REGIONAL FACTORS GOVERNING PERFORMANCE AND SUSTAINABILITY OF WASTEWATER TREATMENT PLANTS IN HONDURAS: LAKE YOJOA SUBWATERSHED

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Introduction

- Honduras
  - 2nd largest & one of poorest countries in Central America
  - Inadequate sanitation, resulting in waterborne disease
- Study site: Lake Yojoa Subwatershed
  - Largest lake in Honduras
  - Many anthropogenic sources of pollution
  - 9 municipalities, 12 microwatersheds
  - Population of about 75,000
  - Identified as a priority watershed by RAS-HON

Lake Yojoa

Water Quality in Lake Yojoa

Water Quality in Lake Yojoa

Aquatic Plant Growth

Aquatic Plant Growth

Stakeholders

- Municipality of Las Vegas
- Aquafinca
- AMPAC mine
- ENEE dam
- Agriculture
- AMUPROLAGO
- Fish restaurants (Las Casetas)
  - Where our work is focused!

Figure 4.1: Various stakeholders in and around Lake Yojoa.

State of Wastewater Treatment in Lake Yojoa Subwatershed

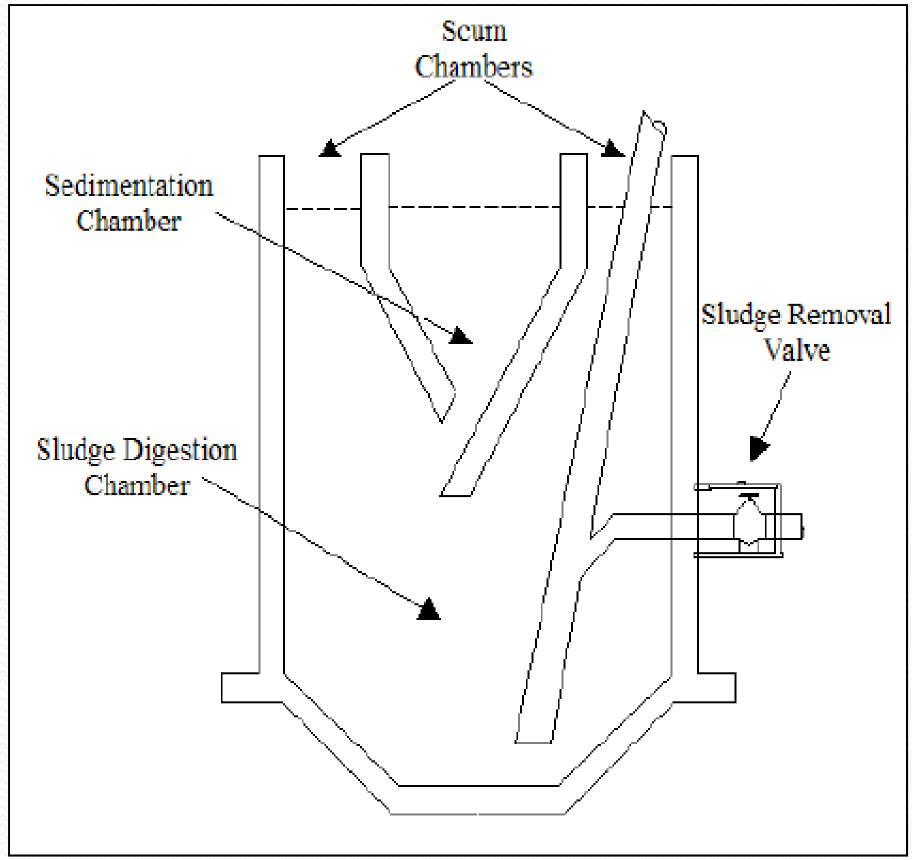
- Many municipalities directly discharging wastewater into local receiving water bodies
- Of those with treatment- many still discharging poor quality effluent
- Many factors
  - Lack of sufficient maintenance
  - Antiquated systems
  - Extreme hydraulic overloading
  - Lack of money and resources

Mayoral Meeting

- Attended mayoral meeting in Santa Barbara, Honduras
- About twenty mayors from local municipalities
- Only one of the over twenty mayors said their municipality did not have problems with wastewater treatment

Imhoff Tank

- Primary treatment wastewater system
- Two levels
  - Upper primary sedimentation
  - Lower anaerobic digester



(From Mikelonis and Hodge, 2008)

Las Vegas Imhoff Tank

Problems

- No control flow gates
- Some inflow bypasses treatment
- No way to reverse the flow

No Baffles

- Unequal flow into the two tanks
- Uneven distribution of solids
- Unequal residence times

Missing Sludge Valves

- Currently have no way to de-sludge the tanks
- Three of the six sludge valves were stolen

Lack of Maintenance

Santa Barbara Imhoff Tank

Sludge Backup

No Control Flow Gates

Missing Sludge Gates

Broken By-pass

Las Casetas

- "The little houses": 51 fish restaurants directly on shore of lake
- Wastewater treatment plant built in 2008 but never connected
- Cost approximately $400,000
- Focus of our work

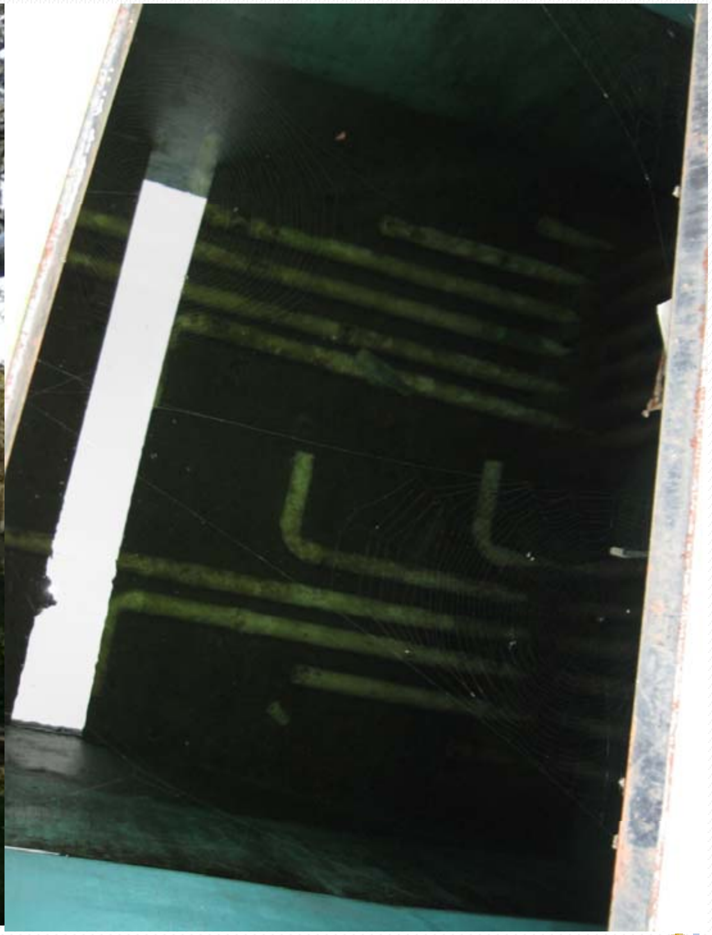
Tilapia

Las Casetas Treatment Plant

Why Las Casetas?

