSTRUCTION

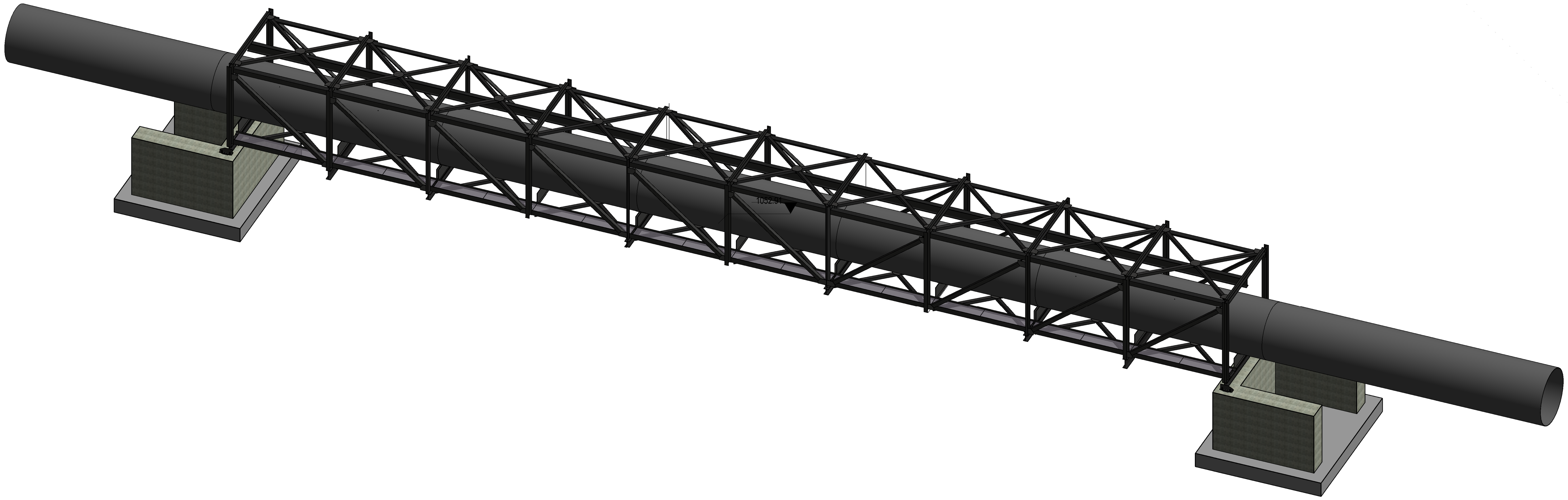
APPROVED

DATE

PROJECT: CLANWILLIAM BRIDGING STUDY

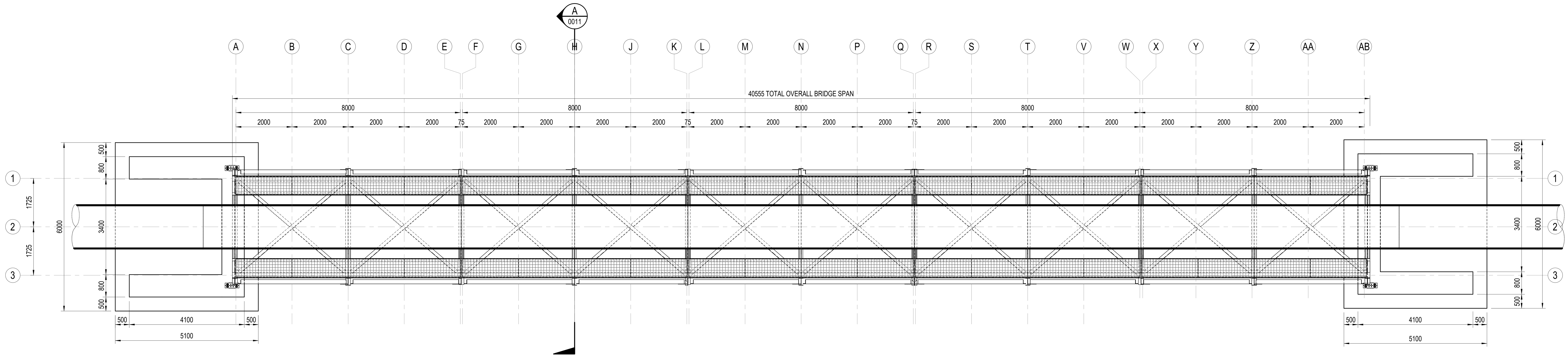
TITLE: RIGHT BANK CANAL BULSHOEK CANAL OUTLET

DRAWING No.: PROJECT No 113834 - WBS 1000 - TYPE DRG - DISC CC - NUMBER 0009 - REV A



PIPE BRIDGE 3D VIEW

NTS



BRIDGE SETTING OUT LAYOUT

NTS

aurecon

CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	A	31.07.20	FEASIBILITY STUDY - NOT FOR CONSTRUCTION	E.v.d BERG

