CONTRACT RESEARCH:

PUMP SUMP MODEL TESTING

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JPS – USM Smart Partnership

The DID-USM smart partnership has conducted a number of projects on physical model testing. Amongst them are as follows:

Project	Purpose	Name of Client	End User	Year of Completion
Pump modeling for Bagan Terap Pump House, Selangor	Irrigation Project	GTS Sdn Bhd	JPS Selangor	1999
Pump modeling for flood mitigation project for pump house in Chai Leng Park, Perai, Penang.	Flood Mitigation	Oristen Engineering Plc.	MPSP Seberang Perai	2000
Pump Modelling For Bina/Pasang – Logi/Kolam Takungan Dan Paip Utama Hilir Perak - Sungkai	Water Supply	Salcon Engineering Bhd	LAP, Perak	2002
Pumping Station model testing for water supply in Muda River Scheme (Phase 4)	Water Supply	Ocean Electrical Engineering Co. Sdn Bhd	PBA, P. Pinang	2002
Inlet channel model testing for Lahar Tiang Pumping Station Water Intake	Water Supply	Ocean Electrical Engineering Co. Sdn Bhd	PBA, P. Pinang	2003
Project Bekalan Air Kedah Tengah – Gurun, Kedah	Water Supply	Ocean Electrical Engineering Co. Sdn Bhd	JBA, Kedah	2003
Pembaikan Sistem Saliran Kg. Datuk Keramat, Kuala Lumpur – Model test	Flood Mitgation	Sam McCoy Engineering Sdn Bhd	JPS, Wilayah	2003
Pump model testing for Sg Dua Pumping Station Package 4, Penang	Water Supply	Ebara Pump (M) Sdn Bhd	PBA, P. Pinang	2004
Pump model testing for Sg Besar, Teluk Intan, Perak	Flood Mitigation	Enersave Sdn Bhd	JPS, Perak	2004
Rancangan Tebatan Banjir Kawasan Perbandaran Pulau Pinang (S18)	Flood Mitigation	ABH Sdn Bhd	JPS, P. Pinang	2004
Pemindahan air dari Sg Muar ke Empangan Talang, Kuala Pilah, Negeri Sembilan	Water Supply	George Kent (M) Bhd	JBA, N. Sembilan	2005
Hulu Terengganu Water Supply Project (Stage 1)	Water Supply	Era Pump Sdn Bhd	JBA, Terengganu	2005
Projek Menaiktaraf Rumah Pam, Sg Bogak, Kerian, Perak	Irrigation	Mashyur Waja Sdn. Bhd.	JPS Perak	2005

Introduction

A scale model is still the most successful and economical method of evaluating the designs of pump station sumps where the vagaries in turbulent hydraulic flow cannot readily be computed mathematically (Ansar, 1997; US Army Corps of Engineers, 1988; Prosser , 1977)

Using scale models allows modifications and remedial work to be quickly and effectively investigated to ensure satisfactory hydraulic condition is achieved.

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The hydraulic problems typically encountered in a limited sump space environment are :

a) surface vortices;

b) submerged vortices;

c) air entrainment;

d) swirl and undulating flow; and

e) dead flow regions.

Why we need hydraulic model studies of pump sumps?

- The performance of the pump is greatly affected by the design of sump. As each pumping station is unique in design and specifications, theoretical prediction of a new installation based on past experience is not enough
- The degradation of pump performance due to sump design is a phenomenon of great concern – loss of pump efficiency is the most expensive to correct.
- It is reported that there were several instances in which pumps overloaded or run roughly because of faulty design.
- As such, hydraulic model studies have to be undertaken to ensure proper hydraulic performance of these costly structures are achieved.

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Model studies should be considered essential

Larsen and Padmanaban (1995) suggest for these:

1. **Nonsymmetrical approach flow.**
2. **Multiple pump bays with variety of pump operating combination.**
3. **Pump capacity greater than 2.5 m^3/s.**
4. **Expending approach channel.**
5. **Possibilities of screen blockages / obstruction.**

For items 1,2,4 and 5, a model study is recommended because the unknown effects a non-uniform approach flow.

For items 3, considering the cost of large pump installation

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Objectives

The purposes of the hydraulic model test is to identify:

- Surfaces vortices which, when severe enough may draw air from the free surfaces into the pump, causing unbalanced loading of the impeller, periodic vibrator and reduction in pump capacity.
- Subsurface vortices, which may emanate from the floor, side or back walls, or both, entering the pump and causing vibration and cavitations.
- Pre-rotation of flow entering the pump which will change the angle of attach of the impeller blades from the design value and may affect pump efficiency and causing cavitations.

To Determine the optimum physical sizing of the pump sump

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Scope of Work for Model Study

The model study to be carried out include the following:

- **Design and construct a model of the pumping station according to scale (geometrically and dynamically similar).**
- **Carry out hydraulic tests on the pump sump model to confirm the suitability of the intake design .**
- **Recommendations on the modification and retested to confirm all recommendations.**