- System already in place – just needs to be connected!
- Support from PRONADERS, AMUPROLAGO, and other organizations
- Provide a model for wastewater treatment in the subwatershed

Primary Tank: UASB



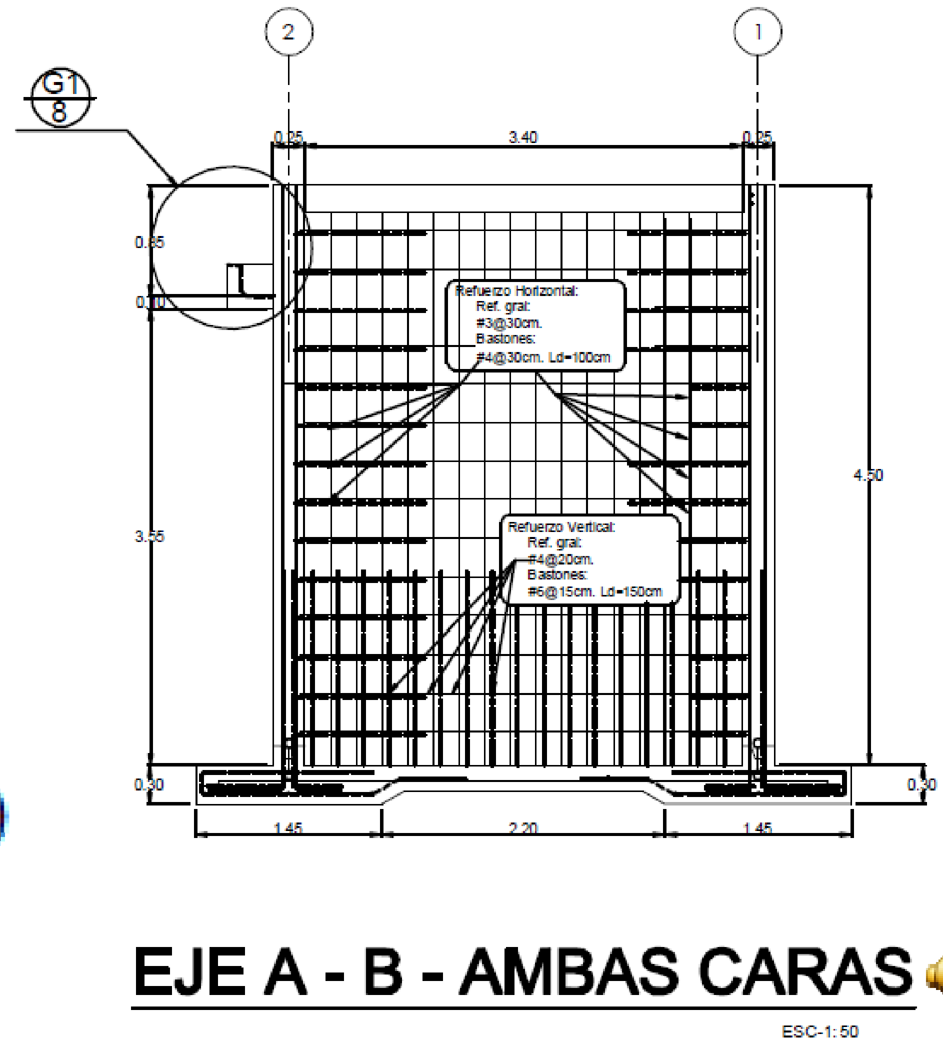
UASB Calculations

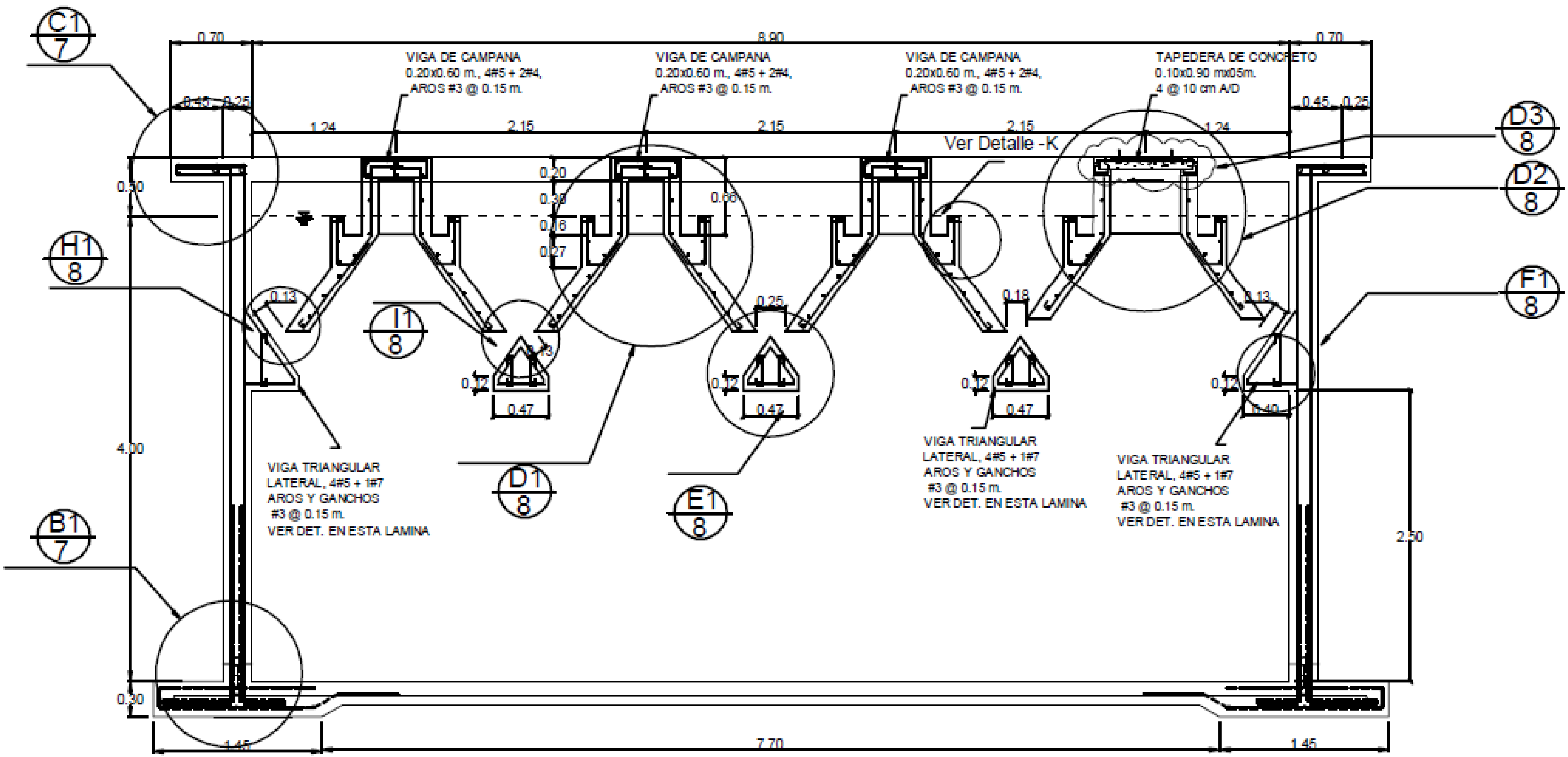
- Design flow: 3.18 L/s
- Peak flow: 9 L/s
- Upflow velocity:

