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1. Executive Summary

S.D. Engineering was developed as part of the International Senior Design (ISD) program at Michigan Tech. In August 2008, ten students were split into three teams and assigned various projects in the City of Santa Cruz, Bolivia. Students spent two weeks in Santa Cruz collecting information for their respective projects, located in Districts 10 and 12 of the city.

S.D. Engineering accepted a project which evaluated the feasibility of several on-site wastewater treatment and storm water drainage systems for the Bolivian National Police Station, located in District 12 of Santa Cruz, Bolivia. The current wastewater stream has surpassed the ability of the present system to treat. The malfunctioning system allows untreated wastewater to enter the soil and overflow to the sidewalk and street. The current storm water drainage system applies collected storm water from the building roof directly into the ground with no mechanism for increased dispersion. This causes flooding of the ground behind the police station.

S.D. Engineering researched multiple wastewater treatment options prior to finding three of the options to be most feasible; composting toilets, constructed wetlands, and an elevated mound drain field. The feasibility of these three systems was further considered until a best solution was apparent. Many constraints affected final system selection which included: usable area, cost, social acceptance, ease of technical implementation and maintenance, groundwater table, and time. An additional constraint was the presence of a soccer field in the potential wastewater treatment area. The ultimate design selection considered each constraint including the hope for unobstructed soccer play.

S.D. Engineering recommends the construction of an elevated mound drain field system for the treatment of the police station's wastewater stream and an updated storm water drainage system including catch basins. The total estimated direct cost of these

systems is $135,000 bolivianos and $19,000 U.S. dollars. These systems were selected due to their effectiveness of treating the design flow, required lifespan, ease of construction and maintenance, and social acceptance at the police station. Design also included anticipated growth of police station personnel. This proposed system will utilize the existing septic tank in addition to a new septic/dosing tank and mound drain field. The new septic dosing tank will be located adjacent to the existing septic tank and mound drain field will be located atop the existing soccer field behind the police station. The mound system will not inhibit soccer play as it is large enough and will function properly with human traffic.

The recommended storm water system improvements include constructing storm piping from the roof drains to a drainage ditch on the north-east side of the building. Catch basins should also be installed with storm piping to alleviate storm water flooding in the rear of the building, as well as runoff coming from the mound area.

The final recommendation by S.D. Engineering is that the police station connects to sanitary sewer lines as soon as they become available. Current plans estimate that sewer lines will be available in about 5-10 years.

2. Introduction

ISD, a class offered through Michigan Tech's Department of Civil and Environmental Engineering, provides students the opportunity to travel to Santa Cruz, Bolivia and work on various engineering projects as needed by the city's Districts 10 and 12. Each team is comprised of three to four students and assigned an engineering design project. Some example projects include roadway design, storm water drainage, and wastewater treatment.

S.D. Engineering is one of three teams working within the August 2008 section of the class. Team members include project manager Aaron Wohlfeil and project members Fritz Burt and Kimberly Landick. S. D. Engineering has been challenged with designing a solution to the wastewater treatment and storm water drainage issues at the National Police Station in District 12 of Santa Cruz, Bolivia. The current wastewater treatment system is not capable of treating the police station's wastewater stream. The standing wastewater causes odor and potential health issues for the staff and surrounding community.

This report details design recommendations for improving the condition of the wastewater system at the police station. The report includes data obtained while in Bolivia, design calculations, construction documents, schedule and estimated costs. It also includes recommendations for alleviating storm water problems immediately around the building.

3. Background

Bolivia is a landlocked South American country, bordered by Brazil, Paraguay, Argentina, Chile and Peru (see Figure 1). The western Andean portion of the country contains the capital city of La Paz while the eastern lowlands contain the country's largest city, Santa Cruz (designated by the red arrow on Figure 1). The western portion is cold and semi-arid while the eastern is humid and tropical. Bolivia has two capitals, the constitutional capital, Sucre, and the administrative capital, La Paz; which is also the world's highest capital city.

Figure 1: Location of Bolivia in South America

Bolivia is divided into 9 departments including Santa Cruz. Each department is divided into municipalities and into districts. Santa Cruz has approximately 1.5 million inhabitants, and is formed of concentric rings that expand from a central downtown area shown in Figure 2 below. Due to the large population growth in recent years, the rings outside the fourth ring lack infrastructure such as wastewater treatment and effective storm water drainage. This flooding results in an increased rate of disease from bacteria present in the wastewater and environmental issues such as increased mosquito borne diseases like dengue fever, yellow fever, and malaria from standing flood waters. Odor is also a concern in many public places where citizens deal with unpleasant smells from partially untreated wastewater. Proper wastewater treatment and storm water drainage are paramount for urban disease prevention and an improved quality of life.

Local tax money collected from the country is sent to La Paz where it is distributed amongst the departments. It is then dispersed to local governments for redistribution to municipalities. The distribution of money to the departments and local governments is politically influenced, resulting in uneven distribution.

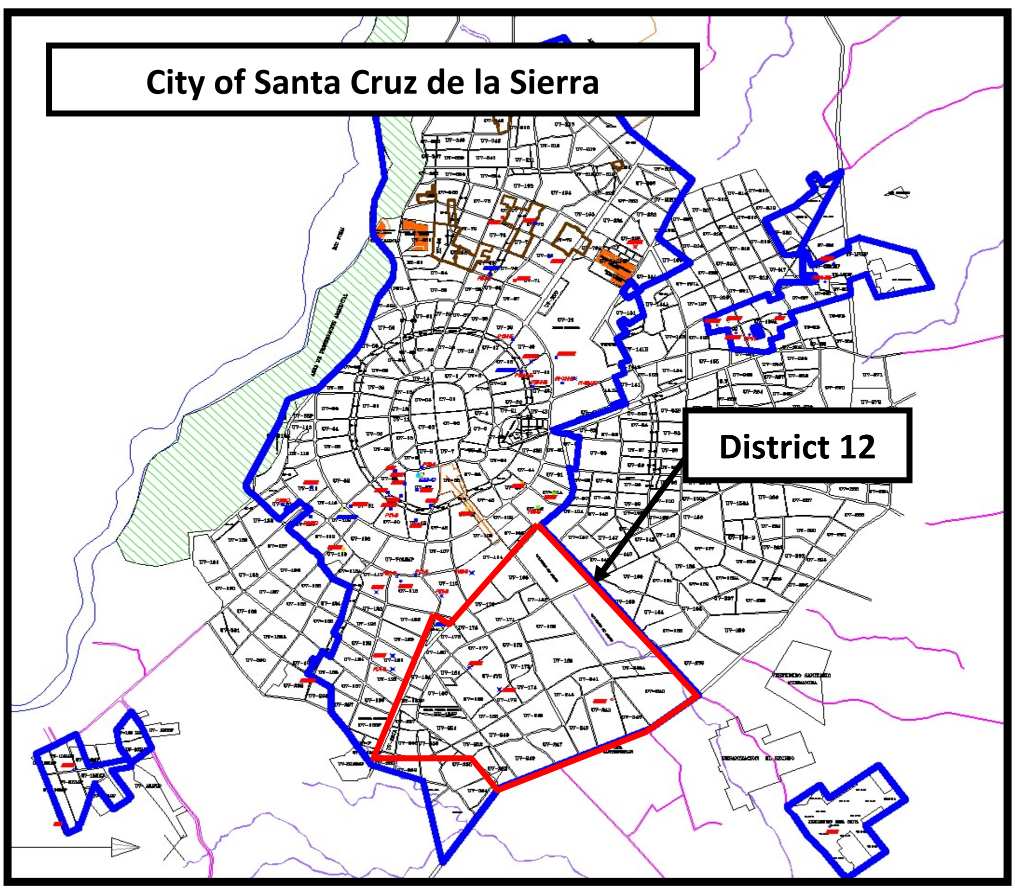


Figure 2: District 12 in Santa Cruz

Each district is governed by its own subalcalde or sub-district mayor. District 12 was created 9 years ago and is outlined in red in Figure 2 above. 150,000 people live in its area of 4,300 hectares. District 12 is currently working towards updating its infrastructure. There are no wastewater sewers near the police station and storm drainage is a system of poorly functioning earth canals, except for two concrete-lined canals currently under construction. Wastewater treatment and storm water drainage issues have been prioritized by the sub district mayor, Ing. Victor Escobar. One high priority project in District 12 is the National Police Station, which has a need for a functioning wastewater treatment and storm water drainage system.

The National Police Station building in District 12 (located near the center of District 12) is the Bolivian government's new standard model police post building design (see Figure 3). The building was constructed in 2006, and since it is newer and larger than surrounding development and other police posts, it is an important influence to the community, and a model for other posts. Currently its existing wastewater treatment and storm water drainage systems are not functioning. There are problems with storm water flooding and standing wastewater. S.D. Engineering will propose a design to alleviate these problems to bring improved environmental and health conditions to the people using the police station.

Figure 3: Front of Police Station Building

4. Methods & Procedures

4.1 Introduction

This section outlines the methods and procedures used by S.D. Engineering for on site investigation and data collection while in Bolivia as well as during the design phase on the Michigan Tech campus. On site investigation, interviews and data collection methods were used to gather necessary information concerning the District 12 National Police Station. Interviews were translated by S.D. Engineering member Fritz Burt.

4.2 Preliminary Design Research

In order to prepare for site investigation, S.D. Engineering performed research and facilitated discussion on traditional Bolivian wastewater treatment systems. Team members were also delegated the task of studying designs which could potentially be implemented. These tasks were carried out before and after the site visit.

4.3 Interviews

Interviews with the client and project benefactors were held at various times during the team's visit to Santa Cruz. The purposes of each meeting varied, but were meant to gather needed information about existing conditions, potential benefits of a new system, current and future infrastructure in the area, and client and benefactor expectations. Meeting minutes and contact information were recorded during each interview and are located in Appendix E. S.D. Engineering held initial meetings with Ing. Victor Pocho Escobar (District 12 Sub Alcalde), Loretta Moreno (Barrio president), and Sargento Freddy Chambi Ygnacio (head of facility maintenance at the District 12 National Police Station) (Figure 4). The data collection phase of the project was concluded through final meetings with the District 12 Sub Alcalde as well as Teniente Coronel Jhonny David Rojas Cabrera.

Figure 4: S.D. Enginnering Meeting with Sargento Freddy Chambi Ygnacio

4.4 Topographic Survey

Equipment used

- Topcon GTS-225 Total Station
- TDS Ranger Data Collector
- Prism Rod
- Tri-pod
- Measuring Tape (metric)

Figure 5: Surveying the Site

S.D. Engineering performed a topographic survey of the National Police station and the surrounding area. Documented locations and appurtenances include building corners, property boundaries, road and sidewalk locations, and the existing septic system and storm water drainage system. Points were collected in order to represent site layout and aid in design. Survey was performed in accordance with the practices taught by Professor Paul Buda of Michigan Tech.

Site surveying of the District 12 National Police Station commenced on Wednesday August 13, 2008. The following procedure was followed.


Figure 6: Bench Mark, BM1

1. A bench mark (which is on record with the city of Santa Cruz) along the Nuevo Palmar canal was used for reference from a control point near northwest corner of District 12 Municipal Park Property. This bench mark was designated BM1, shown in Figure 6 and 7.
2. The control point was in view of the northwest side of the police station, the District 12 Municipal Park, sight to the road Fatima I, and the open soccer field to the northwest of the police station.
3. The survey was conducted over the areas listed above, paying special attention to the soccer field, as well as property boundaries, the building, and related features. Objects also sighted included trees, sidewalks, and the Fatima I – Nuevo Palmar road intersection.
4. Other control points were set up on the northeast side of the soccer field and also along Fatima I in order to gather data from all sides of the building.
5. Control points were marked and then placed by driving a wooden hub wrapped with yellow tape into the ground at the desired location. The exposed surface of the hub was left approximately level with the ground surface to reflect accurate ground elevation (see Figure 8).
6. After control points were set, the site was surveyed using survey equipment.
7. The data was saved as a comma delimited file and imported to a computer aided drawing program in order to check for accuracy and correct orientation in reference to the bench mark and known site locations at the end of each survey day.

Figure 7: Bench Mark 1 Location

To supplement survey data, S.D. engineering also documented the site layout by making sketches and taking photographs (which can be found in Appendix B). The survey was completed on Saturday, August 16, 2008.

Figure 8: Kim Marking a Control Point; Aaron Surveying the Soccer Field

4.5 Water Quality Testing

S.D. Engineering chose various locations around the site to examine water conditions, especially in those areas near the existing wastewater treatment system. Water samples were collected to test for coliform bacteria, which corresponds to contamination by fecal matter. Sampling locations included standing surface water from behind the building, storm water pipe inspection basins, tap water from a ground floor lavatory faucet, and an overflow trench from the existing septic system. The lavatory sink was used as a control sample; four storm drains, one ditch, and one open puddle near the building were sampled in an attempt to understand areas of contamination.

