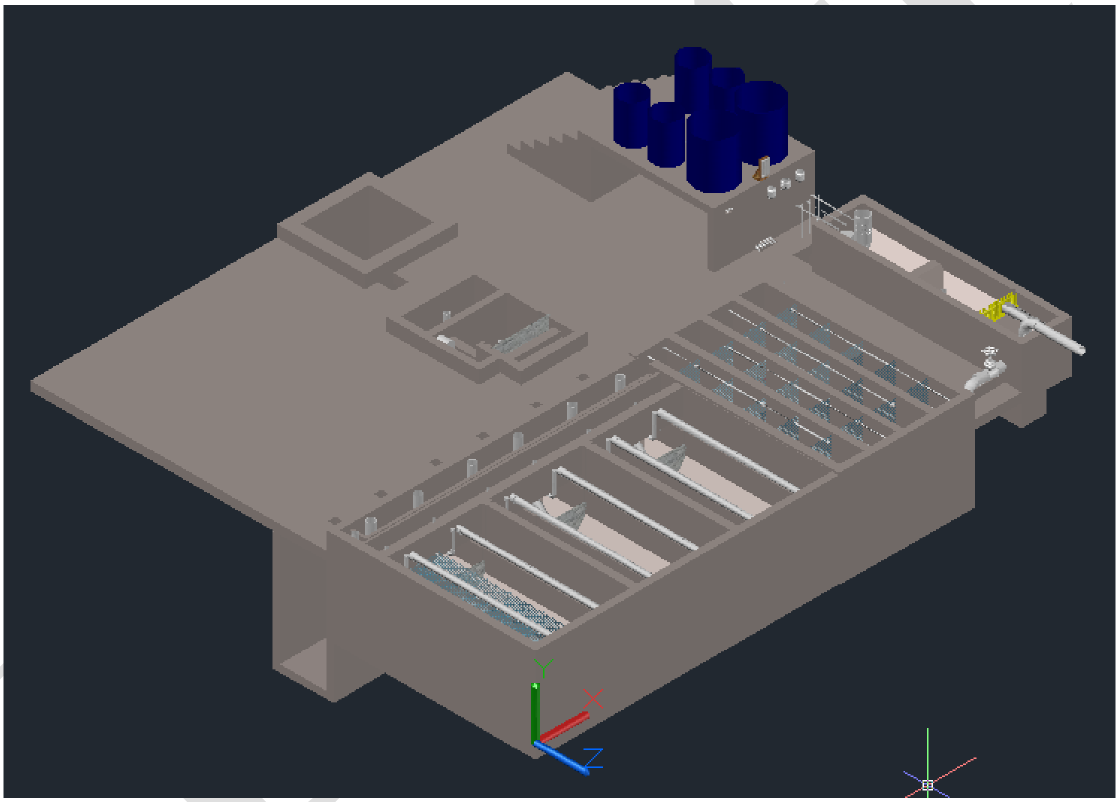
PRELIMINARY DESIGN FOR UI.CITY UI.STATE, UI.COUNTRY

UI.NAME

UI.ORGANIZATION



FEBRUARY 10, 2018 AT 3:14:18 PM

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Cornell University
School of Civil and
Environmental Engineering

AguaClara
http://aguaclara.cee.cornell.edu/
Dr. Monroe Weber-Shirk, Director

This preliminary design was requested by UI.Name.First UI.Name.Last on behalf of UI.Organization. The design was created on February 10, 2018 at 3:14:18 PM by the AguaClara Design Server at Cornell University. The design is for UI.City UI.State, UI.Country and has a design flow rate of 60.0 L/s. The design was created with MathCAD code version 7667.

This design is the result of over 20,000 hours of undergraduate, graduate, and faculty labor. The design incorporates advanced fluid dynamics analysis for the hydraulic design to minimize floc breakup between the flocculator and the sedimentation tank. The chemical feed system is based on a series of inventions by the AguaClara team that make it possible to directly set the desired chemical dose and to maintain that dose automatically even as the flow rate through the plant varies. The high rate, shallow sedimentation tank design is optimized for high performance, low cost of construction, and ease of maintenance. The fabrication techniques that make it possible for a single operator to completely disassemble a sedimentation tank while keeping the rest of the plant in operation were developed by the AguaClara team at Cornell and by our partners in Honduras.

The economic value of this design is approximately 10,000 USD. This estimate is based on the amount of time that would be required to create this design if an environmental engineering firm used the AguaClara design algorithms, but not the automated design tool, to create this design. The AguaClara team is committed to continue providing this design service because we want to encourage new implementation partners to explore the use of this technology. We also recognize that high design costs would prevent this technology from being available to small communities. However, we do require funding to maintain our design team and to continue to integrate improvements into our designs. We recommend that implementation partners include a design fee for the AguaClara design service in the project budget. The nominal fee (far below its true value) for use of this design service is 1000 USD per L/s of plant capacity. You are welcome to create multiple designs for each facility that you intend to construct to obtain an optimal plant configuration. This fee, which will guarantee continued technical support from the AguaClara team, can be paid to AguaClara by check or online to Cornell University. This fee will likely be between 1% and 2% of the overall project cost for a water treatment plant. Thank you for your support.

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Disclaimer

This document is a DRAFT. It has not been reviewed for official release. It is included with the design files to show what we plan to deliver in the near future.

This design, including the files accompanying this document, is only a draft and must be reviewed and approved by a licensed engineer prior to construction. If you have questions about this design please contact the AguaClara design team at Cornell University at CUAguaClara@gmail.com.

Permission and Licensing Information

Authors: The AguaClara team at Cornell University under the supervision of Dr. Monroe Weber-Shirk

Introduction to AguaClara

The sustainable approach

AguaClara is a program in Civil and Environmental Engineering at Cornell University that is improving drinking water quality through innovative research, knowledge transfer, open-source engineering, and replicable design of sustainable municipal water treatment systems. The team is directed by Monroe Weber-Shirk and has worked in partnership with Agua Para el Pueblo, a Honduran NGO specializing in water supply systems, to implement the technologies in rural towns. The AguaClara program received the 2011 Intel Environment Tech Award in recognition of the success of the program in developing sustainable technologies and effective governance models.

Cornell-designed AguaClara municipal water treatment plants are providing six Honduran towns with populations between 1,500 and 15,000 with safe drinking water from their taps. The AguaClara plants produce safe drinking water with turnkey design, construction, operation, training, and transfer costs of $20 to $30 per person served and incremental operating costs of $2-$4 per person per year.

The AguaClara technology is uniquely capable of producing high quality drinking water from turbid surface waters without using electricity. The facilities use gravity powered chemical dosing, hydraulic flocculation (to form large aggregates from the contaminants, or flocs), high-rate sedimentation using custom-fabricated plate settlers (to remove the flocs), stacked rapid sand filtration, and disinfection using liquid chlorine (to kill any residual pathogens that escaped the previous treatment steps). The designs rely on materials that are sourced in the community and national supply chains. The municipal water treatment plants are designed to be easy and economical to operate.

Extending safe drinking water coverage to resource poor communities requires multiple engineering innovations and a new approach to implementation and governance. Our robust technologies do not require electricity or external power sources. Our governance model is based on community ownership, community-based democratic governance, and technologies that are specifically designed to be easy to operate and to encourage pride in ownership. We build implementation partner capacity and intend to encourage the formation of a network of implementation partners that will share best practices for implementation and long-term operation of community-based water treatment facilities.

This integrated model of technology development for compatibility with a sustainable governance model has proven extremely successful. All AguaClara facilities are owned and operated by their respective communities and all facilities continue to provide safe drinking water. This is particularly noteworthy in Honduras where most water treatment plants for large cities do not reliably meet drinking water standards. Several towns with AguaClara facilities are experiencing reverse migration from Tegucigalpa due to their superior water.

Democratic community governance through an elected water board has proven to be very effective and the water boards use the water tariffs (that the community has voted to increase) to fund improvements to their water supply infrastructure. Water boards with AguaClara facilities have invested in reforestation of their watershed, upgrades to their distribution system, extensions to their distribution system to add new customers, and ongoing maintenance of the water supply infrastructure. Customer willingness to pay for safe drinking water is significantly higher than their willingness to pay for unsafe river water and the difference is greater than the increased operation and maintenance cost of providing safe drinking water using AguaClara technologies.

Our goal is to disseminate this technology and our learning regarding sustainable governance globally. The AguaClara engineering designs are shared online to facilitate technology dissemination and to reduce design costs. National engineering firms (non-profit, private, or governmental) are trained to build the water treatment facilities using locally available materials and community labor. Our partners work with locally-trusted organizations to develop a governance model that is suited to the natural resources, national governance framework and available social and human capital of a particular community.

We are seeking funding that will support our research and development work to extend the range of community sizes that can be served using the AguaClara technologies. We have experience with communities between 1,500 and 15,000 and plan to extend that range in both directions. We are researching several technologies that have the potential to reduce the construction and operating costs of the water treatment plants and need funding to support that effort. There are significant engineering and governance challenges as we develop approaches to community based water treatment for communities with fewer than 1,500 inhabitants. Extending our design capabilities for treatment facilities that can serve larger cities is easier. The engineering and technical challenges will require developing new fabrication methods, testing prototypes for performance, and coding the new designs for dissemination via our online design tool.

We are also interested in testing models for implementation and governance. Our experience suggests that partnerships between the AguaClara team at Cornell, implementation partners, and community governance bodies realize their full potential when there is a high level of trust between the organizations and an ongoing technical assistance circuit rider. The AguaClara technologies are designed to encourage the creation of trust and self sufficiency by being easy to understand and easy to maintain even in resource poor communities. We would benefit from experiences with different types of implementation partners and with more governance and technical assistance models to learn which approaches are most effective for various situations.

The AguaClara program overcomes the major barriers to safe drinking water that were previously encountered by small communities. We estimate that well over 100 million people living in Latin America and the Caribbean, Africa, and Asia could benefit from these technologies. The resilient design, innovative fabrication methods based on locally available materials, the automated design tool, and community based governance hold the prospect of improving the quality of life in thousands of communities in the coming years.

The treatment process

AguaClara plants treat turbidity, pathogens, and natural organic matter using rapid mix, coagulation/flocculation, sedimentation, and rapid sand filtration proceses. The treatment process begins with removal of large debris and preliminary sedimentation of large particles. Then coagulant, which promotes the aggregation of suspended particles, is added to the raw water through a semi-automatic chemical dosing system. The coagulant is mixed with water in a rapid-mix pipe, which delivers macro-scale mixing through minor losses due to pipe configuration, and micro-scale mixing through an orifice plate. The rapid-mix pipe carries the mix of water and chemical coagulant to the flocculation tank, where it is forced through a series of 180 degree turns created by the staggered baffles within. The 180 degree turns ensure sufficient collisions among the suspended particulates to form larger aggregate particles, or flocs.

The flocculated water is then delivered to the bottom of the sedimentation tank through a series of diffusers, which ensure that the flow is directed vertically into the tank. The bottom geometry of the sedimentation tank has been designed to suspend flocs in the middle portion of the tank, creating a floc blanket which itself acts as a filter for other flocs. The top of the tank has a several closely-spaced plates, known as lamella, to shorten the horizontal distance a particle must travel before encountering an obstruction and settling down to the bottom of the tank. The water flowing up from the lamella has been cleaned of most flocs and can then be carried to the stacked rapid sand filter.

AguaClara's one-of-a-kind stacked rapid sand filter is composed of six sand layers arranged one on top of the other. The water from the sedimentation tank is divided evenly and delivered to every other sand layer by a pipe network. The main pipelines are connected to a series of slotted pipes, which spread the settled water throughout the plan view area of each layer. As water travels through the sand layers, the remaining flocs are captured in the pore space of the sand, and the filtered water is collected by the receiving sand layers (the remaining three layers that did not deliver water into the filter). A siphon system and pipe stubs that vary the water outlet elevations enable the filter to self-backwash, minimizing demand on the operator.

The final step in the AguaClara water treatment process is disinfection. The semi-automatic chemical doser delivers chlorine to the filtered water. The chlorinated water is stored in a distribution tank to allow for sufficient contact time with the chemical, ensuring the water is fully disinfected. After disinfection, the treated water is ready for distribution to households. Water treated by the AguaClara system is consistently below 5 nephelometric turbidity units (NTU), and frequently meets the US standard for maximum turbidity, 0.3 NTU.