The model prototype scale ratio preferably be no smaller than 1 : 10

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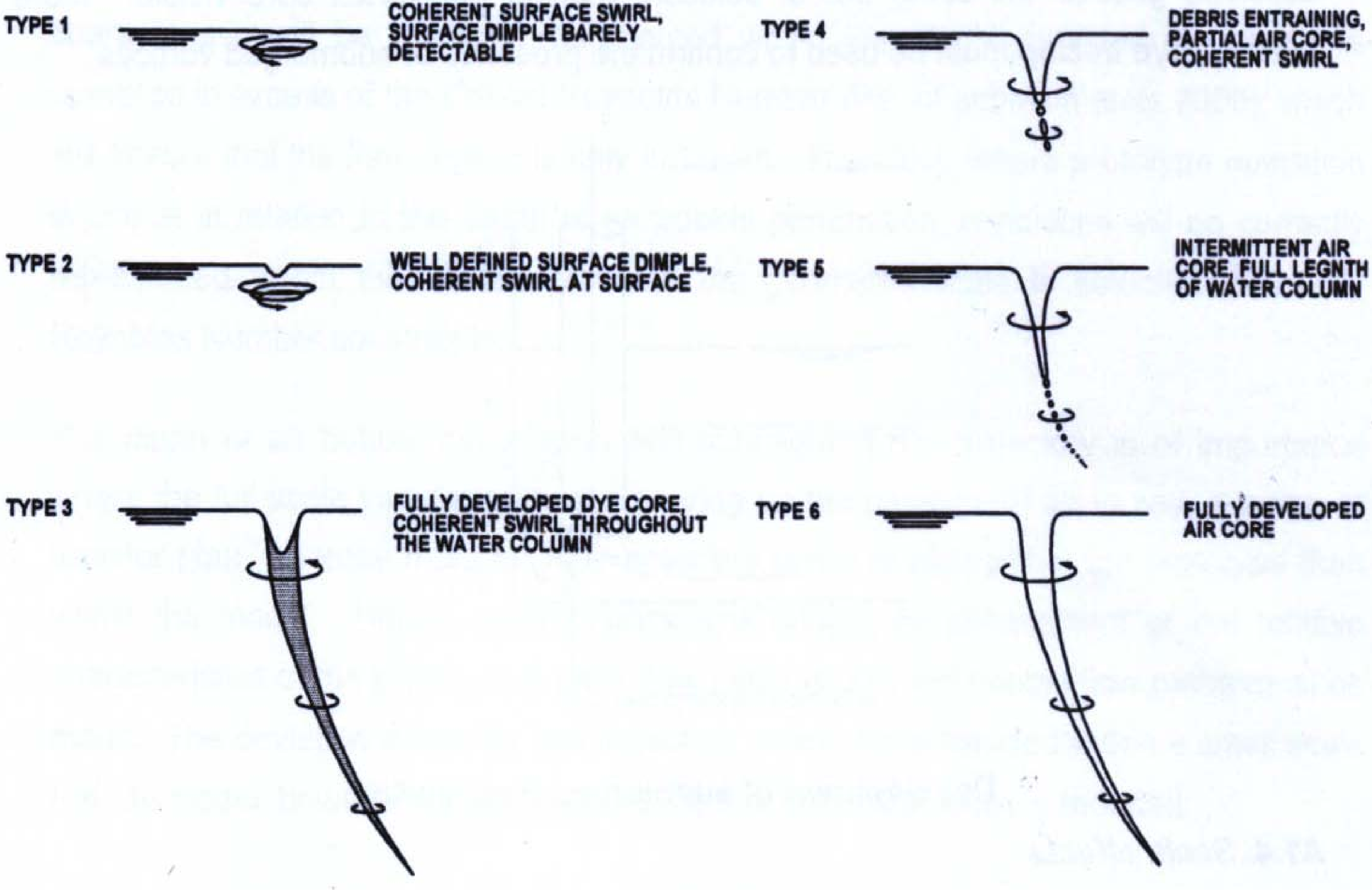
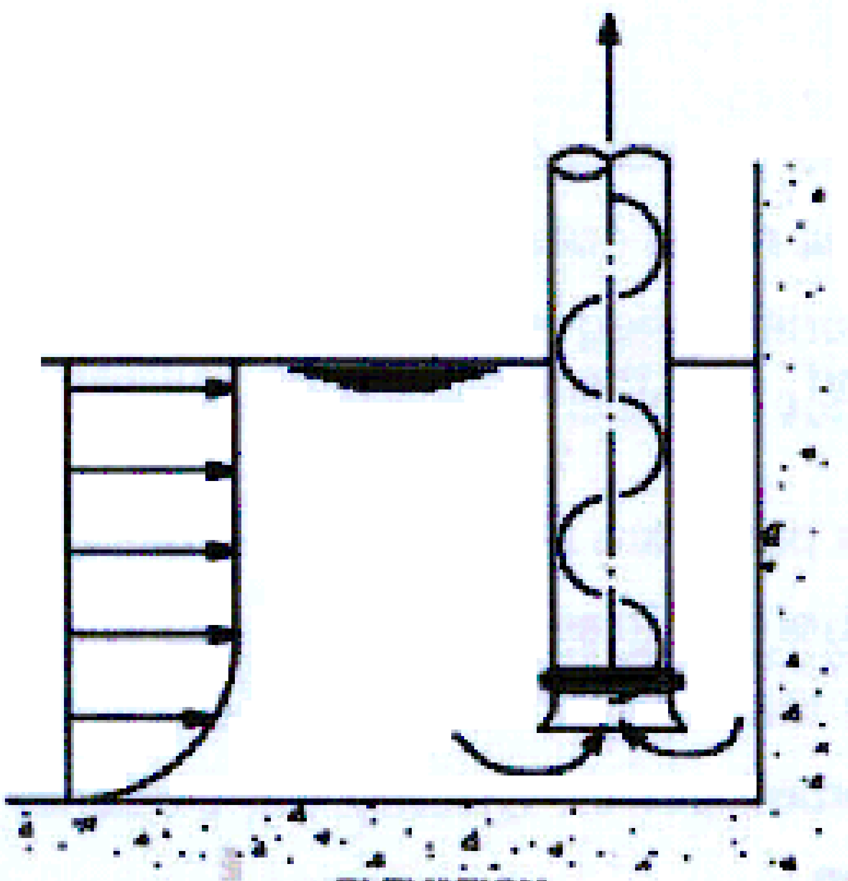
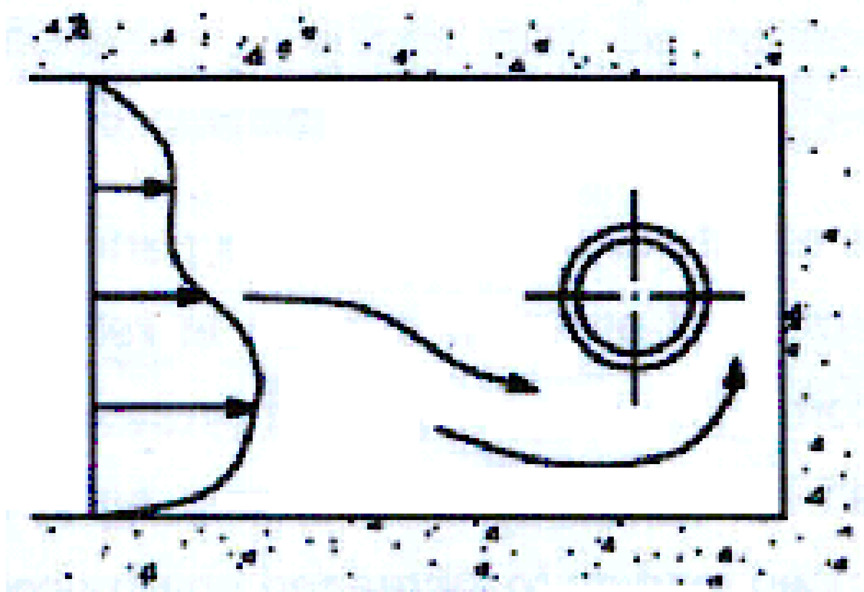
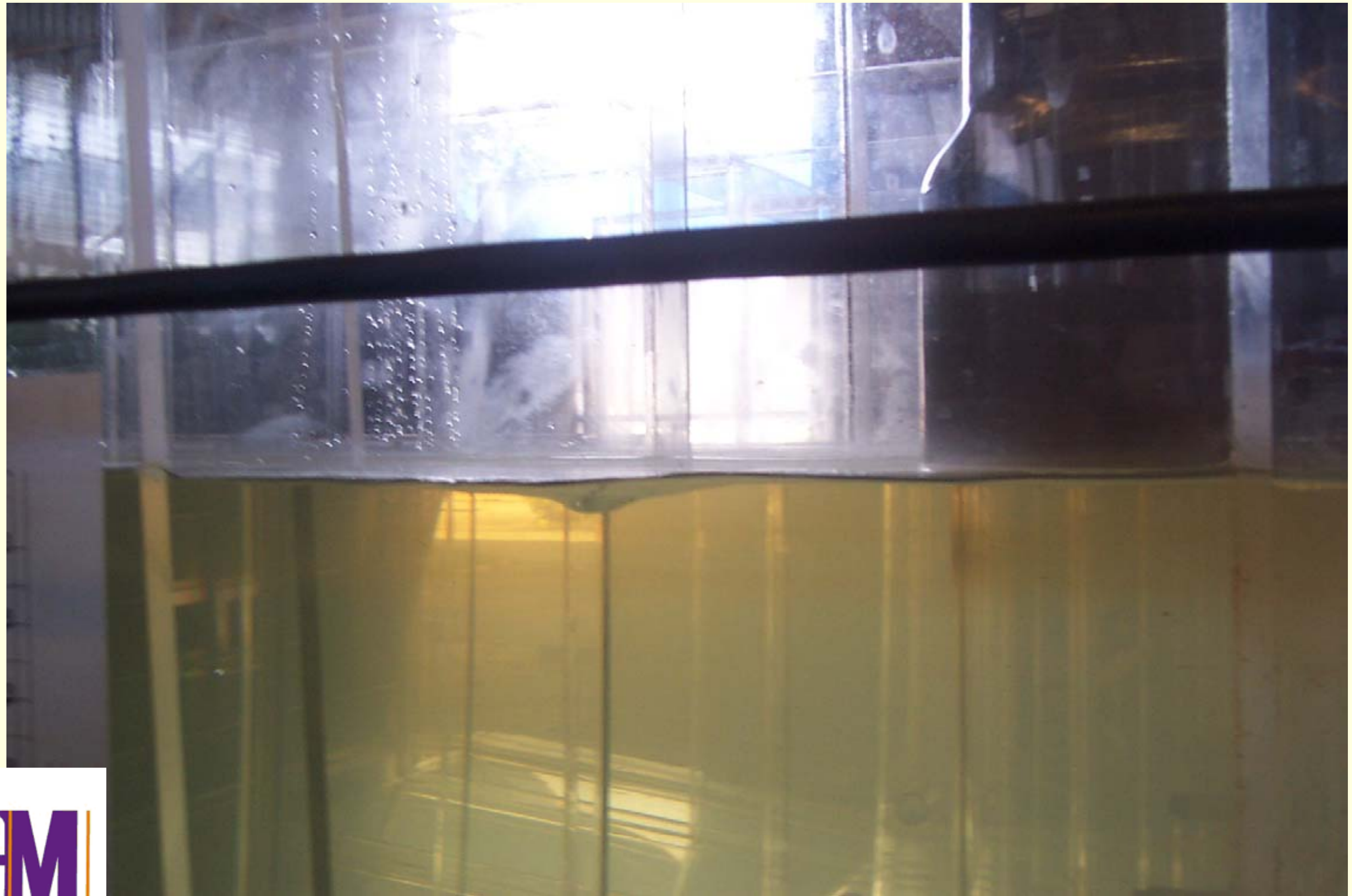

TYPE 1
COHERENT SURFACE SWIRL, SURFACE DIMPLE BARELY DETECTABLE
TYPE 2
WELL DEFINED SURFACE DIMPLE, COHERENT SWIRL AT SURFACE
TYPE 3
FULLY DEVELOPED DYE CORE, COHERENT SWIRL THROUGHOUT THE WATER COLUMN
TYPE 4
DEBRIS ENTRAINING, PARTIAL AIR CORE, COHERENT SWIRL
TYPE 5
INTERMITTENT AIR CORE, FULL LEGNTH OF WATER COLUMN
TYPE 6
FULLY DEVELOPED AIR CORE