$$V_{up} = \frac{Q}{A} = \frac{D}{\theta}$$

- COD Removal: ~80%

$$R = 100(1 - \theta^{-0.68})$$





CORTE A
PLANTA ESTRUCTURAL

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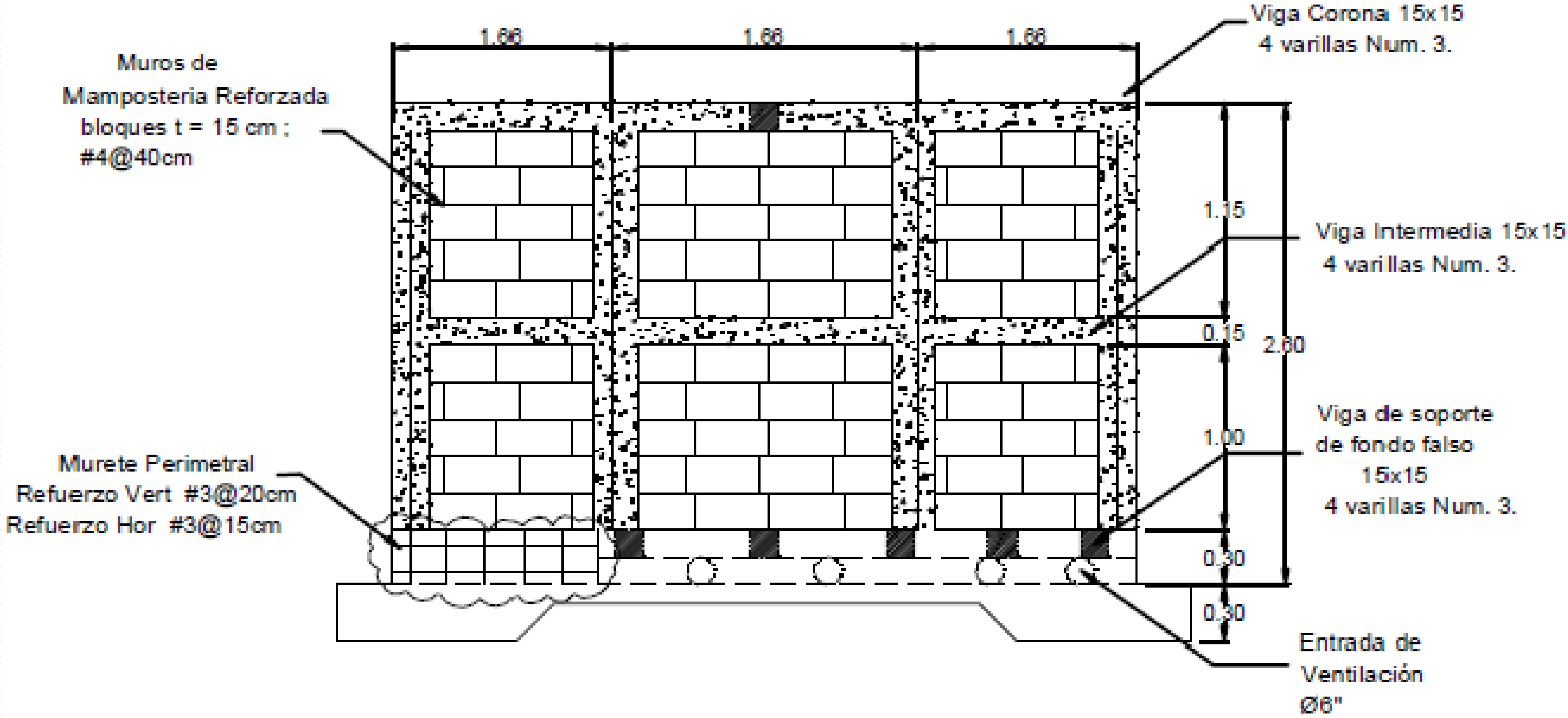
UASB Calculations

Parameter	Calculated Value Under Design Flow	Calculated Value Under Peak Flow	Acceptable Value	Acceptable Under Design Flow?	Acceptable Under Peak Flow?
Reactor volume, m^3	121.04	121.04	< 1000	Yes	Yes
L:W ratio of reactor	2.6:1	2.6:1	< 4:1	Yes	Yes
Upflow velocity, m/h	0.4	1.07	< 1	Yes	No
HRT, hours	10.6	3.74	6 to 12	Yes	No

Secondary Treatment: Trickling Filter

Filter Media



ELEVACIÓN ESTRUCTURAL FILTRO PERCOLADOR

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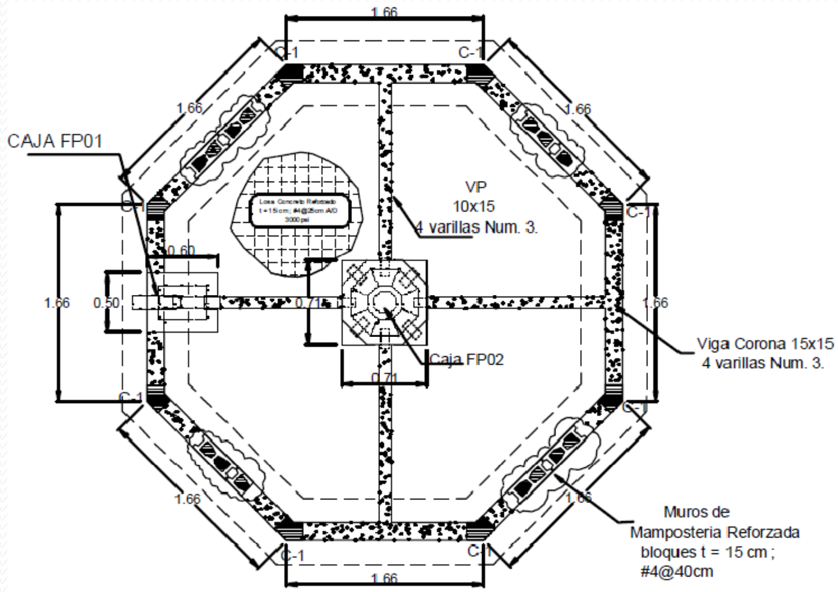
Trickling Filter: Hydraulic Loading

- Volume = 3,114 m^2
- Specific area:

$$\alpha = \frac{6}{D_p}(1 - \varphi)$$

- Using D_p = 5 cm, ϕ = 0.25
  - α = 90 m^2/m^3
  - Hydraulic loading = 0.09 m/d
    - Very low!