SCALE	SIZE
AS SHOWN	A1

DRAWN: S. DAKA
DESIGNED: M. DA SILVER
CHECKED: A. CHANG

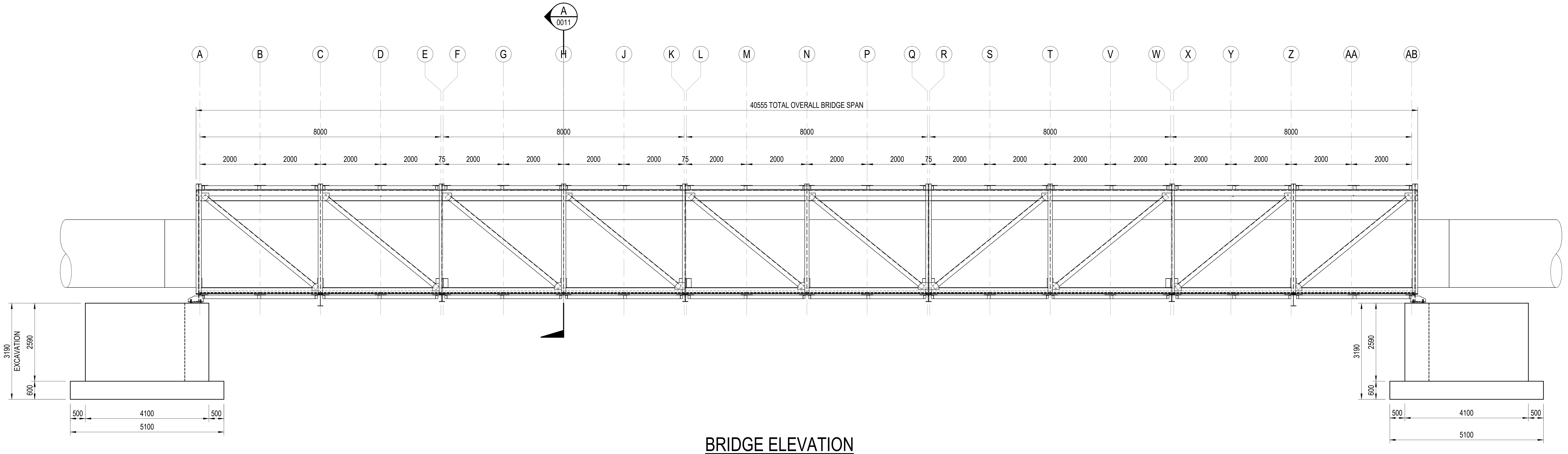
FEASIBILITY
NOT FOR CONSTRUCTION

APPROVED
DATE

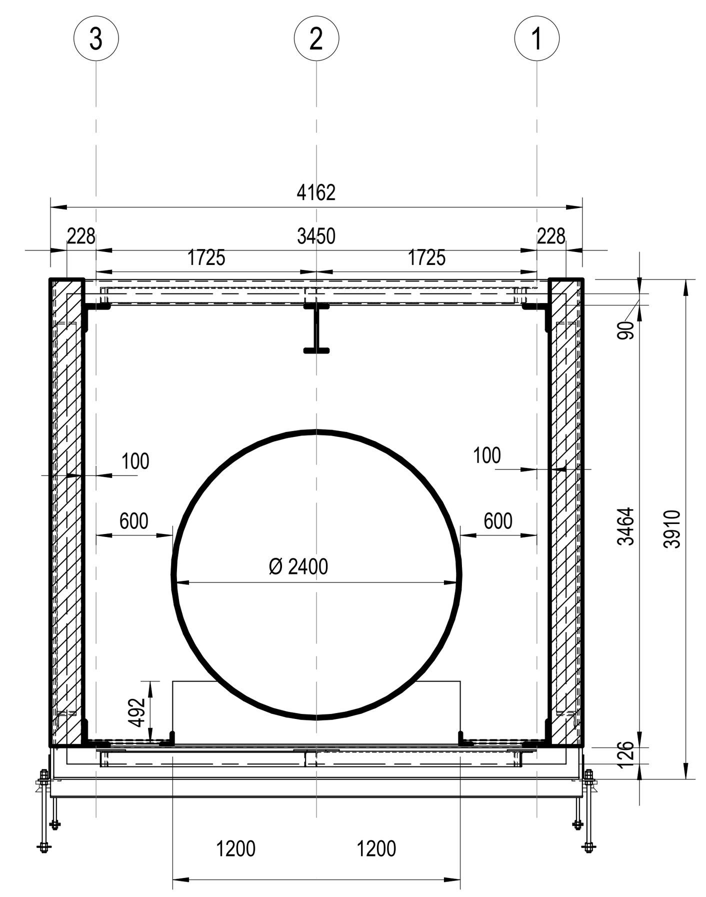
PROJECT: CLANWILLIAM BRIDGING STUDY

TITLE: RIGHT BANK CANAL TYPICAL RIVER PIPE BRIDGE SHEET 1 OF 2

DRAWING No.	PROJECT No	WBS	TYPE	DISC	NUMBER	REV
	113834	1000	DRG	CC	0010	A



BRIDGE ELEVATION
NTS



SECTION A
1 : 50
0010

CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	A	31.07.20	FEASIBILITY STUDY - NOT FOR CONSTRUCTION	E.v.d BERG