ELEVATION


PLAN

Surface Vortex – Type B; Pulling air



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Surface Vortex – Type B; Pulling air (top view)

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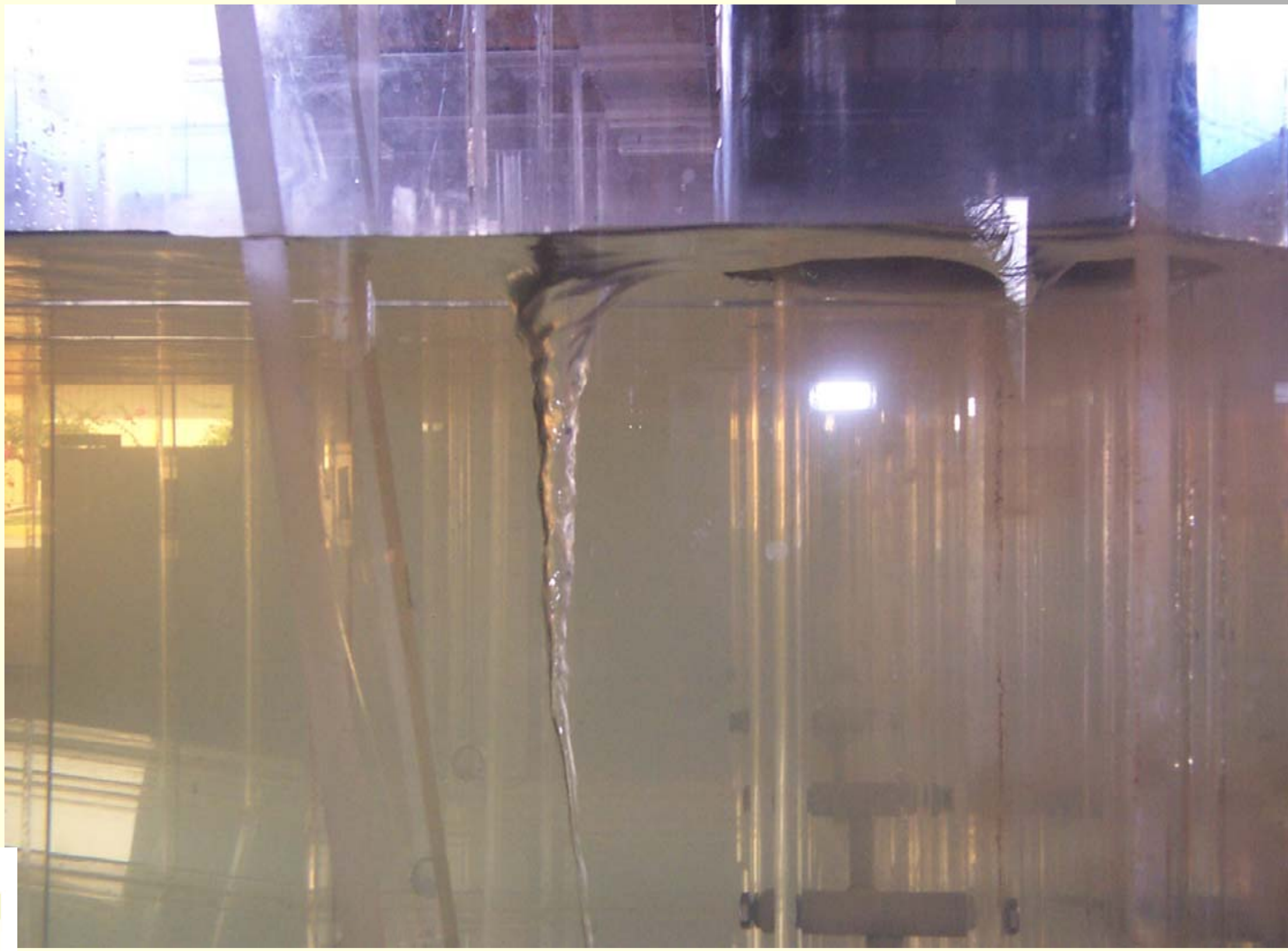
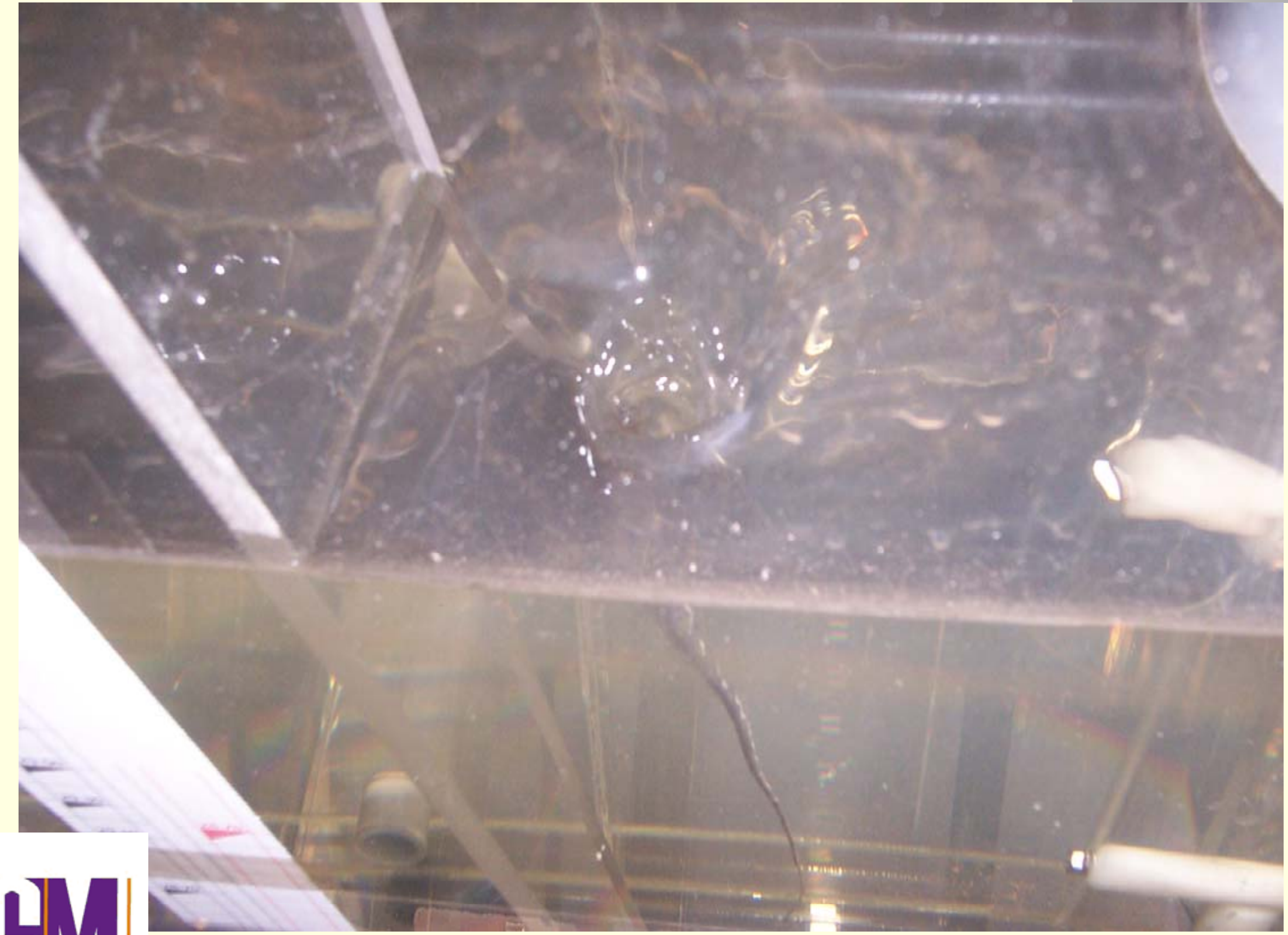
Surface Vortex Type C; Pulling floating trash

Surface Vortex – Type D; Pulling air (top view)



Surface Vortex – Type D; Pulling air (top view)



