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Subdrainage system composed of draining tanks at the SIMA Callao-Peru shipyard.

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ABSTRACT
In 2015, Industrial Services of the Navy (SIMA) began to execute the work “Expansion and improvement of the services of the Naval Arsenal of the Navy of Peru – Phase 1A”, located in the naval base of Callao. The planned area where the construction of the shipyard, had water outcrops due to proximity of the water table to the surface, mainly due to the influence of Rimac River and during the high tide season. As a result, the soil became saturated, lost its resistance to shear and became an inadequate material for the foundation. On the other hand, the capillary effect caused the rise of water, the foundations of the different structures were moisten, and the steel corrosion is generate. In this context, the use of draining tanks as a subdrainage system was adopt in order to deplete water table and evacuate the captured flow towards the Pacific Ocean. The draining tanks allow transmitting the loads of the pavement to the ground without suffering deformations that impair its operation. In addition, these have an optimum hydraulic capacity to drive water. The methodology consisted in performing a groundwater modeling using Slide V.6.0 software of the Rocscience group in its Steady State Finite Element Analysis module in order to evaluate the amount of filtration that will enter the system due to the existing maximum phreatic level (high tide condition). According to the results, the solution alternative consisted in the use of double polypropylene drainage tanks, organized in an “L” shape, and compressive strength of 22 tons/m2. In summary, the application of the draining tanks in the project has allowed capturing, driving and evacuating the water collected in previously defined places. A greater drawdown of the existing groundwater levels was achieved, the reduction of the pore pressure and therefore a greater resistance to the compression of the soil.

Keywords: groundwater drawdown, water table, draining tanks, subdrainage system.

RESUMEN
En el año 2015, Servicios Industriales de la Marina (SIMA) empezó a ejecutar la obra “Ampliación y mejoramiento de los servicios del Arsenal Naval de la Marina de Guerra del Perú – Fase 1A”, ubicada en la base naval del Callao. El área donde se proyectaba la construcción del astillero presentaba afloramientos de agua debido a la cercanía del nivel freático a la superficie, principalmente por la influencia del río Rímac y la etapa de marea alta. En consecuencia, el suelo se saturaba, perdía su resistencia al corte y se convertía en un material inadecuado para la cimentación. Por otro lado, el efecto de capilaridad ocasionaba que el agua ascienda, humedezca los cimientos de las diferentes estructuras y permita la corrosión del acero. En ese contexto, se optó por la utilización tanques drenantes como sistema de subdrenaje con la finalidad de abatir la napa freática y evacuar el flujo captado hacia el Océano Pacífico. Los tanques drenantes permiten transmitir las cargas del pavimento superior al suelo sin sufrir deformaciones que perjudiquen su funcionamiento. Además poseen una óptima capacidad hidráulica para conducir el agua. La metodología consistió en realizar un modelamiento de aguas subterráneas usando el software Slide V.6.0 del grupo Rocscience en su módulo de Steady State Finite Element Analysis con el objetivo de evaluar la cantidad de filtración que ingresará al sistema debido al nivel freático máximo existente (condición marea alta). De acuerdo con los resultados, la alternativa de solución consistió en el uso de tanques drenantes de polipropileno dobles con sección en forma de “L” y resistencia a la compresión de 22 ton/m2. En resumen, la aplicación de los tanques drenantes en el proyecto ha permitido captar, conducir y evacuar el agua recolectada en lugares o zonas previamente definidos. Se ha logrado un mayor abatimiento de los niveles freáticos existentes, la disminución de la presión de poros y por ende una mayor resistencia a la compresión del suelo.

Palabras claves: abatimiento, nivel freático, tanques drenantes, subdrenaje.

1. INTRODUCTION

It is very common to find in the stage of earthworks with subsurface water outcrops in a given project. In these situations, it is very important to know and evaluate the interaction of these outcrops with the project work. Therefore, obtaining better working conditions in a work under the influence of the water table translates into the choice of the best solution for lowering the water table (Ferrer & Cassiraga, 2010).

On the other hand, underground drainage or sub-drainage techniques are one of the most effective methods for stabilization against landslides. In addition, this drainage intended to reduce pore pressure and prevent them from increasing. According to Suarez (2001), the lower pore pressure greater soil resistance.

Subdrainage techniques integrate a system, placed inside the ground that aims to manage groundwater through permeable elements or structures. This system seeks to capture, drive and evacuate collected water in previously defined places or areas (Holtz, Christopher & Berg, 1998). One of the most recent and innovative systems on the market that fulfill this purpose are the 52FC drainage tanks (Figure 1). These systems integrate a set of lightweight structural components, developed with the purpose of providing necessary stability to the load support tank, in addition to presenting optimum hydraulic capacity to transport water.