SCALE	SIZE
AS SHOWN	A1

DRAWN: S. DAKA
DESIGNED: M. DA SILVA
CHECKED: A. CHANG

FEASIBILITY
NOT FOR CONSTRUCTION

APPROVED
DATE

PROJECT: CLANWILLIAM BRIDGING STUDY

TITLE: RIGHT BANK CANAL
TYPICAL RIVER PIPE BRIDGE
SHEET 2 OF 2

DRAWING No.	PROJECT No	WBS	TYPE	DISC	NUMBER	REV
	113834	1000	DRG	CC	0011	A

aurecon

APPENDIX B: Cost Estimate

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)			
NEW MAIN RIGHT BANK CANAL BOQ-00 SUMMARY			
No.	**DESCRIPTION**	**BILL REFERENCE / RATE**	**AMOUNT (Exl VAT) Rand**
1	**Outlet**		
	(a) Use existing Bulshoek Weir Outlet	BOQ-01	-
2	**Canals**		
	(a) Left Bank Upgrade (0.00 km - 3.05 km)	BOQ-02	144 599 200
	(b) Right Bank Reach 1 (3.35 km - 21.91 km)	BOQ-03	351 432 200
	(c) Right Bank Reach 2 (21.18 km - 23.86 km)	BOQ-04	12 912 200
	(d) Right Bank Reach 3 (24.70 km - 33.55 km)	BOQ-05	136 184 600
2	**Syphon 1**		
	(a) Syphon 1 Inlet	BOQ-09	3 449 600
	(b) Syphon 1 Pipework and Pipe Bridge	BOQ-06	26 259 800
	(c) Syphon 1 Typcial Outlet	BOQ-11	718 500
3	**Syphon 2A**		
	(a) Syphon 2A Typical Inlet	BOQ-10	2 656 200
	(b) Syphon 2A Concrete Culvert	BOQ-07	62 388 900
	(c) Syphon 2A Typical Outlet	BOQ-11	718 500
4	**Syphon 2B**		
	(a) Syphon 2B Typical Inlet	BOQ-10	2 656 200
	(b) Syphon 2B Concrete Culvert	BOQ-08	40 843 400
	(c) Syphon 2B Typical Outlet	BOQ-11	718 500
5	**Verdeling Syphon Tie-in Structure**		
	(a) Verdeling Syphon Tie-in Structure	BOQ-12	4 458 400
6	**Typical Road Crossings**		
	(a) R363 Road Crossing (4 No. crossings)	BOQ-13	7 897 200
	(b) Major Farm Road Crossing (11 No. crossings)	BOQ-13	21 717 300
	SUB TOTAL A		**819 610 700**
	Preliminary & General		
	(a) Preliminary & General (% of sub total A)	40%	327 844 300
	SUB TOTAL B		**1 147 455 000**
	Contingencies		
	(a) Contingencies (% of sub total B)	25%	286 863 800
	SUB TOTAL C		**1 434 318 800**
	Professional Fees		
	(a) Professional Fees (% of sub total C)	10%	143 431 900
	Land Acquisition		
	(a) Land Acquisition Costs	BOQ-14	15 979 100
	TOTAL COST (EXCL. VAT)		**1 593 729 800**
	VAT		
	(a) VAT (at 15%)	15%	239 059 500
	TOTAL COST (INCL. VAT)		**1 832 789 300**

A	**Annual Operation and Maintenance Costs**		
	(a) O&M Costs for Civil Works	0.50%	3 297 900
	(b) O&M Costs for Mechanical Components	4.00%	303 500
	(c) O&M Costs for Dams	0.25%	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)		**3 601 400**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-01 BULSHOEK WEIR OUTLET (at 0.00 km)

No	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Use Existing outlet as is**				
	(a) Zero cost	No.	-	0.0	-
	SUB TOTAL A				**-**
	Preliminary & General				
	(a) Preliminary & General (% of sub total A)	%	40%	0.0	-
	SUB TOTAL B				**-**
	Contingencies				
	(a) Contingencies (% of sub total B)	%	25%	0.0	-
	SUB TOTAL C				**-**
	Professional Fees				
	(a) Professional Fees (% of sub total C)	%	10%	0.0	-
	TOTAL COST (EXCL. VAT)				**-**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	0.0	-
	TOTAL COST (INCL. VAT)				**-**

A	**Annual Operation and Maintenance Costs (Indicative)**				
	(a) O&M Costs for Civil Works	%	0.50%	1 000 000.0	5 000
	(b) O&M Costs for Mechanical Components	%	4.00%	2 000 000.0	80 000
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**85 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-02 CANALS - LEFT BANK UPGRADE (0.00 km - 3.05 km)

No.	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	161 205.0	4 836 200
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	161 205.0	354 700
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	22 187.0	2 218 700
	(ii) all materials to spoil	m^3	100	8 604.0	860 400
	(iii) extra over for rock	m^3	430	6 158.2	2 648 100
	(b) Preparation of surfaces to receive concrete	m^2	60	29 693.0	1 781 600
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	22 187.0	3 106 200
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	4 454.0	9 130 700
	(ii) Blinding (15 MPa)	m^2	120	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	371.8	5 577 000
	(ii) Reinforcing bars (> 16 mm)	t	15 000	0.0	-
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	29 693.0	1 484 700
5	**Access Roads**				
	(a) Construct new access roads (Gravel)	km	350 000	0.0	-
	(b) Maintain existing access road during construction	month	65 000	12.0	780 000
6	**Demolition**				
	(a) Demolition of existing cancrete				
	(i) Structural (25 MPa)	m^3	10 000	4 396.0	43 960 000
7	**Temporary Operating Costs**				
	(a) Temporary over-pumping costs for left bank canal upgrade				
	(i) Over-pumping capital costs	No.	34 000 000	1.0	34 000 000
	(i) Over-pumping operating costs	month	3 000 000	5.0	15 000 000
	SUB TOTAL A				**125 738 300**
8	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	125 738 300.0	6 287 000
				Carried Forward	*132 025 300*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-02 CANALS - LEFT BANK UPGRADE (0.00 km - 3.05 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*132 025 300*
9	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	125 738 300.0	12 573 900
	SUB TOTAL B				**144 599 200**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	144 599 200.0	57 839 700
	SUB TOTAL C				**202 438 900**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	202 438 900.0	50 609 800
	SUB TOTAL D				**253 048 700**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	253 048 700.0	25 304 900
	TOTAL COST (EXCL. VAT)				**278 353 600**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	278 353 600.0	41 753 100
	TOTAL COST (INCL. VAT)				**320 106 700**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	76 738 300.0	383 700
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**383 700**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-03 CANALS - RIGHT BANK REACH 1 (3.35 km - 21.91 km)