Seven samples were gathered from different locations around the project site, which are listed below. The locations are also shown on a site layout in Figure 10. Using a small plastic cup, samples of water were gathered and poured into large water bottles (see Figure 9). The bottles were then transported to Saguapac, a local water supplier, who allowed S.D. Engineering to prepare and incubate samples. Approximately 1 mL of each sample was placed on a 3M petrifilm plate (see Appendix D for instructions). The seven plates were then placed in an incubator set at 35 degrees Celsius at 11AM on August 20, 2008 (see Figure 9). On August 21, 2008 at 3PM the samples were taken out of the incubator (28 hrs later) and analyzed.

Figure 9: Kim Gathering a Water Sample; Samples Set in the Incubator

Sampling locations:

- W1: Downstairs bathroom, corner sink, used as a control
- W2: P88 storm water collection, out front behind septic system
- W3: P74 storm water collection, under blue sign out front
- W4: Standing water, just off concrete pad, perpendicular to end of staircase
    - NOTE: Rained yesterday, high turbidity of water
- W5: P52 storm water collection, back of station, between glass door and stairs
- W6: Unlabeled storm water collection on front corner, next to column
- W7: Septic trench between outlet from system and where it empties to road

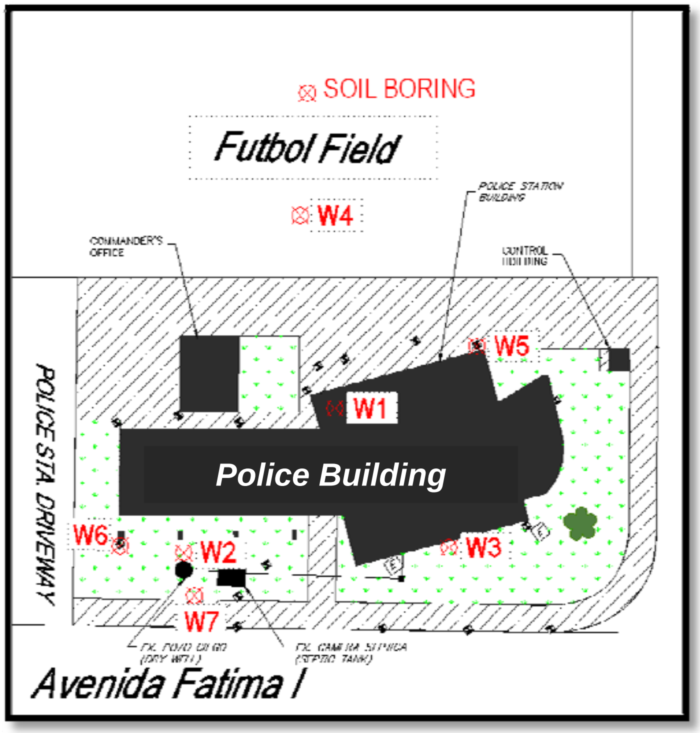


Figure 10: Sample Locations for Water and Soil Analysis at the Police Station

4.6 Soil Boring

Soil boring and sampling is an important aspect of many infrastructural projects, especially on site wastewater treatment. S.D. Engineering, along with the services of Don Teodardo Gandarillas conducted a soil boring on site at the police station for two main purposes; to determine the current level of the groundwater table and understand the basic mechanical and hydraulic properties of the soil. These factors are necessary for the design of a wastewater treatment system.

One soil boring location was chosen in the middle of the soccer field (proposed location of the replacement treatment system) northwest of the police station building (see Figure 11). S.D. Engineering chose to perform only one boring in this location since it will accurately represent soil and groundwater conditions for a field of its size. After the location was chosen and recorded, the auger was assembled and placed upright on the desired sample location. The auger was turned about ten to fifteen times and the extracted soil was then placed onto the nearby ground surface. This process was continued until a depth of one meter had been reached. At this depth, a sample was taken from the bored soil. Samples were bagged, labeled, and documented. The boring was continued and sampling was conducted upon each successive meter in depth. If groundwater was reached before an interval, the depth was recorded, soil sampling was performed, and the boring was discontinued due to instability of the bore hole. After recording all pertinent information, boring holes were backfilled. Depths were verified using a metric tape measure. S.D. Engineering observed and recorded qualitative soil characteristics in a boring log, which can be seen in Appendix C.

Figure 11: Kim Taking Soil Boring Sample

4.7 Soils Testing

4.7.1 Soil Classification

Soil characteristics were a determinant of classification. Optimal tests would follow ASTM procedures, however lab testing equipment was not available. Field variations of ASTM classification procedures were followed (see Appendix C). Tests included examination of soils based on texture, cohesiveness, and simple mechanics. Soil types were classified by the U.S. Department of Agriculture (USDA) system for cross reference in soil characteristics (e.g. permeability).

4.7.2 Particle Size Distribution

A simple settling test was performed to learn about soil sample characteristics. This was done to supplement the aforementioned classification information. Glass jars were filled with soil (samples from borings) and water, and rotated in order to suspend soil particles. After properly mixing the soil and water, the sample jars were left to settle (see Figure 12). This allowed the larger particles to settle, giving both a visual and quantifiable description of particle size distribution. It should be noted that this procedure is not as accurate as recommended ASTM testing procedures. Regardless, it provides valuable insight to existing soil conditions at the police station.

Figure 12: Soil Samples

The experiment was designed and set up using materials available on site at the S.D. Engineering temporary office in Santa Cruz. Glass bottles were first inspected for cleanliness, then measured and marked at specified lines. The first line was set at 7.0 cm from the bottom of the bottle, designating the amount of soil sample. Similarly, the second line designated the height of water in the jar, and was set to 9.5 cm for each apparatus. Each bottle was marked with location and sample information regarding the depth. Soil was placed in the bottle, taking care to avoid over-sized particles. Water was then filled to the specified line. Testing began at 8:20 AM on August 20, 2008, when S.D. Engineering began rotating sample jars to suspend solids in the water. One rotation consisted of holding the sample upright, turning it 180-degrees (up-side down) and returning the jar to its original position. Each sample jar was rotated fifty times in order to ensure proper suspension. After 40 minutes, samples were observed and notes were taken on their condition. They were then allowed to sit for a minimum of 24 hours (after start). At the end of the test, each layer of soil was measured and recorded. Photos were also taken throughout the test to aid examination and documentation. A diagram of the bottles used and measurements shown can be found in Appendix C.

5. Existing Conditions

5.1 Location

The National Police Station is located on Avenida Fatima I, north of the intersection with Nuevo Palmar (shown in blue in Figure 13 below). Nuevo Palmar is a major road in District 12 in the southeast portion of Santa Cruz, whose boundaries are shown in red below. Avenida Fatima I is currently being paved with storm drainage structures. A large storm water canal is also being constructed along Nuevo Palmar. The two story National Police station building was built in 2006 and its ground floor is 300 square meters. Grass surrounds most of the building, except for a concrete pad in the rear of the building. Also behind the main building is a smaller commander's office, a dirt soccer field and covered concrete pad(s) (see Figure 13). The dirt soccer field is 1,100 square meters and is bordered by a park to the south. The covered concrete pad, also called a cancha, is used for soccer and basketball. There are concrete bleachers between it and the soccer field, with surface flow storm drainage from the cancha flooding the soccer field.

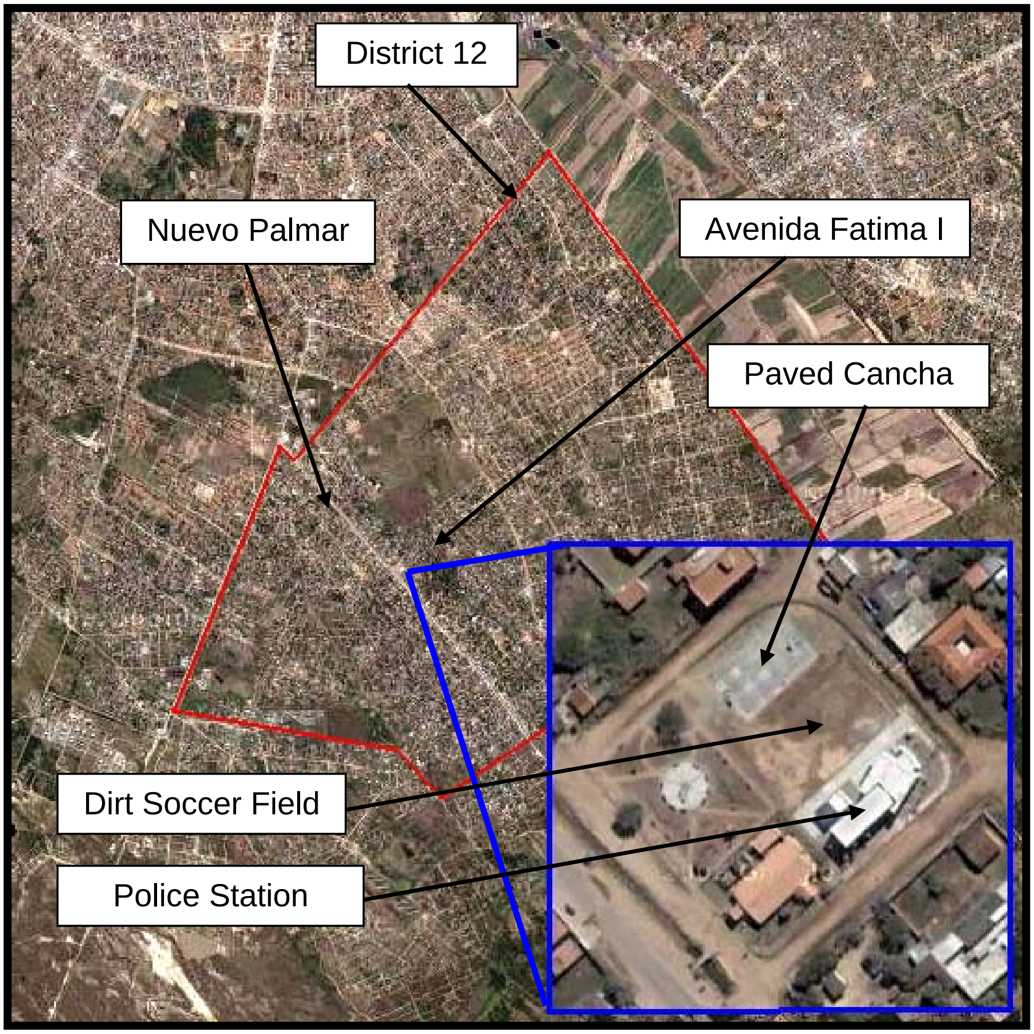


Figure 13: The National Police Station Located in District 12

5.2 Building Layout

On the first floor of the building there are six toilets, one urinal and six sinks (sinks are outlined in blue and toilets in red in Figure 14). Four toilets are for the public to use, one is for the jail cell and one for the conference room. The number of prisoners in the jail cell ranges from one to four and prisoners are temporarily held from 8 to 24 hours, before being taken to the Palmasola prison. This toilet, along with the toilet room in a conference room, is currently not working.