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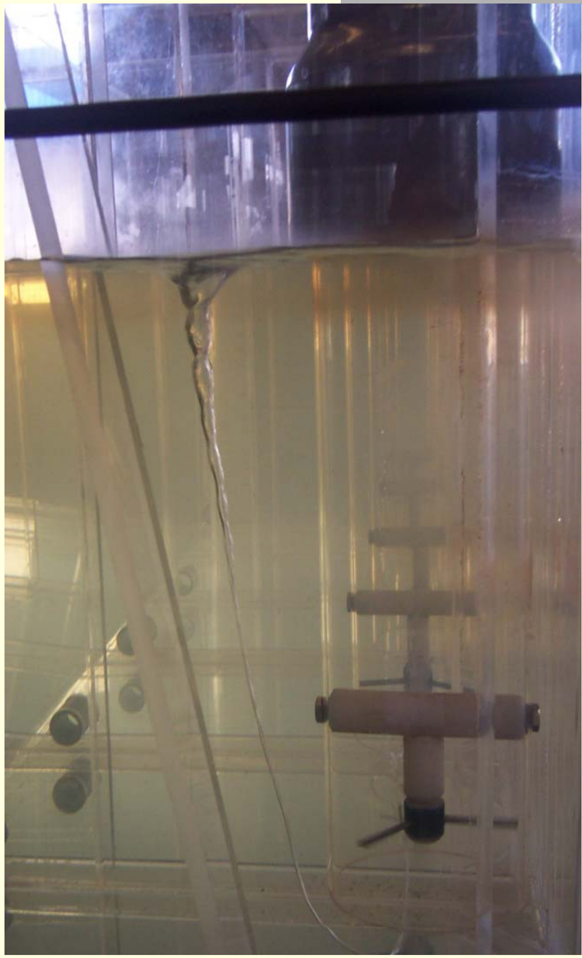
Surface Vortex – Type E; Full air core intake



Proposed Model Pump Sump Testing

In the proposed pump sump model test, the Perai pump station will house 2 Nos. main submersible pumps with the capacity of 1000L/s and 1 Nos. of jokey pump with the capacity of 500 L/s.

The details of the pumping station and associated structures shown on Figures 1 - 2 are provided by the Arup Consultant Sdn Bhd.

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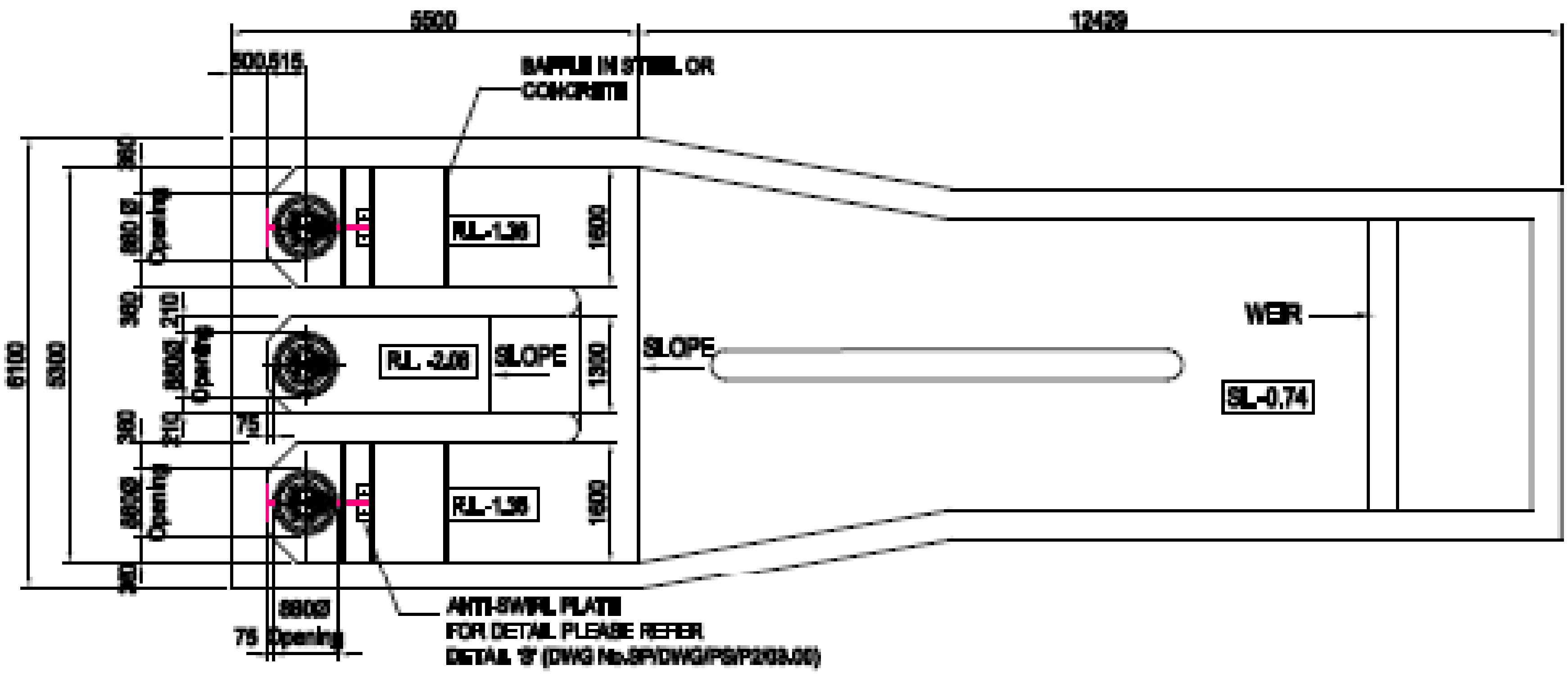
Plan View



PUMP STATION PLAN AT BASE SLAB

SCALE 1:125

Detail drawings :Nos. M1232-L1-M-401, M1232-L1-M-402 and M1232-L1-M-403 Pumping Station are provided by Arup Jururunding Sdn. Bhd. through Adasfa Sdn.Bhd.