No.	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	469 062.0	14 071 900
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	469 062.0	1 032 000
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	344 025.0	34 402 500
	(ii) all materials to spoil	m^3	100	5 745.0	574 500
	(iii) extra over for rock	m^3	430	174 885.0	75 200 600
	(b) Preparation of surfaces to receive concrete	m^2	60	206 295.0	12 377 700
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	344 025.0	48 163 500
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	30 944.0	63 435 200
	(ii) Blinding (15 MPa)	m^2	120	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	2 583.1	38 745 800
	(ii) Reinforcing bars (> 16 mm)	t	15 000	0.0	-
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	206 295.0	10 314 800
5	**Access Roads**				
	(a) Construct new access roads (Gravel)	km	350 000	18.6	6 494 600
	(b) Maintain existing access road during construction	month	65 000	12.0	780 000
	SUB TOTAL A				**305 593 100**
6	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	305 593 100.0	15 279 700
7	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	305 593 100.0	30 559 400
	SUB TOTAL B				**351 432 200**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	351 432 200.0	140 572 900
	SUB TOTAL C				**492 005 100**
				Carried Forward	*492 005 100*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL					
BOQ-03 CANALS - RIGHT BANK REACH 1 (3.35 km - 21.91 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*492 005 100*
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	492 005 100.0	123 001 300
	SUB TOTAL D				**615 006 400**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	615 006 400.0	61 500 700
	TOTAL COST (EXCL. VAT)				**676 507 100**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	676 507 100.0	101 476 100
	TOTAL COST (INCL. VAT)				**777 983 200**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	305 593 100.0	1 528 000
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**1 528 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-04 CANALS - RIGHT BANK REACH 2 (23.18 km - 23.86 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	18 360.0	550 800
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	18 360.0	40 400
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	8 394.0	839 400
	(ii) all materials to spoil	m^3	100	0.0	-
	(iii) extra over for rock	m^3	430	2 518.2	1 082 900
	(b) Preparation of surfaces to receive concrete	m^2	60	7 942.0	476 600
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	8 709.0	2 612 700
	(b) General earthfill from stockpile	m^3	140	8 394.0	1 175 200
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	1 191.0	2 441 600
	(ii) Blinding (15 MPa)	m^2	120	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	99.4	1 491 300
	(ii) Reinforcing bars (> 16 mm)	t	15 000	0.0	-
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	7 942.0	397 100
5	**Access Roads**				
	(a) Construct new access roads (Gravel)	km	350 000	0.00	-
	(b) Maintain existing access road during construction	month	10 000	12.0	120 000
	SUB TOTAL A				**11 228 000**
6	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	11 228 000.0	561 400
7	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	11 228 000.0	1 122 800
	SUB TOTAL B				**12 912 200**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	12 912 200.0	5 164 900
	SUB TOTAL C				**18 077 100**
				Carried Forward	*18 077 100*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-04 CANALS - RIGHT BANK REACH 2 (23.18 km - 23.86 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*18 077 100*
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	18 077 100.0	4 519 300
	SUB TOTAL D				**22 596 400**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	22 596 400.0	2 259 700
	TOTAL COST (EXCL. VAT)				**24 856 100**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	24 856 100.0	3 728 500
	TOTAL COST (INCL. VAT)				**28 584 600**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	11 228 000.0	56 200
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**56 200**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-05 CANALS - RIGHT BANK REACH 3 (24.70 km - 33.55 km)

No.	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	197 251.0	5 917 600
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	197 251.0	434 000
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	124 485.0	12 448 500
	(ii) all materials to spoil	m^3	100	5 679.0	568 000
	(iii) extra over for rock	m^3	430	39 049.2	16 791 200
	(b) Preparation of surfaces to receive concrete	m^2	60	100 688.0	6 041 300
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	124 485.0	17 427 900
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	15 103.0	30 961 200
	(ii) Blinding (15 MPa)	m^2	120	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	1 260.7	18 910 900
	(ii) Reinforcing bars (> 16 mm)	t	15 000	0.0	-
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	100 688.0	5 034 400
5	**Access Roads**				
	(a) Construct new access roads (Gravel)	km	350 000	8.9	3 106 300
	(b) Maintain existing access road during construction	month	65 000	12.0	780 000
	SUB TOTAL A				**118 421 300**
6	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	118 421 300.0	5 921 100
7	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	118 421 300.0	11 842 200
	SUB TOTAL B				**136 184 600**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	136 184 600.0	54 473 900
	SUB TOTAL C				**190 658 500**
				Carried Forward	*190 658 500*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-05 CANALS - RIGHT BANK REACH 3 (24.70 km - 33.55 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*190 658 500*
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	190 658 500.0	47 664 700
	SUB TOTAL D				**238 323 200**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	238 323 200.0	23 832 400
	TOTAL COST (EXCL. VAT)				**262 155 600**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	262 155 600.0	39 323 400
	TOTAL COST (INCL. VAT)				**301 479 000**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	118 421 300.0	592 200
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**592 200**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL					
BOQ-06 SYPHON 1 PIPEWORK AND PIPE BRIDGE (3.05 km - 3.35km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	1 253.4	37 700
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	1 253.4	2 800
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	1 573.4	157 400
	(ii) all materials to spoil	m^3	100	957.8	95 800
	(iii) extra over for rock	m^3	430	2 024.9	870 800
	(b) Preparation of surfaces to receive concrete	m^2	60	112.0	6 800
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	458.2	64 200
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	66.6	50 000
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	293.8	602 300
	(ii) Blinding (15 MPa)	m^2	120	91.8	11 100
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	16.3	245 300
	(ii) Reinforcing bars (> 16 mm)	t	15 000	16.3	245 300
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	91.8	4 600
5	**Pipes**				
	(a) Steel Pipes				
	(i) DN2400, t = 18 mm Steel Pipe	m	36 980	299.0	11 057 100
	(ii) DN600, t = 6 mm Steel Pipe	m	3 660	0.0	-
	(b) Transport of Steel Pipes				
	(i) DN2400, No. of 500 km return trips	No.	10 000	25.0	250 000
	(i) DN600, No. of 500 km return trips	No.	10 000	0.0	-
	(b) Bedding for Pipes				
	(i) Selected granular material	m^3	260	794.8	206 700
	(ii) Selected fill material	m^3	230	320.4	73 700
	(c) Installation of Pipes				
	(i) DN2400, t = 18 mm Steel Pipe	m	7 400	299.0	2 212 600
	(ii) DN600, t = 6 mm Steel Pipe	m	740	0.0	-
	(d) Overhaul of material for bedding and selected fill				
	(i) Limited overhaul	m^3	5	2 531.2	12 700
	(ii) Long overhaul	m^3/km	7	0.0	-
				Carried Forward	*16 206 900*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-06 SYPHON 1 PIPEWORK AND PIPE BRIDGE (3.05 km - 3.35km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*16 206 900*
6	**Structural Steel (galvanised)**				
	(a) Structural Steelwork (incl. delivery and erection)	t	61 840	90.0	5 565 600
	(b) Handrails	m	1 000	240.0	240 000
	(c) CAT Ladder	No.	12 000	2.0	24 000
	(d) Rectagrid (Type RS 40)	m^2	6 650	120.0	798 000
	SUB TOTAL A				**22 834 500**
7	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	22 834 500.0	1 141 800
8	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	22 834 500.0	2 283 500
	SUB TOTAL B				**26 259 800**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	26 259 800.0	10 504 000
	SUB TOTAL C				**36 763 800**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	36 763 800.0	9 191 000
	SUB TOTAL D				**45 954 800**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	45 954 800.0	4 595 500
	TOTAL COST (EXCL. VAT)				**50 550 300**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	50 550 300.0	7 582 600
	TOTAL COST (INCL. VAT)				**58 132 900**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	22 834 500.0	114 200
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**114 200**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-07 SYPHON 2A CONCRETE CULVERT (21.91 km - 23.18 km)

