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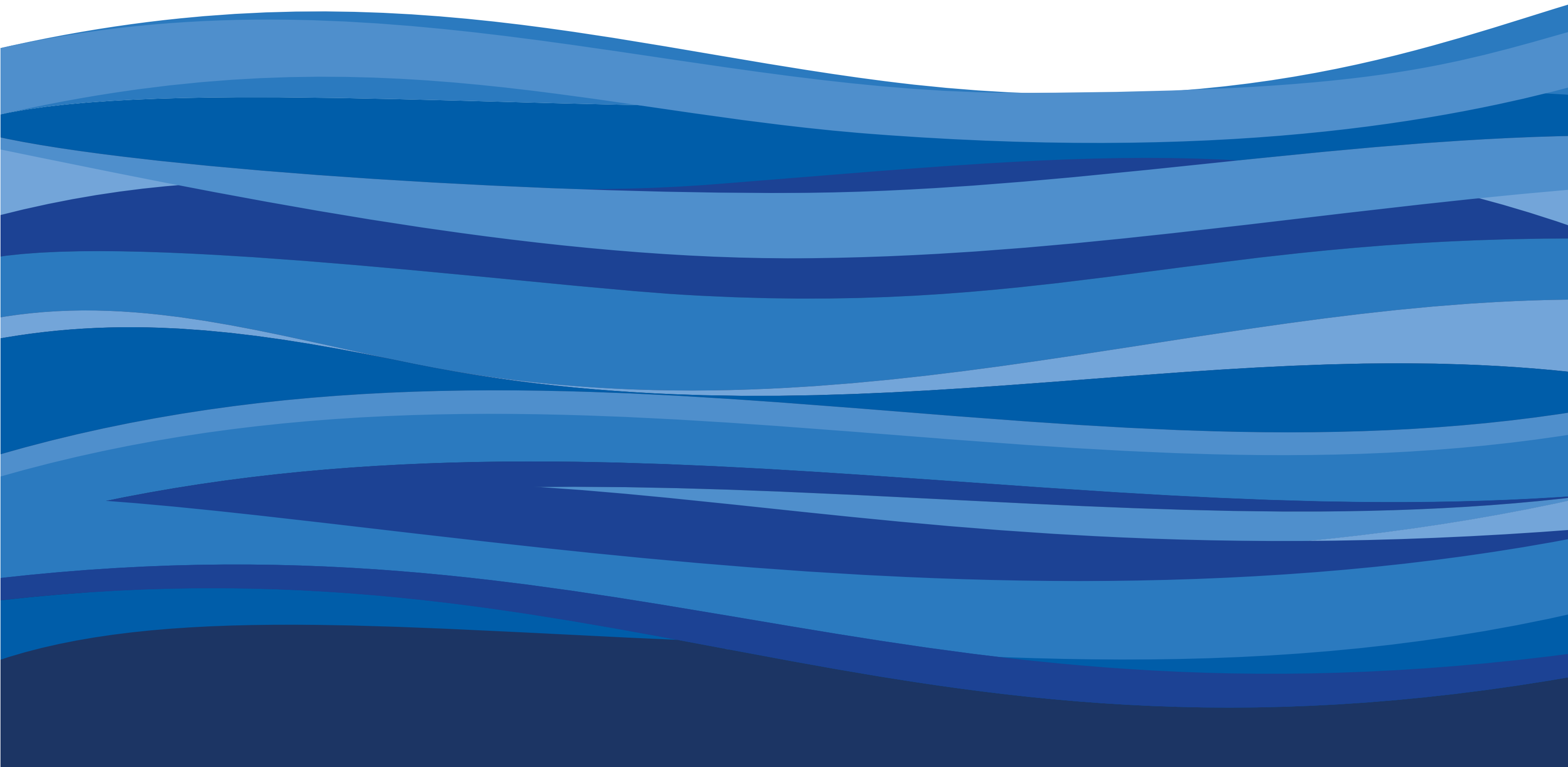
Astrolabe Park Gross Pollutant Trap – Physical Model Testing

WRL Technical Report 2015/18
November 2015

By B M Miller and D S Rayner



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University of New South Wales
School of Civil and Environmental Engineering

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1. Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Australia was commissioned by Enviropacific Services to undertake a physical model study of the Gross Pollutant Trap and diversion chamber to be constructed on the Astrolabe Park stormwater upgrade. Technical design was provided by Royal HaskoningDHV on behalf of Enviropacific Services.

Twin Rocla 3000 CDS units were proposed to be constructed on either side of the Astrolabe Park stormwater upgrade in the eastern suburbs of Sydney. The aims of the physical modelling were:

- to ensure that the diversion chamber would evenly split inflows between the two CDS units; and
- determine the maximum treatment capacity before bypassing occurs; and determine the hydraulic grade line (HGL) during high flow events.

Physical model testing using the downstream flow conditions supplied by Royal HaskoningDHV identified that the diversion chamber will be in tailwater control which limits the CDS flow capacity before bypassing. Testing without downstream tailwater control (i.e. having the exit pipes in inlet control) also showed the downstream water levels limit the CDS capacity. Baffling in the diversion chamber trialled to reduce the downstream levels to increase capacity was not successful.

The hydraulic grade line (HGL) was determined for high flow events and found to be significantly above the top of the chamber.