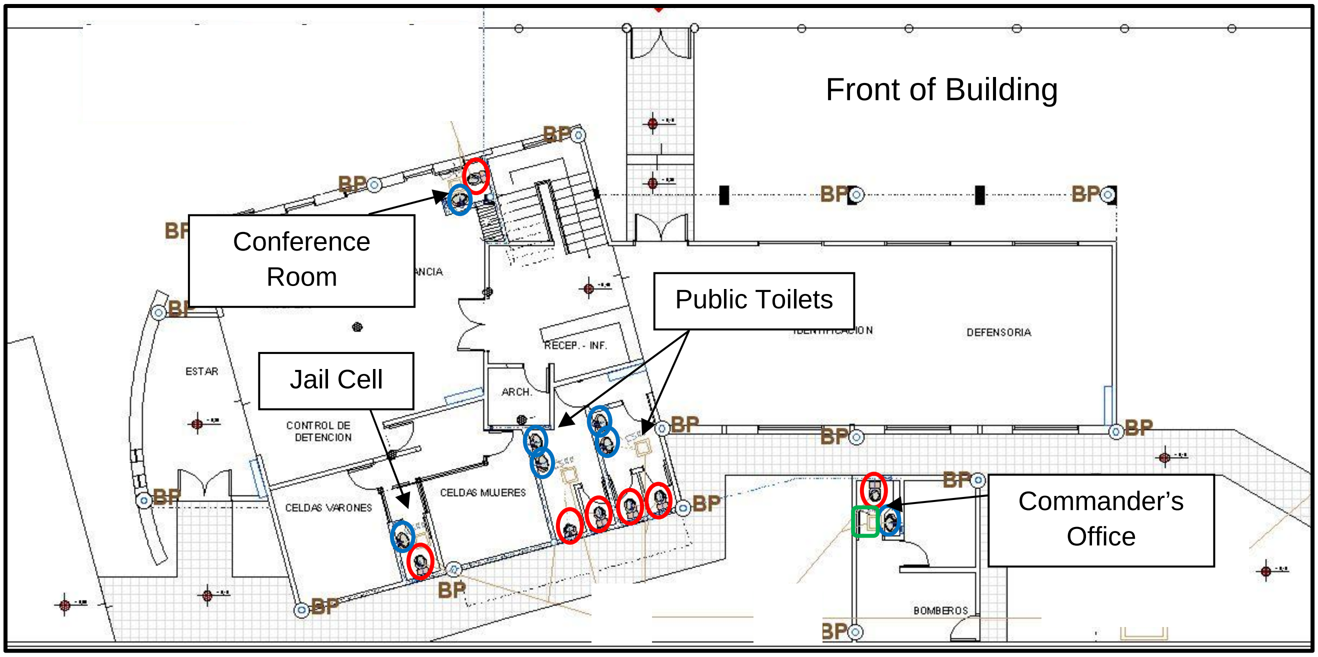


Figure 14: First Floor Building Layout

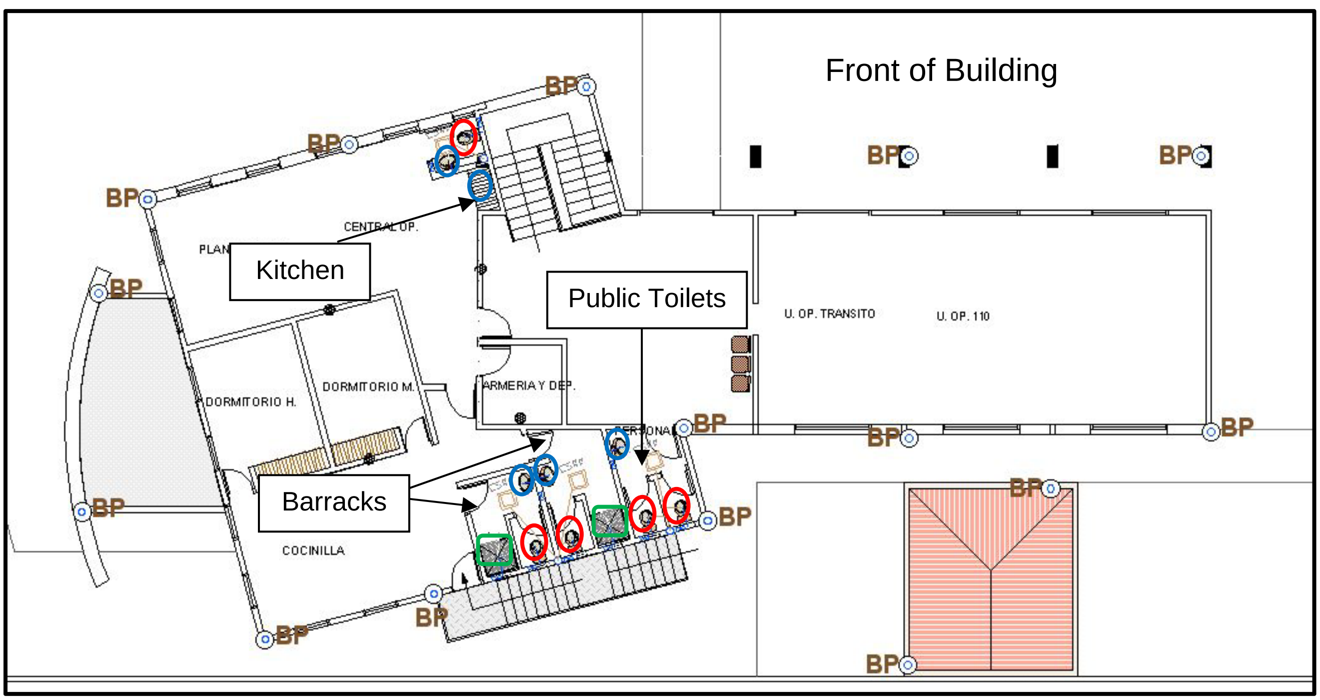


Figure 15: Second Floor Building Layout

On the second floor of the building there are two toilets and one sink for public use as well as three toilets, three sinks and two showers in the barracks. There is also a kitchen in the barracks as well with one sink (toilets are outlined in red, sinks in blue and showers in green in Figure 15). Behind the building in the commander's office there is another sink, toilet and shower. In total, there are 12 toilets, 11 sinks, 1 urinal, and 3 showers currently installed in the building (examples of these fixtures are shown in Figure 16). In the future, the police station operations are expected to expand, however, an addition on the building and more bathroom facilities would be needed.

Figure 16: Bathroom Fixtures at the Police Station

5.3 Building Occupants

According to Sargento Freddy Chambi Ygnacio on August 13th, 2008, 30 policemen currently work during each shift, rotating every 24 hours. S.D. Engineering contacted Teniente Coronel Jhonny David Rojas Cabrera on October 4th, 2008 to confirm this number. The Teniente Coronel confirmed that 35 policemen work each shift; however only 12 personnel are in the building 24 hours a day, 7 days a week. He also stated that during some weekends, community meetings are held at the police station, where 70-75 people are present in the building at one time.

5.4 Wastewater

The traditional Bolivian septic system was installed when the station was built and according to Sargento Freddy Chambi Ygnacio, it has not functioned properly since. The wastewater leaves the building in a single pipe, shown in red in Figure 17 below, and enters an inspection tank before flowing into a septic tank. Both grey water (water used for domestic processes such as dish washing and bathing), and black water (water containing fecal matter and urine) enter the septic tank. After settling in the septic tank the water enters a dry well (pozo ciego), where it is to seep into the soil. The combined grey and black water wastewater system is uncommon in this area of Santa Cruz; typically wastewater systems are designed for only black water.

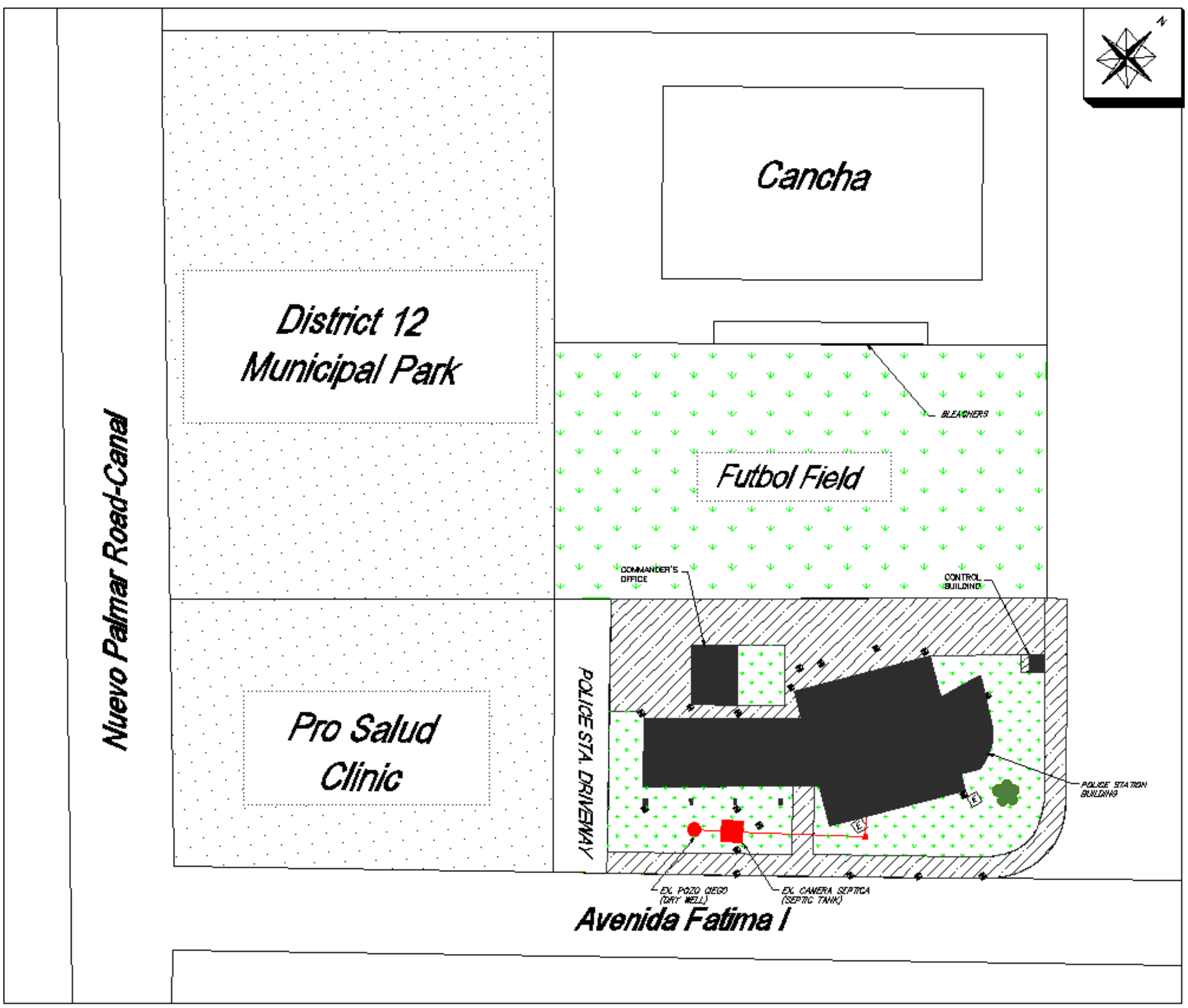


Figure 17: Site Layout

The treatment system was built in front of the police station, in an area of approximately 28 square meters. On August 13th, 2008 the septic tank was excavated by a prisoner to expose the tank top which was found to be two square meters. According to the head of facility maintenance, Sargento Freddy Chambi Ygnacio, the tank is two meters in depth. The inspection tank was found to be full of raw wastewater, and the septic tank and pozo ciego were overflowing. A ditch had been dug along the sidewalk from the overflowing septic tank and pozo ciego, draining raw wastewater into the street, Avenida Fatima I (see Figure 18). When these systems do not function, the dry well fills, becoming a holding tank with scum built up inside of it. Currently, the wastewater overflows from the dry well and septic tank, contaminating the soil and area around it. Additionally, storm water flooding during the rainy season mixes with the sewage and increases the contamination on the site.

Figure 18: (L to R) Wastewater Next to Sidewalk, Full Inspection Tank, and Current Septic System

Standard police module construction plans were received from District 12 Sub Alcalde Ing. Victor Pocho Escobar on August 22nd, 2008. These plans show that two septic systems were to be constructed when building the police station; one in the present location and one in the back of the building (highlighted in red in Figure 19 below). This was obviously not completed at the District 12 National Police Station.

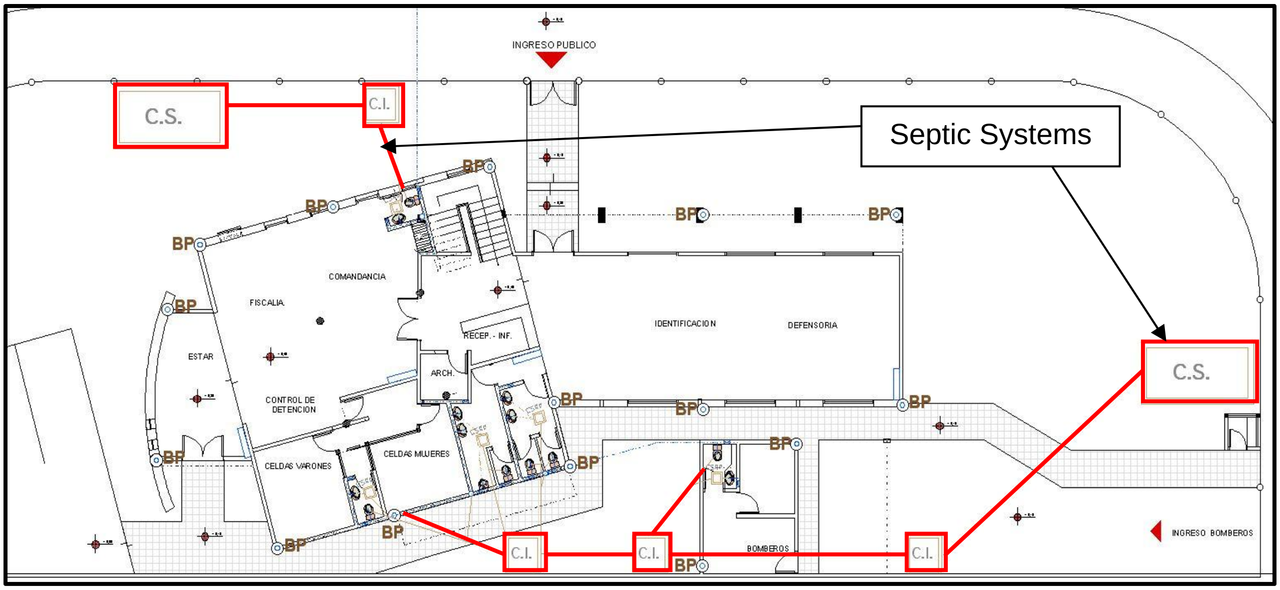


Figure 19: Standard Police Module Construction Plans

5.5 Storm water

The building was constructed with an interior storm water drainage system. Currently, storm water from the roof is collected and drained through pipes inside the building walls, exiting below ground level into inspection tanks. It is then piped underground away from the building in the back; however the piping discharges underground in an unspecified location. At the front of the building, storm water is directed into Avenida Fatima I. S.D. Engineering inspected the storm drains in mid-August during the dry season and found them to be approximately half full. The 2-3 weeks before the inspection, three non-sequential full day rains occurred leading to more storm water than usual during the dry season. According to the head of facility maintenance, Sargento Freddy Chambi Ygnacio, during the rainy season the ground becomes saturated with storm water and the grassy areas around the building mix with black water and become flooded.