No.	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	17 239.5	517 200
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	17 239.5	38 000
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	34 951.5	3 495 200
	(ii) all materials to spoil	m^3	100	14 264.1	1 426 500
	(iii) extra over for rock	m^3	430	9 843.1	4 232 600
	(b) Preparation of surfaces to receive concrete	m^2	60	5 491.1	329 500
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	34 951.5	4 893 300
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	13 791.6	10 343 700
	(ii) Sloped	m^2	1 250	0.0	-
	(iii) Horizontal	m^2	1 250	3 447.9	4 309 900
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	6 333.9	12 984 600
	(ii) Blinding (15 MPa)	m^2	120	5 491.1	659 000
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	352.5	5 287 300
	(ii) Reinforcing bars (> 16 mm)	t	15 000	352.5	5 287 300
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	8 939.0	447 000
	SUB TOTAL A				**54 251 100**
5	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	54 251 100.0	2 712 600
6	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	54 251 100.0	5 425 200
	SUB TOTAL B				**62 388 900**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	62 388 900.0	24 955 600
	SUB TOTAL C				**87 344 500**
				Carried Forward	*87 344 500*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-07 SYPHON 2A CONCRETE CULVERT (21.91 km - 23.18 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*87 344 500*
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	87 344 500.0	21 836 200
	SUB TOTAL D				**109 180 700**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	109 180 700.0	10 918 100
	TOTAL COST (EXCL. VAT)				**120 098 800**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	120 098 800.0	18 014 900
	TOTAL COST (INCL. VAT)				**138 113 700**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	54 251 100.0	271 300
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**271 300**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-08 SYPHON 2B CONCRETE CULVERT (23.86 km - 24.70 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	11 286.0	338 600
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	11 286.0	24 900
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	22 881.3	2 288 200
	(ii) all materials to spoil	m^3	100	9 338.1	933 900
	(iii) extra over for rock	m^3	430	6 443.9	2 770 900
	(b) Preparation of surfaces to receive concrete	m^2	60	3 594.8	215 700
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	22 881.3	3 203 400
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	9 028.8	6 771 600
	(ii) Sloped	m^2	1 250	0.0	-
	(iii) Horizontal	m^2	1 250	2 257.2	2 821 500
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	4 146.6	8 500 500
	(ii) Blinding (15 MPa)	m^2	120	3 594.8	431 400
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	230.8	3 461 400
	(ii) Reinforcing bars (> 16 mm)	t	15 000	230.8	3 461 400
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	5 852.0	292 600
	SUB TOTAL A				**35 516 000**
5	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	35 516 000.0	1 775 800
6	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	35 516 000.0	3 551 600
	SUB TOTAL B				**40 843 400**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	40 843 400.0	16 337 400
	SUB TOTAL C				**57 180 800**
				Carried Forward	*57 180 800*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-08 SYPHON 2B CONCRETE CULVERT (23.86 km - 24.70 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*57 180 800*
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	57 180 800.0	14 295 200
	SUB TOTAL D				**71 476 000**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	71 476 000.0	7 147 600
	TOTAL COST (EXCL. VAT)				**78 623 600**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	78 623 600.0	11 793 600
	TOTAL COST (INCL. VAT)				**90 417 200**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	35 516 000.0	177 600
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**177 600**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL					
BOQ-09 SYPHON 1 INLET (at 3.05 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	217.0	6 600
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	217.0	500
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	0.0	-
	(ii) all materials to spoil	m^3	100	0.0	-
	(iii) extra over for rock	m^3	430	0.0	-
	(b) Preparation of surfaces to receive concrete	m^2	60	112.0	6 800
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	0.0	-
	(c) Rip rap & rockfill from river boulders	m^3	300	60.0	18 000
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	122.0	91 500
	(ii) Sloped	m^2	1 250	42.0	52 500
	(iii) Horizontal	m^2	1 250	0.0	-
	(iv) Narrow width and Curved	m^2	1 250	0.0	-
	(v) Soffit	m^2	1 250	0.0	-
	(vi) Intricate Formwork	No.	800	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	129.0	264 500
	(ii) Blinding (15 MPa)	m^2	120	112.0	13 500
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	7.2	107 700
	(ii) Reinforcing bars (> 16 mm)	t	15 000	7.2	107 700
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	148.8	7 500
5	**Pipes**				
	(a) Steel Pipes				
	(i) DN2400, t = 18 mm Steel Pipe	m	36 980	0.0	-
	(ii) DN600, t = 6 mm Steel Pipe	m	3 660	3.1	11 300
	(b) Transport of Steel Pipes				
	(i) DN2400, No. of 500 km return trips	No.	10 000	0.0	-