PLANTA ESTRUCTURAL FILTRO PERCOLADOR

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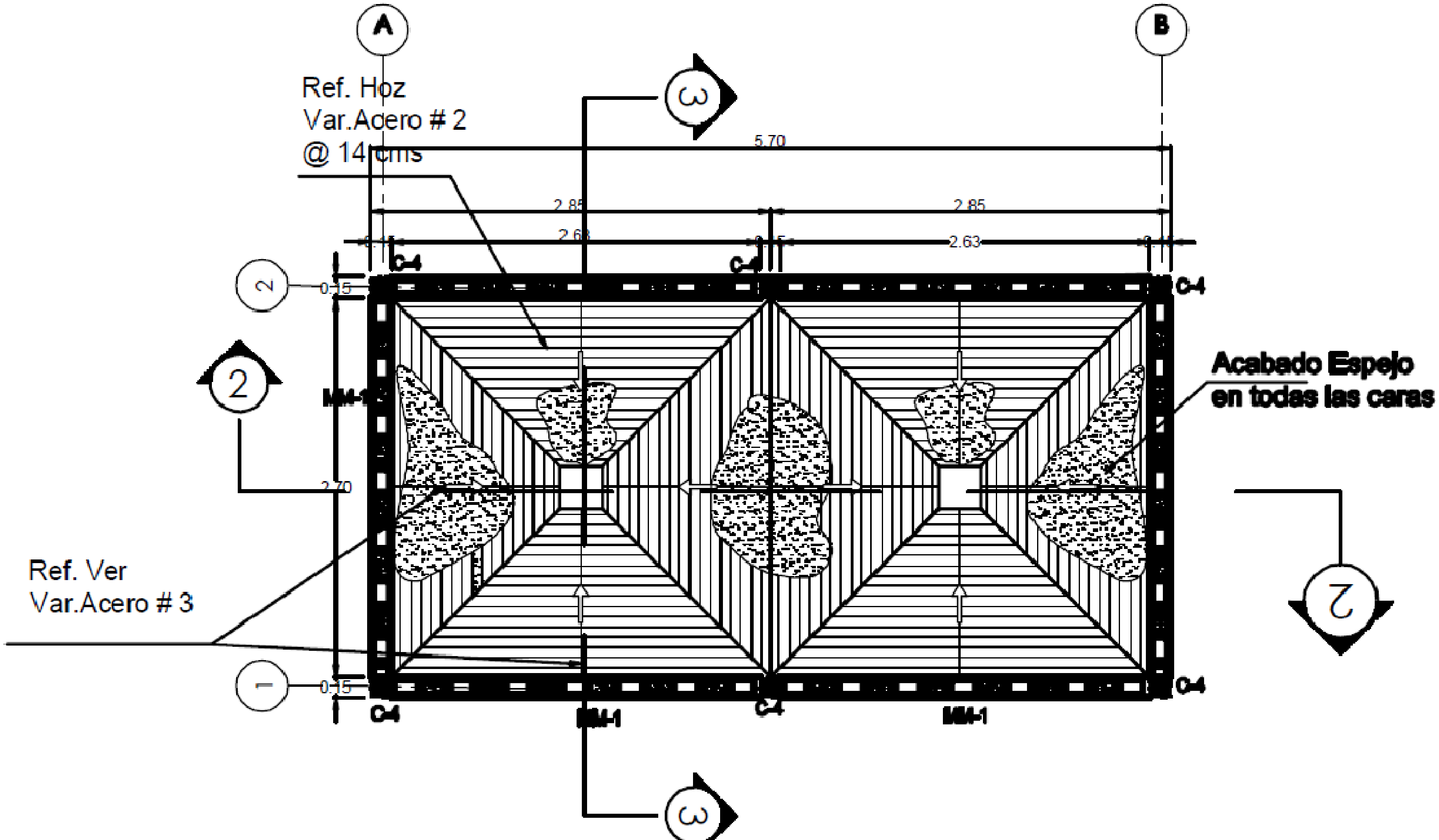
Secondary Clarifier



PLANTA ESTRUCTURAL CLARIFICADOR

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Recommended Overflow Rates

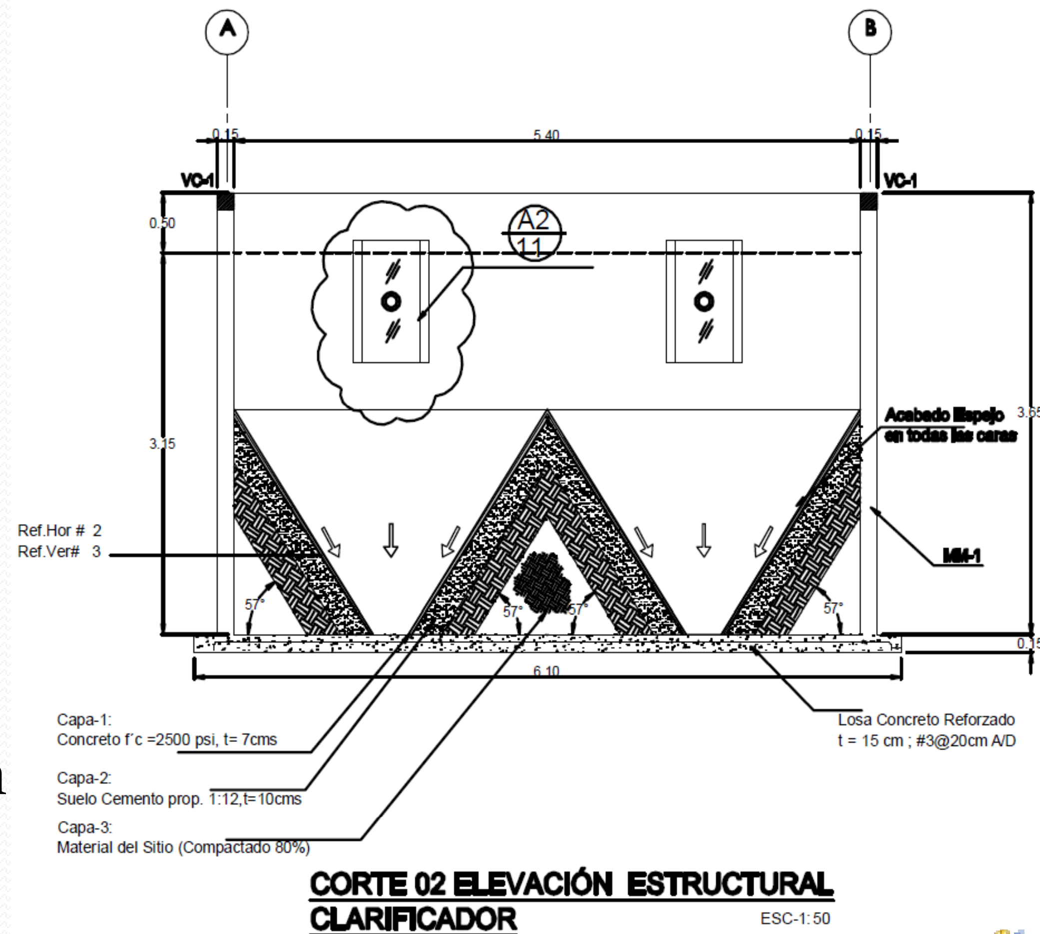
Sidewater depth, m	Average overflow rate, m/h	Maximum overflow rate, m/h
2	0.4	0.75
3	0.8	1.6
4	1.2	2.2
5	1.4	2.8