S. D. Engineering will provide design solutions to improve the building wastewater system and storm water management issues to alleviate water buildup on the property. Storm water improvements may be needed for proper wastewater treatment.

5.6 Testing Results

S.D. Engineering collected and analyzed different types of data while in Santa Cruz, Bolivia. The results from these data sets have been used to determine the best wastewater treatment system option for the National Police Station in District 12. Types of data collected in-country included water quality, survey, and soil properties. The results below are products of the testing methods and procedures that were performed by S.D. Engineering for the Santa Cruz District 12 National Police Station.

5.6.1 Water Quality Analysis

The presence of fecal coliform bacteria is indicated by the 3M™ Petrifilm™ plates by a color change (red) in the growing medium and the presence of gas bubbles. No color change suggests that no fecal coliform were present, light pink or red coloration indicates that there may be some fecal coliform present, and a dark red strongly suggests the presence of fecal coliform. Additionally, visible fecal coliform colonies are shown by the presence of concentrated red dots. Confirmed fecal coliform presence is denoted by TNTC (too numerous to count). Below is a list of the results obtained from the seven samples S.D. Engineering collected, these are also shown in Figure 20.

- W1: Light pink, no color change, no visible colonies no gas bubbles
- W2: ¾ dark pink, ¼ light pink, visible colonies; TNTC
- W3: ¼ dark pink, ¾ light pink, 27 visible colonies with gas bubbles, 6 red dots per square (approx. 160 total), no gas bubbles
- W4: Dark pink, visible colonies, gas bubbles; TNTC
- W5: Dark pink, visible colonies, gas bubbles; TNTC
- W6: Light pink, 10 visible colonies per square (approx. 200 total), no gas bubbles
- W7: Dark pink, visible colonies, gas bubbles; TNTC

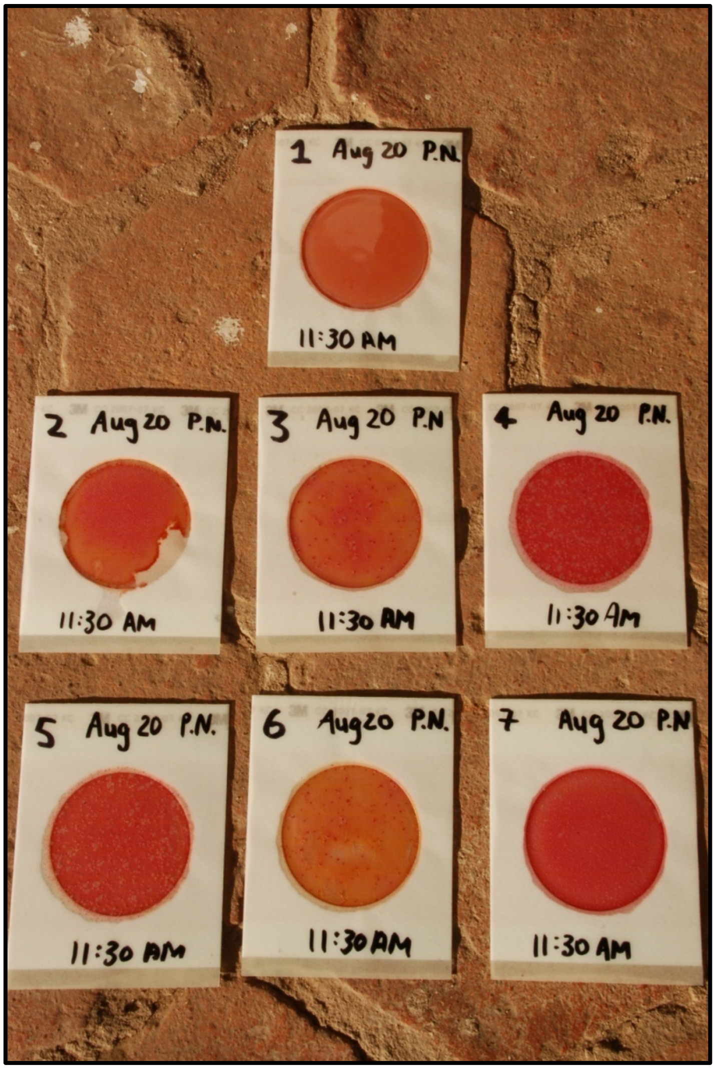


Figure 20: Sampling Films after Incubation

All samples except for the control exhibited the presence of fecal coliform bacteria. This suggests that all sample locations except for the control have been contaminated with untreated wastewater. Samples W4, W5, and W7 were found to have the most extensive contamination. These three samples had all of the signs of fecal coliform contamination while the remaining four had only some or zero.

5.6.2 Soil Properties

On site soil conditions at the police station were determined through soil borings and classification of samples according to USDA systems. One soil boring was performed near the center of the soccer field and samples were taken for testing. Due to the size of the site, S.D. Engineering decided that one boring was sufficient for investigation and sampling.

The soil borings resulted in two samples at 1.0 meters below ground surface (bgs) and 1.57 meters bgs, respectively. From visual observation, the soils at 1.0 meters were composed of light brown and grey sand particles. As the boring continued, the soil was mainly light grey, with some brown sand. Water was found at 1.57 meters where the removed soil was fully saturated. S.D. Engineering concluded that the level of the groundwater table was at 1.57 meters bgs at the time of boring.

Although the water table was 1.57 meters at the time of boring, it is important to consider seasonal fluctuation of levels throughout the year. During the time of S.D. Engineering's site visit, Bolivia receives less rain than other times of the year (the dry season). The water table is probably higher during other seasons. It is also important to note a precipitation event in Santa Cruz the day before soil borings were conducted. The previous measurement is a valid estimation of the groundwater level during the dry season and was used in determining a wet-season level. For safety in design calculations, S.D. Engineering assumed a high water table of 1.0 meter below ground surface.

Physical testing was performed on the soil samples. Both samples exhibited non-cohesive qualities over a range of moisture conditions. The two samples also left a gritty residue after testing, indicating the presence of a smaller particle. The above results show both samples to be Medium Sand by USDA classification.

Settling tests were performed on both samples to determine particle size distribution. Test results are shown in Table 2. S.D. Engineering determined sand to be the primary layer in both samples with a small secondary layer of silt particles. The settling test confirmed earlier indications and provided a more detailed distribution of particle size.

Table 1: Settling Test Results

	Primary Layer Height (cm)	Primary Layer % of Total Volume	Secondary Layer Height (cm)	Secondary Layer % of Total Volume
SD1m	5.2	**95%**	0.3	**5.5%**
SD2m	6.5	**97%**	0.3	**4.4%**

6. Wastewater Flow Determination

For the design of an on site wastewater treatment system, S.D. Engineering investigated flow generation and performed several calculations in order to find a daily design flow contribution.

6.1 Growth and Usage Assumptions

For regular personnel at the police station, officers work in twelve hour shifts of 35 people. Each shift is composed of people from around the district. Only twelve of the 35 employees are present in the District 12 station at a time; the remainder is on traffic patrol, performing investigations, or carrying out other duties. It is reasonable to assume a maximum peak when the shifts change. Depending on their location, officers may stop at the station to use the bathroom or shower.

Regular personnel present in building = 12
Officers changing shifts = 23

While many of the officers are out, the station is frequented by citizens who come to seek information or report crimes. Bathrooms are open to the public on the second floor and it is reasonable to assume a number of the visitors contribute to flow generation.

Estimated number of toilet/lavatory sink uses per day by public visitors = 15

According to police station personnel, it is normal to hold conferences on various topics (e.g. transportation signage, etc.) for officers as well as for the public. The station's conference room can hold approximately 60 people, with the meeting to last a few hours at the most.

- Estimated number of people at a conference = 60
- Assume 80% use the bathroom while at conference = 48 people

City officials estimated it would be between five to ten years before sanitary sewer would be extended to the area, providing service to the District 12 police station. With this in mind, it is important to consider possible growth of station personnel. According to Tcnl. DEAP. Rojas, it is hard to project growth because of varied resources and funding of police stations. He stated it would be fair to estimate an additional 2 people per year.

Two additional people per year (all of which are added to station personnel)
Estimating 10 years, maximum, for sewer service to be extended = **20 extra people**

Therefore,
Ultimate Design Population = 12 + 20 = **32 people** present in the station

6.2 Current Estimated Average Flow Calculation

(Flow calculation methods can be followed in Appendix F)

Table 2: Current Daily Flow Calculation

Method Name	Flow value (gpd)	Flow per Capita (gpd)
Water costs per month	2,054	113.3
Contribution per capita	1,551	72.4*
Fixture calculations per capita	1,151	39.0*

*Flow per capita figure reflects the twelve personnel consistently present (i.e. other irregular values are factored out before this calculation)

Method 1: Wastewater Cost/Month

According to information supplied by Sargento Chambi, the station's water usage costs between 1,350 to 1,400 Bolivianos (Bs) per month. Water costs about 6 Bs for one cubic meter of water; a total of 233.3 cubic meters (61,639 gallons) of water each month based on the water bill (note: S.D. Engineering was unable to obtain formal water usage documentation of any form or calculated flow from Sargento Chambi's information). By this calculation, the average daily flow equals 2,054 gallons per day. This is a high flow, especially when considering an equivalent per capita contribution of 113.3 gallons per day (gpd). The contribution per person includes conservative factors for facility use by the public, conference attendees, as well as shift changes for the twenty-three non-office personnel (see Appendix F spreadsheet for calculations). A general per capita estimate for flow based on a U.S. study is 74 gpd per person. Conventional studies in water usage would likely suggest that Bolivian numbers would be lower than those in the U.S. (Salvato, 1992), however trends can change and this flow could be high for other reasons. For example, leaks in the water supply system (i.e. in the building or near the service connection) could cause this number to be inaccurate. Regardless, this estimate is very high and should be scrutinized with respect to other estimates.

Methods 2 and 3

S.D. Engineering also performed two separate calculations based on fixture contribution per day per capita (information from (1)Tchobanoglous, Burton, and Stensel, 2003, and (2) Wastewater Engineering: Treatment and Reuse, Metcalf and Eddy). Flow calculation methods can be reviewed in the Appendix F spreadsheets. Both methods are considered to be conservative (i.e. generally higher than actual) in their consideration of leaks in infrastructure as well as other factors. These estimations are also based on U.S. consumption data and although they may vary from Bolivian usage, will be conservative values. In both of the secondary methods, daily flows are lower than the information supplied by the police station personnel.

Conclusion: Flow Method Chosen

In the interest of the station personnel and visitors, it is best to use a conservative flow estimate. In the absence of water bill documentation, and with a large per capita estimate (based on info from station personnel), the flow found in Method 1 should not be used. A more reasonable value of 1,551 gpd (72.4 gpd per person) was found in Method 2. This choice is conservative for growth in the number of personnel stationed in the office, given its flow value per capita. The case of leaking utilities would result in diluted wastewater being applied to the drain field; which would prolong the life of the system, therefore this is not a concern.

6.3 Projected Average Flow Calculation

To accommodate potential station growth, a number of 32 people can be assumed to remain in the station all day. This includes growth of 2 people per year for ten years (assuming the station will grow at this rate, and that sanitary sewer will be extended). This also assumes all the new employees stay in the station which is the worst case – in comparison to if they worked outside the station and contributed only on shift change. It is also reasonable to assume the number of public users contributing; which is an estimated increase of 15 users per day (a total of 30).

Using the per capita rate of 72 gpd from Method 2, including growth, results in a total flow of 3,000 gallons per day (see attached spreadsheet for projected growth).

6.4 Ultimate Design Flow Calculation

The Wisconsin Pressure Distribution Component Manual recommends multiplying the estimated future average flow by a factor of 1.5 for peak flow.

As shown in Appendix F, 1.5 multiplied by 3,000 gpd provides an ultimate design flow of 4,600 gallons per day. This value is greater than potential peaks from shift changes in the station or conferences and is a valid estimate of design flow.

7. Design Options and Analysis

After collecting and analyzing all data, S.D. Engineering researched 12 design options for treating wastewater at the National Police Station. These designs are listed below, divided into not feasible and potentially feasible option categories for this specific project.