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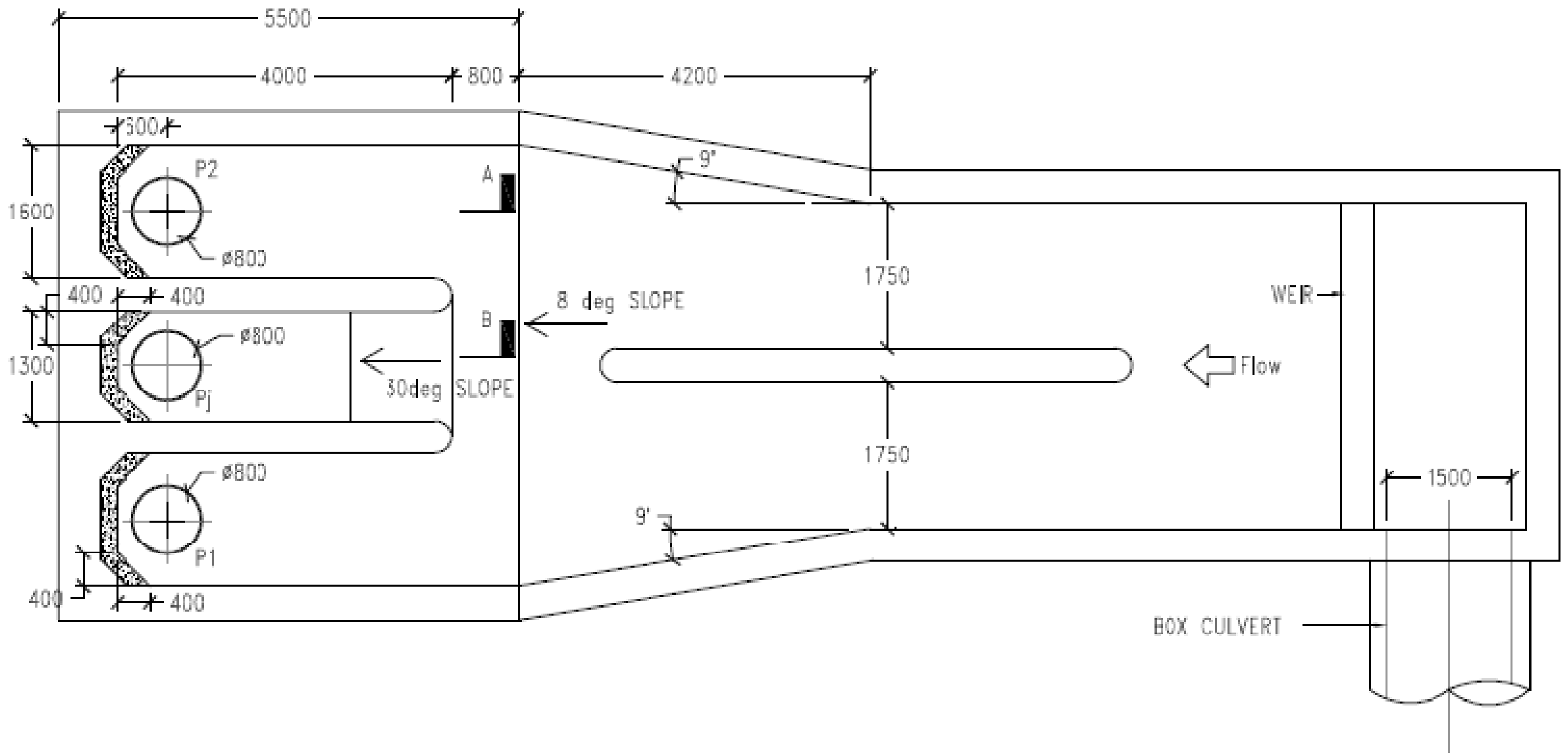
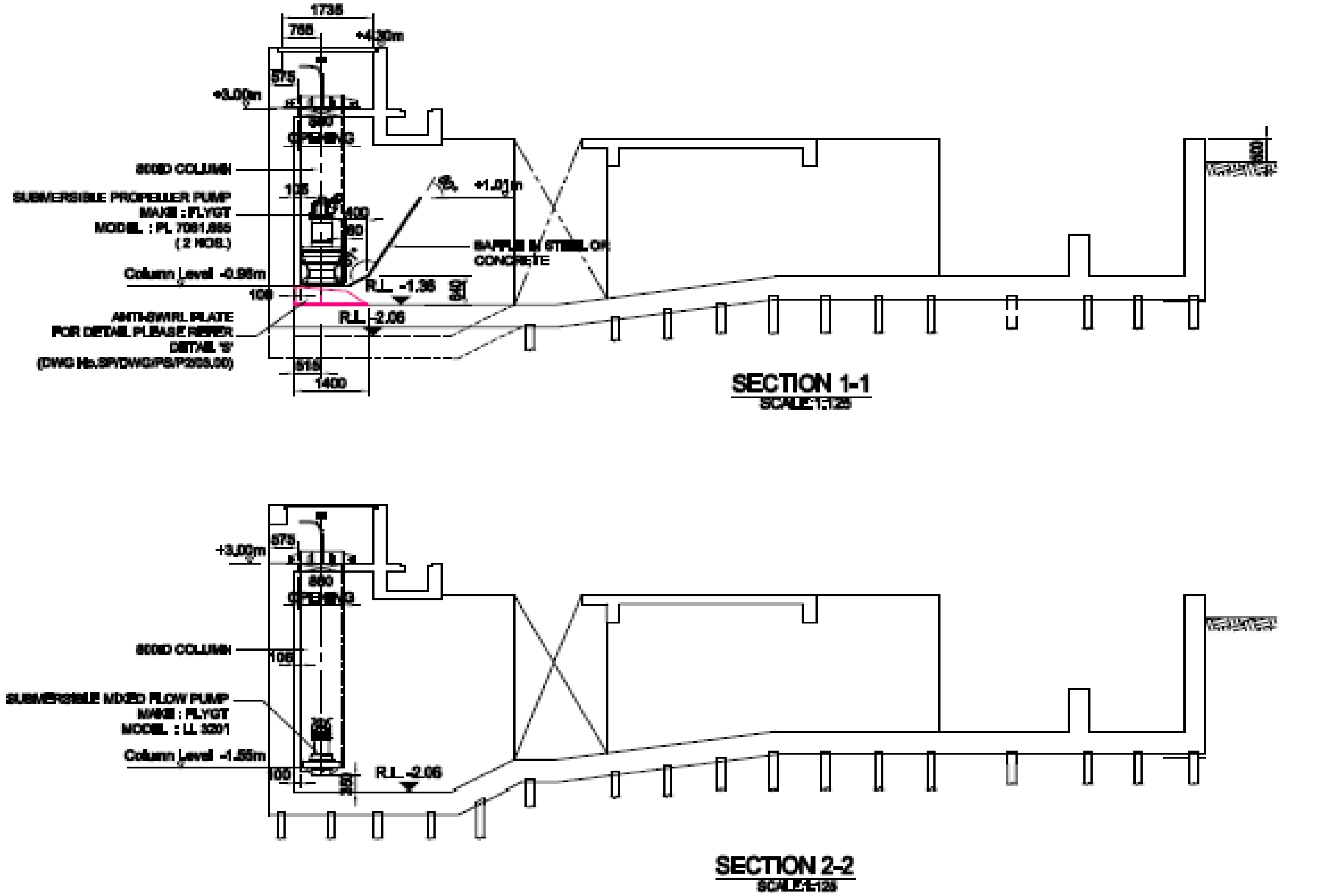


PLAN VIEW – PUMP STATION @ +0.00

Side View



1735
+4.30m
575
+3.00m
OPENING
SUBMERSIBLE PROPELLER PUMP
MAKE : FLYGT
(2 NOS.)
+1.01m
BAFFLE IN STEEL OR
CONCRETE
R.L. -1.36
R.L. -2.06
ANTI-SWIRL PLATE
FOR DETAIL PLEASE REFER
1400
SECTION 1-1
SUBMERSIBLE MIXED FLOW PUMP
MAKE : FLYGT
R.L. -2.06
SECTION 2-2

Similitude

To achieve individual forces acting on the corresponding fluid elements (Newton's Second Law) as

$F_i = F_p + F_g + F_v + F_{st}$

Froude Number

- inertia + gravitational

$$F = \frac{V}{(gL)^{0.5}}$$

Reynolds Number

- fluid viscosity

$$R = \frac{VL}{K}$$

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Pumping station and inlet structure

An undistorted model scale of 1/10th was considered and thus, model/prototype relationships as follows:

Property	Scale Relationship	Model Value
Geometric	$S = L_m/L_p$	1/10
Velocity	$V_m = V_p S^{0.5}$	1/3.16
Flow	$Q_m = Q_p S^{2.5}$	1/316
Time	$T_m = T_p S^{0.5}$	1/3.16

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Calculation – Model Pump Capacity

$$Q_m = {}^{Qp}\!/_{S^{2.5}}$$

$Q_m = 1000/10^{2.5}$

$Q_m = 3.16$ L/s

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Construction of Model

A water circulation delivery system.

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INSTRUMENTATION AND MEASUREMENT

The flow measurement use in the model testing is flow velocity Badger Meter, West Germany (Serial No. 72/3/34811C).

The swirl angle was determined using the following relationship (Alden Research Laboratory):

$$\theta = \left(\frac{V_R}{V_A} \right)$$

where V_R is the rotational velocity of the vortimeter vanes,
V_A is the axial velocity in the pump intake.

Generally, swirl angles should be lower than ten degrees (10°) or less is typically considered to be acceptable (Nakato et al, 1996)

Pump Testing Configurations

Test Run	Water Level	Jockey	Pump No. 1	Pump No. 2	Remarks
Run 1	MSL +0.20	1.58 L/s			
Run 2	MSL +0.45 (181mm from the bottom of the sump)		6.32 L/s		Single pump in operation
Run 3				6.32 L/s	
Run 4	MSL +1.04 (240 mm from the bottom of the sump)	1.58 L/s	6.32 L/s		Double pumps in operation
Run 5		1.58 L/s	6.32 L/s	6.32 L/s	
Run 6		1.58 L/s		6.32 L/s	