	(i) DN600, No. of 500 km return trips	No.	10 000	1.0	10 000
	(b) Bedding for Pipes				
	(i) Selected granular material	m^3	260	0.0	-
	(ii) Selected fill material	m^3	230	0.0	-
				Carried Forward	*698 100*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-09 SYPHON 1 INLET (at 3.05 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*698 100*
6	**Structural Steel (galvanised)**				
	(a) Structural Steelwork (incl. delivery and erection)	t	61 840	0.0	-
	(b) Handrails	m	1 000	44.0	44 000
	(c) CAT Ladder	No.	12 000	0.0	-
	(d) Rectagrid (Type RS 40)	m^2	6 650	1.7	11 400
7	**Mechanical & Electrical**				
	(a) Fine Screens	Sum	21 100	1.0	21 100
	(b) DN2400 Bellmouth	No.	200 000	1.0	200 000
	(c) 2.0 x 1.0 m Vertical Sluice Gates	No.	320 000	3.0	960 000
	(d) 1.6 x 0.8 m Vertical Sluice Gates	No.	240 000	3.0	720 000
	(e) DN600 90 deg Elbow	No.	20 000	2.0	40 000
	(f) Manhole cover and frame	No.	56 000	1.0	56 000
8	**Demolition**				
	(a) Demolition of existing cancrete				
	(i) Structural (25 MPa)	m^3	10 000	24.9	249 000
	SUB TOTAL A				**2 999 600**
9	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	2 999 600.0	150 000
10	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	2 999 600.0	300 000
	SUB TOTAL B				**3 449 600**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	3 449 600.0	1 379 900
	SUB TOTAL C				**4 829 500**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	4 829 500.0	1 207 400
	SUB TOTAL D				**6 036 900**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	6 036 900.0	603 700
	TOTAL COST (EXCL. VAT)				**6 640 600**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	6 640 600.0	996 100
	TOTAL COST (INCL. VAT)				**7 636 700**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-09 SYPHON 1 INLET (at 3.05 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	1 002 500.0	5 100
	(b) O&M Costs for Mechanical Components	%	4.00%	1 997 100.0	79 900
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**85 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-10 SYPHON TYPICAL INLET					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	510.0	15 300
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	510.0	1 200
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	375.0	37 500
	(ii) all materials to spoil	m^3	100	55.0	5 500
	(iii) extra over for rock	m^3	430	86.0	37 000
	(b) Preparation of surfaces to receive concrete	m^2	60	88.0	5 300
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	375.0	52 500
	(c) Rip rap & rockfill from river boulders	m^3	300	60.0	18 000
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	415.0	311 300
	(ii) Sloped	m^2	1 250	54.0	67 500
	(iii) Horizontal	m^2	1 250	21.0	26 300
	(iv) Narrow width and Curved	m^2	1 250	54.0	67 500
	(v) Soffit	m^2	1 250	0.0	-
	(vi) Intricate Formwork	No.	800	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	201.0	412 100
	(ii) Blinding (15 MPa)	m^2	120	88.0	10 600
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	11.2	167 800
	(ii) Reinforcing bars (> 16 mm)	t	15 000	11.2	167 800
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	109.0	5 500
5	**Pipes**				
	(a) Steel Pipes				
	(i) DN2400, t = 18 mm Steel Pipe	m	36 980	0.0	-
	(ii) DN600, t = 6 mm Steel Pipe	m	3 660	3.9	14 300
	(b) Transport of Steel Pipes				
	(i) DN2400, No. of 500 km return trips	No.	10 000	0.0	-
	(i) DN600, No. of 500 km return trips	No.	10 000	1.0	10 000
	(b) Bedding for Pipes				
	(i) Selected granular material	m^3	260	0.0	-
	(ii) Selected fill material	m^3	230	0.0	-
				Carried Forward	*1 433 000*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-10 SYPHON TYPICAL INLET					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*1 433 000*
6	**Structural Steel (galvanised)**				
	(a) Structural Steelwork (incl. delivery and erection)	t	61 840	0.0	-
	(b) Handrails	m	1 000	19.0	19 000
	(c) CAT Ladder	No.	12 000	2.0	24 000
	(d) Rectagrid (Type RS 40)	m^2	6 650	0.0	-
	(e) Vastrap/checked plates	m^2	4 000	0.0	-
	(g) Industrial Staircase	No.	20 000	0.0	-
7	**Mechanical & Electrical**				
	(a) Fine Screens	Sum	57 700	1.0	57 700
	(b) DN2400, PN16 Butterfly Valve	No.	2 000 000	0.0	-
	(c) DN2400 Bellmouth	No.	200 000	1.0	200 000
	(d) 2.0 x 1.0 m Vertical Sluice Gates	No.	320 000	0.0	-
	(e) 2.4 x 2.6 m Vertical Sluice Gates	No.	480 000	1.0	480 000
	(f) DN600 90 deg Elbow	No.	20 000	2.0	40 000
	(d) Manhole cover and frame	No.	56 000	1.0	56 000
	SUB TOTAL A				**2 309 700**
8	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	2 309 700.0	115 500
9	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	2 309 700.0	231 000
	SUB TOTAL B				**2 656 200**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	2 656 200.0	1 062 500
	SUB TOTAL C				**3 718 700**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	3 718 700.0	929 700
	SUB TOTAL D				**4 648 400**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	4 648 400.0	464 900
	TOTAL COST (EXCL. VAT)				**5 113 300**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	5 113 300.0	767 000
	TOTAL COST (INCL. VAT)				**5 880 300**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-10 SYPHON TYPICAL INLET					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	1 476 000.0	7 400
	(b) O&M Costs for Mechanical Components	%	4.00%	833 700.0	33 400
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**40 800**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)