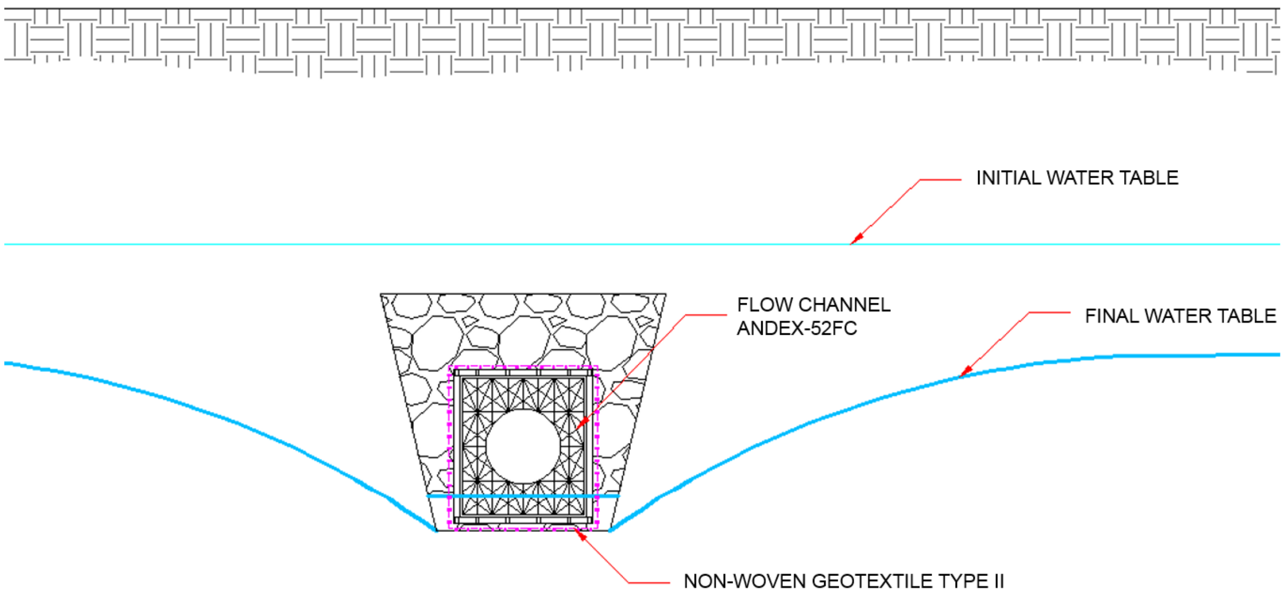

Figure 1: Groundwater drawdown by draining tanks.

These systems are made of black polypropylene, coated with nonwoven geotextile. The standard dimension of the system is 408x685x450 mm, with 95% of voids. The system is characterized by working as an optimized subdrainage system. It allows the filtration and conduction of water from the water table or existing filtrations, in order to lower its level.

For the area of application of the project, high water tables were witnessed, mainly generated by high tides and the presence of the mouth of the Rimac River. This effect generated the presence of saturated soils and little resistant to shear stress that would subsequently affect the foundation. In that context, the 52FC drainage tank system was applied in order to reduce the high water table in the area where the construction of the shipyard was planned. The proposed solution involved an analysis of the underground behavior of the water table with the application of the draining tank system and its subsequent application in the study area.

2. STUDY AREA AND METHODS

2.1 Study area

The study area is located in the naval base of Callao, central coast of Peru. This area is at an approximate level between 2 and 3 meters above sea level (Figure 2). According to the study of SIMA (2014), the project area is within the limits of the influence of the dejective cone of the quaternary corresponding to the Rimac River and some sectors of the Chillon River. In addition, the deposits of alluvial fluvial origin are composed of boulders, sand, clays and silt, of different thickness, which alternate in a heterogeneous manner. On the other hand, according to the study “Evaluation of water resources in the Rimac River basin” (ANA, 2010), the total annual rainfall recorded at the International Airport Weather Station is 10.3 mm. This value denotes the desert characteristic of the project area.

Figure 2: Location of the study area: SIMA CALLAO, PERU.

Initially, due to the high groundwater levels produced during the high tide stage and times of increased flow of the Rimac River, water outcrops were generate on the surface where the construction of the shipyard was projected. This condition affected the foundation due to the soil become saturated and its resistance to cutting were lost. In addition, another of the big problems that were present at the construction stage were the capillary processes. Mainly because as the water ascended the foundation of the different structures were moistened, consequently they caused the corrosion of the steel. Figure 3 shows the presence of water outcrops and capillary problems in the project area.