The AguaClara Design Tool

In the AguaClara Design Tool (ADT), the basic design parameters requested (e.g. flow rate, wall thickness, number of sedimentation tanks desired, the dimensions of purchased lamella material, etc.) are used as variables in a series of hydraulic and geometric algorithms that define the dimensions of the plant reactors and their accessories. The design algorithms in the ADT are based on fundamental physics, and thus are scalable over a wide flow range. Algorithms have been revised and constrained based on lab research and feedback from the field to ensure both efficient material usage and ease of operation. The software output based on these parametric algorithms is a three-dimensional drawing in AutoCAD of each reactor that is to be given to the designer. The designer completes the design based on the ADT output by adding the final treatment components, the plant building, and distribution system, and then the designer must perform a full structural analysis of the plant. This document provides a summary of AguaClara processes with regard to the design of closed facilities. Consequently, all calculated values (e.g. lengths of plant reactors, distances between the centers of the orifices, etc.) are specific to this plant design, and do not necessarily apply to other AguaClara plants.

Design Parameters

Included is the design for a plant for **UI.CITY** having a maximum flow rate of 60.0 L/s L/s. The design was created assuming specific input parameters, shown in Table 1 below. The software uses these parameters together with the requested flow rate as variables in a series of hydraulic and geometric calculations that define the dimensions of the various plant components. The goal of the plant with respect to water quality is to reduce the turbidity as much as possible and to have it meet international water quality standards (less than 5 NTU), maintain the color within norms (15 Unidades de Color – UC), disinfect the water with chlorine, and maintain a residual chlorine concentration throughout distribution between 0.3 and 1.0 mg/L. The plant treats water without using electricity, utilizing preliminary sedimentation, flow control, rapid mix, coagulation/flocculation, hydraulic upflow sedimentation, filtration, and chlorination.

Maximum flow rate	60.0 L/s	
Geometric Assumptions		
Thickness of the plant walls	0.165 m	
Minimum concrete thickness	T.ConcreteMin	
Minimum tank dimension for construction worker to fit inside	W.HumanMin	
Minimum height from bottom of drain channel to top of walkway so that operator can fit inside	H.HumanAccess	
Minimum width of a channel for constructability	W.ChannelMin	
Plant freeboard height	10.0 cm	
Entrance Tank		
Maximum hopper angle	AN.EtSlope	
Maximum upflow velocity	V.EtUp	
Maximum water height for ease of operation	HW.EtMax	
Thickness of the ledge between hoppers	T.EtLedge	
Chemical Dosing		
Turnover time for the chemical stock	Ti.CoagStock	
Height of the chemical tanks above the constant head tanks	30.0 cm	
Minor loss coefficient for small diameter tubing	K.CdcTube	
	Coagulant	Chlorine
Maximum dose	40.0 mg/L	C.ChlorineDoseMax
Maximum stock concentration	C.CoagStockMax	C.ChlorineStockMax
Maximum head loss through small-diameter tubing	HL.CoagCdc	HL.ChlorCdc
Flocculation		
Minor loss coefficient for flow around a baffle	2.50	
Desired collision potential	79 m^(2/3)	
Desired energy dissipation rate	ED.Floc	
Maximum time required to drain the tank	15 min	
Sedimentation		
Angle of side slopes	50 degrees	
Angle of plate settlers	60 degrees	
Angle of floc hopper slopes	AN.SedHopperSlope	
Minimum spacing between plate settlers	S.SedPlateMin	
Upflow velocity	1.00 mm/s	

Capture velocity	120 microm/s
Stacked Rapid Sand Filter	
Wall thickness	0.250 m
Backwash velocity	11.0 mm/s
Number of sand layers	6
Time required to drain backwash water above fluidized bed	T.FiBwInitiationBod
Material Dimensions	
Width of plate settler material	1.06 m
Length of plate settler material	L.SedPlateSheet
Thickness of plate settler material	2.00 mm

Table 1. Automated Design Tool assumptions used to calculate the included design.

The treatment processes – preliminary sedimentation, coagulation, flow control, rapid mix, EN.FlocType hydraulic flocculation, hydraulic upflow sedimentation, filtration, and chlorination – have been designed according to the maximum flow rate, 60.0 L/s L/s. While the resulting dimensions and layout have been cost optimized wherever possible, the user may choose to change some calculated values, such as those given in Table 2, to alter the plan view area of the plant for specific site requirements.

Number of sedimentation tanks	10
Number of sedimentation bays per tank	N.SedBays
Flocculator depth	2.06 m
Flocculator type	EN.FlocType

Table 2. Calculated values for UI.City, UI.Country that may be altered to produce optimized plan view areas for site-specific constraints.

Plant Components

Entrance tank/preliminary sedimentation

The main functions of the entrance tank are to remove solids from the water through preliminary sedimentation, to measure the flow through the plant, and to provide a place where the quality of the raw water can be observed. The preliminary sedimentation process removes solids such as sand, silt, and clay from the water before applying the coagulant to the influent. Water enters the plant on the right side of the entrance tank shown in Figure 1. A sample entrance tank for an 18 L/s plant. Water enters the tank through the inlet pipe shown at the right. Water flows linearly over the hoppers to the end of the tank, where it flows into the orifices of the linear flow orifice meter, and then on to the flocculator.Figure 1 and flows linearly over the top of the inverted pyramidal traps, or hoppers, at the bottom of the tank. The first hopper contains an overflow weir pipe to waste any water entering the plant in excess of the plant flow rate. The overflow pipe has a nominal diameter of ND.EtOverflowDrain, sized to handle half of the total plant flow rate. A slot is cut from the pipe such that 10% of the vertical dimension of the pipe is lost, giving a W.EtOverflowSlot wide opening, starting at a height of H.EtOverflowCutaway below the natural inner diameter of the pipe. The length of the slot is designed to fit along the length of the first hopper, giving an effective weir length (two times the slot length) of L.EtOverflowWeir. A drain is also embedded into the first hopper, allowing the operator to manually adjust the plant flow rate by opening the flow control valve by a desired amount, wasting water into the channel below. The ND.EtFlowControl nominal diameter drain is designed to handle the drain the full plant flow rate if needed.

Large particulates settle out into the hoppers, and collect near the drains at the bottom. When the water reaches the end of the tank, it flows through the orifices of the riser pipe, which acts as

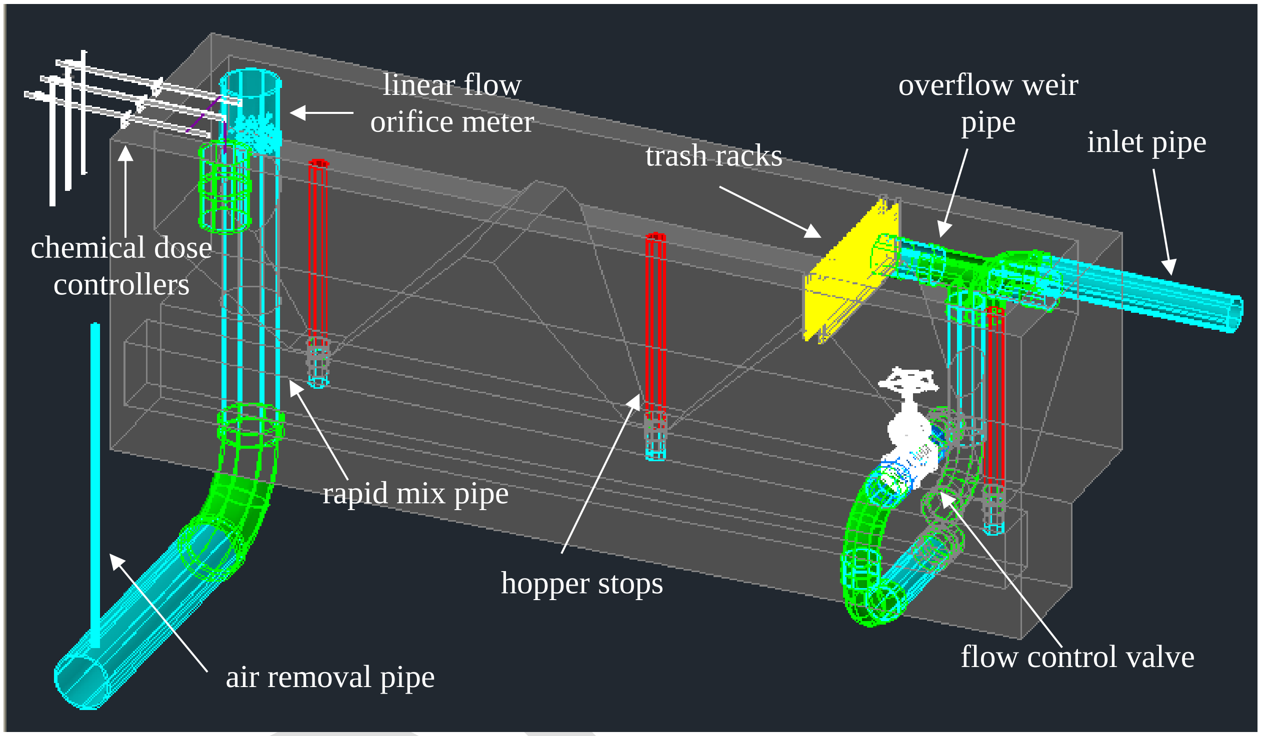


Figure 1. A sample entrance tank for an 18 L/s plant. Water enters the tank through the inlet pipe shown at the right. Water flows linearly over the hoppers to the end of the tank, where it flows into the orifices of the linear flow orifice meter, and then on to the flocculator.

a linear flow orifice meter (LFOM). It is designed for a capture velocity of W.EtCapture to remove these particulates. A length of 2.11 m is assigned to the entrance tank to correspond to the sedimentation tank length plus enough space to fit the float of the chemical dose controller and the rapid mix pipes. The width, 63.0 cm, is then assigned to ensure the minimum desired capture velocity is met while still allowing enough space for a person to fit inside and construct the tank. The depth of the tank is then determined such that the velocity in the upper rectangular portion of the tank does not exceed the velocity in the flocculator, 242 mm/s, while ensuring the depth is sufficiently small that the drains are easy to access. In this case, the tank has a height of 2.52 m.

To allow for easy maintenance, N.EtHoppers hoppers must be built into the entrance tank, at an angle of AN.EtSlope, forcing sediments to slide to the bottom where the 15.2 cm (6.00 in) drains are located. When too much sediment has accumulated, the upper drain pipes must be removed until the sludge is flushed out. Directly below the entrance tank, there is a drain channel to collect the waste.

As the raw water flows from the first hopper to the subsequent ones, it must pass through two trash racks, preventing large debris from entering the treatment process. Having two trash racks allows the plant to run with a grit screen even while the operator cleans one of them. The trash racks are made of rebar and slide into two slots built into the entrance tank wall. The center-to-center distance between the rebar, B.EtRebar m, is set to ensure that debris large enough to clog the orifices in the linear flow orifice meter downstream (LFOM) are kept out.

Suspended particulates in the water settle out over the length of the entrance tank into the hoppers below. When enough sludge has accumulated at the bottom, the hopper stops can be removed to flush out the debris down into the drain channel below, and they can then be replaced to resume normal operation. The 15.2 cm (6.00 in) in nominal diameter hopper stop is 2.55 m m long, ensuring the top of the pipe is above the maximum water height in the tank. Table 3 summarizes the entrance tank design specifications below.

Entrance Tank	
Residence time	
Capture velocity	
Tank length	2.11 m
Tank width	63.0 cm
Tank height	2.52 m
Hopper length	L.EtHopper
Hopper height	H.EtHopper
Last slope height	H.EtLastSlope
Hopper side slope angle	AN.EtSlope
Hopper back slope angle	
Thickness of ledge between hoppers	T.EtHopperLedge
Number of full hoppers	N.EtFullHopper
Hopper Drains	
Hopper drain diameter	15.2 cm (6.00 in)
Hopper stop length	2.55 m
Flow Control Components	
Flow control valve diameter	ND.EtFlowControl
Overflow weir pipe diameter	ND.EtOverflowDrain
Overflow weir pipe slot length	
Overflow weir slot depth	
Trash Rack	
Trash rack rebar spacing	
Trash rack rebar diameter	

Table 3. Entrance tank characteristics for UI.City.