Not Feasible Options:

7.2.1 Traditional Bolivian System (septic tank and pozo ciego)
7.2.2 Activated Sludge
7.2.3 Lagoons
7.2.4 Gravity Drain Field
7.2.5 Pressurized Drain Field
7.2.6 Drip line Effluent Drain Field
7.2.7 Box Sand Filter
7.2.8 Trickling Filter
7.2.9 Imhoff Septic Tank

Potentially Feasible Options:

7.3.1 Composting Toilets
7.3.2 Constructed Wetlands
7.3.3 Mound Drain field

When treating wastewater there are usually two main processes: primary treatment and secondary treatment. Primary treatment removes the solids from the wastewater. This reduces the initial Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS). Secondary treatment further reduces BOD and TSS in the wastewater by filtration and biological activity. The most common form of primary treatment in the U.S.

and Bolivia is a septic tank (see Figure 21). The options, except for the Imhoff septic tank and composting toilets, utilize a traditional septic tank in their system.

Traditional septic tanks include an inlet, settling zone, and outlet. Most also include baffles (to allow for additional settling, chamber separation and less water turbulence). They often have a length-to-width ratio of 2-1 and can vary in water depth from less than 4 feet to more than 8. They allow for primary treatment of wastewater and removal of TSS and BOD. Septic tanks collect solids on the bottom which needs to be removed periodically.

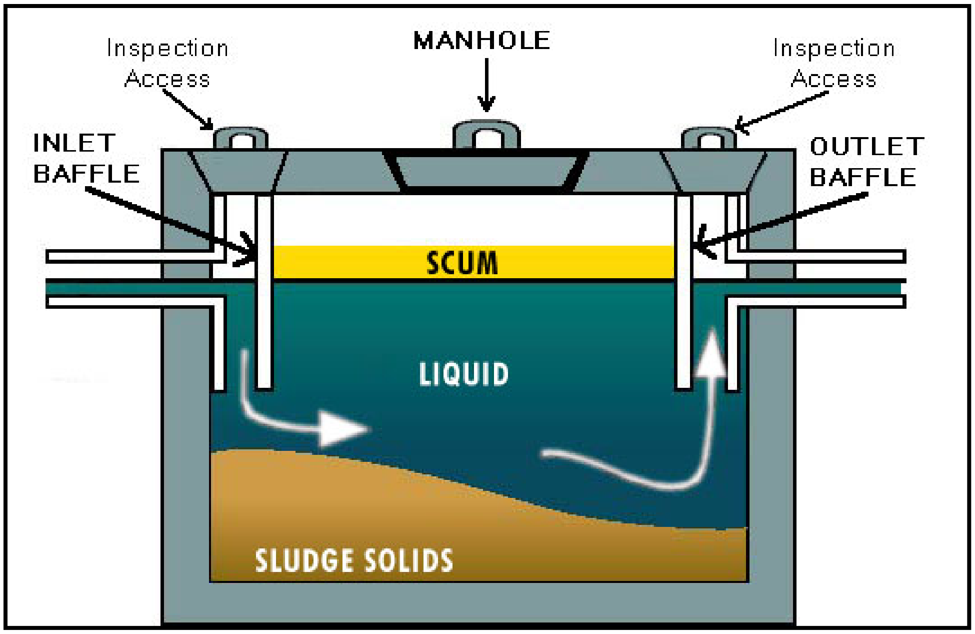


Figure 21: Traditional Septic Tank

There are varied options for secondary treatment including drain fields or wetlands. The secondary treatment system (or the non-septic tank composting toilet system) needed to be compatible with the constraints at the police station site. Constraints include available area, soil and groundwater depth, financial, maintenance, technical, time and social. These constraints were described in the existing conditions section.

7.1 Site and Location Constraints:

- Available area: 1,096 square meters available behind building plus small area in front of building that is already large enough to contain a septic tank and pozo ciego
- Soil: USDA Medium Sand that accepts 0.7 gallons per ft^2 per day
- Groundwater depth: soil boring data coupled with information from locals indicates a seasonally variable groundwater depth of 1.0 to 1.5 meters
- Financial: Funds are dispersed from the city of Santa Cruz to sub-districts. The National Police Station wastewater treatment system is considered one of the highest priority infrastructural project in District 12
- Maintenance: Goal is to choose a system that will not require frequent maintenance
- Technical: Engineer a system that adequately treats the station's wastewater effluent without being overly engineered
- Time: It is estimated that the station will be connected to a sewer system within 5-10 years. The challenge presented is to produce a system that will become effective quickly and not become an eyesore or hazard when decommissioned
- Social: The selected system should be accepted by the personnel and others associated with the station

S.D. Engineering researched various wastewater treatment systems and eliminated eight initially, but researched four other options further. Designs are discussed below.

7.2 Not Feasible Options:

7.2.1 Pozo Ciego System

This system is currently being used by the police station; it has not been performing properly and is contributing to the current wastewater problem. The pozo ciego (dry well) wastewater treatment system consists of a septic tank for primary treatment and a pozo ciego for secondary treatment. Although this system has not been functioning at the police station and is seeping wastewater into the groundwater table and surface, this system can function in other applications. This system is familiar to the Bolivian people and is used in Bolivia. The constraint that restricts the implementation of dry wells is depth to groundwater table.

Dry wells are constructed of sound material and share a similar appearance with a typical lined drinking well. The primary difference is that a dry well is not meant to retain liquid. Holes are created in the walls of the well allowing the wastewater from the septic tank to seep out into the soil medium that surrounds the well. The system can be entirely underground or have an inspection port atop the well accessible with some soil removal. Variations of pozo ciegos, called galaria filtrante, have laterals of perforated PVC, extending radially from the well. When the wastewater reaches the levels of the laterals it is fed into the surrounding soil medium. The performance of this system depends upon the presence of a low water table and adequate soil medium. Due to the high water table at this site, which varies between 1.0 and 1.5 meters, the wastewater will be unable to percolate through the required 1.2 meters of soil media; therefore this system is not feasible.

7.2.2 Activated Sludge

The activated sludge treatment system employs microorganisms to engage in a process called biological flocculation. These microorganisms, mostly bacteria, consume carbon based matter from the waste and utilize it for cell growth. The byproducts of this process are carbon dioxide and water. It requires aeration, a more complex system, including a pump and additional tubing. This system is not commonly used for decentralized systems in the United States. Disadvantages of this system are its high initial cost, care of operation and maintenance and its unfamiliarity in Bolivia. For these reasons, S.D. Engineering believes this system is not feasible.

7.2.3 Lagoons

Lagoons for the secondary treatment of wastewater can be used effectively. Two lagoons are required. The first is kept under anoxic (anaerobic) conditions while the second is kept aerobic. As the wastewater stream moves through the two lagoons, nutrients, BOD, and pathogens are removed. They are an effective means of secondary wastewater treatment, but will not work with the conditions present at the police station because they require a large area, are aesthetically displeasing, can become a breeding ground for mosquitoes, and have a higher initial cost than other options. Lagoons do provide some advantages however, such as compatibility with high groundwater table and require little maintenance.

Lagoons have been used for industrial wastewater discharge but are not appropriate for a small application. Lagoons would occupy the soccer field and leave no possibility for other land use. Even if lagoons did not occupy the entire field, it could not be used for soccer or any other activities requiring large areas of open space. The Cancha (hard-surface soccer court) nearby would also become a less favorable area to play soccer. Because lagoons are not contained within structures that prevent access to wastewater, a barrier would need to be constructed to prevent citizens from coming into contact with the untreated wastewater. Children play soccer on the nearby Cancha and it would be undesirable to have an open source of untreated wastewater easily accessible. Lagoons require a clay and sometimes also plastic liner. Having large open lagoons on the site is highly undesirable. For these reasons, S.D. Engineering believes this system is not feasible.

7.2.4 Gravity Drain Field

A gravity drain field utilizes the native soil. Wastewater from a septic tank leaves via gravity into a drain field where microbial biological processes in the soil remove BOD and TSS (Figure 22). Advantages of this system include low construction cost and compatibility with soils found at the site. There are also a few disadvantages to this system; primarily non-compatibility with a high groundwater table.

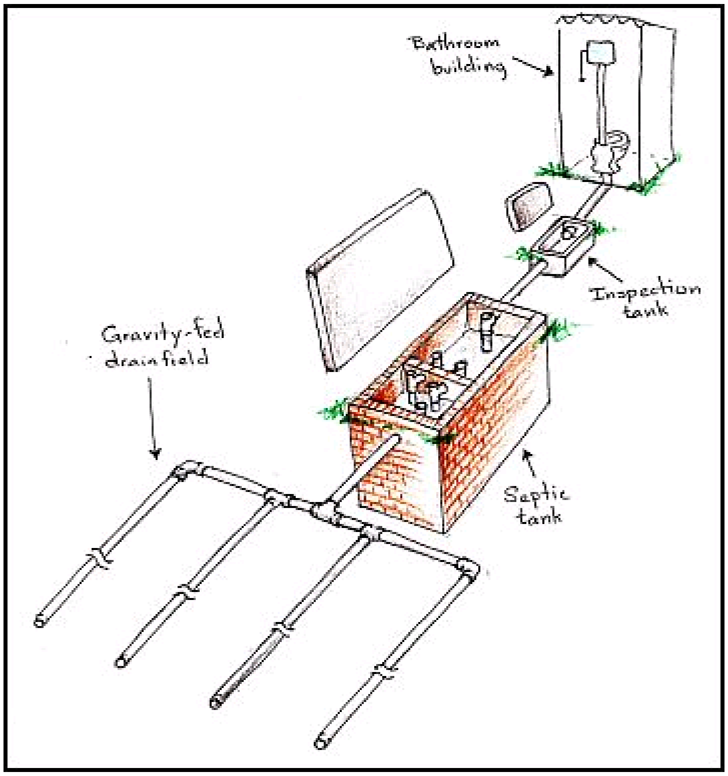


Figure 22: Typical Gravity Drain Field

The groundwater table at the site fluctuates in depth throughout the year from a maximum depth (dry season) of 1.5 meters below ground surface to a minimum depth (rainy season) of 1.0 meters. In order for a gravity drain field to function properly, an elevation difference is required between the distribution box effluent and the laterals for proper treatment. Such an elevation difference does not exist at the police station site. To provide this required elevation difference, the laterals of the drain field would need to be below grade and into the groundwater. This system would not function. The required vertical travel distance for wastewater effluent through soil is 1.2 meters. Even if this required difference in elevation did exist, the distribution laterals are located .5 meters below the ground surface. Therefore, the system would not work in any season and would consistently pollute the groundwater. Due to the high groundwater table at the site and small elevation difference between the front on the building and the soccer field, this option is not feasible.

7.2.5 Pressurized Drain Field

A pressurized drain field treatment system is a common decentralized system in the United States. With the addition of a pump to the gravity drain field system, wastewater from a septic tank is pumped into a drain field. Advantages of this system include low construction cost, and compatibility with soils found at the site. There are also a few disadvantages to this system; primarily non-compatibility with high groundwater table.

Due to the groundwater table conditions at the police station, this system is not an option because a pressurized drain field operates at the existing soil grade. The high groundwater table found at the site will not allow enough depth for the degradation of BOD and elimination of TSS to take place. Without proper depth to the groundwater table the possibility for groundwater contamination from partially treated wastewater effluent is a concern. Effluent discharged to soil requires a minimum soil depth of 1.2 meters for adequate treatment. It necessitates the operation and maintenance costs of running a pump to convey the wastewater from the septic tank to the drain field. A pump would be required to overcome the head loss between the septic tank outlet and the distribution box of the drain field. The soccer field is the only area large enough to hold this system. Because of the distance between the entrance of this system and the outlet of the septic tank, discharge to the soil medium would begin too far underground to allow for enough percolation through unsaturated soil. This system is not feasible.

7.2.6 Dripline Effluent Drain Field

Dripline Effluent Drain field systems use a finger-like pressurized system that branches into different drip compartments. The incoming wastewater stream from the septic tank enters a distribution box before proceeding to branching laterals. These branching laterals (typically made of PVC pipe) distribute wastewater at a typical depth of 0.5 meters beneath the ground surface (see Figure 23). Some of the advantages of such systems are their use of existing soils, and require less excavation. The USDA classified Medium Sand at the site could accommodate this system.