Calculated Overflow Rate

- Equation:

$$v_0 = \frac{Q}{A}$$

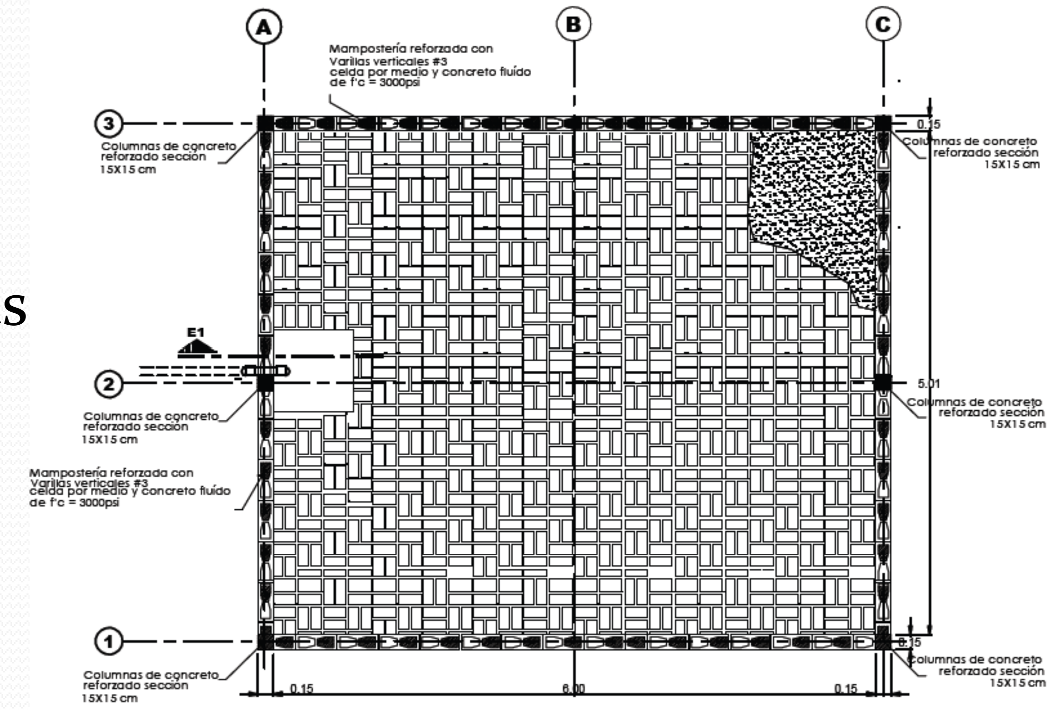
- For single clarifier, 1.6 m/h at design flow, 4.6 m/h at max flow
- Sidewater depth = 3.15 m
  - For recommended overflow rate, need both tanks!



Sludge Drying Bed

Sludge Drying Bed Area

- In general, need 0.01-0.015 m^2/person
- Design population:
  - 522 permanent residents
  - + 643.5 floating population
  - = 1165.5 people total
- Total area = 30 m2
  - 0.026 m^2/person!



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Conclusions So Far

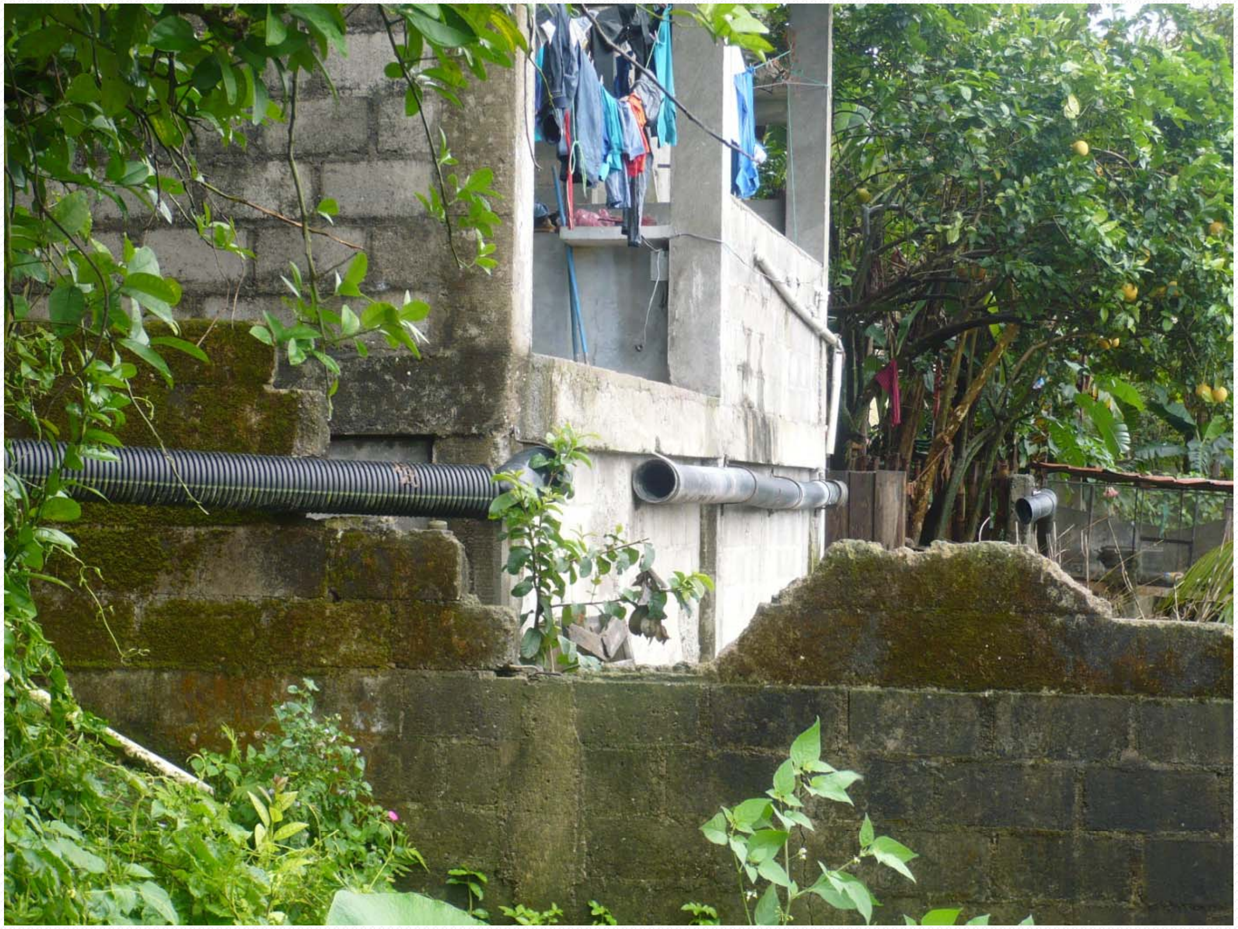
- UASB well designed
- Trickling filter may need to be reevaluated depending on results of analysis (recirculation, intermittency)
- Single secondary clarifier is not sufficient to ensure removal of suspended solids generated by filter
- Sludge drying bed is sufficient and in good shape
- Still need to:
  - Estimate BOD loading for UASB and trickling filter
  - Rework hydraulic loading calculations for trickling filter