Linear flow orifice meter (LFOM)

The linear flow orifice meter, or LFOM, is the riser pipe found in the leftmost hopper of the entrance tank. Water exits the entrance tank through the orifices in the LFOM, is dosed with coagulant, undergoes rapid mix, and then enters the flocculation tank. The diameter of the pipe is set such that cross-sectional area of the pipe required is Pi.LfomSafety times the minimum area required to carry the average velocity of water in the pipe, giving a 45.7 cm (18.0 in) in nominal diameter pipe. The additional area ensures that water free falls into the rapid mix pipe so the flow in the pipe is hydraulically disconnected from the flow through the entrance tank. The orifice pattern in the LFOM is designed to approximate the shape of a sutro weir, which forces a linear relationship between the flow rate over the weir and the head loss over the weir. The maximum head loss over the weir is set to be HL.Flowmeasure m, since the sutro weir approximation is not valid at higher head losses. Assuming a 5.00 cm m spacing between the rows of orifices, the theoretical flow area required in the top 5.00 cm m of the LFOM can be calculated, and the orifice size is set to be no larger than that to ensure at least one orifice can be placed in the top row. This design requires 4.45 cm (1.75 in) m diameter orifices. The number of orifices in each row is calculated by minimizing the mean square error as compared to perfectly linearized flow. Table 4 gives the orifice pattern for this specific design.

Row Height (m)	Number of Orifices
H.LfomOrifice1	N.LfomOrifices1
H.LfomOrifice2	N.LfomOrifices2
H.LfomOrifice3	N.LfomOrifices3
H.LfomOrifice4	N.LfomOrifices4
H.LfomOrifice5	N.LfomOrifices5
H.LfomOrifice6	N.LfomOrifices6
H.LfomOrifice7	N.LfomOrifices7
H.LfomOrifice8	N.LfomOrifices8
H.LfomOrifice9	N.LfomOrifices9
H.LfomOrifice10	N.LfomOrifices10

Table 4. The orifice pattern in the LFOM for UI.City. The row height is measured from the bottom of the orifices in the first row.

Chemical dose controller (CDC)

The chemical dose controller is hydraulically connected to the entrance tank, enabling the control system to automatically adjust the flow of chemical solution through the plant to maintain the desired dose at even varying flow rates. As pictured in Figure 2, a 20.3 cm (8.00 in) diameter pipe float hangs from the dosing lever arm and sits in the last hopper of the entrance tank. The left side of the lever arm is marked with a dosing scale and has a drop tube attached to a slider. The operator moves the slider along the left side of the arm to set the desired dose. The chemical is administered to the drop tube from the constant head tanks using a flexible tube, and the constant head tank is fed through a tube connected to the stock tanks. The flow of chemical from the stock tanks is controlled using a float valve, which

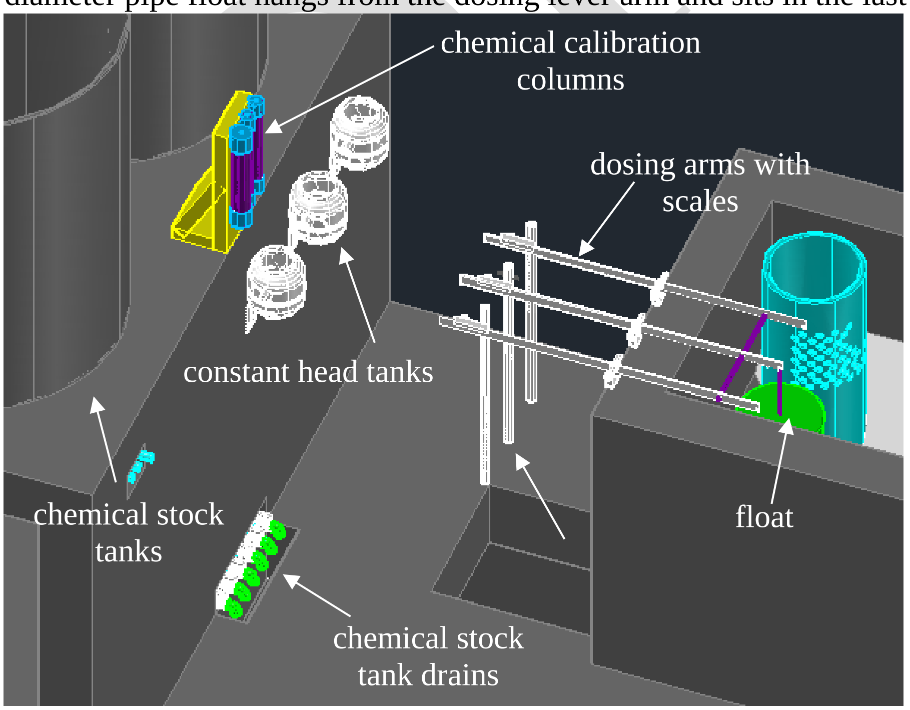


Figure 2. The chemical dosing center for an 18 L/s plant. The dosing lever arm is mounted to the left side of the entrance tank, and the constant head tanks are mounted on the east wall of the chemical stock tank platform.

maintains the desired fluid reference level in the constant head tanks.

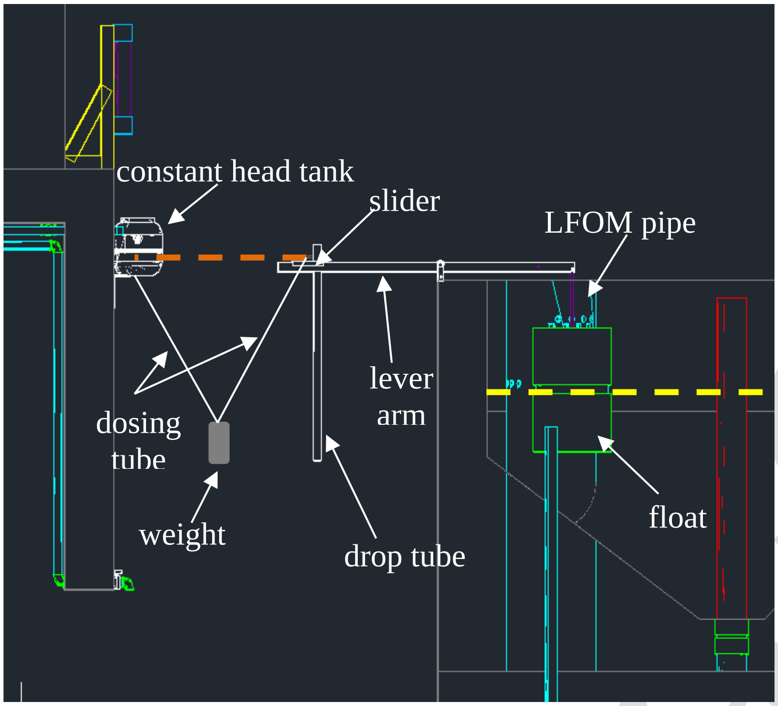


Figure 3. Chemical dose controller configuration in "no flow" mode. The yellow line delineates the water level in the entrance tank (just below the bottommost row of orifices in the LFOM), and the orange line delineates the stock chemical solution level in the constant head tanks. In no flow mode, the fluid level elevation in the constant head tanks is same as that of the dosing point, meaning there will be no flow of chemical into the plant.

When there is no flow through the plant, as shown in Figure 3, the dosing arm is level, and there is no head to drive the flow of chemical. When water is flowing through the plant, the float rises along with the water level in the tank, dropping the dosing point below the elevation of the fluid level in the constant head tank, and thus providing a driving head for chemical flow. This situation is pictured in Figure 4. To decrease the chemical dose, the operator needs to move the slider to the desired dose marked on the scale of the level arm. With the slider moved further to the right, the dosing point elevation does not decrease as much as the float rises, and so the driving head – and thus the chemical flow – decreases. This situation is pictured in Figure 5.

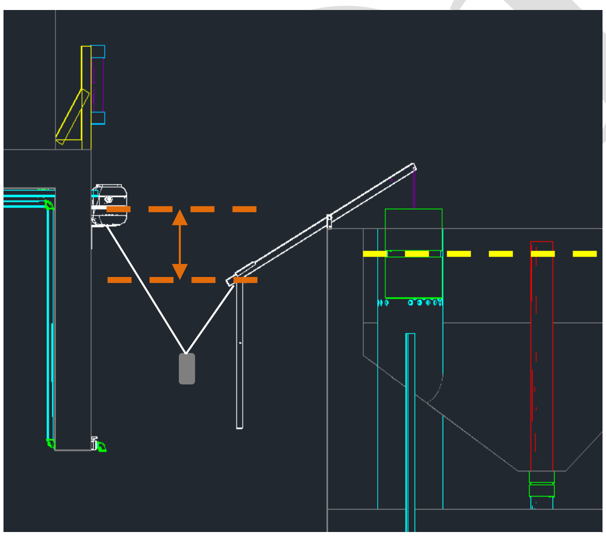


Figure 4. Chemical dose controller configuration in operating mode. The yellow line delineates the water level in the entrance tank; in this case the water level is at its maximum and the plant is running at full capacity. The orange arrow represents the driving head for the chemical stock solution, given by the elevation difference between the fluid level in the constant head tank and the dosing point. Note that the slider is at the maximum dose point.

Recall that the water height in the entrance tank changes linearly with the flow rate going through the plant due to the LFOM. Similarly, the flow of chemical stock solution is linearly related to the elevation difference between the fluid level in the constant head tanks and the dosing point. The linear relationship between the driving head of the chemical and the chemical flow rate is established by designing the dosing tubes such that the head loss is dominated by major (shear) losses. The lengths of the dosing tubes are limited by the need to have the tubes drape without hitting the floor. The tubes must hang freely and have space for a weight to keep the tube as straight as possible, minimizing additional losses that would cause errors in the flow calculation. Moreover, the tubes cannot be too short, or else the number of tubes required to supply the needed flow gets high, and the apparatus gets complicated. To determine the best combination of lengths and numbers of tubes, we need to first determine the possible flow rates available from purchasable tubing diameters. Allowing no more than a $\Pi_{LinearCdcError}$ = 10% deviation from the desired linear flow relationship due to minor losses, the flow rate, $Q_{Available}$, through each available tube size is calculated as given in $$Q_{Available} = \pi D^2 \sqrt{\frac{(1-\Pi_{LinearCdcError})HL_{Cdc}g}{8K_{CdcTube}\frac{1}{\Pi_{LinearCdcError}}}}$$ Eq 1 below.

$$Q_{Available} = \pi D^2 \sqrt{\frac{(1-\Pi_{LinearCdcError})HL_{Cdc}g}{8K_{CdcTube}\frac{1}{\Pi_{LinearCdcError}}}} \quad \text{Eq 1.}$$

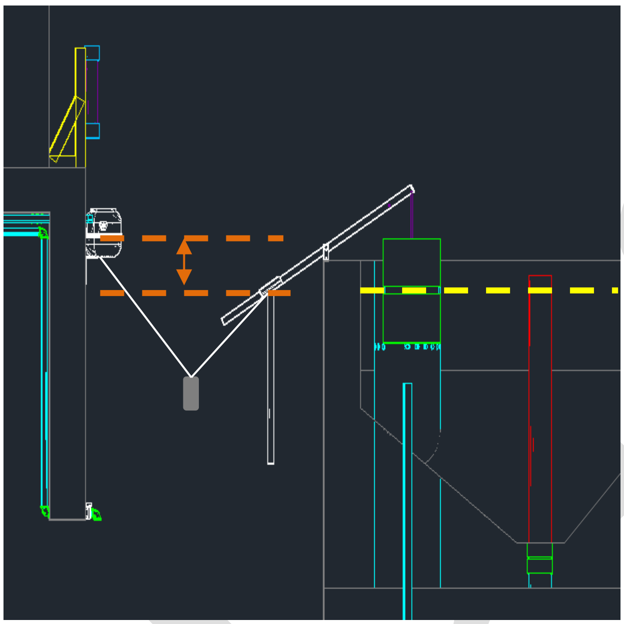


Figure 5. Chemical dose controller configuration in operating mode. The yellow line delineates the water level in the entrance tank; in this case the water level is at its maximum and the plant is running at full capacity. The orange arrow represents the driving head for the chemical stock solution, given by the elevation difference between the fluid level in the constant head tank and the dosing point. Note that the slider is at an intermediate dose point, resulting in less driving head for the chemical and thus a lower fluid flow rate.

The diameter of the tube is D, the maximum headloss through the dosing system is HL_{Cdc}, g is the gravitation constant, and $K_{CdcTube}$ = K.CdcTube is the minor loss coefficient for the tube.