The influence of a side inflow pipe into the chamber on the distribution of flow and litter to each CDS unit was tested and was found to have an influence on flow distribution between CDS units when the side inflow was a significant proportion of the total inflow.

2. Model Construction

The hydraulic model was constructed at a Froude scale of 8:1. At this scale, the entrance and exit channels to the CDS units were modelled with Reynolds numbers greater than 2x10^5 ensuring that turbulent flow processes in the diversion chamber were still being well represented. Also at this scale, the 100 year ARI event of 15.7 $m^3.s^{-1}$ (prototype) could be modelled with a manageable flow rate of 86.7 $L.s^{-1}$. Table 1 summarises the various scaling ratios.

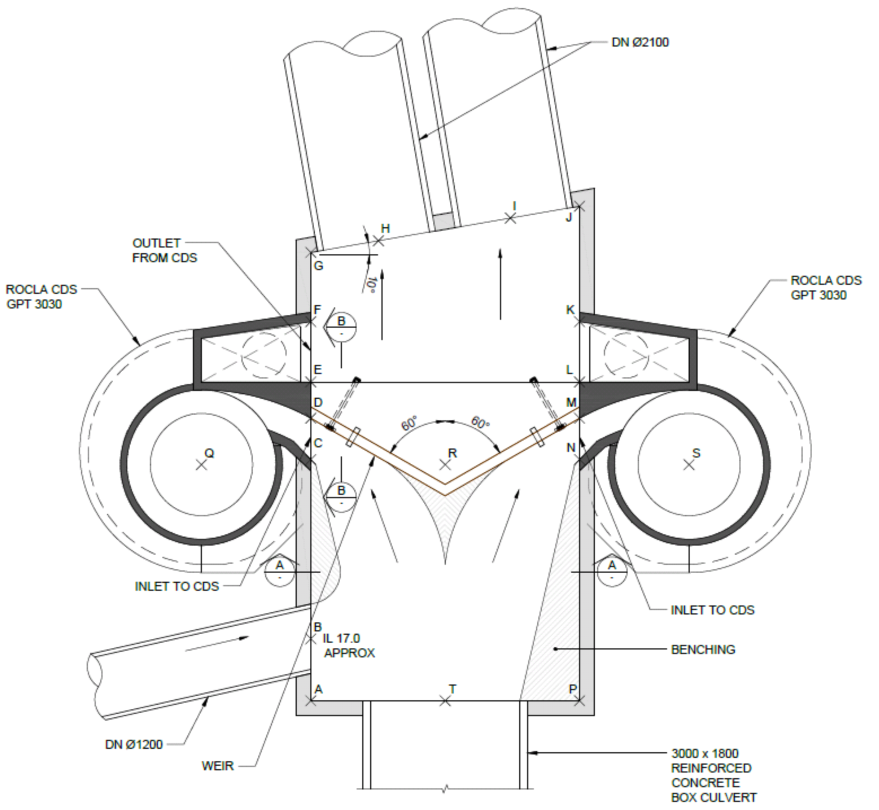
Table 1 - Model Scaling Ratios

Ratio	Formula	Value
Length ratio	L_R	8
Time ratio	$(L_R)^{\frac{1}{2}}$	2.83
Velocity ratio	$(L_R)^{\frac{1}{2}}$	2.83
Flow ratio	$(L_R)^{\frac{5}{2}}$	181

Figure 1 presents a photograph with an overview of the physical model. Detailed dimensions of the diversion channel are presented in Figure 2. The CDS units were constructed to the drawings provided by Royal HaskoningDHV from Rocla, which are reproduced in Appendix A.

The model was constructed of wood, steel, high density foam and clear acrylic.

Figure 1 – Model Overview



PIT SET-OUT

MARK	X	Y
A	0	0
B	0	1242
C	0	4840
D	0	5670
E	0	6400
F	0	7610
G	0	9000
H	1360	9233
I	4011	9690
J	5400	9929
K	5400	7610
L	5400	6400
M	5400	5640
N	5400	4840
P	5400	0
Q	-2197	4740
R	2700	4740
S	7597	4740
T	2700	0

Figure 2 – Diversion Chamber Details

All elevations are to local AHD. The floor of the diversion chamber was level at RL 16.7m. The crest of the diversion weir was RL 17.9m. The inlet culvert was sloped at 1.2% and the outlet pipes sloped at 0.8%. The height of the diversion chamber was 2.4m.

As the HGL would increase above the top of the diversion chamber, testing included three configurations of the chamber lid:

- a sealed diversion chamber;
- with a 2m by 2m grated opening; and
- with a 3m by 3m grated opening.

Photographs of the physical model are presented in Figure 3.