Recommendations

- Install preliminary treatment mechanism (grit removal / screening)
- Construct another secondary clarifier tank
- Divide sludge bed into two sections
- Chlorination (included in proposal)

Major Problem

Piping Network



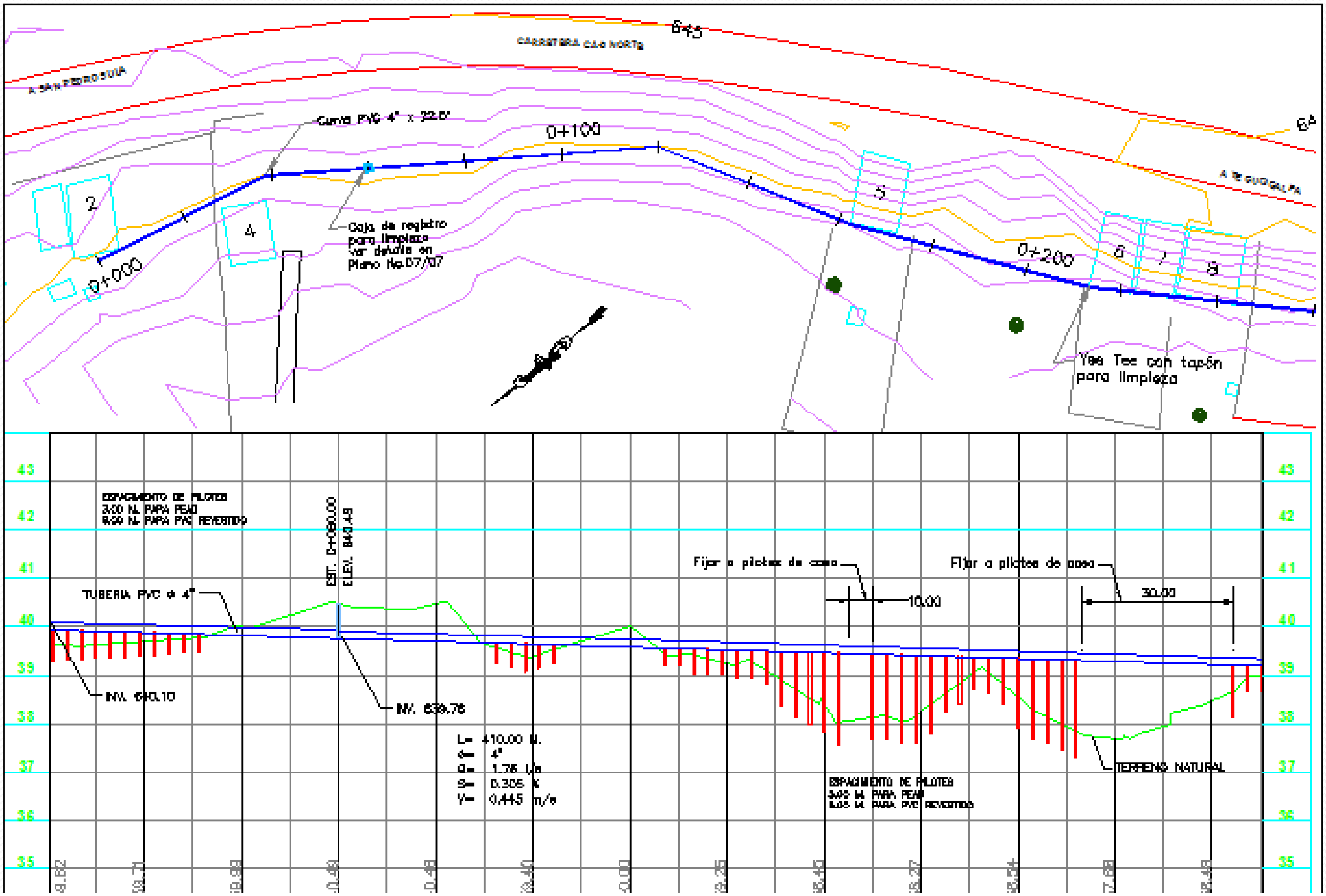
Piping Network

Piping Network

Distribution Tank

High Water

Construction Plans



Piping Specifications

- Plans call for coated PVC or HDPE pipe

- Instead they used black corrugated piping that sagged in the sun

Hydraulic Head

- Span of the piping system is 1.1 km
- There is 3.35 m of head to drive the flow to the distribution box
- With a constant slope of 0.305% is there enough head to drive the flow?

Head Loss Due to Friction

- Equated the head loss due to friction and other minor losses to the available head.

- Darcy-Weisbach equation

$$h_f = f\frac{L}{4R_h}\frac{V^2}{2g} = \frac{V^2}{2g}\left[\frac{fL}{4R_h} + \Sigma K\right]$$