NEW MAIN RIGHT BANK CANAL

BOQ-11 SYPHON TYPICAL OUTLET

No.	DESCRIPTION	UNIT	RATE Apr-20 Rand	QUANTITY	AMOUNT (Exl VAT) Rand
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	143.0	4 300
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	143.0	400
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	71.0	7 100
	(ii) all materials to spoil	m^3	100	214.0	21 400
	(iii) extra over for rock	m^3	430	57.0	24 600
	(b) Preparation of surfaces to receive concrete	m^2	60	72.0	4 400
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	71.0	10 000
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	126.0	94 500
	(ii) Sloped	m^2	1 250	27.0	33 800
	(iii) Horizontal	m^2	1 250	0.0	-
	(iv) Narrow width and Curved	m^2	1 250	0.0	-
	(v) Soffit	m^2	1 250	0.0	-
	(vi) Intricate Formwork	No.	800	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	102.6	210 400
	(ii) Blinding (15 MPa)	m^2	120	72.0	8 700
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	5.7	85 700
	(ii) Reinforcing bars (> 16 mm)	t	15 000	5.7	85 700
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	72.7	3 700
5	**Pipes**				
	(a) Steel Pipes				
	(i) DN2400, t = 18 mm Steel Pipe	m	36 980	0.0	-
	(ii) DN600, t = 6 mm Steel Pipe	m	3 660	0.0	-
6	**Structural Steel (galvanised)**				
	(a) Structural Steelwork (incl. delivery and erection)	t	61 840	0.0	-
	(b) Handrails	m	1 000	30.0	30 000
	SUB TOTAL A				**624 700**
				Carried Forward	*624 700*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-11 SYPHON TYPICAL OUTLET					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*624 700*
7	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	624 700.0	31 300
8	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	624 700.0	62 500
	SUB TOTAL B				**718 500**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	718 500.0	287 400
	SUB TOTAL C				**1 005 900**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	1 005 900.0	251 500
	SUB TOTAL D				**1 257 400**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	1 257 400.0	125 800
	TOTAL COST (EXCL. VAT)				**1 383 200**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	1 383 200.0	207 500
	TOTAL COST (INCL. VAT)				**1 590 700**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	624 700.0	3 200
	(b) O&M Costs for Mechanical Components	%	4.00%	0.0	-
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**3 200**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-12 VERDELING SYPHON TIE-IN STRUCTURE (at 33.55 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	510.0	15 300
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	510.0	1 200
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	375.0	37 500
	(ii) all materials to spoil	m^3	100	55.0	5 500
	(iii) extra over for rock	m^3	430	86.0	37 000
	(b) Preparation of surfaces to receive concrete	m^2	60	239.0	14 400
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	375.0	52 500
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	339.8	254 900
	(ii) Sloped	m^2	1 250	110.6	138 300
	(iii) Horizontal	m^2	1 250	122.0	152 500
	(iv) Narrow width and Curved	m^2	1 250	0.0	-
	(v) Soffit	m^2	1 250	0.0	-
	(vi) Intricate Formwork	No.	800	0.0	-
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	219.0	449 000
	(ii) Blinding (15 MPa)	m^2	120	239.0	28 700
	(iii) Mass Concrete (15 MPa)	m^3	1 890	0.0	-
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	12.2	182 900
	(ii) Reinforcing bars (> 16 mm)	t	15 000	12.2	182 900
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	291.1	14 600
5	**Structural Steel (galvanised)**				
	(a) Structural Steelwork (incl. delivery and erection)	t	61 840	0.0	-
	(b) Handrails	m	1 000	93.0	93 000
6	**Mechanical & Electrical**				
	(a) Fine Screens	Sum	18 300	2.0	36 600
	(b) DN2400, PN16 Butterfly Valve	No.	2 000 000	0.0	-
	(c) DN2400 Bellmouth	No.	200 000	0.0	-
	(d) 2.2 x 2.1 m Vertical Sluice Gates	No.	600 000	1.0	600 000
	(e) 1.6 x 0.8 m Vertical Sluice Gates	No.	240 000	3.0	720 000
	(f) DN600 90 deg Elbow	No.	20 000	0.0	-
	(d) Manhole cover and frame	No.	56 000	0.0	-
				Carried Forward	*3 016 800*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL					
BOQ-12 VERDELING SYPHON TIE-IN STRUCTURE (at 33.55 km)					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*3 016 800*
7	**Demolition**				
	(a) Demolition of existing cancrete				
	(i) Structural (25 MPa)	m^3	10 000	86.0	860 000
	SUB TOTAL A				**3 876 800**
8	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	3 876 800.0	193 900
9	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	3 876 800.0	387 700
	SUB TOTAL B				**4 458 400**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	4 458 400.0	1 783 400
	SUB TOTAL C				**6 241 800**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	6 241 800.0	1 560 500
	SUB TOTAL D				**7 802 300**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	7 802 300.0	780 300
	TOTAL COST (EXCL. VAT)				**8 582 600**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	8 582 600.0	1 287 400
	TOTAL COST (INCL. VAT)				**9 870 000**