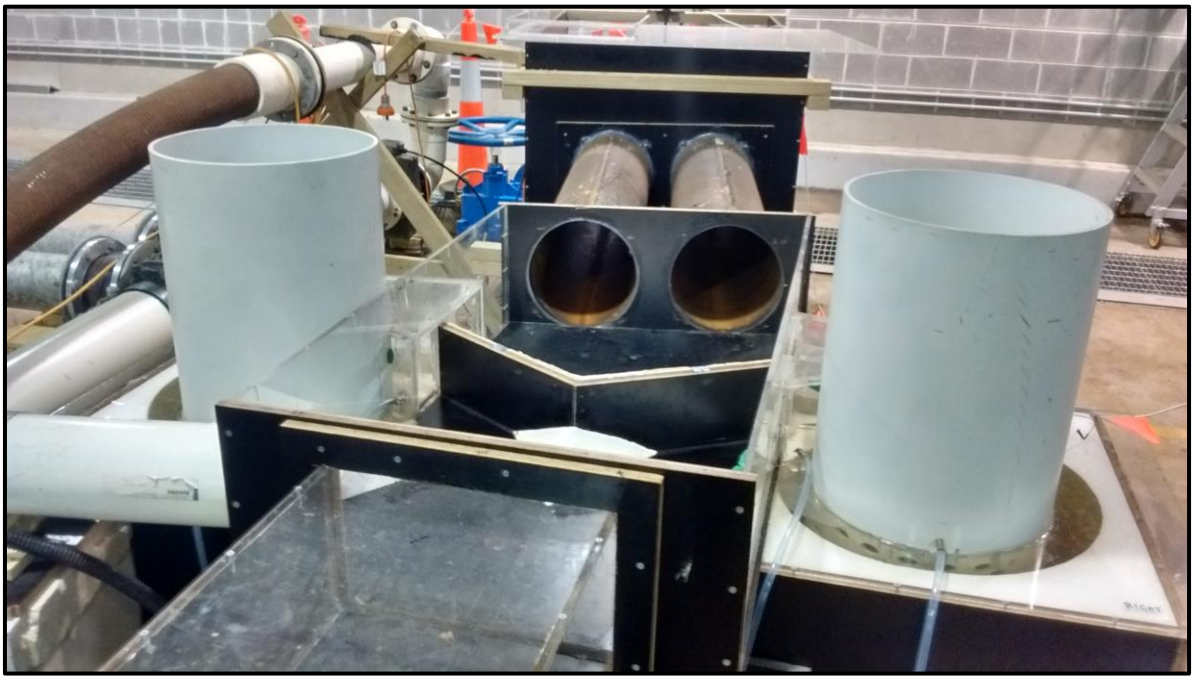


Figure 3 – Photographs of the Physical Model

Inflows to the model were measured using a calibrated electro-magnetic flow meter. Piezometric water levels (the Hydraulic Grade Line) were measured through tappings connected to a manometer board.

3. Model Testing

3.1 Hydraulic Grade Line

Table 2 presents the hydraulic grade line (HGL) in prototype scale during each of the scenarios. The flow rates and tailwater levels were supplied by Royal HaskoningDHV.

Table 2 – Hydraulic Grade Lines During Scenarios

Scenario		**Max flow with no weir overtopping**	**Design flow**	**0.2 x 2yr ARI**	**2 year ARI**	**100 year ARI no grate**	**100 year ARI 2.0m x 2.0m grate**	**100year ARI 3.2m x 3.2m grate**
Total Flow Rate (m3/s)		2.62	3.49	3.91	12.42	15.86	15.69	15.71
Main Culvert Flow Rate (m3/s)		2.62	3.49	3.91	11.71	13.16	12.82	12.91
Side Pipe Flow Rate (m3/s)		0.00	0.00	0.00	0.71	2.70	2.88	2.81
Manometer Location	**ID**	**HGL m AHD**	**HGL m AHD**	**HGL m AHD**	**HGL m AHD**	**HGL m AHD**	**HGL m AHD**	**HGL m AHD**
Tailwater	1	16.84*	17.30	17.53	18.41	20.11	20.10	20.11
Downstream in Main chamber	2	17.50	17.60	17.67	18.60	20.25	20.13	20.11
Left GPT discharge point	3	17.53	17.62	17.68	18.57	20.24	20.15	20.11
Right GPT discharge point	4	17.53	17.62	17.68	18.57	20.26	20.17	20.12
Left GPT inlet (bottom)	5	17.72	17.86	17.90	18.75	20.42	20.21	20.11
Right GPT inlet (bottom)	6	17.72	17.86	17.90	18.75	20.53	20.31	20.24
Left GPT inlet (side)	7	17.60	17.74	17.79	18.70	20.34	20.17	20.10
Right GPT inlet (side)	8	17.60	17.74	17.79	18.70	20.42	20.29	20.24
Upstream in Main Chamber	9	17.92	18.04	18.10	18.81	20.54	20.25	20.12
Inlet Culvert	10	17.92	18.04	18.08	18.80	20.51	20.21	20.09

* No tailwater level for this flowrate was specified. However the levels in the diversion chamber were affected by exit control and not the tailwater level.

Caution should be made in converting the drop in HGL to headloss factors for the final two scenarios with lid grates as there was significant volumes of water being pushed out through these grates. Figure 4 shows a photograph of surcharging under these conditions.