Equate Head Loss to Available Head

$$h_f = f\frac{L}{D}\frac{V^2}{2g} = f\frac{L}{R_h}\frac{V^2}{2g}$$

$$A = f(d, D)$$

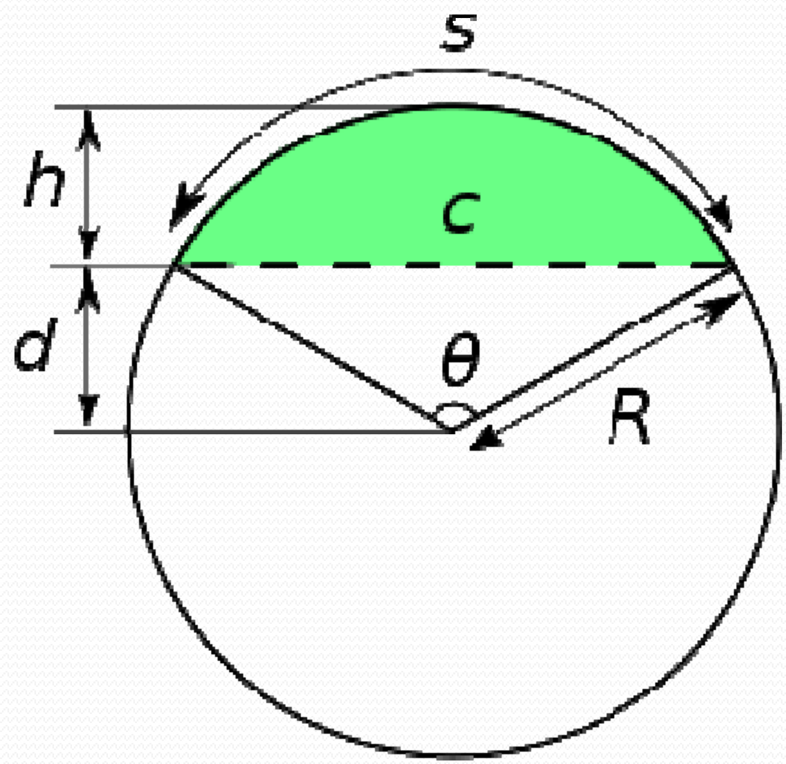
$$R_H = \frac{A}{W_p}$$

$$W_p = f(d, D)$$

$$h = LS$$

Equate

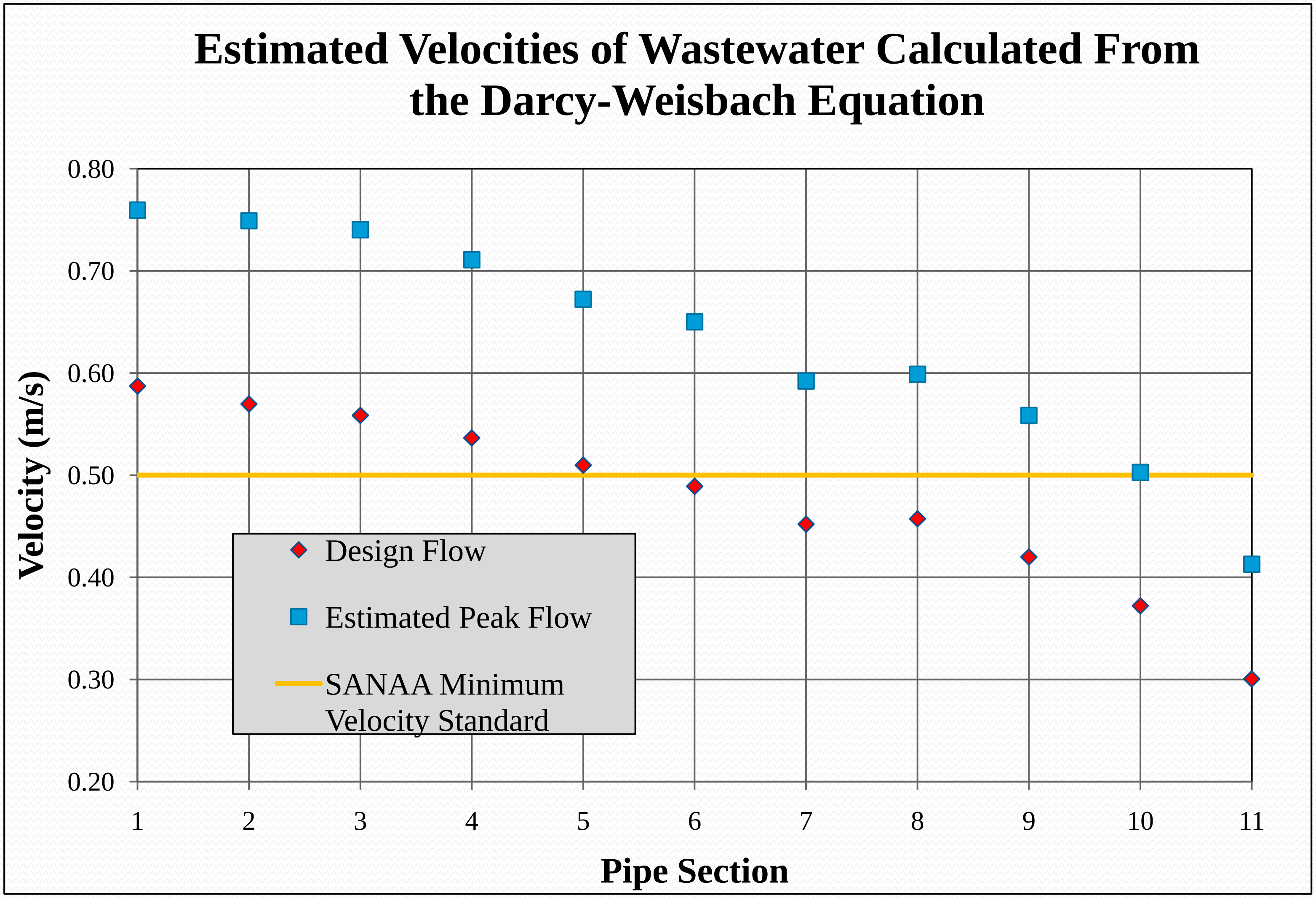
$$LS = f\frac{L}{R_h}\frac{V^2}{2g}$$



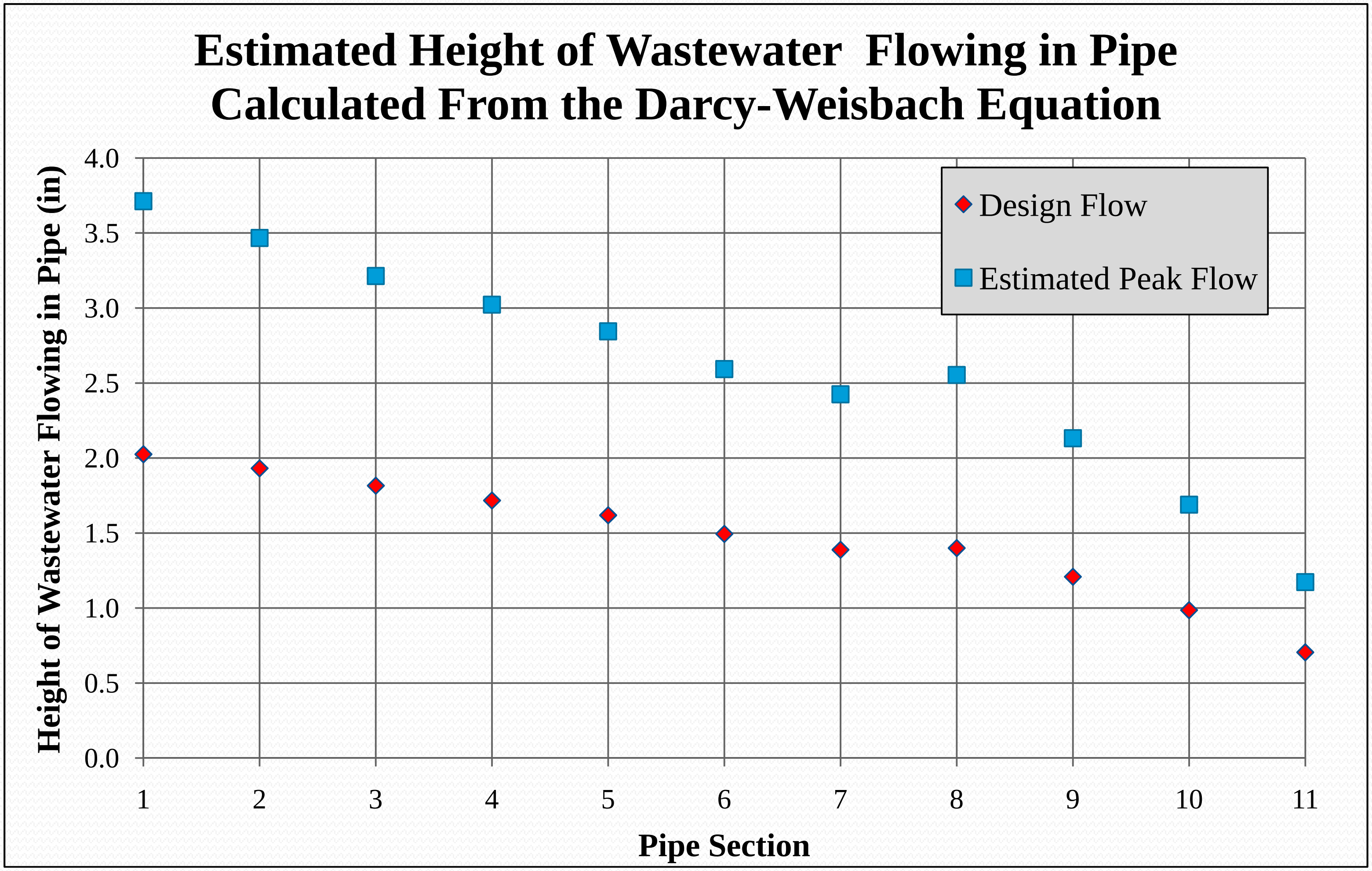
http://en.wikipedia.org/wiki/Circular_segment