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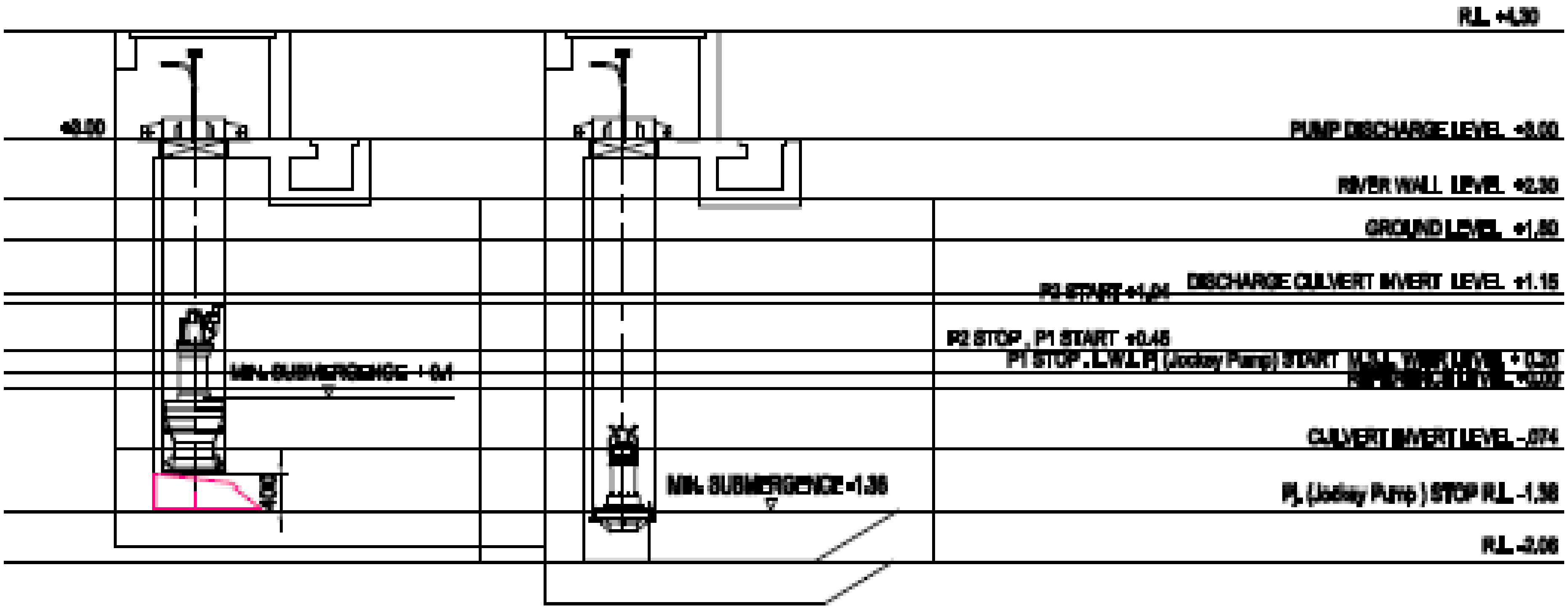
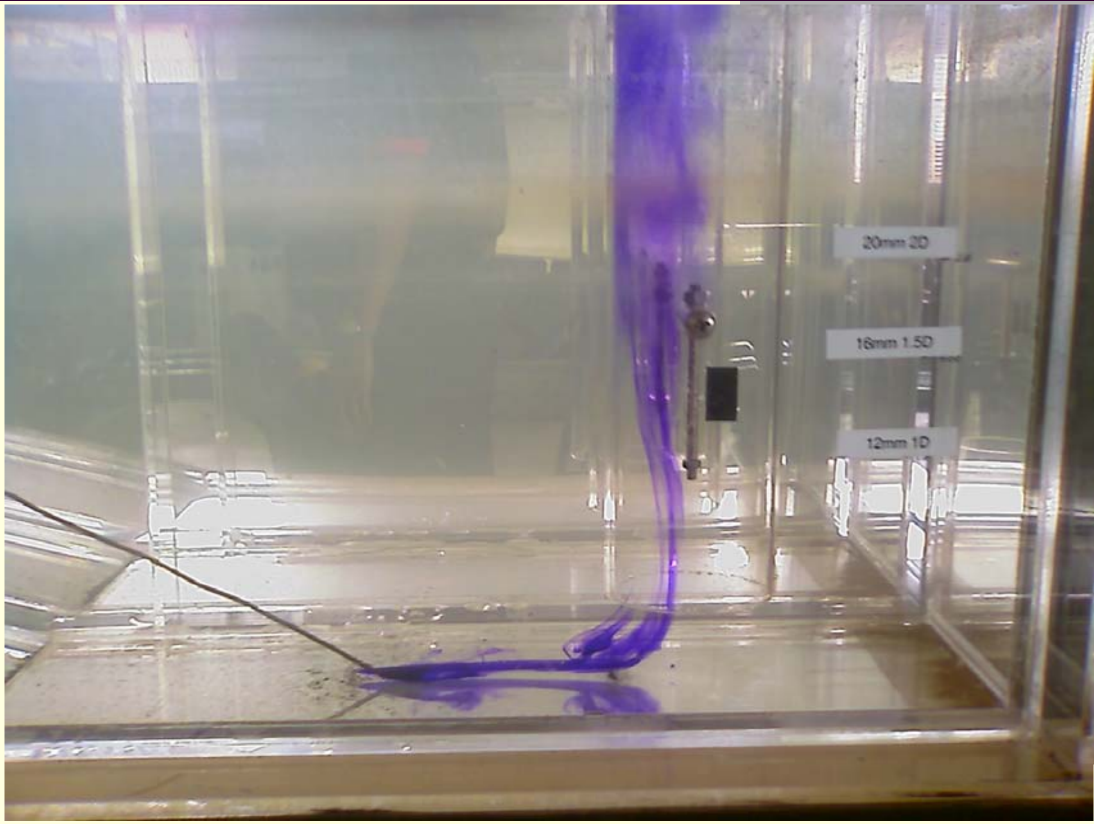
Pump Testing Configurations



SECTION 1-1 & 2-2 (LEVEL)

Visual Indication

The dye tracing techniques to determine flow pattern of the pumping sump model test.



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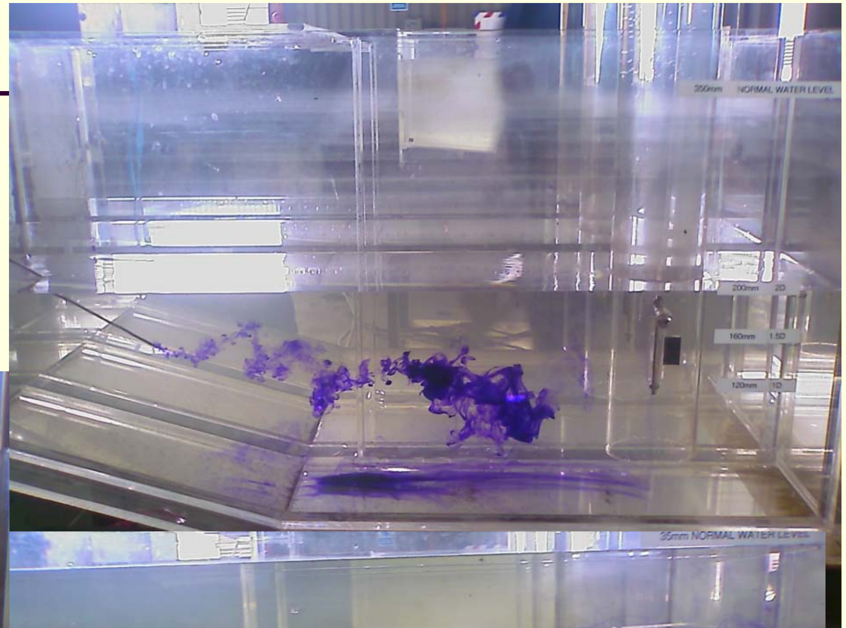