Modifying the Hagen-Poiseuille equation for the length of a tube, given major head loss h_f, tube diameter, fluid viscosity ν, and fluid flow rate (Eq 2), the required length $L_{CdcTube}$ of each tube to obtain the desired head loss at maximum flow may then be calculated for each available flow rate (Eq 4).

$$L_{CdcTube} = \frac{h_f g \pi D^4}{128 \nu Q_{Available}} \quad \text{Eq 2.}$$

$$h_f = HL_{Cdc} - K_{CdcTube}\frac{8Q^2}{g\pi^2 D^4} \quad \text{Eq 3.}$$

$$L_{CdcTube} = \frac{\frac{HL_{Cdc} g \pi D^4}{Q_{Available}} - K_{CdcTube}\frac{8Q_{Available}}{\pi}}{128\nu} \quad \text{Eq 4.}$$

When the length of the tube is being calculated, the true viscosity of the fluid is unknown, and so the viscosity of the maximum stock solution is assumed for the case of the coagulant. The viscosity of chlorine is assumed to be that of water since the solution must be sufficiently dilute to produce simple designs.

Once all possible lengths for each diameter have been calculated, the algorithm chooses the longest tube and associated diameter that is smaller than the maximum length to ensure draping. This decision minimizes the number of tubes, keeping the doser as simple as possible.

At this point, the number of dosing tubes $N_{CdcTubes}$ assuming the maximum chemical stock concentration $C_{ChemStockMax}$ can be calculated as follows in Eq 5:

$$N_{CdcTubes} = \frac{Q_{Plant} C_{MaxDose}}{Q_{Tube} C_{ChemStockMax}} \quad \text{Eq 5.}$$

where Q_{Plant} is the maximum plant flow rate, $C_{MaxDose}$ is the maximum allowable dose, and Q_{Tube} is the flow rate through the design tube.

Finally, the required chemical stock concentration can be specified based on the calculation in Eq 6.

$$C_{ChemStock} = \frac{Q_{Plant} C_{MaxDose}}{N_{CdcTubes} Q_{Tube}} \quad \text{Eq 6.}$$

In the event that the required tube length is not long enough to reach from the constant head tank to the drop tube, the small-diameter design tube may be linked to a larger diameter tube just long enough to reach the dosing point. If a large diameter tube is required for a particular chemical, its length is indicated in Table 5, along with the complete specifications for the chemical dosers.

Chemical Dose Controller Specifications					
Coagulant Type	EN.Coag				
Float diameter	20.3 cm (8.00 in)				
Float height	L.EtFloat				
Lever arm length					
	Chemical stock concentration	*Maximum head loss*	*Float valve orifice diameter*	*Stock tank to constant head tank tube diameter*	*Large tube diameter*
Main plant coagulant	150 g/L	HL.CoagCdc			
Chlorine	11.3 g/L	HL.ChlorCdc			
Filter coagulant	C.FiCoagStock	HL.FiCoagCdc			

Chemical Dose Controller Tube Design			
	Number of Tubes	*Length of Tube*	*Diameter of Tube*
Main Plant Coagulant	N.CoagCdcTubes	L.CoagCdcTube	D.CoagCdcTube
Chlorine	N.ChlorCdcTubes	L.ChlorCdcTube	D.ChlorCdcTube
Filter Coagulant	N.FiCoagCdcTubes	L.FiCoagCdcTube	D.FiCoagCdcTube

Table 5. Chemical dose controller design for UI.City.

For the doser to function optimally, it is crucial for each component to be installed correctly. To properly calibrate the doser once it has been mounted to the entrance tank, the no flow situation needs to be simulated in the entrance tank (Figure 3) by draining the tank until its water level is just below the bottom of the LFOM's bottommost row of orifices. Then, with the lever arm perfectly horizontal, adjust the length of the rope attached to the float so that the float sits exactly vertically. With the lever arm in the horizontal position, mount the constant head tank such that its fluid level is at the same elevation as the dosing point. Then, fill the entrance tank until the water height corresponds to the maximum flow rate (where the topmost orifices of the

LFOM are just submerged, as in Figure 4). The elevation of the maximum dose point on the scale should have decreased by the maximum allowable head loss for the chemical. Position the slider to an intermediate dose. (It is important to calibrate the doser at an intermediate dose – as in Figure 5 – because this method leaves extreme flow rates less susceptible to calibration errors.) At the intermediate dosing position, measure the flow of chemical through the dosing tube and compare it to the theoretical flow rate, which can be calculated by rearranging Eq 2 as follows:

$$Q_{theoretical} = \frac{\pi D^4 g h_f}{128 \nu L_{CdcTube}} \quad \text{Eq 7.}$$

where h_f is given by the elevation difference between the dosing point and the fluid level in the constant head tank. If the flow rate is greater than the theoretical, cut the tube and repeat the test until the theoretical value matches the measured value. If the flow rate is less than the theoretical, a longer tube must be obtained and the calibration must begin again from the first step. Once the theoretical and measured values match, the doser is ready for use.

In addition to good calibration, the doser must be periodically cleaned for good performance. Any sediment that may be clogging the valves or fittings must be cleaned out to prevent underdosing. Additionally, air bubbles in the tubes will cause dosing errors. If bubbles are present, remove the tube from the dosing system and force the bubbles out.

Chemical storage tanks

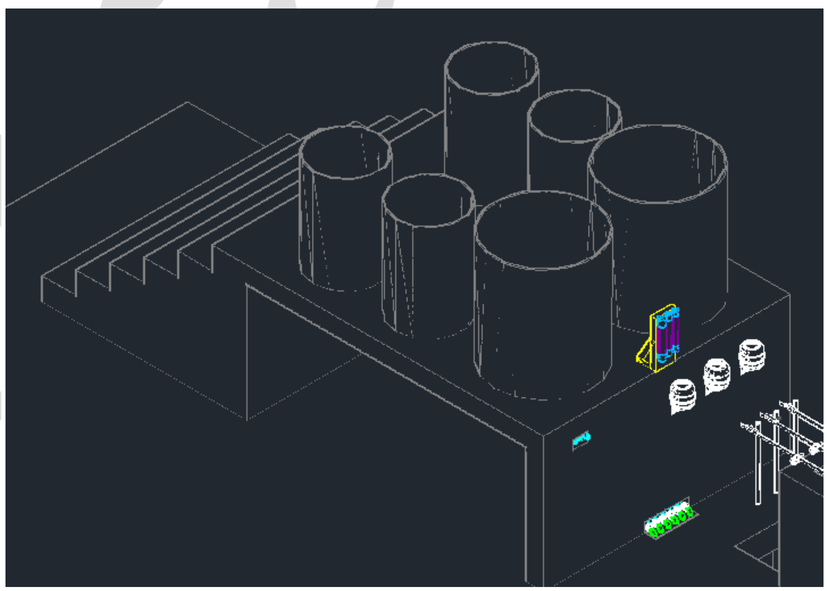


Figure 6. Chemical stock tanks for an 18 L/s plant.

There are two to four storage tanks for each chemical on the stock tank platform – two for the main plant coagulant, two for chlorine disinfection, and optionally two for coagulant dosing before filtration, as shown in Figure 6. The stock tanks are set at an elevation of Z.CoagTank to provide enough head to overcome minor losses in the system, ensuring the desired flow rate can be attained. The design of the chemical storage tanks is based on the tank volumes available for purchase through Rotoplast for Latin America, and it is assumed that the stock tank will be refilled no more frequently than once every Ti.StockMin. In order to determine the required volume of a chemical tank, the maximum chemical flow rate, $Q_{ChemStockMax}$, must first be determined as follows:

$$Q_{ChemStockMax} = \frac{Q_{Plant} \times C_{ChemDoseMax}}{C_{ChemStock}} \quad \text{Eq 8}$$

where $C_{ChemDoseMax}$ is the maximum allowable chemical dose, and $C_{ChemStock}$ is the stock concentration in the chemical tank. Using the maximum chemical flow rate, the volume of the stock tank, $Vol_{ChemTank}$, is computed using the following formula:

$$Vol_{ChemTank} = Q_{ChemStockMax} \times Ti_{StockMin} \quad \text{Eq 9}$$

For plants that require stock tank volumes slightly larger than the nearest available tank volume, the ADT automatically rounds down to the nearest desired volume to make the size as small as possible. Specifications for this particular stock tank design are given in Table 6 below.

Dose and drain plumbing size	ND.CoagPiping
Coagulant tank volume	Vol.CoagTank
Chlorine tank volume	Vol.ChlorineTank
Filter coagulant tank volume	Vol.FiCoagTank
Height of stock tanks above constant head tanks	30.0 cm

Table 6. Chemical storage tank design for UI.City.

All of the piping required to administer the dose and drain the stock tanks (Figure 7. Southeast isometric (a), front (b), and top (c) views of the chemical stock tanks for an 18 L/s plantFigure 7) uses a nominal diameter of ND.CoagPiping. The piping that connects to the

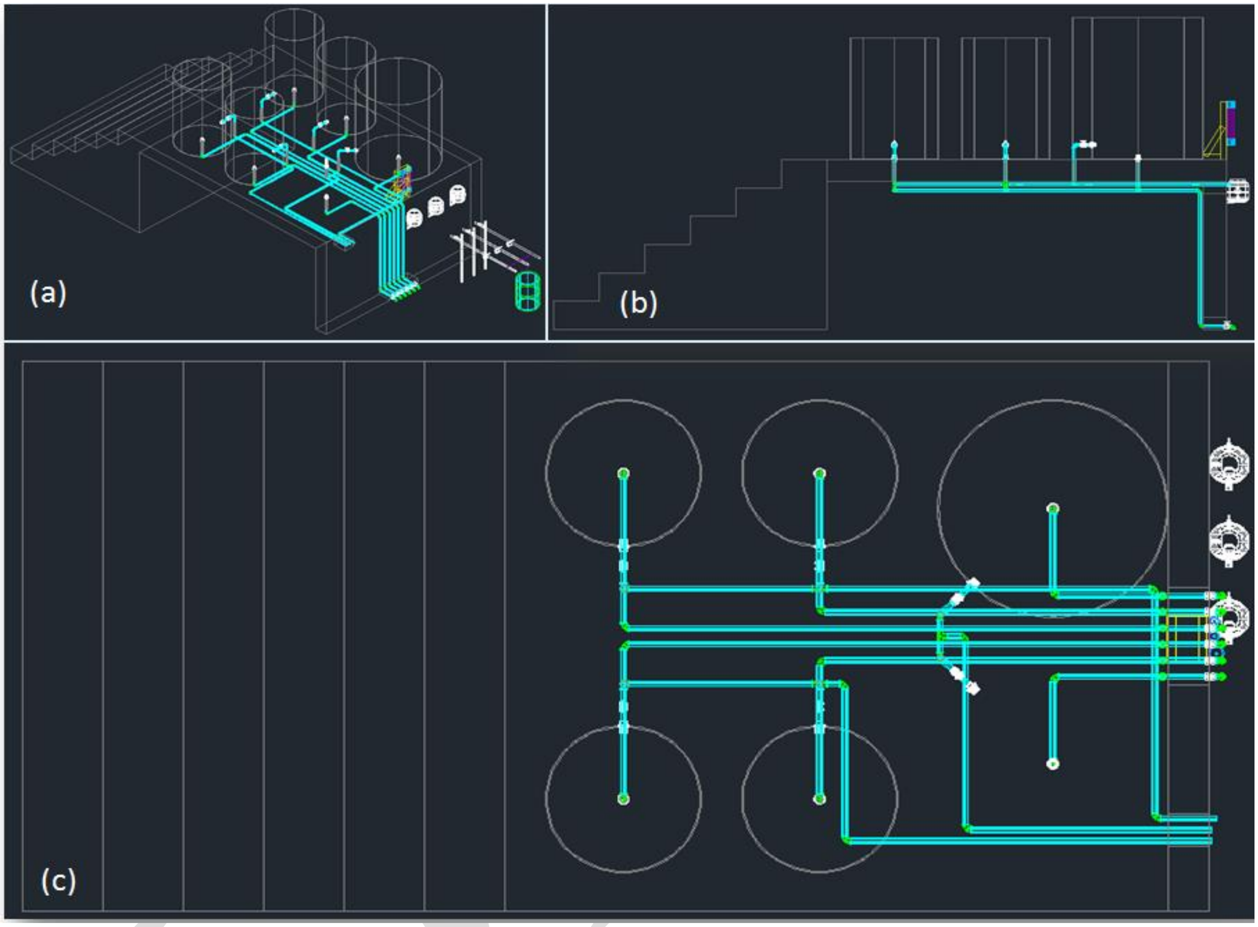


Figure 7. Southeast isometric (a), front (b), and top (c) views of the chemical stock tanks for an 18 L/s plant with a main plant coagulant tank left out for a clearer view of the piping.

constant head tanks begin at a bulkhead fitting set at an elevation of B.StockOutlet higher than the bottom of the stock tanks to prevent sediment from entering the pipes. The flow is controlled at the top of the stock tank platform using a ball valve, and the plumbing continues down through the platform, and out through the wall facing the entrance tank at the approximate elevation of the constant head tanks. The stock tank drains are connected from the bottom center of the tanks, starting with a male insert, and continuing under the platform and exiting via ball valve at the edge of the main plant drain channel. Figure 8 shows more close up details of the dosing and chemical drain plumbing.