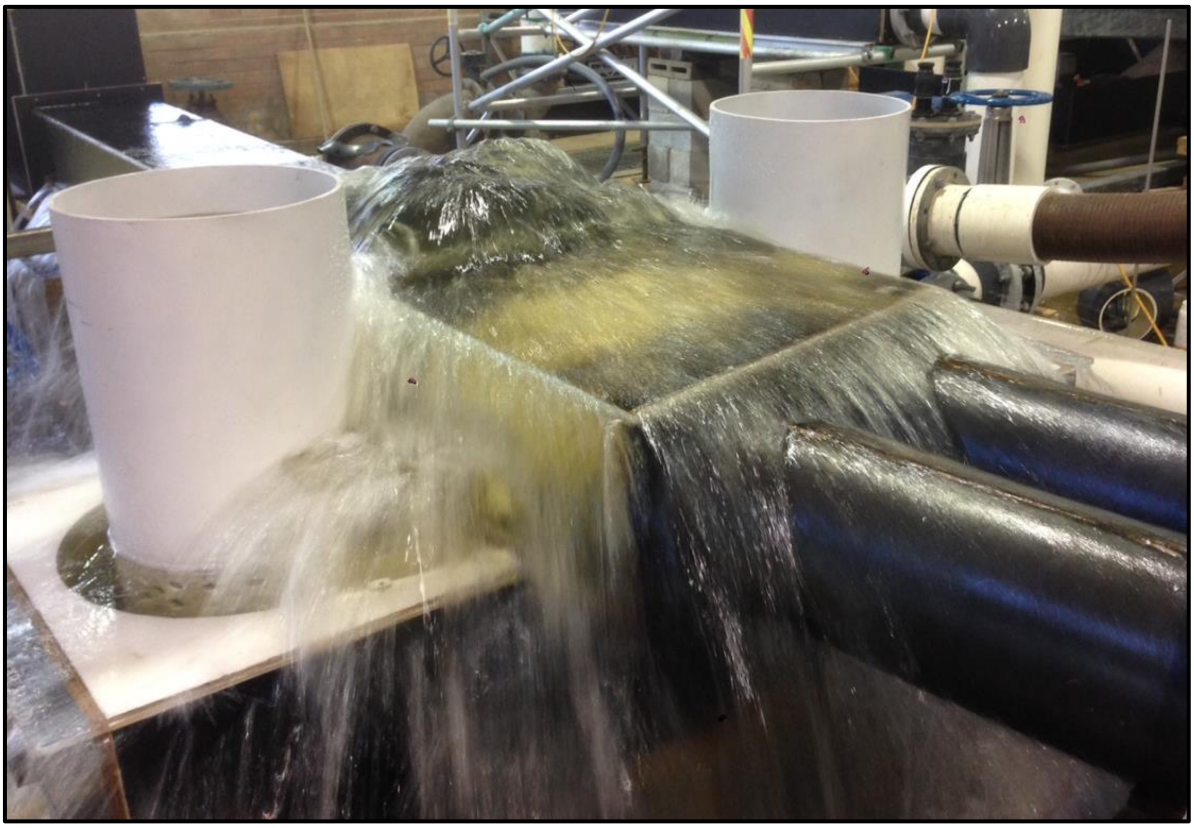


Figure 4 – Water Surcharging During 100 year ARI 2m x 2m Grate Test

3.2 Flow Rate Before Bypassing

The design flow before any flow bypassed over the diversion weir for the twin CDS units was $3.5m^3.s^{-1}$. Testing demonstrated that the maximum that could be achieved was $2.6m^3.s^{-1}$.

The CDS units have a headloss associated with the inlet loss, the internal loss and the exit loss. It was observed that the majority of this loss was associated with the inlet and outlet as can be seen in Figure 5. The internal losses through the CDS were not considered significant in the model, noting though that no attempt was made to calibrate these internal losses to any prototype measurements.

Figure 5 – Flow Exiting the CDS

The capacity of the CDS units was limited by the water level present where CDS flow returns to the main chamber. Increasing the height of the diversion weir above 1.2 m was not desirable as this would create too great a headloss in the high flow events.

Efforts were made to reduce the water level in the downstream section of the diversion chamber. Sensitivity testing presented in Table 3 demonstrates that the downstream section is influenced by the inlet control of the exit pipes.

Table 3 – Tailwater Sensitivity Testing During 3.5 $m^3.s^{-1}$ Discharge

Tail (m)	D/S Weir (m)	U/S Weir (m)	Comment
16.50	17.56	18.02	WL d/s of weir in inlet control of pipes
17.06	17.56	18.02	WL d/s of weir in inlet control of pipes
17.40	17.57	18.04	WL d/s of weir in inlet control of pipes
17.51	17.63	18.03	Tailwater starting to influence WL d/s of weir
17.57	17.66	18.06	Tailwater starting to influence WL d/s of weir
17.71	17.80	18.08	Tailwater influencing WL d/s of weir

Consideration was made of lowering the floor of the downstream section so that the step at the weir would be greater. However, the sensitivity testing demonstrated that if the floor were lowered, the downstream water levels would change to tailwater control and minimal benefit would be gained. The tailwater level for low flows is approximately RL 17.3m. The existing exit pipes change to tailwater control at RL 17.5m. Therefore it stands that the maximum that the floor and exit pipes could be dropped before tailwater takes control of the water levels is approximately 200 mm.

An attempt was made to reduce the water levels downstream of the diversion weir by improving the hydraulic efficiency of the exit pipes when flowing in inlet control. The "benching" shown in Figure 6 was constructed from foam in an attempt to improve the streamlines approaching the pipes. These tests were undertaken at 2.62 $m^3.s^{-1}$ when the weir does not overtop, so this trial benching was not required to be tied back into the weir.