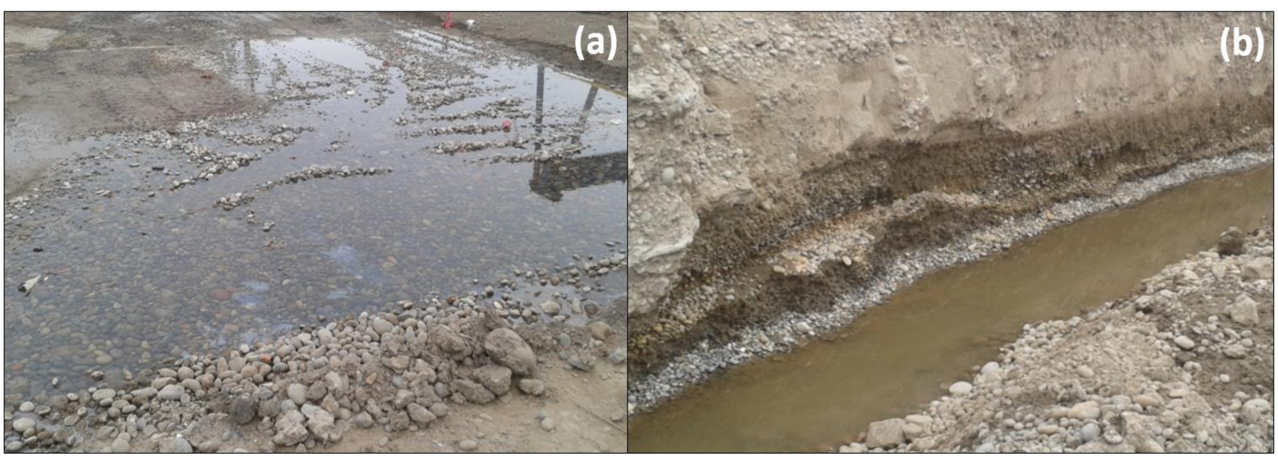

Figure 3: Problems observed in the study area. (a) Water outcrops. (b) Capillarity problems.

2.2 Methods

As a part of the information provided for the study, surveys were conducte to determine the type of soil present in the area where the constructions were projected. For this, six boreholes in the field (PPT) and four boreholes performed as part of the preliminary project (PT) were studied. The distribution of the perforations performed in the study area is shown in Figure 4.

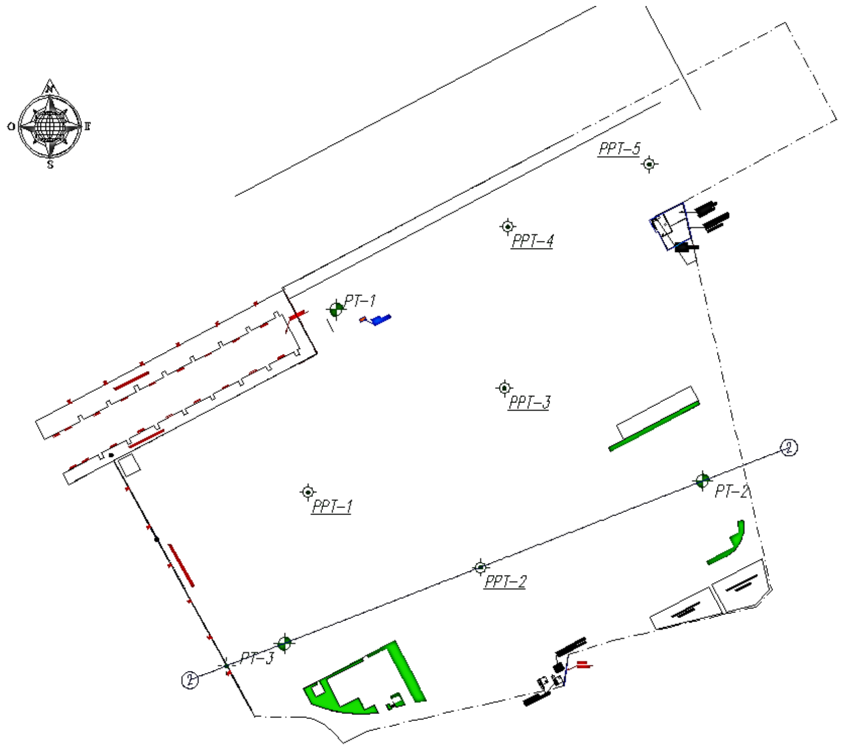

Figure 4: Distribution of boreholes in the project area.