A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	2 520 200.0	12 700
	(b) O&M Costs for Mechanical Components	%	4.00%	1 356 600.0	54 300
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**67 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-13 TYPICAL ROAD CROSSING					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Clearing**				
	(a) Strip 150 mm topsoil over footprint & stockpile	m^2	30	0.0	-
	(b) Clear trees, Shrubs & Bushes in Basin	m^2	2.20	0.0	-
2	**Excavation**				
	(a) Bulk				
	(i) all materials to stockpile	m^3	100	150.0	15 000
	(ii) all materials to spoil	m^3	100	60.0	6 000
	(iii) extra over for rock	m^3	430	105.0	45 200
	(b) Preparation of surfaces to receive concrete	m^2	60	100.0	6 000
3	**Earthfill/Backfill**				
	(a) General earthfill from quarry	m^3	300	0.0	-
	(b) General earthfill from stockpile	m^3	140	150.0	21 000
	(c) Rip rap & rockfill from river boulders	m^3	300	0.0	-
4	**Foundation Fill**				
	(a) Rockfill	m^3	300	3.0	900
	(b) Crushed stone fill	m^3	230	3.0	700
	(c) Compacted granular material	m^3	260	5.0	1 300
4	**Concrete Works**				
	(a) Formwork				
	(i) Gang formed	m^2	750	217.0	162 800
	(ii) Sloped	m^2	1 250	40.0	50 000
	(iii) Horizontal	m^2	1 250	55.0	68 800
	(iv) Permanent formwork in deck using armco pipes	No.	800	83.0	66 400
	(b) Concrete				
	(i) Structural (35 MPa)	m^3	2 050	167.0	342 400
	(ii) Blinding (15 MPa)	m^2	120	100.0	12 000
	(iii) Mass Concrete (15 MPa)	m^3	1 890	5.0	9 500
	(c) Reinforcing				
	(i) Reinforcing bars (< 16mm)	t	15 000	6.5	97 200
	(ii) Reinforcing bars (> 16 mm)	t	15 000	25.9	388 800
	(d) Precast concrete units	m^3	2 000	0.0	-
	(e) Surface Finishes				
	(i) Steel Floated	m^2	50	395.0	19 800
5	**Expansion Joints**				
	(a) Galvanised angle with R10 lugs	m	1 770	13.0	23 100
6	**Bearings**				
	(a) Fixed bearings with a maximum vertical load of 660 kN	No.	8 900	2.0	17 800
	(b) Undirectional bearings with a maximum vertical load of 660 kN	No.	8 900	2.0	17 800
				Carried Forward	*1 372 500*

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-13 TYPICAL ROAD CROSSING					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
				Brought Forward	*1 372 500*
7	**Structural Steel (galvanised)**				
	(a) Steel Railings	m	1 750	25.0	43 800
8	**Drainage**				
	(a) Drainage pipes				
	(i) 50 mm dia PVC pipes	m	50	2.5	200
	(b) Weep holes				
	(i) 50 mm dia PVC pipes	m	50	3.0	200
9	**Additional foundation investigations**				
	(a) Provisional sum for additional foundation investigations	No.	200 000	1.0	200 000
10	**Access and Drainage**				
	(a) Provisional sum for access and drainage	No.	100 000	1.0	100 000
	SUB TOTAL A				**1 716 700**
11	**Landscaping**				
	(a) General Ladscaping (% of items sub total A)	%	5%	1 716 700.0	85 900
12	**Miscellaneous (% of 1-9)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	1 716 700.0	171 700
	SUB TOTAL B				**1 974 300**
	Preliminary & General				
	(a) Preliminary & General (% of sub total B)	%	40%	1 974 300.0	789 800
	SUB TOTAL C				**2 764 100**
	Contingencies				
	(a) Contingencies (% of sub total C)	%	25%	2 764 100.0	691 100
	SUB TOTAL D				**3 455 200**
	Professional Fees				
	(a) Professional Fees (% of sub total D)	%	10%	3 455 200.0	345 600
	TOTAL COST (EXCL. VAT)				**3 800 800**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	3 800 800.0	570 200
	TOTAL COST (INCL. VAT)				**4 371 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-13 TYPICAL ROAD CROSSING					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
A	**Annual Operation and Maintenance Costs**				
	(a) O&M Costs for Civil Works	%	0.50%	1 681 100.0	8 500
	(b) O&M Costs for Mechanical Components	%	4.00%	35 600.0	1 500
	(c) O&M Costs for Dams	%	0.25%	0.0	-
	TOTAL ANNUAL O&M COST (EXCL. VAT)				**10 000**

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM (WP0485)					
NEW MAIN RIGHT BANK CANAL BOQ-14 LAND ACQUISITION					
No.	**DESCRIPTION**	**UNIT**	**RATE Apr-20 Rand**	**QUANTITY**	**AMOUNT (Exl VAT) Rand**
1	**Bulshoek Weir Inlet**				
	(a) Small undeveloped areas of less than 150 ha				
	(i) Irrigable Area	ha	28 000	0.00	-
	(ii) Assume additional 20% of land required	ha	11 200	0.00	-
	(b) Developed areas				
	(i) Developed areas	ha	600 000	0.00	-
2	**Canals**				
	(a) Small undeveloped areas of less than 150 ha				
	(i) Irrigable Area	ha	28 000	56.44	1 580 300
	(ii) Assume additional 20% of land required	ha	11 200	11.29	126 500
	(b) Developed areas				
	(i) Developed areas	ha	600 000	18.88	11 326 300
3	**Syphons**				
	(a) Small undeveloped areas of less than 150 ha				
	(i) Irrigable Area	ha	28 000	1.28	35 800
	(ii) Assume additional 20% of land required	ha	11 200	0.26	2 900
	(b) Developed areas				
	(i) Developed areas	ha	600 000	2.00	1 199 300
4	**Other Structures**				
	(a) Small undeveloped areas of less than 150 ha				
	(i) Irrigable Area	ha	28 000	0.15	4 300
	(ii) Assume additional 20% of land required	ha	11 200	0.03	400
	(b) Developed areas				
	(i) Developed areas	ha	600 000	0.42	250 600
	SUB TOTAL A				**14 526 400**
5	**Miscellaneous (% of 1-4)**				
	(a) General Miscellaneous (% of items sub total A)	%	10%	14 526 400.0	1 452 700
	TOTAL COST (EXCL. VAT)				**15 979 100**
	VAT				
	(a) VAT (15% of total cost (excl. VAT))	%	15%	15 979 100.0	2 396 900
	TOTAL COST (INCL. VAT)				**18 376 000**

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