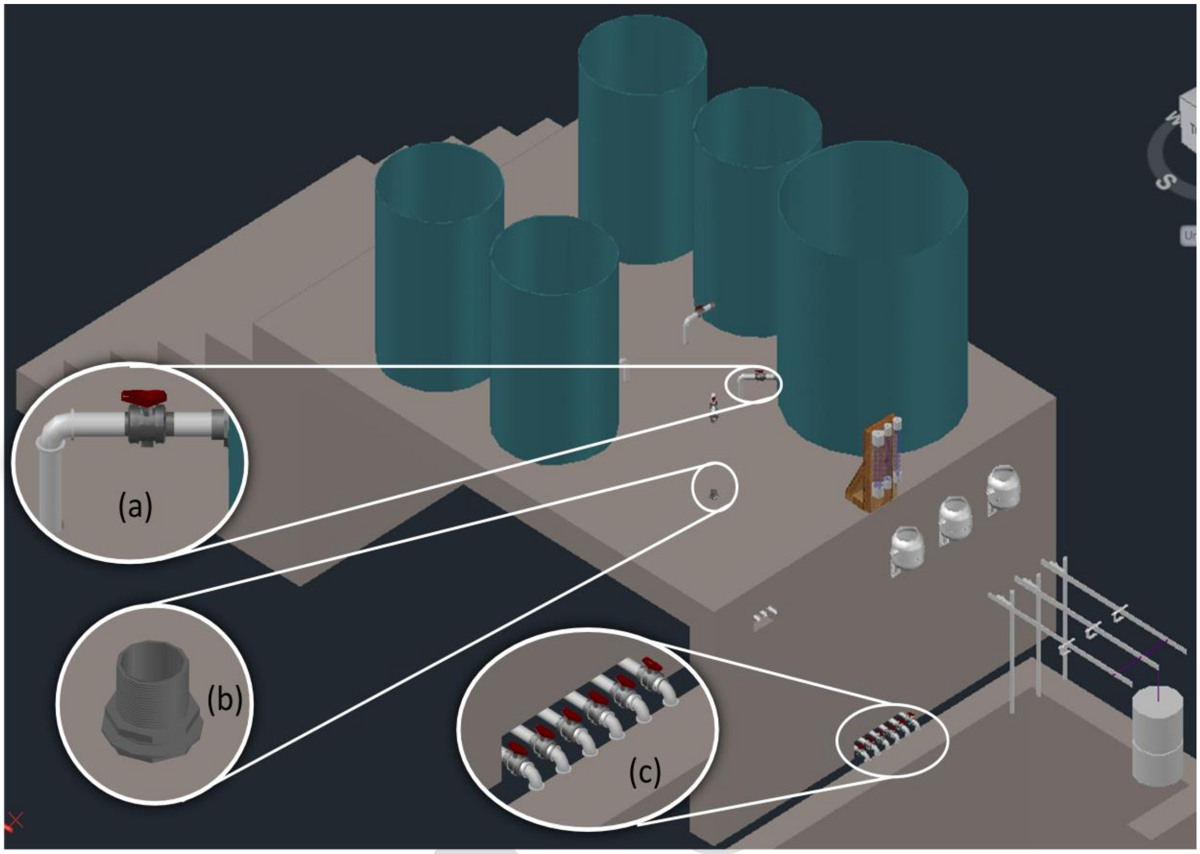


Figure 8. 18 L/s plant with a main plant coagulant tank left out for a clearer view of the piping. The dosing plumbing (a) is connected to the stock tanks via bulkhead fitting and the flow is controlled using a ball valve. A male insert (b) is affixed to the bottom of the stock tanks, ultimately leading to ball valves (c) that sit at the edge of the main plant drain channel.

Rapid Mix

Once it has been dosed with coagulant, the water passes through the rapid mix system. Rapid mix serves to uniformly distribute the coagulant through the raw water. In this plant, the rapid mix occurs as turbulent flow through a L.RMPipe long pipe, with an inner diameter of 45.7 cm (18.0 in). This pipe brings water from the point at which coagulant is dosed to the entrance of the flocculator.

Flocculation

Velocity Gradient	G.Floc
Collision Potential	79 m^(2/3)
Maximum Energy Dissipation Rate	24 mW/kg
Average Energy Dissipation Rate	12 mW/kg
Residence Time	7.9 min

The purpose of flocculation is to agitate the coagulated water, so that the newly-neutralized suspended particles collide together to form larger particulates, or flocs. Collisions are encouraged by forcing the water to make several 180 degree turns around staggered baffles secured in the channels of the tank. The flocculator is designed for a collision potential of 79 m^(2/3), and a maximum energy dissipation rate of ED.Floc. The collision potential characterizes the probability of flocs colliding and sticking together, which the energy dissipation rate characterizes the likelihood of flocs breaking up. The flocculator encourages the particulates in the water, now neutralized with coagulant, to collide and stick together. As these particulates, or flocs, collide and stick together, they grow heavy enough to settle out by the time they reach the sedimentation tank. Since the particles collide more easily in turbulent flow, turbulence is created by a series of staggered baffles that force the water to make 180 degree turns. The baffles are spread throughout several consecutive channels to maintain a compact design and minimize cost of construction by sharing channel walls. To allow the two tanks to share a wall, the flocculator length is set to that of the sedimentation tank, 7.11 m. There are a total of 4 channels in the flocculator, each channel having an inner width (excluding wall thickness) of 63.0 cm.

The flocs need to collide enough times that they grow large enough to settle out in the sedimentation tank, but not so large that they settle out in the flocculator. The required collision potential (the possibility of colliding in the flocculator) is 79 m^(2/3), while the actual collision potential is CP.FlocTotal. Note that the value of the actual collision potential may be significantly higher than the required since the number of floc channels must be an integer.

The height of the flocculator was calculated by summing the head losses within the flocculator, the water height in the sedimentation tank, and a freeboard height of 10.0 cm, giving a total height of 2.06 m (excluding floor thickness). The total width (perpendicular to the channels) of the flocculator, including all walls except for the one shared with the sedimentation tank, is W.FlocWithWalls. The total length of the floc tank, including wall thickness, is L.FlocWithWalls. The floor of the flocculator, above the floor thickness, is elevated Z.FlocTank from the sedimentation tank floor, also above the floor thickness. These dimensions together give a residence time in the flocculator of 7.9 min. The average velocity in the flocculator is 242 mm/s.

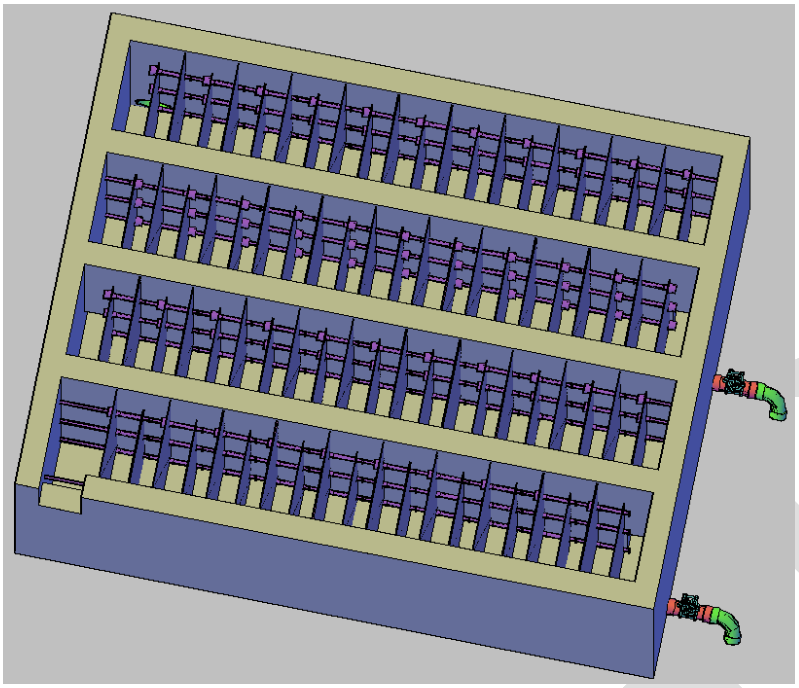


Figure 9: Top view of a vertical flocculator

Length	7.11 m	
Width	W.Floc	
Channel Width	63.0 cm	
Port Height	66.4 cm	
Port Width	37.3 cm	
Baffle Module Design		
Baffle Material		
Thickness of Baffles	2.00 mm	
Module Pipe Size	ND.FlocModulesMain	
Module Spacer Size	ND.SpacerPipe	
Oversized Cap Size	ND.FlocModulesLarge	
	First Channels	*Last Channels*
Number of Baffles in a channel	N.FlocChannelBafflesFirst	N.FlocChannelBafflesLast
Spacing between baffles	S.FlocBaffleFirst	S.FlocBaffleLast
Number of Long Modules	N.FlocChannelModulesLongFirst	N.FlocChannelModulesLongLast
Number of Baffles per Long Module	N.FlocChannelBafflesLongFirst	N.FlocChannelBafflesLongLast
Number of Baffles per Short Module	N.FlocChannelBafflesShortFirst	N.FlocChannelBafflesShortLast
Length of outer pipes	L.FlocModuleLongOuterFirst	L.FlocModuleLongOuterLast
Length of middle pipes	L.FlocModuleLongFirst	L.FlocModuleLongLast

Length of outer spacers	
Length of middle spacers	

General Flocculator Design

Gate valves at the bottom of alternate channels in the flocculator allow for draining. The nominal diameter of the flocculator drain pipes is ND.FlocValve, calculated to ensure the tank can drain in less than 15 min. Since each valve is draining the water from at least two channels, this design requires N.FlocValves valves. Elbows connected at the end of the drain piping redirect the flow of water into the drain channel, minimizing splashing.

Since the center of the valve is aligned with the floor (above the floor thickness), slopes need to be built in to allow efficient draining. The width of the slope is the inner diameter of the drain piping, while the depth of it is the inner radius. The length is given to make the slope 30 degrees. In the even that a 30 degree slope causes a slope longer than the space between baffles, the end of the slope is simply set to 5 cm away from the nearest baffle.

Number of Drains	N.FlocValves
Drain Diameter	ND.FlocValve
Slope Height	H.FlocSlope
Slope Width	
Flocculator Drain Time	15 min

Sedimentation Tank

Number of Tanks	10
Height	1.80 m
Length	7.11 m
Width	1.06 m
Number of Bays per Tank	N.SedBays
Width of a Bay	W.SedBay

Capture Velocity	120 microm/s
Upflow Velocity	992 microm/s
Residence Time	24 min

The influent to the sedimentation tank passes through a channel that distributes the water to the individual bays within each tank. This channel is designed to ensure that the flocs can be transferred to the bottom of the sedimentation tanks without being broken. Other restrictions on the dimensions include: sufficient width to accommodate the inlet manifolds that deliver water to the bottom of tank, tiene que tener suficiente profundidad para apoyar los tubos recolectores de salida de los tanques de sedimentación, tiene que ser poco profundo para permitir fácil acceso al fondo, y tiene W.SedInletchannelPreweir de espacio libre.

Length	L.Channel
Width	W.InletChannel
Height	H.InletChannel
Water height	HW.InletChannel

Table 7. Dimensions of the inlet channel

El canal distribuidor también tiene un vertedero de 52.0 cm de altura sobre el nivel del fondo y un tubo de 4 pulgadas de diámetro fundido en el final del canal. Este tubo se mantiene tapado excepto cuando se quiere botar agua floculada al canal de limpieza para que no ingrese a los tanques de sedimentación. Cuando se desborda agua del canal, el vertedero mantiene el canal y el tanque de floculación llenos de agua para evitar cambios abruptos en el nivel de agua que pueden perjudicar el tratamiento.