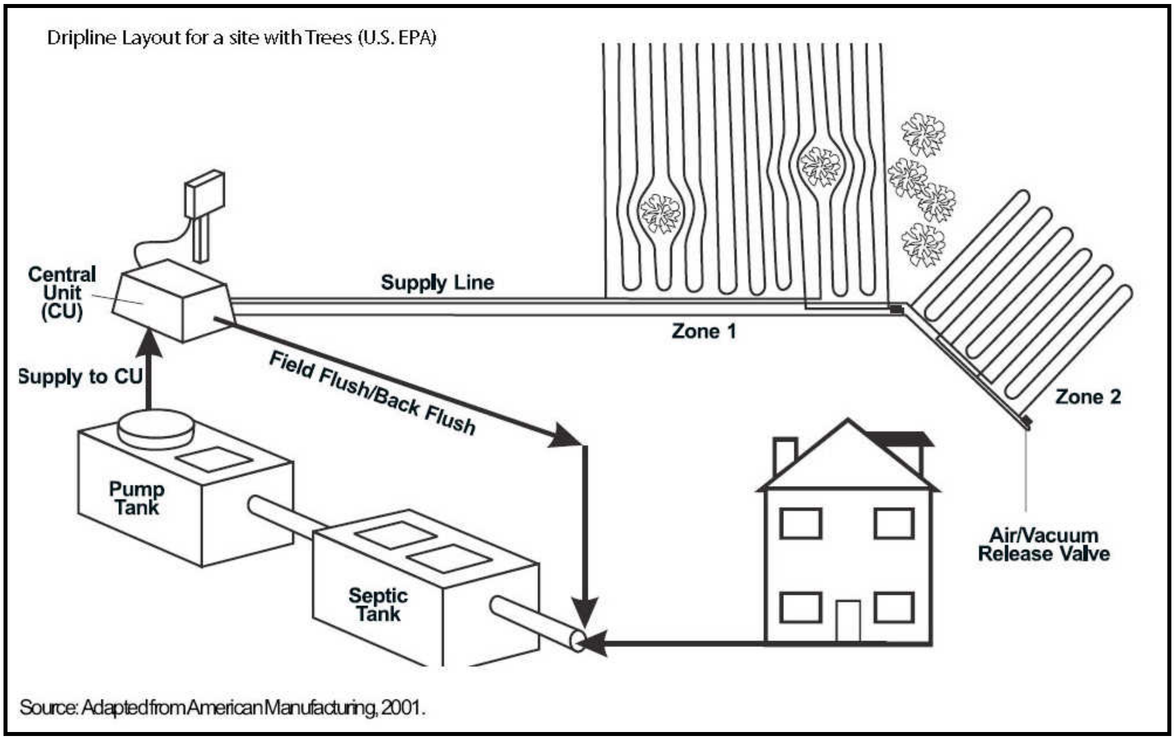


Figure 23: Typical Dripline Effluent Drain Field

This system requires pumps and timers, thus making them a more complex and technical option. Additionally, with groundwater levels encountered at the police station, this option becomes even less favorable. Because the laterals distribute the wastewater stream at 0.5 meters below grade, there would not be sufficient travel depth (minimum of 1.2 meters) for sufficient treatment. Theoretically, the wastewater would need to travel 1.7 meters below ground to become treated. Groundwater table fluctuation has been determined from interviews with locals to be 1.0 to 1.5 meters, depending on the time of year. These depths mean that this system would never fully treat the wastewater and would eliminate groundwater. This design has been deemed not feasible.

7.2.7 Box Sand Filter

Box Sand Filters utilize an isolated sand medium for secondary wastewater treatment. These systems are isolated within a box, allowing the possibility for use at sites where high groundwater tables are a constraint. The box can be topped off with either topsoil and vegetation or an impermeable cover such as concrete. The wastewater arriving from the septic tank is distributed through laterals from within the top of the medium. The effluent then percolates throughout the sand filter, encountering various mediums. The first layer is encountered when the effluent leaves the distribution pipes, which are surrounded by highly-permeable pea rock. It then travels through the thickest layer of the filter, which is sand. The effluent travels next through a second layer of pea rock and then leaves the filter via an underdrain, which is typically pumped to a drain field. If sand filters can achieve such high level of purification, a drain field may not be required, if regulations allow (See Figure 24 below).

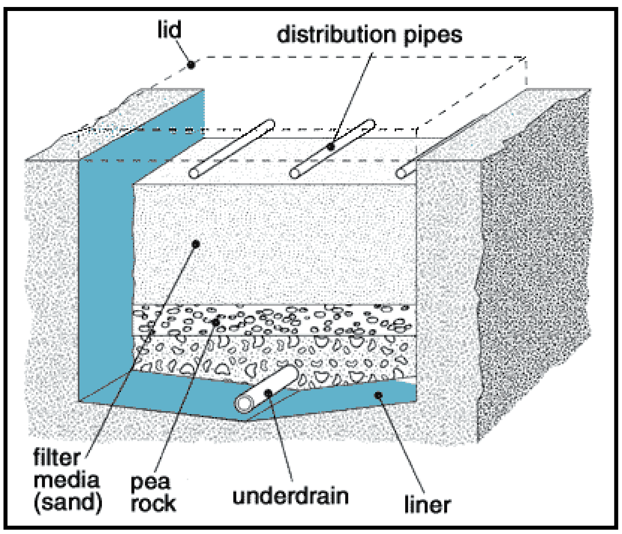


Figure 24: Typical Box Sand Filter

One drawback of sand filters is their unfamiliarity in common wastewater treatment practices. They are frequently utilized for drinking water treatment, but fewer wastewater applications are known. This lack of familiarity, specific construction and material requirements, as well as careful operation and maintenance procedures make this an unfavorable design option.

The cost to obtain sand, pea rock, and liner would be greater than other technically feasible options. From a maintenance perspective, it would be difficult to determine the location of a malfunction in the system due to the multiple layers and underdrain component. The underdrain adds a component not seen in other unconfined systems. This system is also unfamiliar in not only wastewater treatment applications, but Bolivia as well. In order to provide the National Police Station with a reliable, maintainable, and cost-effective system, S.D. Engineering does not recommend this option.

7.2.8 Trickling Filter

Trickling Filters are used for nutrient removal along with a septic tank for primary treatment of wastewater and a drain field or other secondary treatment component. Generally they are used for small communities at wastewater treatment plants, but they can also be used on a smaller scale for individual homes. There are two general differences between trickling filters and box sand filters; flow orientation and construction location. Trickling filters distribute wastewater from the center of a “tower” and allow it to percolate downward and collect in a central drainage area. This differs from a box sand filter, which has a horizontal orientation (flow collects at bottom and moves along bottom through underdrain). With respect to construction location, box sand filters are constructed so that their tops are near the ground level while trickling filters are constructed above ground.

Trickling filters provide aerobic treatment where wastewater flows from a septic tank to a pump tank to the trickling filter and then to a secondary treatment component. It is then either discharged at an outlet or re-circulated back to the septic tank to increase biological growth. The wastewater is sprayed in the trickling filter by a nozzle in order to evenly distribute it across the treatment bed. It then passes through a biofilter media where attached microorganisms remove unwanted bacteria and chemicals from the water, specifically nitrification of ammonia (see Figure 25).

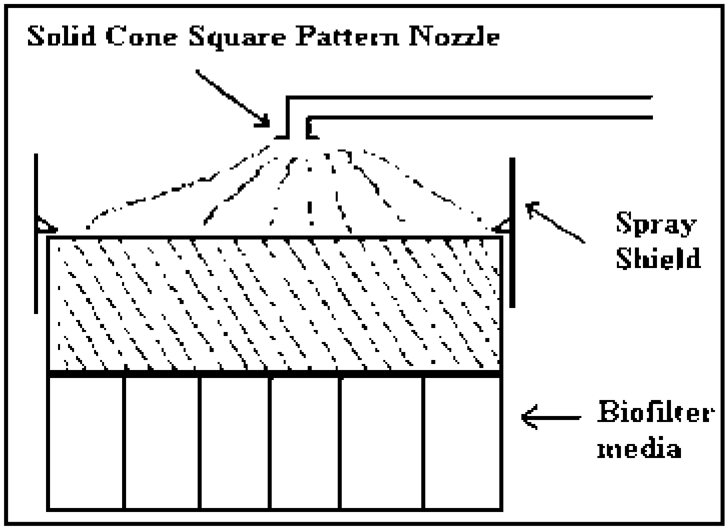


Figure 25: Typical Trickling Filter

Unfortunately, this system does not provide secondary treatment. Trickling filters denitrify wastewater and reduce ammonia the concentration of ammonia. BOD and TSS removal are the main goals of secondary treatment. This system does not have these abilities and will not be further considered as a secondary treatment option.

7.2.9 Imhoff Septic Tank

The Imhoff Septic Tank is a modification of the traditional septic tank. The main difference between this type of tank and the traditional is the sloped lower area (see Figure 26). This sloped area provides a greater solids collection area. It has an established presence in Bolivia and is found in La Norma Boliviana 688. Advantages are that it is technically feasible and because of its established use and presence in Bolivia, it would be socially acceptable.

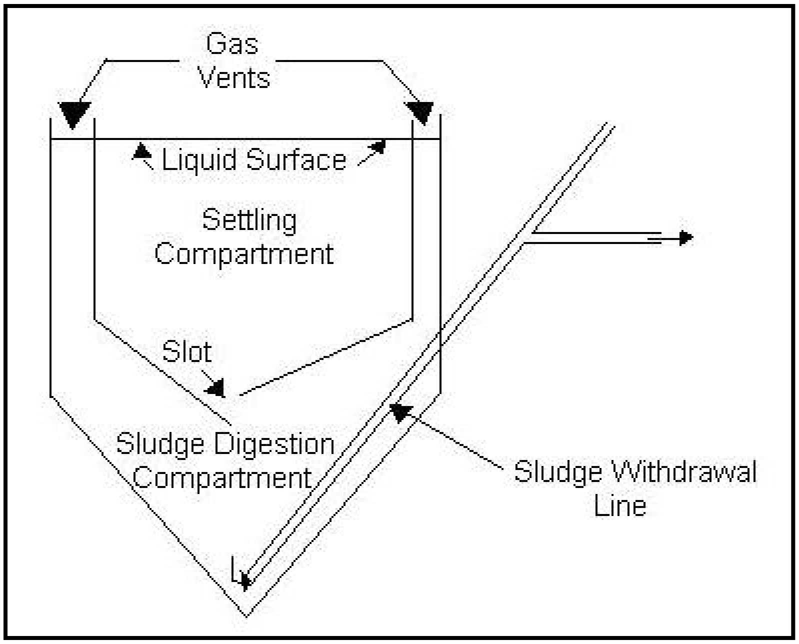


Figure 26: Typical Imhoff Septic Tank

Unfortunately, this system is not as the familiar in the United States. State regulations (Wisconsin and Michigan) do not mention an Imhoff septic tank, making research and determinations about this option difficult. The design of this tank is also more complex than a traditional septic tank, requiring gas ventilation and a “chamber-in-chamber” layout. It also may intercept the groundwater table due to its depth. This system is also marked by a higher initial cost (larger than traditional septic tank).

Consultation with university mentors further reinforced the decision to eliminate this option and to select the traditional septic instead of an Imhoff. Primary treatment will be sufficient using a traditional septic tank. For these reasons, S.D. Engineering does not recommend this option.

7.3 Potentially Feasible Options:

7.3.1 Composting Toilets

Composting toilets differ greatly from most decentralized wastewater treatment systems mainly due to lack of septic tank. The biggest differences are the waste is never fully immersed in water and the system is inside of the building. Because of the lack of water, it is important that the ventilation system be properly maintained to avoid odor problems. Composting toilets have traditionally been installed at campgrounds, parks, public facilities, rural areas of Bolivia and other remote locations. The secondary treatment that takes places in the composter component of the system is performed by aerobic bacteria and fungi (Figure 27). Composting toilets can reduce the volume of waste to 10 to 30% of its original volume. This reduced waste material (called "humus") must then be used as organic fertilizer or removed by a septic hauler. The exhaust fan in Figure 27 is only a recommendation, not necessary.

Advantages:

- Requires no water
- Reduce volume of waste to 10 – 30% its original size
- Functional at remote sites
- Effectively prevent pathogens and nutrients from reaching soil
- Low power consumption (if fan is used)
- Low cost in outdoor applications

Disadvantages:

- Extensive management required to ensure sustained performance
- Indoor installation in present building would require toilet room reconstruction and be cost-prohibitive

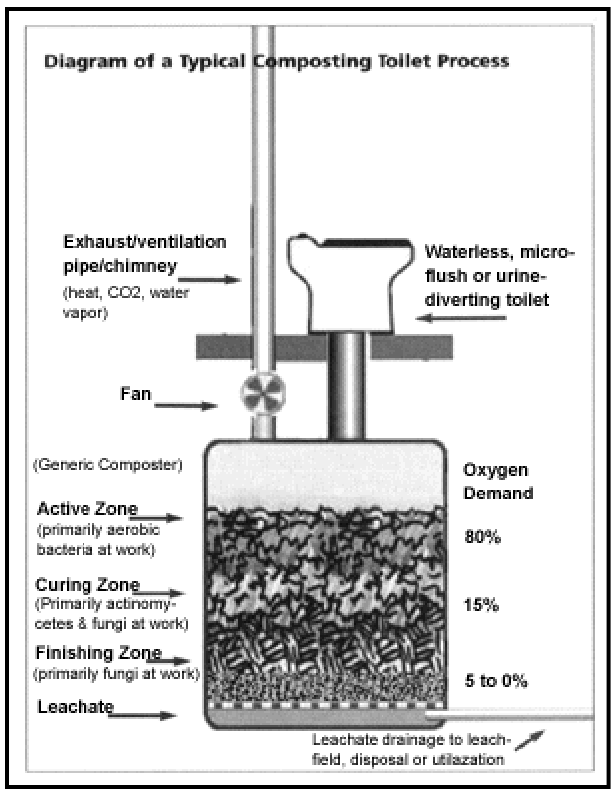


Figure 27: Typical Composting Toilet

- Social acceptance of a non-flush toilet
- Outdoor installation could have social acceptance concerns

An interesting challenge presented by this system is selecting how many to construct. If the police station were to construct composting toilets outside, it would be relatively easy to construct many at a cost less than those of other systems discussed in this section. On the other hand, if multiple composting toilets were constructed inside of the station, the cost of structural and building alterations would be infeasible. Although this option for outdoor use is technically feasible, it is infeasible for indoor use. Social, financial, and technical constraints are the most significant negative factors.