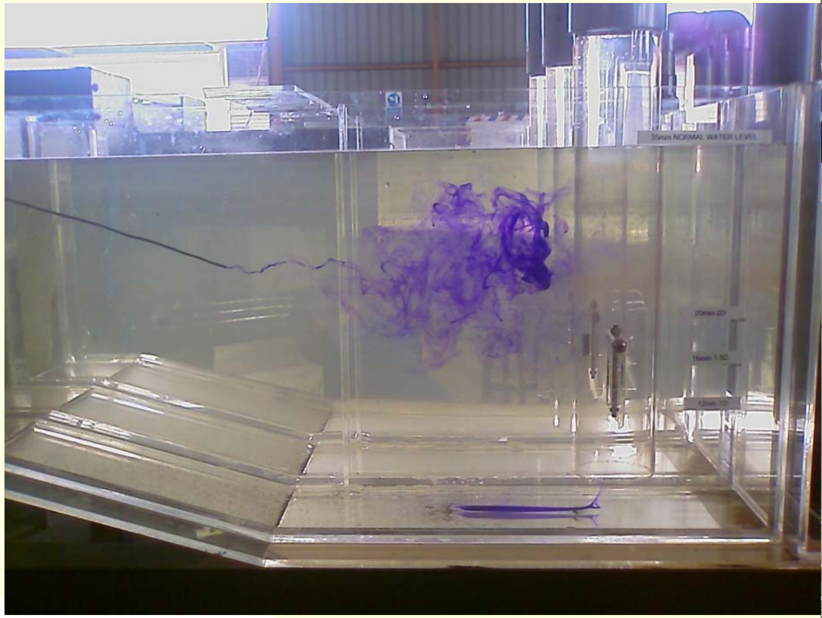

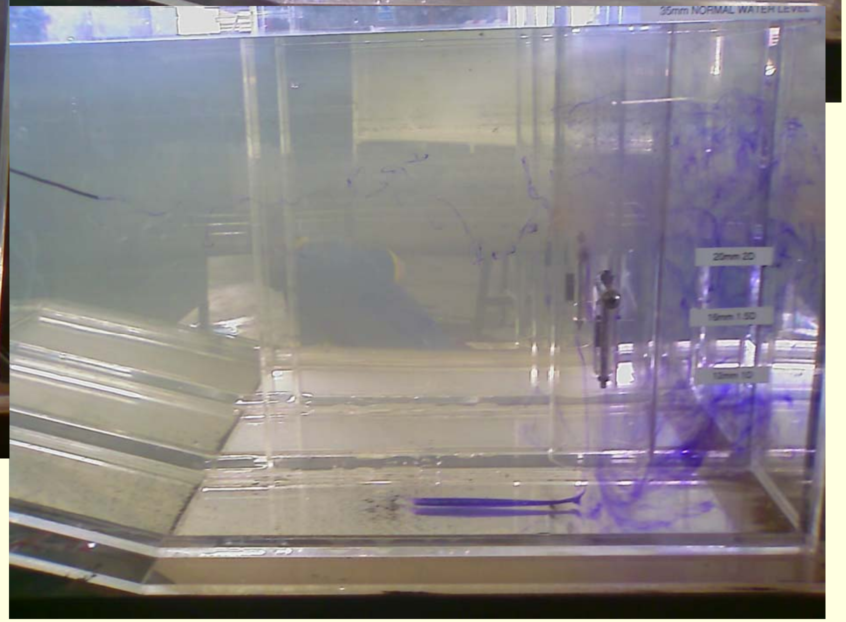

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Initial Result

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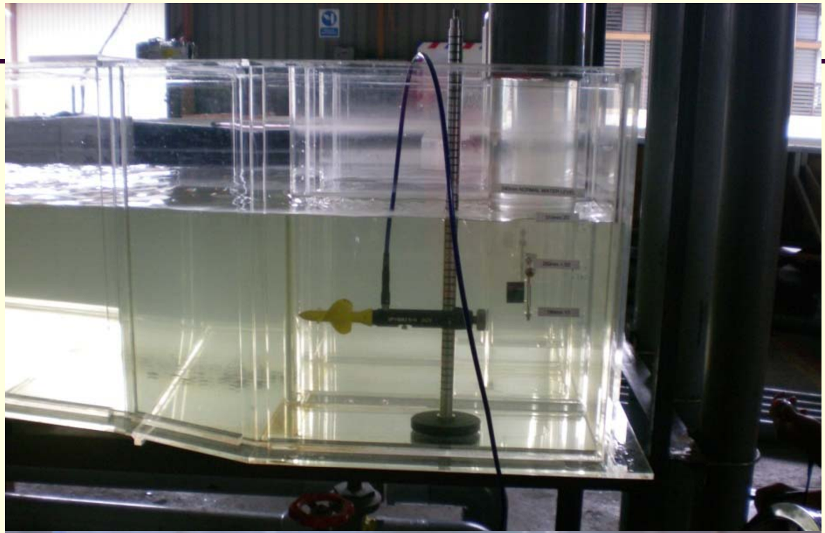
Components of the Vortimeter



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Run 5		1.58 L/s	3.16 L/s	3.16 L/s	
Run 6		1.58 L/s		3.16 L/s	

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Physical Model Result

Table 3: Velocity profile for Perai (240mm) both pumps in operation

Case 1 - water level 240mm

No. of operation pump - 2 (Pump 1 & 3)

Water Level	Pump 1		Pump 3	
	1	2	1	2
0.2 D	0.156		0.113	0.113
	0.123	0.440	0.113	0.093
	0.044	0.054	0.103	0.074
0.4 D	0.133	0.044	0.074	0.103
	0.113	0.044	0.064	0.084
	0.044	0.064	0.103	0.113
0.6 D	0.450	0.044	0.084	0.044
	0.145	0.054	0.054	0.044
	0.055	0.000	0.123	0.113
0.8D	0.156	0.054	0.064	0.063
	0.144	0.044	0.084	0.063
	0.044	0.044	0.133	0.123

Divider Section

1		2	
Flat	Slope	Flat	Slope
0.064	0.133	0.113	0.211
0.054	0.064	0.103	0.113
0.044	0.000	0.211	0.167

Table 4: Velocity profile for Perai (240mm) Pump 1 in operation

Water Level	Pump 1	
	1	2
	i	i
0.2 D	0.211	0.084
	0.167	0.084
	0.054	0.123
0.4 D	0.189	0.084
	0.178	0.084
	0.044	0.113
0.6 D	0.200	0.054
	0.200	0.074
	0.000	0.093
0.8D	0.200	0.044
	0.167	0.093
	0.064	0.093

Divider Section

1		2	
Flat	Slope	Flat	Slope
0.000	0.000	0.178	0.167
0.000	0.000	0.178	0.167
0.000	0.000	0.093	0.113

Table 5: Velocity profile for Perai (240mm) Pump 3 in operatio

Water Level	Pump 3	
	1	2
	i	i
0.2 D	0.133	0.133
	0.145	0.113
	0.133	0.113
0.4 D	0.123	0.113
	0.133	0.113
	0.113	0.123
0.6 D	0.103	0.103
	0.113	0.113
	0.123	0.054
0.8D	0.094	0.113
	0.064	0.084
	0.064	0.054

Divider Section

1		2	
Flat	Slope	Flat	Slope
0.000	0.000	0.175	0.103
0.000	0.000	0.175	0.145
0.000	0.000	0.145	0.175

Table 6: Velocity profile for Perai (180mm) Pump 1 in operation

Case 2 - water level 180mm

No. of operation pump - 1 (Pump 1)

Water Level	Pump 1	
	1	2
	i	i
0.2 D	0.189	0.084
	0.200	0.093
	0.064	0.093
0.4 D	0.196	0.084
	0.189	0.093
	0.064	0.103
0.6 D	0.167	0.044
	0.178	0.074
	0.064	0.074
0.8D	0.189	0.064
	0.189	0.074
	0.084	0.044

Divider Section

1		2	
Flat	Slope	Flat	Slope
0.000	0.000	0.145	0.167
0.044	0.054	0.156	0.145
0.000	0.044	0.156	0.113

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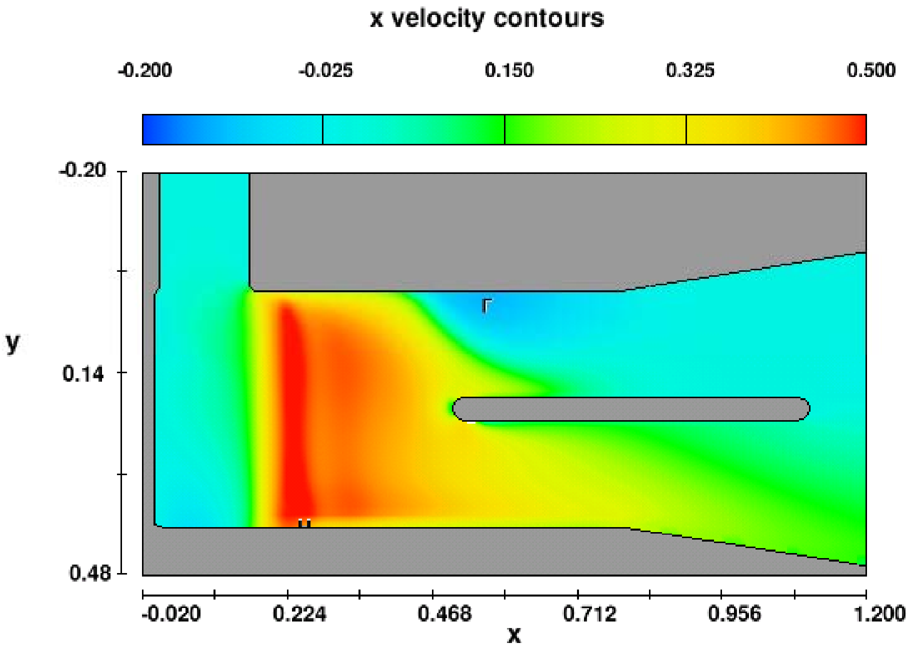