Type of weir	Perpendicular
Length	W.SedWeirInlet
Height	52.0 cm
Head loss	1.91 cm

Table 8. Dimensions of the inlet channel weir

Sedimentation Tanks

The objective of the sedimentation tanks is to remove, by gravity, the flocs that have been formed in the flocculator. Los tanques de sedimentación de flujo ascendente tienen cinco partes: los tubos distribuidores, los canales de drenaje, las tolvas, las placas sedimentadoras, y los tubos recolectores del agua decantada.

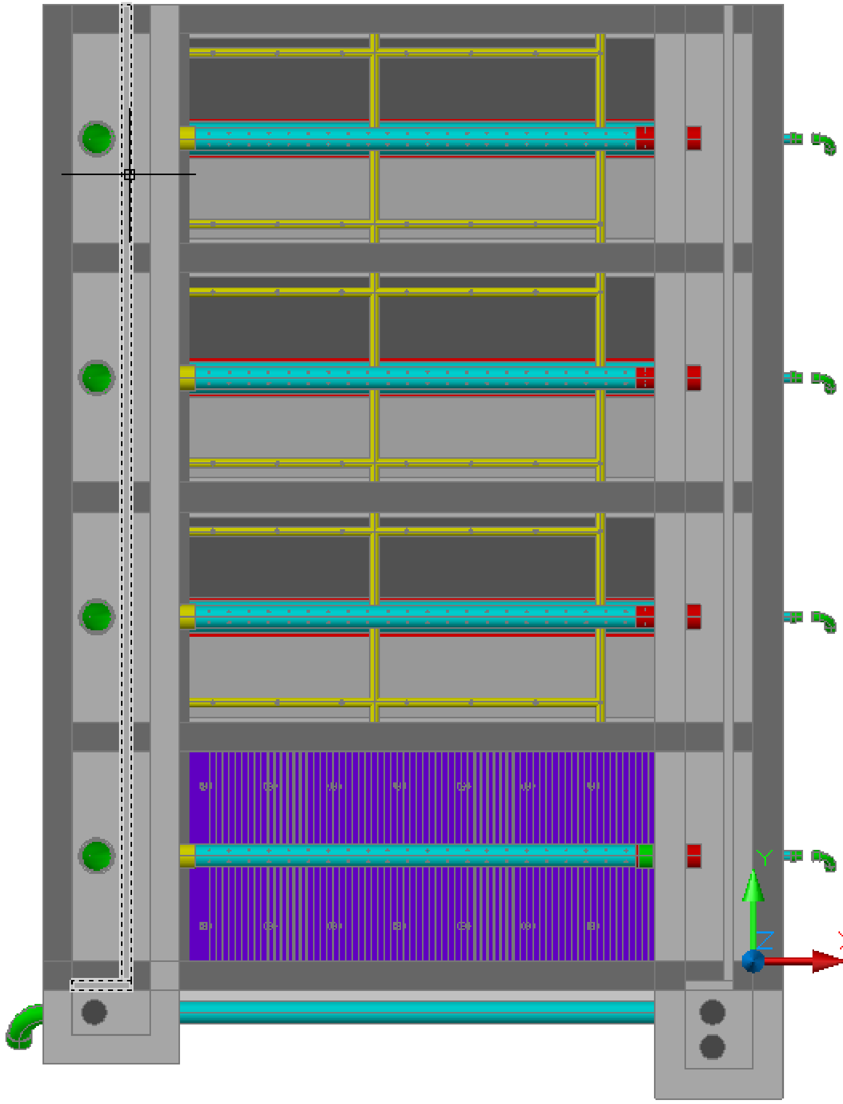


Figure 10:Top view of the sedimentation tank

Assigning dimensions to the sedimentation tank

Se dimensionan los tanques de sedimentación en base a los criterios de diseño de las varias partes descritas anteriormente así como las dimensiones estándares del material de las láminas usadas para las placas sedimentadoras. Láminas de policarbonato, un buen material para placas sedimentadoras por su resistencia y lisura, son comerciales en dimensiones de 3.66 de largo por 1.08 m de ancho por 0.02 m de espesor. Para hacer el uso más eficiente de este material, el algoritmo de dimensionamiento de los tanques de sedimentación de la herramienta de diseño de AguaClara fija el ancho de cada tanque al ancho de la lámina, en 1.08 m, y usa un algoritmo de optimización para escoger un solo largo de todas las placas de tal manera que el diseño requiere la compra de un mínimo número de láminas. Utilizando este constante además de los constantes $V_{ascendente}$, V_c, α, el ángulo de inclinación de las tolvas, el número de tanques de sedimentación deseados, y el caudal máximo de la planta, se calculan las dimensiones de los tanques de sedimentación.

Number of sedimentation tanks	10
Number of sedimentation bays per sedimentation tank	N.SedBays
Width of each bay	W.SedBay
Length of each bay and tank	7.11 m
Altura de las paredes inclinadas	H.SedBayDivider
Ancho de las paredes inclinadas	W.SedSlope
Angulo de inclinación de las paredes	50 degrees

Table 9. Dimensions of the sedimentation tank

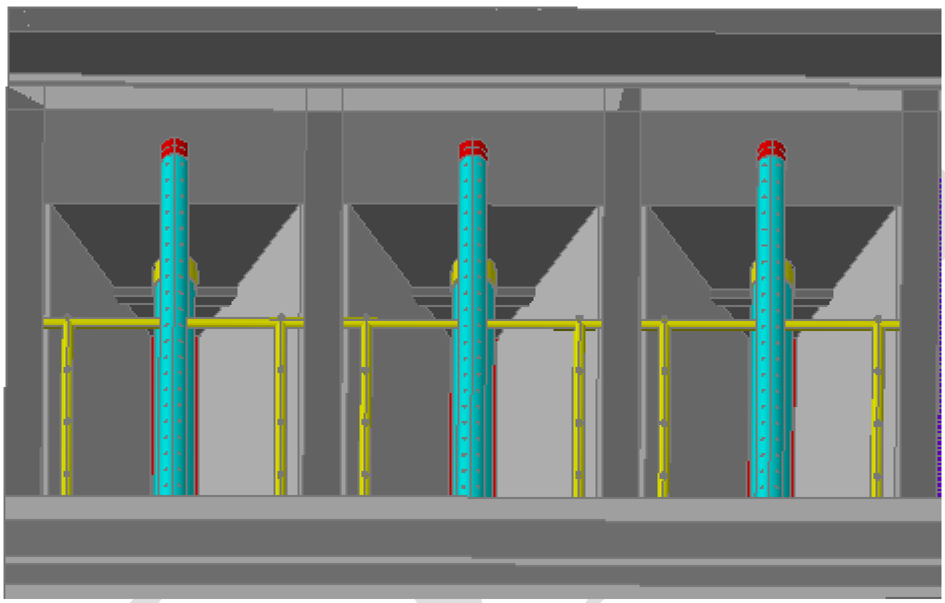


Figure 11: Cámaras sedimentadoras y tolvas del tanque de sedimentación

Inlet Manifolds

The objective of the inlet manifolds is to transport the flocs into the bottom of the sedimentation tank without breaking them. El diseño de los tubos distribuidores también depende del factor de la tasa de disipación de energía máxima, ε_{max}, la idea siempre siendo pasar los flóculos formados a los tanques de sedimentación sin romperlos por demasiada turbulencia. Se determina el diámetro de los tubos de entrada fijando ε_{max} = 6 mW/kg en el lugar donde hay el mayor potencial de romper flóculos: la entrada a los tubos en el fondo del canal distribuidor.

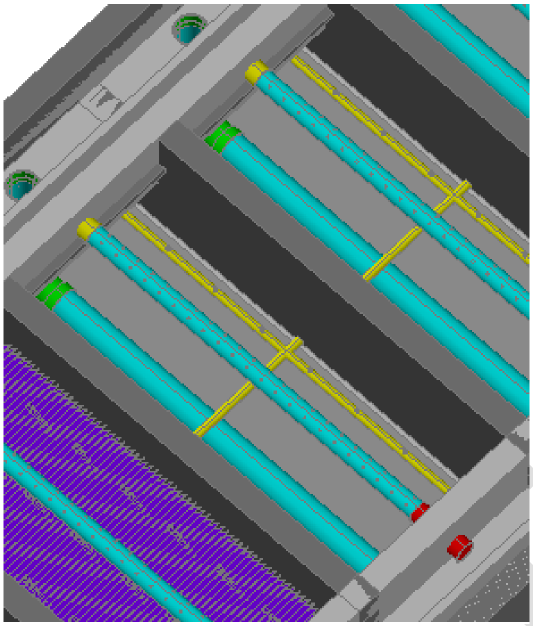


Figure 12: Tuberías del tanque de sedimentación

Each one of the N.SedBays bays in each sedimentation tank has a maximum flow rate of Q.SedBay, which, according to this equation, requires a 20.3 cm (8.00 in) inlet manifold pipe to prevent floc breakup. The length of each inlet manifold pipe is L.SedManifoldPipe, and the pipes have an elevation of Z.SedManifoldLift from the sedimentation tank floor.

The inlet manifolds distribute water along the length of the sedimentation tank through orifices along the bottom of the pipe. The total cross-sectional area of the jets coming out of the manifold must equal the approximate inner diameter of the pipe itself, given by the maximum energy dissipation constraint. La suma de las áreas de los chorros de estos agujeros tiene que ser aproximadamente igual al diámetro del tubo para preservar la tasa de disipación de energía máxima que se toma como criterio para dimensionar el tubo, tomando en cuenta las restricciones de tamaños estándares de brocas para perforar los agujeros. Cada tubo distribuidor tiene N.SedManifolPorts de 3.17 cm (1.25 in) de diámetro espaciados a S.SedManifoldBetween centro a centro a lo largo del tubo.

Adjuntos a los agujeros, y en posición perpendicular al tubo de distribución, se encuentran tubitos de longitud L.Diffuser y diámetro D.Diffuser. El propósito de estos tubos verticales es evitar la creación de corrientes circulares en el fondo del tanque de sedimentación y la creación de zonas muertas, donde los sedimentos pueden ser acumulados.

Nominal diameter	20.3 cm (8.00 in)
Diameter of the orifices	3.17 cm (1.25 in)
Number of orifices	93
Center-to-center distance between orifices	B.SedManifoldPort
Length	L.SedManifoldPipe
Elevation from the sed tank floor	Z.SedManifold

Espacio entre el centro de la tubería y la cubierta	S.SedManifoldBetween

Table 10. Dimensions of the inlet manifold

Sludge drain

El en fondo de cada tanque de sedimentación hay un canal de drenaje para purgar los lodos acumulados en el proceso de sedimentación. El canal es un hueco de W.SedSludge ancho por H.SedSludge de alto que recorre todo el largo del fondo del tanque. En un lado del tanque, el canal da a una válvula de bronce de D.SedSludgeValve de diámetro que controla el nivel de lodo en el tanque. Encima del canal de cada tanque se colocan placas de ferrocemento perforados con N.SedsludgeOrifices de D.SedsludgeOrifice espaciados a B.SedSludgeOrifices de centro a centro. Estos agujeros están distribuidos uniformemente a lo largo del canal para lograr purgar los lodos de todas las partes del tanque uniformemente. Los diámetros de los agujeros en el canal y el diámetro de la válvula están diseñados para vaciar un tanque en Ti.SedDrain .

Width	W.SedSludge
Height	H.SedSludge
Ancho de la tapadera	W.SedDrainCover
Grosor de la tapadera	T.SedSludge
Diameter of the sludge orifices	D.SedSludgeOrifice
Center-to-center distance between the sludge orifices	B.SedSludgeOrifices
Número de orificios	N.SedSludgeOrifices

Table 11. Dimensions of the sludge drain

Tolvas

Cada tanque tiene una tolva de 50 degrees de inclinación y una elevación de Z.SedSlopes. Esta geometría crea mayores velocidades en el fondo del tanque que en la parte superior de la tolva, lo cual sirve para mantener los flóculos sedimentados en suspensión, maximizando el potencial de floculación y retención de partículas en un manto de lodo. La velocidad ascendente del agua en la parte superior de la tolva se fija en $V_{ascendente}$ = 69 m/día (8 mm/s) en la herramienta de diseño de AguaClara.

Plate settlers

Plate settlers, used to remove small particulates that cannot settle in the bottom of the tank, sit above the slopes in the sedimentation tank. The plate settlers are set an an angle of 60 degrees to ensure efficient sedimentation. Los algoritmos de diseño de la AguaClara Design Tool utilizan el constante de la velocidad de captura V_c = 9.0 m/día (0.104 mm/s) que garantiza una velocidad conservadora para un alta remoción de sólidos.