Moreover, Table 1 shows the water levels recorded in the boreholes developed. The water table level of the perforations closest to the sea have a lower level that the perforations farthest from the sea. This is probably of leaks from the Rimac River, which reach a water table with a water table with a level greater than 2 meters above sea level. Then, the water table falls as it approaches the sea.

Table 1: Recorded water levels (SIMA, 2014).

Boreholes	Final depth	Ground level (m.a.s.l.)	Benchmark (m.a.s.l.)	Water levels (m.a.s.l.)	
				From	To
CURRENT CAMPAIGN					
CPT-6				---	
PPT-5	9.75	3.50	6.25	1.40	2.10
PPT-4	9.70	3.50	6.20	1.50	2.00
PTT-3	9.55	3.20	6.35	1.45	1.75
PTT-2	13.60	4.20	9.40	1.58	2.62
PPT-1	20.25	4.20	16.05	3.00	1.20
DRAFT					
PT-1	8.85	3.40	-5.45	2.15	1.25
PT-2	10.75	3.50	-7.25	1.30	2.20
PT-3	18.70	3.40	-15.30	2.15	1.25
PT-4					

*m.a.s.l: meters above sea level.

The design parameters were define from the tests carried out in the study area. The PPT-2 and PTT-3 boreholes recorded soil permeabilities of $5.09x10^{-2}$ cm/sec and $6.23x10^{-2}$ cm/sec, respectively. In addition, a maximum daily high tide level of 1.00 m, a minimum daily high tide level of -0.27 meters and an extraordinary maximum tidal level of 1.40 meters were considered. Finally, an expected level of depletion of +1.40 meters was taken. With all this information, the water table design with the draining tanks system were carry out.

3. RESULTS AND DISCUSSION

3.1 Modelling phase

It was carried out a modeling of the level of the water table was carried out, as part of the methodological evaluation. For this, groundwater modeling was perform using the Slide V.6.0 software in its State Finite Element Analysis module. Figure 5 shows the profile of the section evaluated. The level of the platform (+3.61 meters) and the reference level (+0.00 meters) can be observed. On the left side is the sea and on the right side the limit of the area where the construction of the shipyard will be carried out. Figure 6 shows a water table model, where the water level (violet line), the platform level (dotted brown line) and the location of the PT-3, PPT-2 and PT-2 boreholes can be seen.

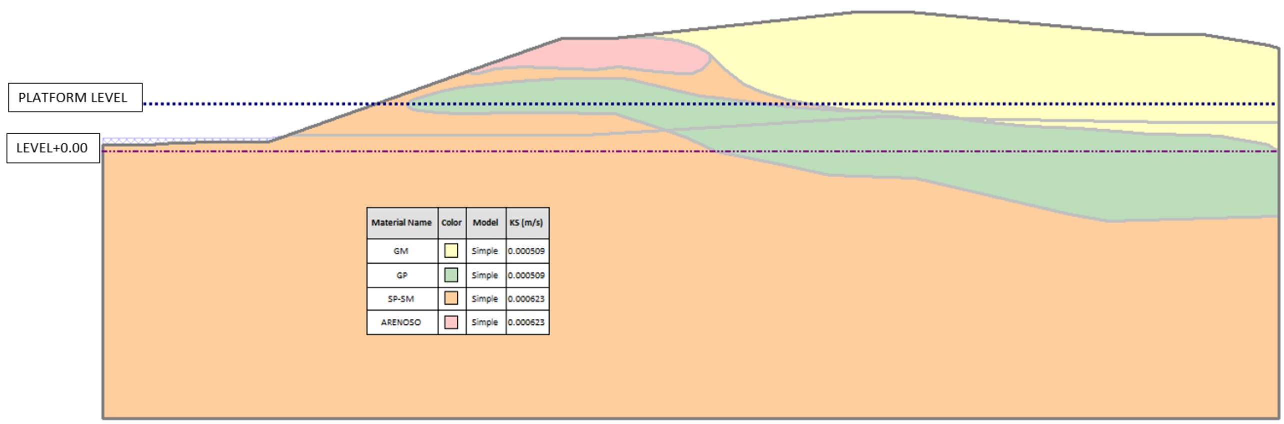

Figure 5: Profile evaluated in Slide V.6.0.