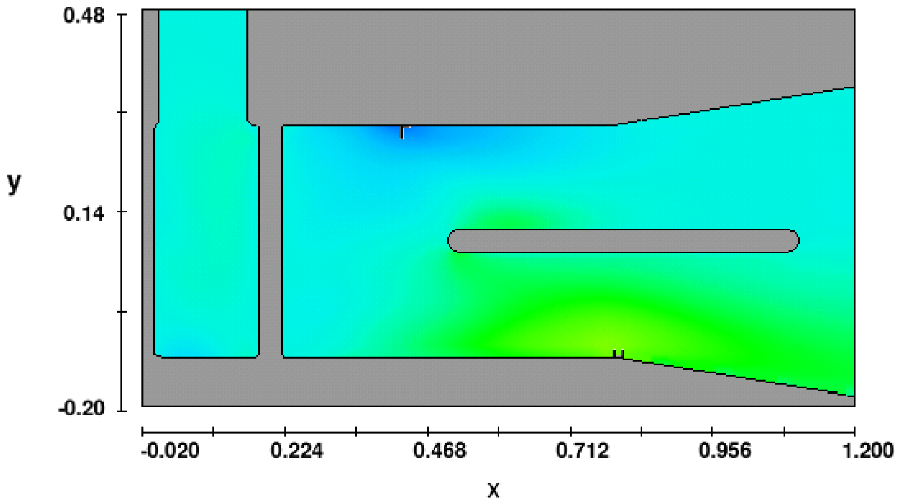

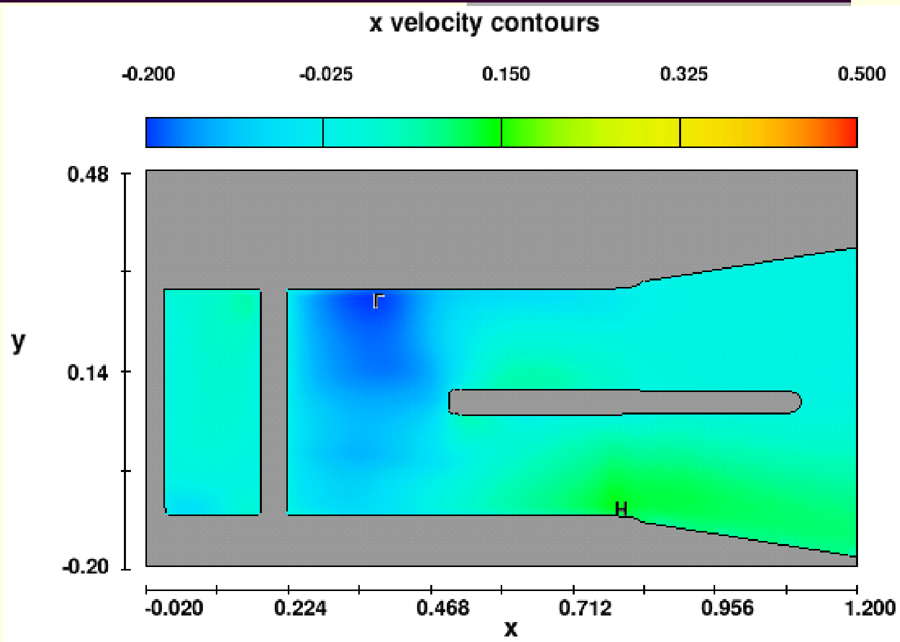

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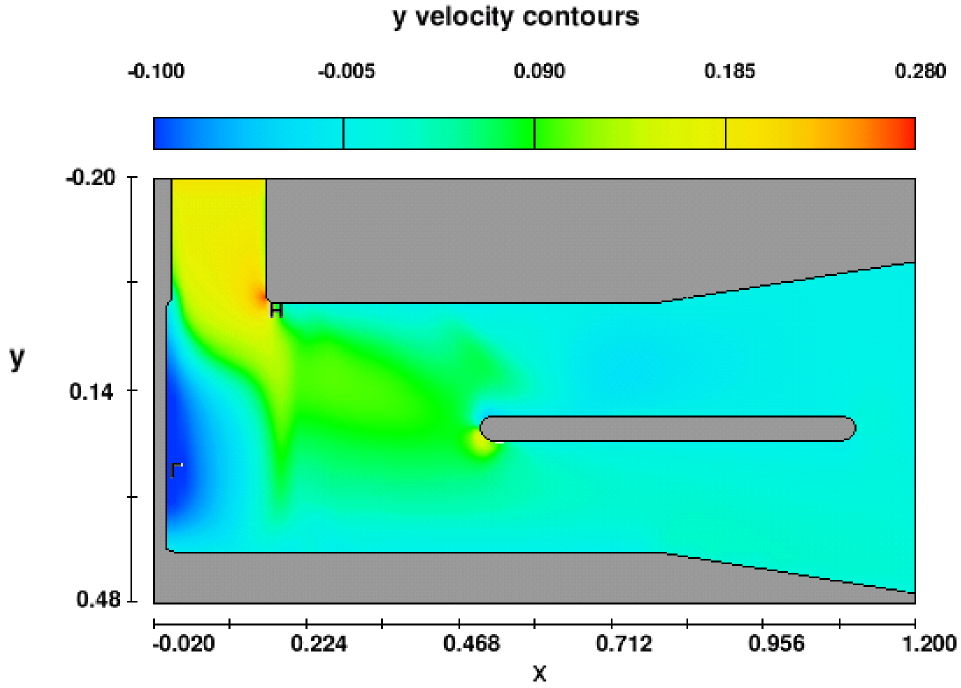

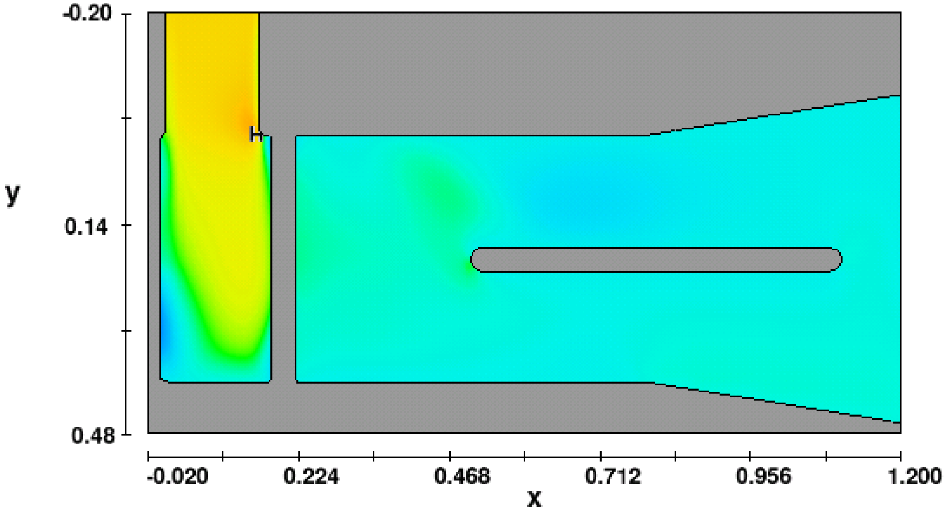

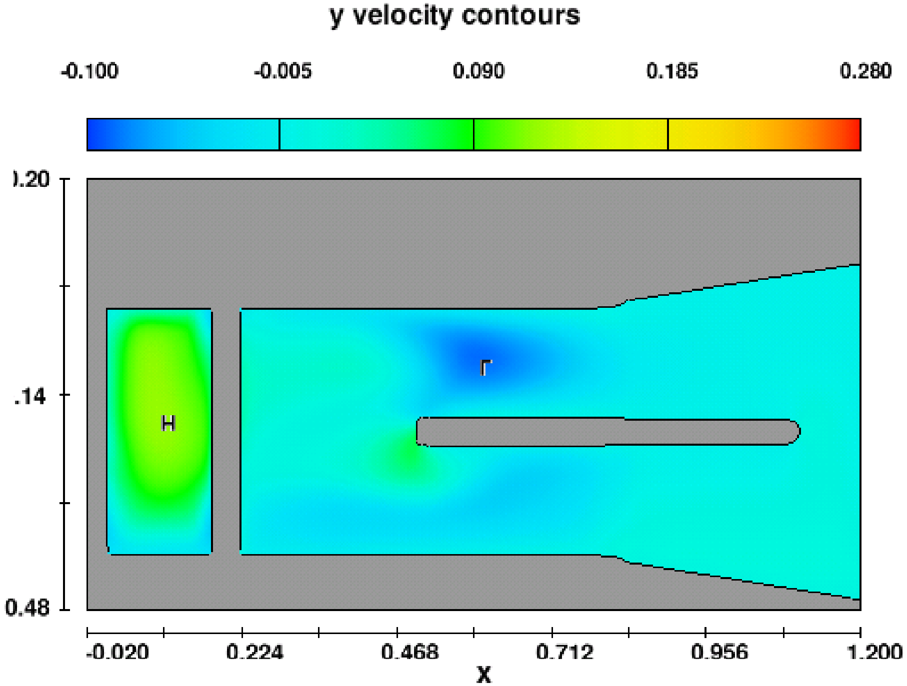

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Thank you

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