Cada canal del tanque de sedimentación de la planta tiene un total de 176 placas sedimentadoras organizadas en 22 módulos de N.SedModulePlates placas. Los módulos descansan en un marco de tubería de PVC colocado en la parte superior de las tolvas.

Width of the plate settlers	1.06 m
Length of the plate settlers	50.0 cm
Center-to-center spacing of the plate settlers	2.70 cm
Number of plate settlers	176
Number of plate settler modules	22
Number of plate settlers in each module	N.SedModulePlates

Table 12. Dimensions of the plate settlers

Launders

En el tanque de sedimentación el agua pasa por el tubo distribuidor en el fondo, la tolva, y las placas sedimentadoras. Al salir de las placas el agua ya está decantada o aclarada. Sale del tanque por un tubo recolector perforado ubicado inmediatamente sobre la parte superior de las placas. El tubo recolector está diseñado para proporcionar significativamente más pérdida de carga hidráulica en las pérdidas menores de los orificios perforados que en las pérdidas mayores ocasionadas por el flujo turbulento dentro del tubo, de tal manera que el flujo que entra el tubo recolector por los orificios es uniforme a lo largo del tanque. Por esta razón cada tubo recolector de 15.2 cm (6.00 in) de diámetro lleva 54 agujeros de 1.59 cm (0.625 in) de diámetro espaciados a B.sedLaunderOrifices de centro a centro en N.SedLaunderOrificesRow filas en la parte superior del tubo. Este diseño tiene el beneficio de crear un sobrenadante sobre el tubo recolector que evita que material flotante en la superficie del agua salga del tanque de sedimentación.

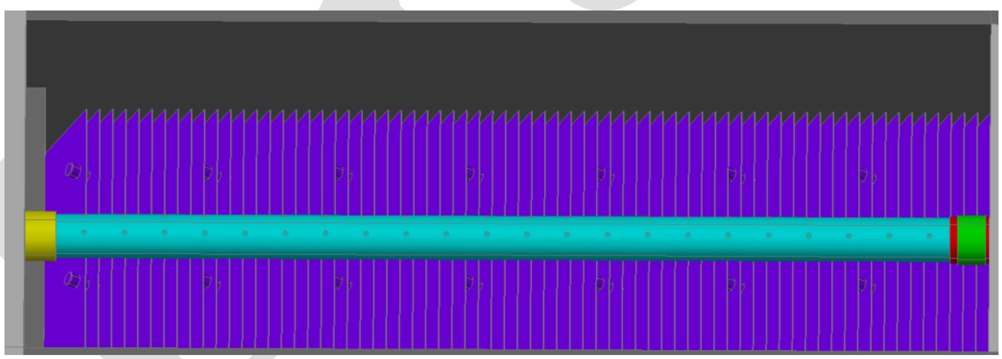


Figure 13: The launder in a sedimentation bay

Number of orifices in the launder	54.
Nominal diameter of the launder	15.2 cm (6.00 in).
Elevation of the launder	Z.SedLaunder.
Total number of launders in the plant	N.Launders.
Length of each launder	5.54 m.

Table 13. Launder dimensions

Canal de salida

El agua decantada sale de los tubos recolectores a un canal recolector de salida que lleva el agua al proceso de desinfección. Este canal tiene dimensiones de H.ExitChannel de profundidad, W.ExitChannel de ancho, y L.ExitChannel de largo. Un vertedero longitudinal de cresta aguda de H.SedExitChannelWeir de elevación en medio del canal garantiza que los tanques de sedimentación se mantienen llenos de agua con un mínimo de pérdida ocasionada por el vertedero.

Chlorine Disinfection

Se dosifica una solución de hipoclorito de calcio al agua decantada en la caja distribuidora al final del canal de salida. El sistema de dosificación de cloro es parecido al del coagulante y consiste en: tambos para almacenar la solución de cloro, una mesa para elevar los tambos, y un dosificador sencillo gravitacional.

Se monta el dosificador sencillo en el borde de la caja distribuidora de tal manera que las gotas de cloro caen al efluente de la planta, donde se mezclan con el agua. El operador de la planta maneja la manguera dosificadora de este dispositivo para escoger la dosis apropiada de cloro para el caudal que se trata. Hay suficiente tiempo de contacto en las líneas de conducción y los tanques de abastecimiento para lograr la desinfección. La válvula flotadora del dosificador sencilla se posiciona sobre el borde de la solera superior del canal de salida. La mesa para los tambos de cloro debe ser diseñada con una elevación suficiente para proporcionar la carga hidráulica necesaria para que la solución de cloro pueda llegar a la botella con flotador, superando las pérdidas ocasionadas por la válvula flotadora y la manguera de suministro. Se almacenan las soluciones de cloro en dos tambos colocados encima de la mesa.

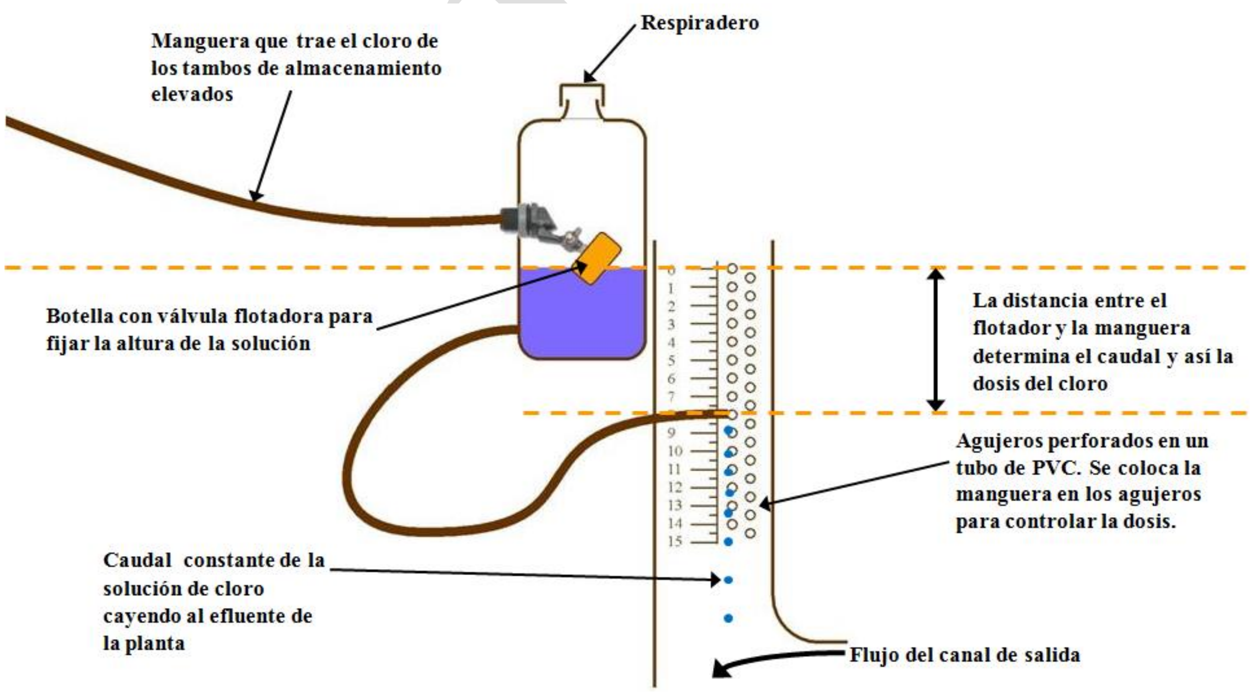


Figure 14: Diagrama de un dosificador de cloro

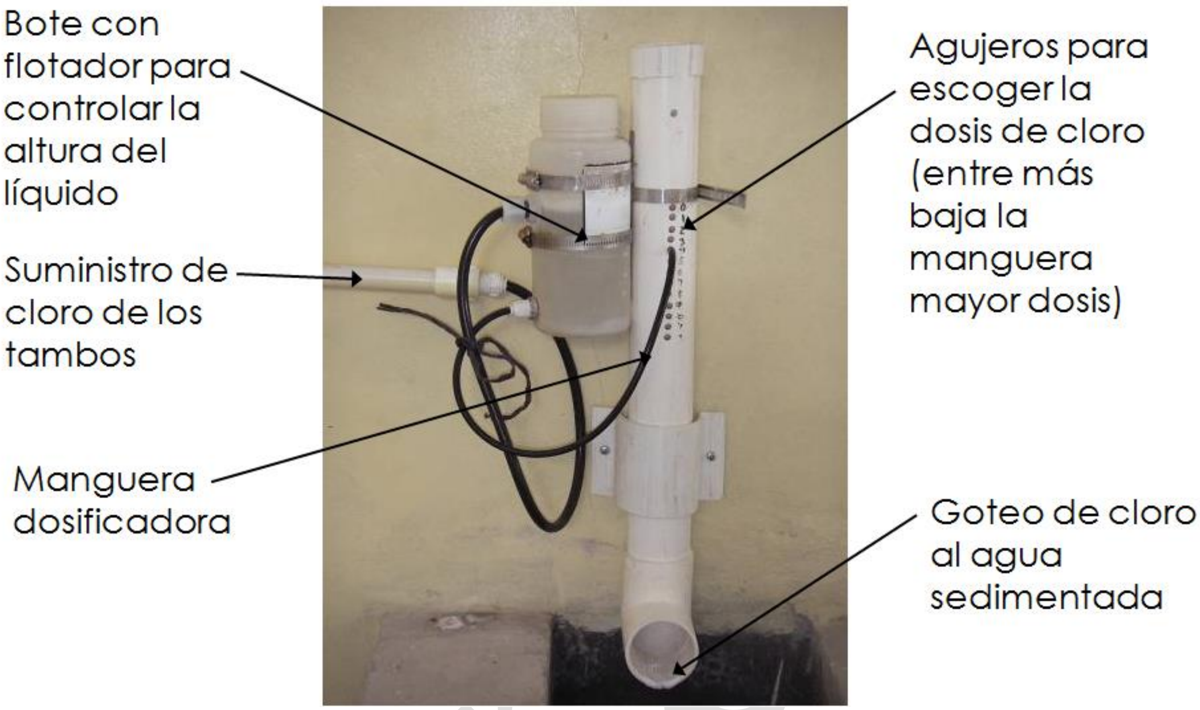


Figure 15: Fotografía de un dosificador de cloro en una de las plantas existentes de AguaClara

Manejo de lodos

Cada proceso de la planta produce residuos. El tanque de entrada produce sólidos sedimentables, los tambos de coagulante residuos de impurezas de la solución química, los tanques de floculación y sedimentación lodos de flóculos, y los tambos de cloro residuos químicos. Hay dos salidas de lodos principales. La primera salida es el canal de lodos del tanque de entrada, que tiene un ancho de W.EtDC, un largo de L.EtDC, y una altura de H.EtDC. La segunda salida recoge los residuos de los procesos de floculación y sedimentación y conduce los residuos a un canal de limpieza ubicado a lo largo de la pared posterior de la planta. El acceso a las válvulas manuales de floculación y sedimentación es a través de tapaderas en el pasillo que cubre el canal de limpieza. Este pasillo queda debajo del piso del resto de la planta para permitir acceso manual a las válvulas. Esta salida tiene una altura de H.DC, una longitud de L.DC, y un ancho de W.DC.

Stacked Rapid Sand Filtration: SRSF

Number of Filters	3

Wall Thickness	0.250 m	
Flow through single Filter	20.0 L/s	
Bottom Elevation	Z.FiBottom	
Sand		
Number of Filter Layers	6	
Height of Filter Layers	20.0 cm	
Height of Bottommost Layer	23.0 cm	
Height of Sand	1.28 m	
d_{60}	825 microm (0.0325 in)	
Porosity	Porosity.Sand	
Trunk Lines		
Main Trunk Diameter	15.2 cm (6.00 in)	
Backwash Trunk Diameter	20.3 cm (8.00 in)	
Branches		
	Main Layers	Backwash Layer
Branch Diameter	2.54 cm (1.00 in)	3.81 cm (1.50 in)
Slot Spacing	3.17 mm	B.FiBwManSlot

Las plantas de AguaClara cuentan con un sistema de filtración no convencional. Comúnmente, solamente plantas de grandes caudales pueden permitirse la incorporación de un filtro de arena. Los filtros de arena convencionales usan grandes cantidades de agua limpia para el retrolavado, electricidad, y son de construcción y mantenimiento complejo, incluyendo varias válvulas y piezas que se rompen con facilidad y son difíciles de reponer.