Distance (L) =	1100	m		
Height (Z) =	3.35	m		
Slope (S) =	0.00305	ND		
Pipe Diameter (D) =	0.1524	m		
Pipe Radius (R) =	0.0762	m		
Flow (Q) =	3.18	L/s		
Q =	0.00318	m^3/s		
Height of Water In Pipe (h) =	0.051538939	m		$h < R = 0.0762$
Height of Water In Pipe (h) =	2.029092077	in		
d =	0.024661061	m		$d = R - h$
θ =	2.4825	Radians		$\theta = 2 \arccos(d/R)$
θ =	142.23	Degrees		$\theta = 180*\theta(rad)/\pi$
c =	0.1442	m		$c = 2R \sin(\theta/2)$
Arc Length (S_{arc}) =	0.1892	m		$S_{arc} = R\theta$ (rad)
Area of Sector (A_{sector}) =	0.00721	m^2		$A_{sector} = [\theta\ (deg)/360]\ \pi R^2$
Area of Triangle (A_t) =	0.00178	m^2		$A_{triangle} = 0.5cd$
Area of the Segment (A_s) =	0.00543	m^2		$A_{segment} = A_{sector} - A_{triangle}$
Wetted Perimeter (W_p) =	0.1892	m		$W_p = S_{arc}$
Hydraulic Radius (R_h) =	0.0287	m		$R_h = A_{segment} / W_p$
Velocity (v) =	0.5857	m/s		$v = Q / A_{segment}$
*Min Velocity =	0.5	m/s	No Error	
*Max Velocity =	3	m/s	No Error	
f =	0.02			
g =	9.8	m/s^2		
$fv^2/2g\ \ 1/4R_h$ =	0.00305	*Used solver and set equation equal to 0.00305		

Velocity Plot

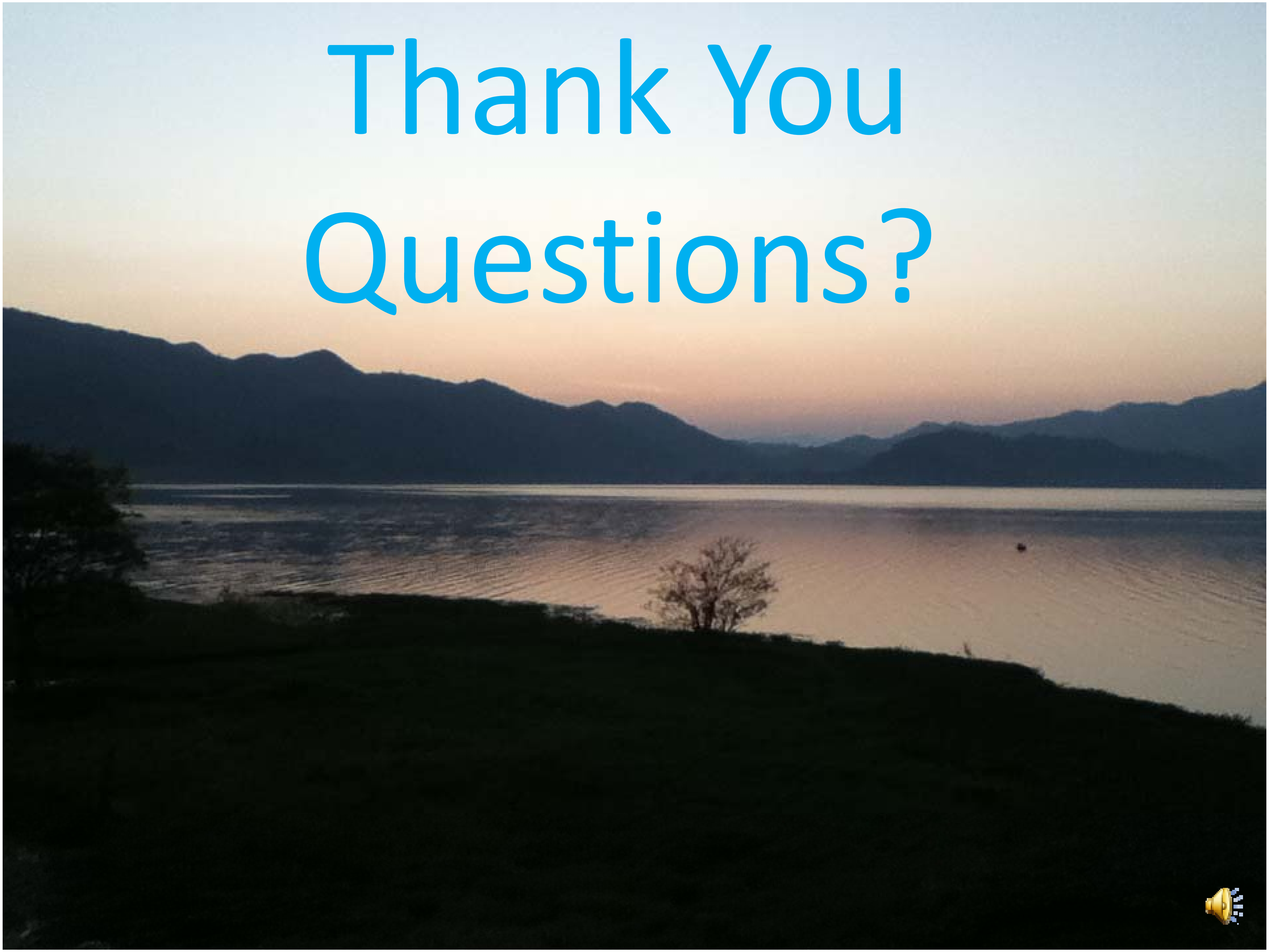


Height of Wastewater in Pipe



Conclusions

- First order analysis the piping system is a good design
- There are still some unanswered questions
  - Issues with low velocities
  - No low flow calculations
  - Possibility of solid drag due to the low flows
  - Buoyancy of distribution tank


Thank You
Questions?