Figure 6 – Benching Trial in Downstream Section

Water levels in the downstream section reduced by less than 10 mm (prototype). Water levels upstream of the weir were not observed to reduce at all and the water level remained at the weir crest. These additional trials demonstrated that it is the critical flow conditions at the entrance to the pipes that is controlling the subcritical water levels downstream of the weir and not any turbulent flow behaviour in the chamber itself.

3.3 Influence of Side Entry Pipe

The 1.2 m side entry pipe has the potential to influence the flow and litter capture distribution. Scenarios were run with the total flow rate of 2.6 $m^3.s^{-1}$ (that being the flowrate before any diversion over the weir) but with varying distribution between the main culvert and the side entry pipe. The results are presented in Table 4.

Table 4 – Influence of the Side Entry Pipe on Flow and Capture Distribution

Scenario (main culvert: side pipe)	**100% : 0%**	**95% : 5%**	**75% : 25%**	**50% : 50%**
Total Flow ($m^3.s^{-1}$)	2.6	2.6	2.6	2.6
Main Culvert Flow ($m^3.s^{-1}$)	2.6	2.5	1.8	1.3
Side Pipe Flow ($m^3.s^{-1}$)	0.0	0.1	0.8	1.3
Left Hand Side GPT				
Approx. inlet flow - LHS ($m^3.s^{-1}$)	1.3	1.2	1.1	1.0
Approx. Flow (%)	49.5	49.6	43.4	39.1
Particle Capture (%)	50.5	50.7	27.0	38.0
Right Hand Side GPT				
Approx. inlet flow -RHS ($m^3.s^{-1}$)	1.3	1.3	1.4	1.5
Approx. Flow (%)	50.5	50.4	56.6	60.9
Particle Capture (%)	49.5	49.3	73.0	62.0

Flow through each CDS unit was estimated using manometer readings and mini current meter velocity measurements. Depth and velocities were observed to increase on the right hand side CDS unit as the contribution from the DN1200 pipe increased.

Floatables capture was tested by placing 100 balsa particles across the inlet channel and repeated three times. The particle capture rate in the table is an average capture of the repeated tests.

A 5% contribution from the DN1200 pipe has no influence on flow or particle distribution. Particle capture and flow distribution increased in the right hand side GPT (when viewed downstream) as DN1200 pipe flows increased.

4. Summary

Physical model testing was undertaken of the diversion chamber and twin CDS units proposed for Astrolabe Park. This model demonstrated that:

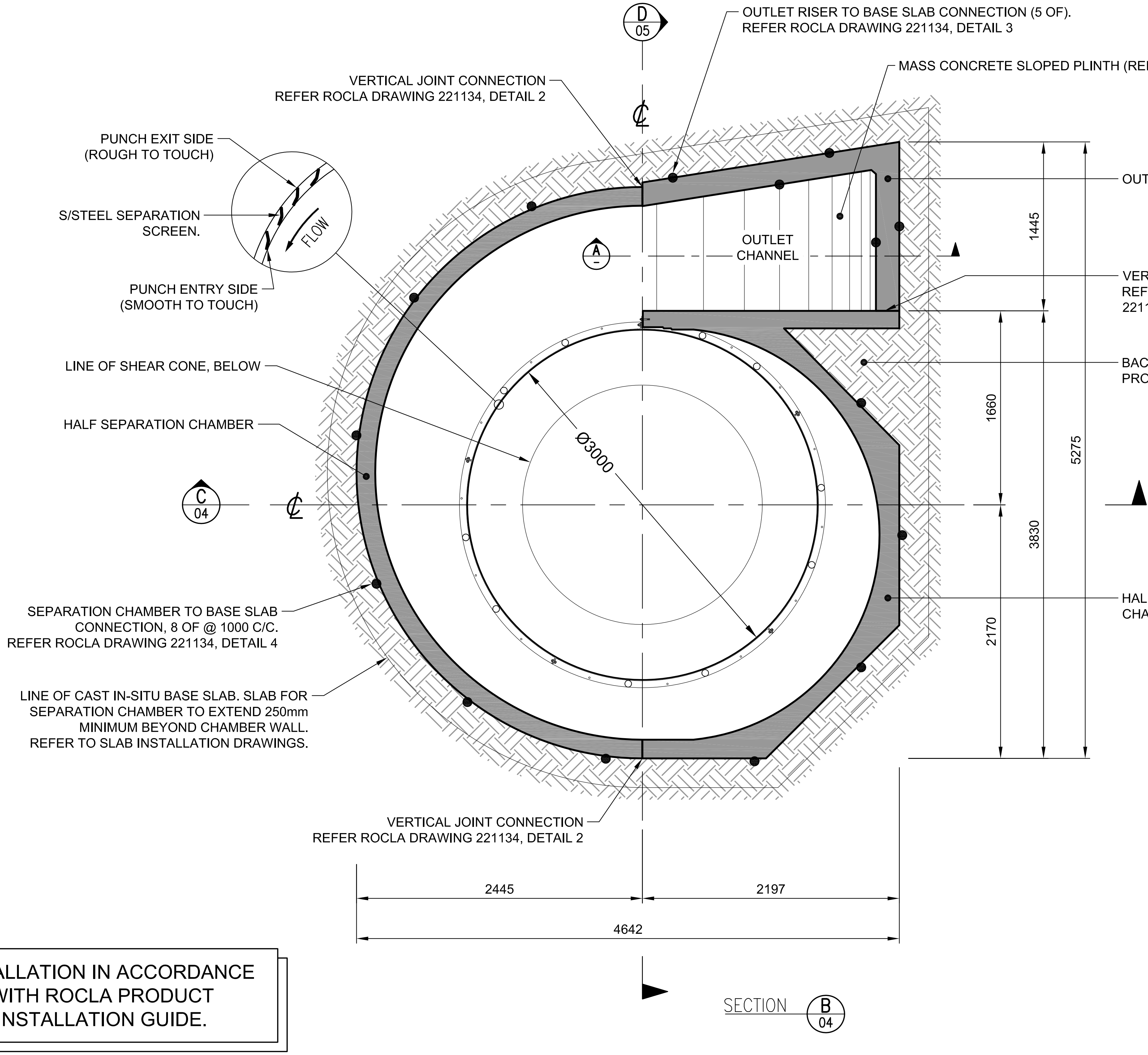
- The maximum flow rate that could be achieved through the CDS units before bypassing over the weir was 2.6 $m^3.s^{-1}$.
- This maximum flowrate was influenced by the water levels in the downstream section of the diversion chamber. The headloss through the CDS units was primarily in the inlet and exit losses and not the losses through the screen.
- The downstream water levels were either influenced by tailwater levels (from the next downstream pit) or from the inlet control to the exit pipes. Attempts to reduce these levels through flow baffles were not successful.
- The distribution between the two CDS units remains equal when the proportion of flow from the side entry pipe is less than 5% of the main culvert. With approximately equal flows from the culvert and the main pipe, the distribution is approximately 60% to the right hand side CDS (the one opposite the side entry pipe).
- During the 100 year ARI flow event, the hydraulic grade line is approximately 1 m above the top of the flow diversion chamber and will be surcharging to the ground surface.