Por estas razones, el equipo de AguaClara ha diseñado un filtro con unas restricciones de diseño que no use electricidad, evite el uso de válvulas y piezas caras y de difícil obtención, que use poca agua, que cada parte del filtro sea visible y accesible para el operador, y que sea de fácil manejo.

Usando los principios de perdida de cabeza y aprovechando las diferencias de altura del agua, el equipo de AguaClara creo un diseño de tres filtros de arena en uno (FRAMCa). Este diseño reduce la cantidad de agua que se necesita, y gracias a su tamaño compacto y sencillo, una planta de relativamente poco flujo puede contar con tres filtros de arena.

Filtration begins once the settled water leaves the sedimentation tank. To ensure the filter functions optimally, the water must be sufficiently treated at the start of the process to a low turbidity. The filter must be washed regularly to liberate particulates trapped in the void space of the filter media. Once the water leaves the filter, it is sent to a distribution tank where chlorine is applied to destroy the last of the particulates.

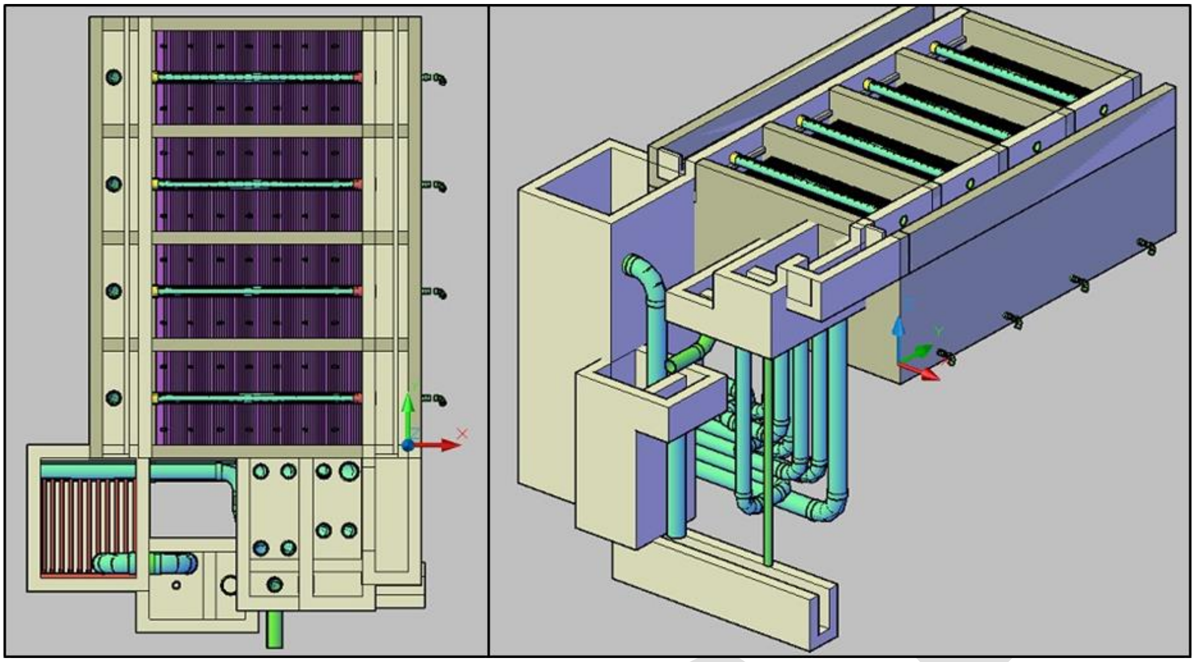


Figure 16. (Left) Top view of the sedimentation tank and a single filter below it. (Right) Isometric view of the filtration unit and sedimentation tank.

The SRSF has eight components:an entrance channel, an entrance box, a filter box, a distribution tank, caja de salida, caja de rebose, a backwash channel, a backwash box, and a siphon.

Figure 17 and **Error! Reference source not found.** show the layout of the filter. Water from the sedimentation tank enters the entrance channel then into the entrance box over a weir, flowing into the inlet manifold pipes. During filtration, all four pipes are utilized to distribute flow evenly to each of the six sand layers in the filter box and flow exits through the exit manifold into the exit box. Once in the exit box, the filtered water flows over a weir and is then piped to a distribution tank.

Figure 16**Error! Reference source not found.** more clearly shows the parts of the filter associated with backwash. For backwash operation, all water in the entrance channel will only flow through the bottom inlet manifold pipe. The dirty backwash water will then flow through the siphon into the backwash box. The backwash weir makes up one wall of the backwash box and controls the height of water throughout the filtration system. The dirty water flows over the weir from the backwash box into the backwash overflow box, then down a pipe to the drain channel.

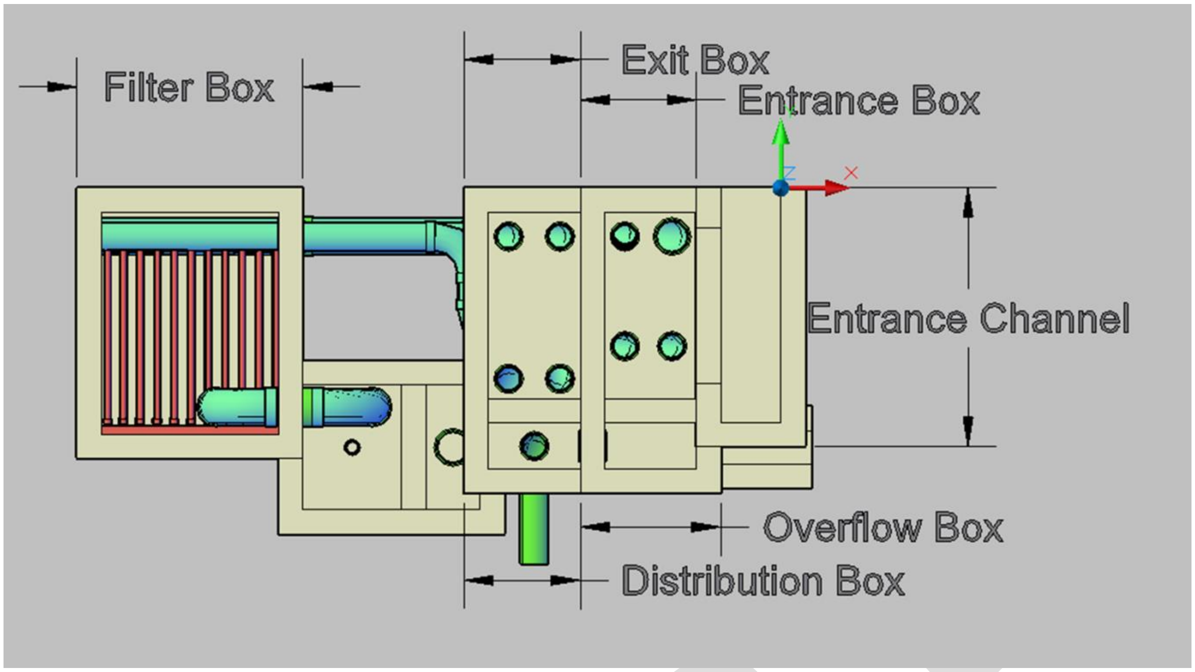
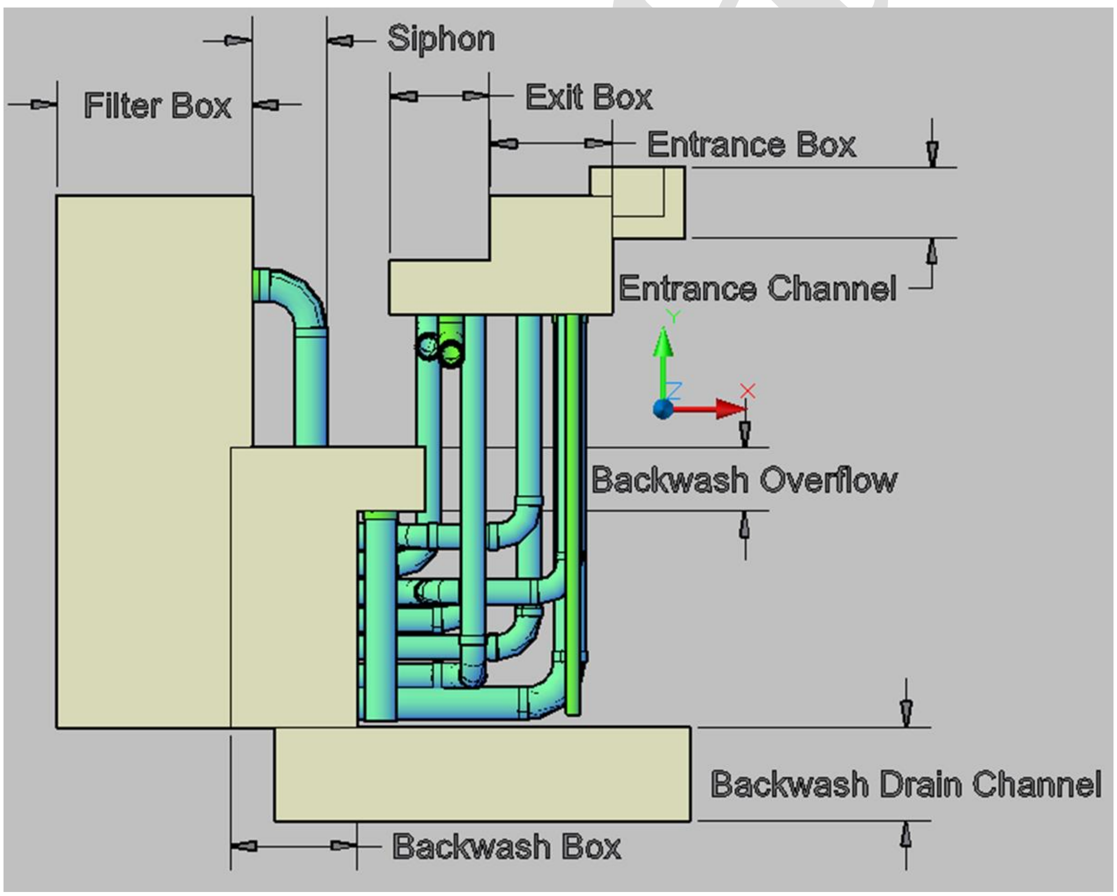


Figure 17. Top view of the filter labeled for filtration flow.



The siphon must be large enough to allow for draining all the water in the filter in a reasonable amount of time, set to be 3 minutes as well as have less than 10 cm of head loss at steady state.

Materials List

Esta seccion describe parametros utiles y estimaciones de los materials necesarios para la construccion de esta planta. Las dimensiones y materials descritas aqui estan divididas acorde a la unidad operacional de la planta a la que pertenecen.

Entrance Tank

- El volumen de concreto necesario para construir el tanque de entrada es Vol.EntranceTank.
- El suelo del tanque de entrada tiene un area de A.EtFloor.

Flocculation Tank

- El volume de concreto necesario para construir los suelos del tanque de floculacion es Vol.FlocFloor y Vol.FlocWallsn par alas paredes del tanque.
- Este suelo tiene un area de A.FlocFloor.
- Hay N.FlocValves valvulas en el tanque de floculacion , cada una con un día metro nominal de ND.FlocValve.
- Esta planta no tiene laminas de plastico.

Sedimentation Tank

- Los volumenes de concreto necesario para construir el tanque de sedimentación son:

Vol.SedSlopes	Para las tolvas del tanque
Vol.SedWalls	Para las paredes del tanque
Vol.SedFloor	Para el suelo del tanque

- El area de la superficie del tanque de sedimentación es A.SedFloor.
- Hay N.Launders tuberias de salida de agua limpia, cada una de longitude 5.54 m length y 15.2 cm (6.00 in) de día metro. Cada tuberia de salida tiene dos filas de orificios con un total de 54 orificios, cada uno de día metro 1.59 cm (0.625 in).
- Cada una de las tuberias distribuidoras tiene longitud de L.SedManifoldPipe, con un día metro nominal de 20.3 cm (8.00 in). Hay N.SedBays tuberias distribuidoras.
- Hay un total de 1760 placas sedimentadoras, cada una de longitud 50.0 cm y 1.06 m de ancho.
- Hay N.Valves valvulas, cada una de ND.SedSludgeValve día metro nominal.

SRSF