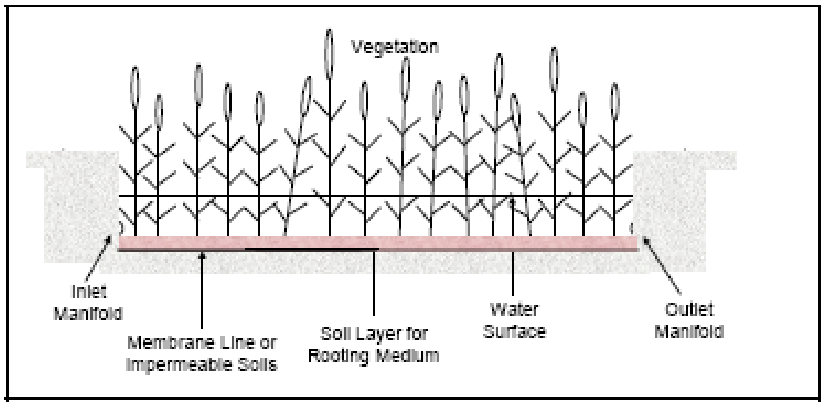
After considering the various advantages and disadvantages of composting toilets, S.D. Engineering does not recommend the use of this system. Although advantages such as no water requirements are of great benefit, they do not outweigh the greater problems of toilet room reconstruction, financial constraints, and social acceptance.

7.3.2 Constructed Wetlands

Constructed wetlands are systems that are typically comprised of one or two shallow basins that support some form of vegetative growth (e.g. moss, grasses, cattail, etc.) and aerobic bacterial activity. The bottoms of these basins are typically lined in order to prevent groundwater seepage of under-treated wastewater (see Figure 28). Constructed wetlands can provide adequate secondary treatment of wastewater, adhering to standards required for groundwater or subsurface effluent discharge. In addition to the necessity of wastewater treatment, constructed wetlands can provide new habitat for wildlife and an attractive “green space” for nearby residents. Numerous advantages make constructed wetlands a good choice for certain treatment applications. However, disadvantages exist such as the large space requirements and the post-construction duration in which the wetland needs to reach secondary treatment levels.

Advantages:

- Effective secondary treatment of wastewater
- Provides aesthetically pleasing “green space”
- Applicable to a wide variety of climates
- Require little maintenance, power, and mechanical equipment



Source: Adapted from drawing by S.C. Reed, 2000.

Figure 28: Layout of Constructed Wetlands

Disadvantages:

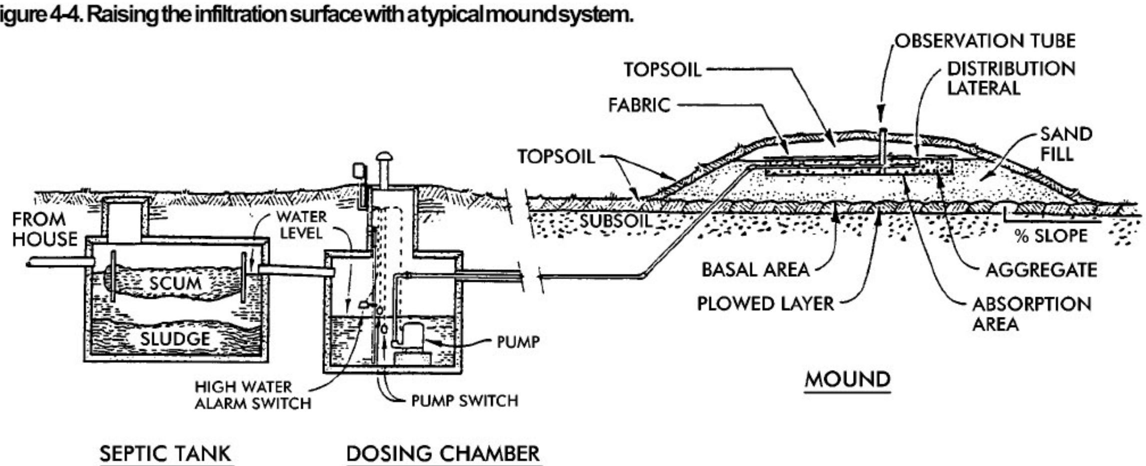
- May take years (up to five) for wetland to become an effective secondary treatment component
- Input of garbage or pollutants can decrease the system’s treatment efficiency
- Residual metals and persistent organics become trapped in the sediments over time, making the wetland toxic to wildlife
- Standing water can become breeding grounds for mosquitoes carrying infectious diseases
- May not lower fecal coliform concentrations to required standards

Constructed wetlands for the use of secondary wastewater treatment can be very effective for some applications. Although natural flowing wetlands exist within 2 blocks of the police station, the time required for the wetland to become an effective form of treatment, make this option unattractive. Since the Police Station is to be connected to a centralized sewer system within 5-10 years, this option is not feasible.

7.3.3 Mound Drain field

A mound drain field works on the same principles as the above mentioned pressure, gravity, and drip line effluent systems; however it is compatible with high groundwater tables. A mound drain field is an elevated drain field that uses a traditional septic tank, distribution box, laterals, a pump, and additional soil media for the secondary treatment and biological processes (see Figure 29). The wastewater effluent first enters the septic tank and removes a portion of the TSS and BOD. Effluent enters the dosing chamber where it is intermittently pumped into the distribution box in the mound. The intermittent pumping method (6 to 12 doses per day) rather than a continuous pumping method is desirable because it allows the mound to aerate. Aeration of the mound is required in order to sustain aerobic conditions in the mound. An aerated mound is preferred to an anaerobic mound because microbes that thrive in aerobic conditions are more effective than anaerobic ones. If the mound was kept under anoxic conditions it would need to be made higher so that the less-efficient anaerobic microbes would be able to sufficiently treat the waste stream.

Figure 4-4. Raising the infiltration surface with a typical mound system.



Source: ASAE, Converse and Tyler, 1998b.

Figure 29: Typical Mound Drain Field

A submergible pump at the bottom of the dosing tank will pump the primarily treated wastewater to the distribution box in the mound. The distribution box becomes pressurized by the pumped wastewater. Laterals connected to the distribution box will evenly distribute the wastewater atop the sand fill. The effluent undergoes secondary biological treatment upon reaching the base of the mound. Ideally, microbial colonies in the mound will reduce the levels of BOD and TSS in the wastewater to levels conforming to Bolivian regulations.

Advantages:

- Compatible with high groundwater table conditions
- Effectively removes BOD and TSS from septic tank effluent
- No odor problems
- System becomes effective more quickly than constructed wetlands
- Relatively simple construction compared to trickling filter or indoor composting toilets
- Can handle large wastewater flows
- Will fit within property constraints at police station site

Disadvantages:

- Land footprint of field dependent on permeability of sand medium
- Dosing tank required
- Pump required to move dosing tank wastewater to mound
- Specific sand media required for effective secondary treatment

The greatest advantage of using this system over other drain fields is its compatibility with the groundwater table at the police station site. For adequate secondary treatment through a drain field the wastewater must pass through a minimum of 1.2 meters of sand medium. A quick calculation reveals that if the groundwater table were at a conservative depth of 1.0 meters, the height of the distribution laterals above the existing ground surface could theoretically be in place 0.72 meters above the ground. S.D. Engineering considers this to be a feasible option open for further consideration.

In summary, S.D. Engineering determined one wastewater treatment option that is feasible to resolve the wastewater problems at the National Police Station in District 12: a mound drain field.

8. Storm Water Design Options

While in Bolivia, S.D. Engineering inspected many storm drains at the police station site and found them approximately half full during the dry season. Even though three days with heavy rains had occurred in the 2-3 weeks before the inspection, Sargento Freddy Chambi Ygnacio stated that during the rainy season areas around the police station building become flooded.

All storm water from the roof of the police station is collected and drained to ground level through pipes inside the building walls. In the front of the building this storm water is then drained out to Avenida Fatima I. This road is currently being paved and drainage structures are being installed. Storm water in the front of the building can continue to be drained out to the road into the canal.

In the back of the building, the storm water from the roof is drained through pipes in the building walls and exits underground past the edge of the current concrete pad. The soil becomes saturated quickly due to the high water table and the soccer field behind the building floods. Additionally, if a wastewater treatment design was constructed on the soccer field behind the building, there would be the possibility for more flooding on the concrete pad due to runoff. S.D. Engineering researched options for alleviating the extra storm water.

A drainage ditch exists to the northeast side of the police station and is shown in Figure 30 below. Both designs investigated by S.D. Engineering allow for the storm water from the back of the building to drain to this canal and then into a larger canal being constructed along Avenida Fatima I. A portion of the concrete pad behind the building would have to be demolished during construction. Piping would be placed along the concrete pad to the drainage canal and connections from the roof drains would be made to this larger storm drain piping. Inlet structures would have to be installed into the piping network before the concrete is replaced. Two design options for the drainage structures were further researched; trench grates and catch basins.

Figure 30: Existing Drainage Canal

8.1 Trench Grate

A trench grate consists of a long, narrow piece of metal that has holes throughout it for the storm water to drain through (see Figure 31). This would be placed parallel to the police building, in the back along the length of the concrete pad. It provides a good interceptor for large quantities of water and possible slip resistance during wet weather conditions. However, a trench grate requires a large amount of metal and is therefore more expensive to construct. It also can clog easily and is harder to keep clear of debris due to its larger size. For these reasons, S.D. Engineering does not recommend this option.

Figure 31: Trench Gate

8.2 Catch Basin

A catch basin is similar to a trench grate, however is smaller in size (Figure 32). For this reason, they are cheaper to construct and easier to maintain than trench grates. Each catch basin can only handle a certain amount of water, so they are typically constructed every 10-15 meters along a project site. The concrete pad behind the police station is approximately 40 meters in length, requiring a total of three catch basins. S.D Engineering considers this design option to be feasible.

Figure 32: Catch Basin

9. Final Recommendation and Conclusion

9.1 Design Recommendations

S.D. Engineering has considered the potential solutions to the wastewater and storm water problem at the National Police Station in District 12. As outlined above, this study and design is based on site investigation, as well as information supplied by personnel at the District 12 station. Assumptions were made based on this data in order to work towards a design proposal. Any variation in this information or data will require review and adjustment of the proposed design outlined in this report. Based on S.D. Engineering's understanding of the needs and growth of the police station, and the pros and cons of each option studied, S.D. Engineering recommends the implementation of a wastewater system containing a septic tank, dosing tank, and mound drain field in the soccer field adjacent to the police station property.

To improve the storm water system, S.D. Engineering recommends installation of a storm sewer with catch basins (in the rear of the building) and provision of roof drain connections to the storm pipe. System selection was based on the following factors:

- Available construction area
- Soil type
- Financial constraints
- System performance
- Time required for system to become effective
- Social acceptance
- Use of soccer field after installation
- Maintenance level
- Wastewater flow quantity

9.1.1 Wastewater Treatment Design

Construction of the mound drain field atop the soccer field is necessary due to space constraints for this component. Factors that needed to be considered with respect to construction location were land availability, soil permeability, groundwater table height, and field use. The mound system does not restrict the area's use as a soccer field and can be utilized as such, as long as the seeding and growth of grassy vegetation is successful. Consideration of the force of soccer playing on the mound and its components will not affect the mound system or components.

S.D. Engineering has proposed construction of this system in the area of the soccer field based on information describing the land as city property and its use as designated by the district. Since the wastewater treatment situation at the police station is considered high priority for the district, S.D. Engineering believes that construction on this property is warranted (pending proper verification from city officials). It is important that the legality of this construction is approved by the appropriate city and/or government officials prior to construction.

Conclusions drawn on the soil type at the National Police Station were based on only one soil boring. This soil boring was taken at a location in the soccer field where it was believed the most representative sample could be taken. S.D. Engineering realizes that a single sample may not reach the desired level of accuracy. A more thorough determination of the soil properties by a professional should be performed prior to beginning construction. One suggestion may entail collecting more samples in the area of the proposed mound construction. This would allow a better determination of whether or not the selected sand medium in the mound would be hydraulically compatible with the soil below. If such an analysis showed a significant difference from the single sample taken by S.D. Engineering, review of and appropriate changes may need to be made to the design.