Appendix A

Rocla CDS Drawings as provided.

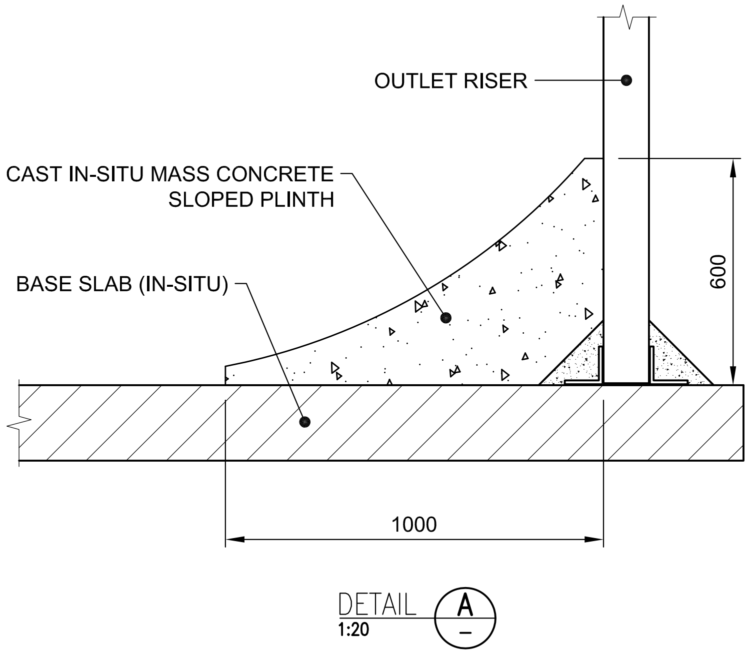
DO NOT SCALE

THESE PLANS ARE TO BE READ IN CONJUNCTION WITH PROJECT PLANS AND SPECIFICATIONS



SECTION B
04

- ▬ PRECAST COMPONENTS
- ▨ CAST IN SITU WORKS
- ░ MASS CONCRETE



DETAIL A
1:20 –

INSTALLATION IN ACCORDANCE WITH ROCLA PRODUCT INSTALLATION GUIDE.

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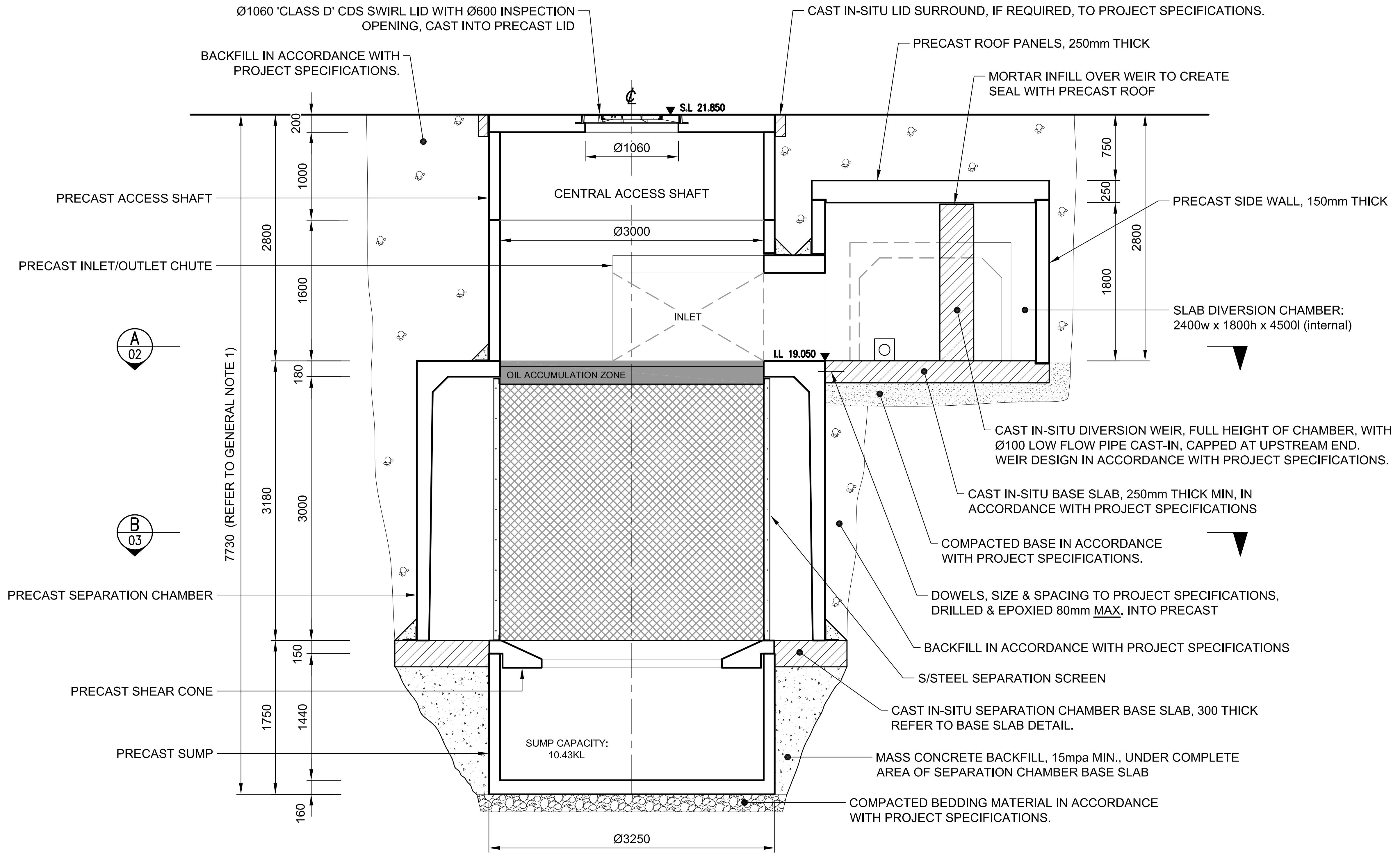

SECTION C 02

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▭	PRECAST COMPONENTS
▨	CAST IN SITU WORKS
▒	MASS CONCRETE

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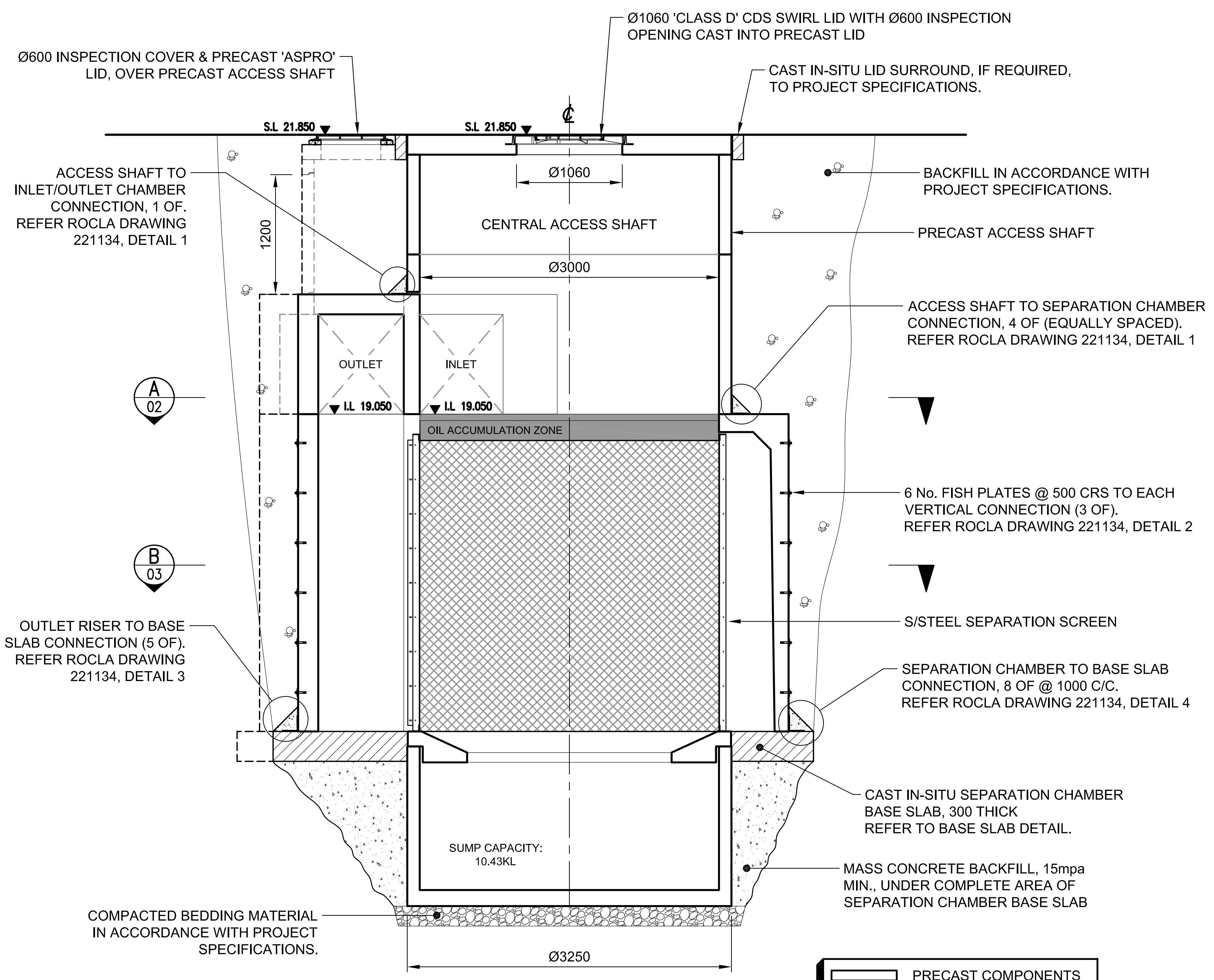