S.D. Engineering recommends a design that will treat the wastewater from the National Police Station through a mound drain field system. This system will collect wastewater effluent from the front of the building and send it through the proposed system. It is believed that the treated wastewater will conform to U.S. and Bolivian standards for BOD and TSS. This system will also utilize the existing septic tank in the front of the police station site. The proposed system will consist of the following main components:

- Existing septic tank: connection to septic tank from building discharge will be utilized in initial treatment, which will reduce cost. Tee-filters will be installed or inlet and outlet to improve solids removal.
- Proposed second tank: dual-chamber settling and dosing tank: existing tank will not provide sufficient volume to obtain required 24 hour retention time. The new tank will contain two compartments and inlet/outlets will have tee-filters. The first chamber will be large and accommodate settling of solids (in combination with the existing tank).
- Dosing chamber: dosing compartment is designed to be second partition of the proposed dual chamber tank and will have a submersible pump for transport of wastewater to the distribution valve and mound drain field.
- Mound drain field: The elevated drain field provides effective distance and treatment separation from the groundwater table. Effluent enters distribution valve and travels through laterals for pressurized and balanced distribution to the drain field.

Components were sized to the design wastewater flow of 4,600 gallons per day. The existing wastewater (WW) pipe exits from the front of the building (north of the sidewalk) and turns 90-degrees, as it passes through an inspection basin. It travels south, under the sidewalk and enters the existing septic tank. This tank was integrated into the existing design to reduce costs. After exiting, the WW travels to the proposed dual-chamber septic/dosing tank. This tank is required in order to treat the effluent before sending it to the drain field. If only the existing septic tank is used, solids will be sent to the drain field. The performance as well as the life of the field will be compromised or worse, it will fail. The dual-chambered tank has two purposes; the first compartment is larger than the second (13.46 cubic meters; 3,556 gallons) and completes the process of settlement and initial biological treatment. The initial section has a length to width ratio of about three to one, which will provide for better settlement and limit the chance for solids passing to the dosing chamber.

Both compartments are also equipped with filters in the form of a vertical tee with a pipe extending downward into the center third (depth) of the tank (Figure 33). By only transporting effluent from the middle area of the tank, the filter diverts the majority of solids which haven't settled, as well as any scum and grease which is normally near the surface of the liquid. This design will protect both the pump and the drain field and increase the longevity of both.

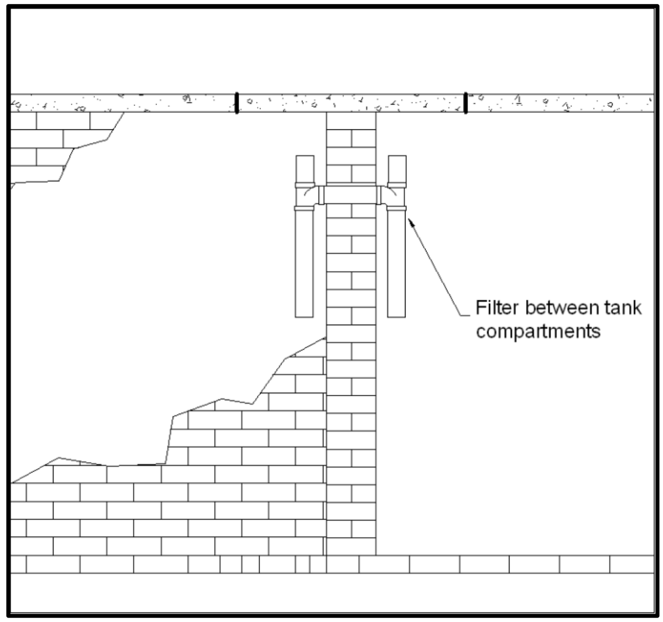


Figure 33: Tee-Filters

The second compartment of this tank is separated by a brick wall with two filters. This is where the pump is housed; the dosing chamber. Effluent will accumulate until the volume reaches a specific amount, when the pump will activate by means of a float switch. The pump will turn off when then the liquid level reaches a designated level. In the event of pump failure, an alarm will activate when the liquid rises 30.5 cm (1 foot) above the pump on level. The dosing tank is sized to accommodate approximately 8 hours of flow in this or a similar situation (i.e. the maximum amount of time allowed to replace or fix the pump). The proposed tank is also equipped with access lids over both compartments, where the fittings and pump can be reached for maintenance.

The wastewater is pumped to the drain field in the rear of the building, where it will be dosed to the mound over areas of the soccer field. The mound consists of different soil materials including sand fill, filter media, and top soil. The purpose of each component is as follows:

- Sand fill raises the pressure distribution system to ensure a greater level of treatment and provides distance from the groundwater table. Treatment also takes place in the fill material as the effluent travels to the existing ground.

- Filter media contains the distribution laterals and is where wastewater enters the mound (i.e. the filter media and the distribution laterals make up the distribution cell). This material treats the wastewater and its hydraulic characteristics allow the effluent to enter the fill.
- The top soil provides a fertile layer for plant growth. This layer is of equal importance as it protects the distribution cell from problems to due to erosion and particle migration.

The pressurized mound system promotes even distribution of wastewater over the area while providing consistent soil conditions in the mound itself (i.e. above the in-situ soil). The drain field is partitioned into six components, each consisting of six sets of laterals. In addition to the indexing (distribution) valve, lateral sets (versus one large field of laterals) reduces the size of the pump and associated piping (see Figure 34). The indexing valve is also important for increasing the lifespan of the drain field. It facilitates dose rotation to each component throughout the day, which allows aeration and avoids overloading of the filter media. At the design flow rate, it is estimated that the drain field will receive a total of 10 doses per day; 2 doses per component (at maximum allowed flow rate).

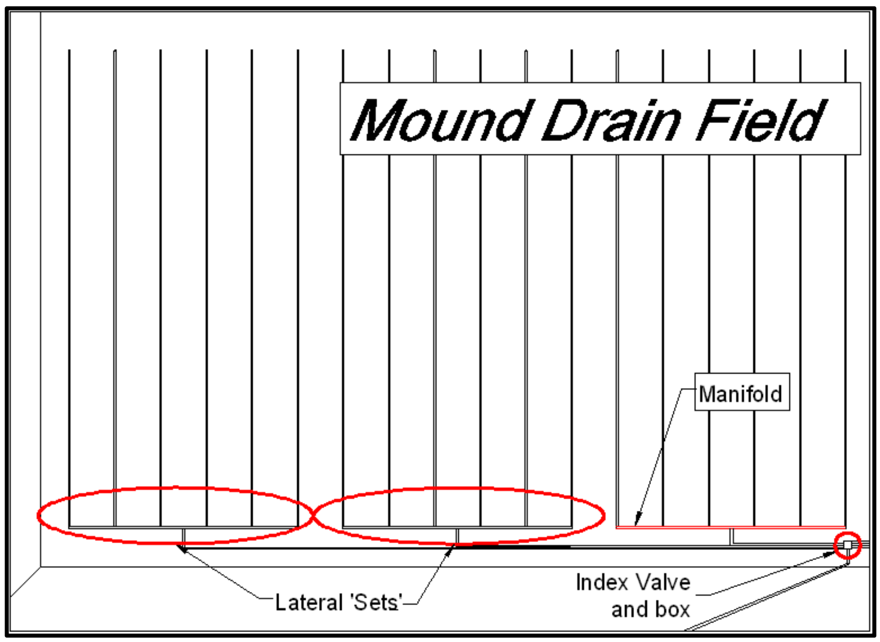


Figure 34: Drain Field Diagram

As noted previously, the mound area can be utilized for some recreational activities. Soccer, running, and other human exercises are appropriate as long as the mound vegetation remains healthy, the mound surface remains fairly level (i.e. no major settlement or erosion), and no ponding of water exists on the surface. The soccer goal posts can also be replaced at the edge of each end of the mound approximately 2 feet away from the edge of the distribution cell. The mound area is limited to human activities. No vehicles or machinery should operate on mound or side slopes under any circumstance. If vehicle or machine traffic takes place on the mound, this activity will compromise the treatment capability and integrity of the mound system. S.D. Engineering recommends signage and education to inform the public of this condition. If further measures are needed to protect the mound, one option is to install bollards around the perimeter of the mound. The cost estimate and documents supplied with this study include signage only.

Regular maintenance and checks of the system components are important in maximizing the longevity and effectiveness of the system. Regular maintenance items should include:

- Weekly (minimum) checks on the dosing tank/pump, condition of electrical components/alarm, drainage field cleanouts, and indoor toilet and shower utilities. Maintain these utilities when necessary.
- Weekly monitoring of mound area to examine condition of vegetation and identify any potential problems (e.g. ponding on surface, settlement of areas, etc).
- Monthly checks of the dose frequency, dose rate and dose volume.
- Monthly checks of lateral clean-outs. Clean-outs should be flushed with water every 6 months to ensure proper operation.
- Monthly checks on both of the septic tanks for sludge accumulation.
- Annual removal of solids from the septic tank by a qualified professional
- Vegetation on top of the mound should be maintained. Reseeding in areas should take place annually and as needed. All activity should be limited to an intensity that will not compromise the fidelity of the vegetation, as it is crucial to the performance of the mound. The health of those using the mound area for recreational activity may also be threatened if the surface suffers from sediment erosion.

9.1.2 Storm Water Collection Improvements

S.D. Engineering also considered storm water improvements at the National Police Station. Current conditions were considered with respect to affects on the proposed wastewater treatment system. Recommendations are outlined below.

Storm water infrastructure is considered important with respect to the operation of the mound drain field. Recommended construction includes storm sewer installation behind the building in the vicinity of the mound, as well as the addition of catch basins to collect storm runoff. Roof drains which currently terminate underground will be connected to the proposed storm sewer piping and routed to an adjacent storm drain catch basin, thereby eliminating ground saturation behind the building. From the catch basin, water will be transported parallel to the building (to the north), where it will outfall into an existing drainage ditch. The ditch currently empties to drainage along Avenida Fatima I. After the construction of the Fatima I road and canal, the storm water from the Police Station will be directed to an inlet structure in the form of a manhole grate along the center line of Fatima I. These storm manholes are designed to drop directly to underground storm water pipes which will carry water to the existing Nuevo Palmar canal (refer to the May 2008 ISD report entitled "Avenida Fatima I Design Report" by Cinco Cero Engineering; Project Manager Kari Klaboe). Interception of this extra water will be especially critical during the rainy season, when the ground is partially saturated and becomes problematic in and around the building. It is also worthy to note that reducing the amount of groundwater infiltration is only a benefit to the performance of the mound treatment system (since there is an already high groundwater table).

9.1.3 Benefits and Costs

S.D. Engineering recognizes several benefits for District 12 and the police station personnel upon implementation of this design. The recommendation outlined above will alleviate the wastewater treatment issues at the station. Overflow of septic water in front of the station will no longer be a problem, thereby eliminating odor and potential health concerns for both station personnel and public citizens in the vicinity of the police station. Social benefits exist due to this, not only from the general health of people, but more tangibly in missed days of work and the cost of treating illnesses.

S.D. Engineering distinguishes the health risks specifically to children who play in the area or pass by the police station. Children are more susceptible to health problems associated with fecal coliform bacteria and should be protected from this danger. Removing the overflow of septic water also stops environmental degradation of the soils around the station, in the Nuevo Palmar canal waters, and especially the groundwater. Wastewater infiltration into the groundwater table is a concern with the existing system, but will be absolved with the implementation of the proposed tank and pressurized mound system. This is an obvious benefit and improvement to the police station and the environment.

The storm water collection improvements will not only alleviate flooding, but stop the spread of septic water in combination with the proposed treatment system. Excess storm water on site during the rainy season will be reduced and will be routed to runoff infrastructure. Health concerns associated with insects like mosquitoes will also be controlled (e.g. malaria, dengue fever, etc.) due to the prevention of standing storm water.

Lastly, implementation of these recommendations will enhance the general image of the District 12 National Police Station. Employees and local citizens will take pride in a station facility which is in pristine operating condition and appearance, and which is functioning to serve the general public in various capacities.

S.D. Engineering projects the cost of this construction to be approximately $b 135,000 (US $19,000). This estimate includes work needed to refurbish or update existing utilities which will be included in the proposed design. The recommended design is estimated to take approximately 68 days from start to finish. S.D. Engineering recommends the construction of this design during the dry season. The cost estimate and schedule are based on this assumption and deviation from this recommendation could incur longer construction time and unexpected costs. Both the estimate and schedule were prepared based on common practices and costs and should be verified by a Bolivian professional engineer before advertisement of the work takes place.

9.2 Future Recommendation

This design considers the estimated changes in the load size of the wastewater effluent as well as the anticipated connection to a sanitary sewer system in 5 to 10 years. S.D. Engineering favors the connection to a sanitary sewer system as a permanent long-term solution to the treatment of wastewater generated by the District 12 National Police Station. However this option is not currently available – hence the reason for this study and design. S.D. Engineering considers the pressurized mound design outlined in this report to improve the wastewater treatment system at the District 12 National Police station.

9.3 Conclusion

S.D. Engineering acknowledges the importance of this project within District 12 as well its importance for parties affected by the non-functioning system at the police station. This project has been considered a high-priority infrastructure improvement in the district as deemed by its officials. S.D. Engineering has considered many factors in its selection and design of a wastewater treatment system that meets the needs of the District 12 National Police Station, as well as alleviating storm water flooding. Some such factors include technical, social, economic, and environmental considerations. Based on this study and design, S.D. Engineering concludes these design recommendations to be an improvement to its benefactors and an advantageous development until sanitary sewer can be installed.