SECTION D 02

▭	PRECAST COMPONENTS
▨	CAST IN SITU WORKS
▒	MASS CONCRETE

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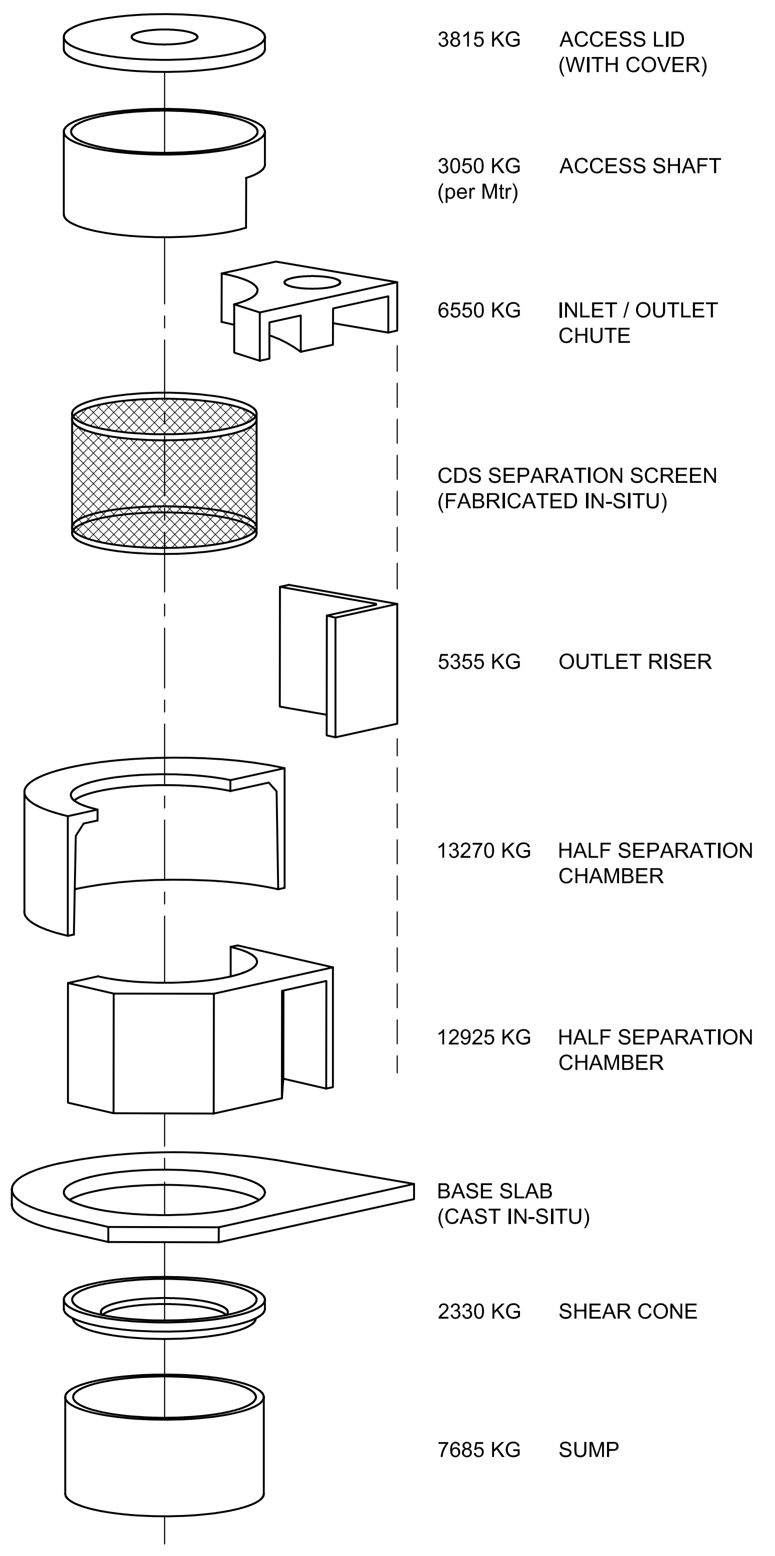

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GPT SECTION D

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