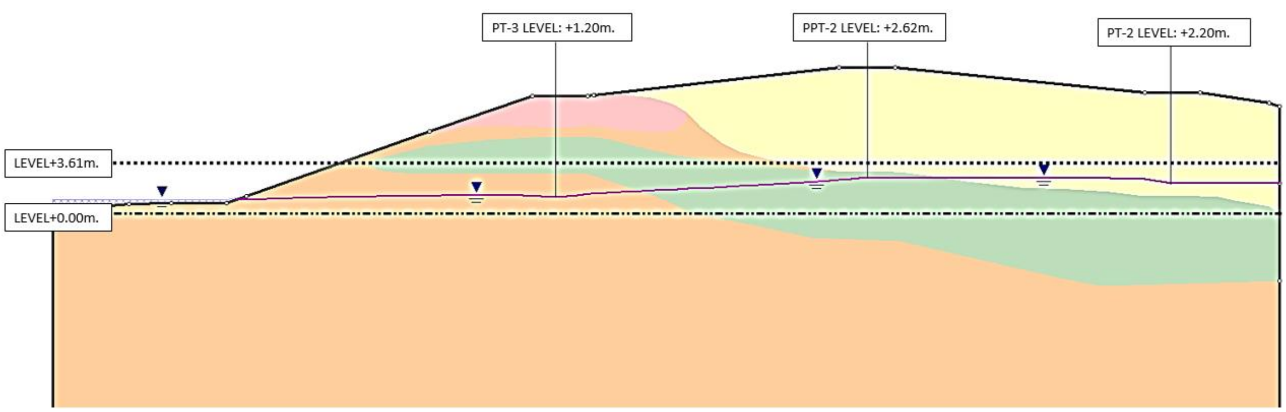

Figure 6: Water table model evaluated before the implementation of the solution.

On the other hand, modeling of the proposed solution was performe in the software defined under certain scenarios. In the first place, a modeling of water table was evaluated by using a single downhole. According to this analysis, the need to have a well with a depth greater that 3.20 meters follows, which would mean that the bottom level of the draining tanks would be +0.40 meters. A gravity drain could not be generate with this analysis, so a permanent pumping of water would be necessary to evaluate the flows above the tide level. Likewise, sections close to the sea should be isolated to avoid that with each level of maximum daily tide (+1.00 meters) there is a flooding effect. In that context, this first scenario was discarded.

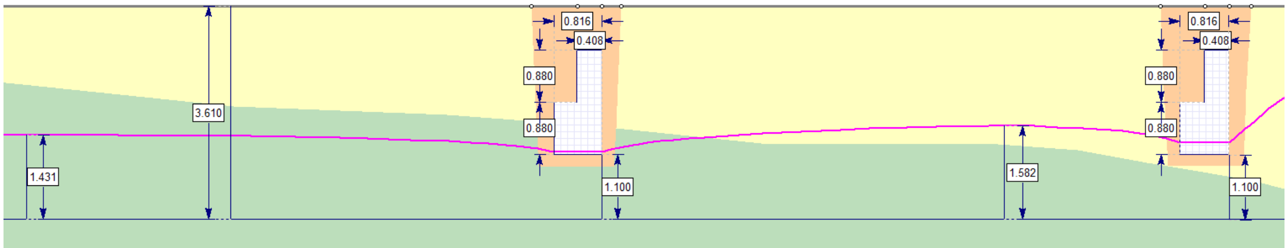

Figure 7: Water table model evaluated with the implementation of the solution.

Secondly, the use of two drainage ditches with 52FC draining tanks separated by 10 meters was evaluate in order to reduce the level of water and its evacuation. For this, the evaluations were carry out with the maximum daily tide level and the extraordinary maximum tide level. Figure 7 shows the model for a maximum daily high tide level, where the depression of more than 1 meter can be seen compared to the first scenario. Consequently, a water table level of +1.43 meters was obtain.

The evaluation contemplates that the ditches contain draining tanks of 816 mm wide in total and that the bottom level of the tanks is +1.10 meters as shown in Figure 7. This level of elevation was define because the maximum level of daily tide was +1.00 meters. A lower level than this would generate that the water collected in the draining tank is not drained or that a flooding effect may occur due to the proximity of the sea.

3.2 Adopted design

In accordance with the analysis performed, the last suggested alternative solution was considered. This consisted of the use of double polypropylene drainage tanks for two drainage ditches separated 10 meters from each other. In each ditch, 3 double tanks were arranged, as shown in Figure 8. According to the technical specifications, the draining tanks have a compressive strength of 22 ton/m^2, which allows the tank to be able to transmit the pavement loads above the ground without undergoing deformations that impair its functionality. Likewise, the tank has 95% of voids, which allows it to take better advantages of its ability to contain water from the water table.

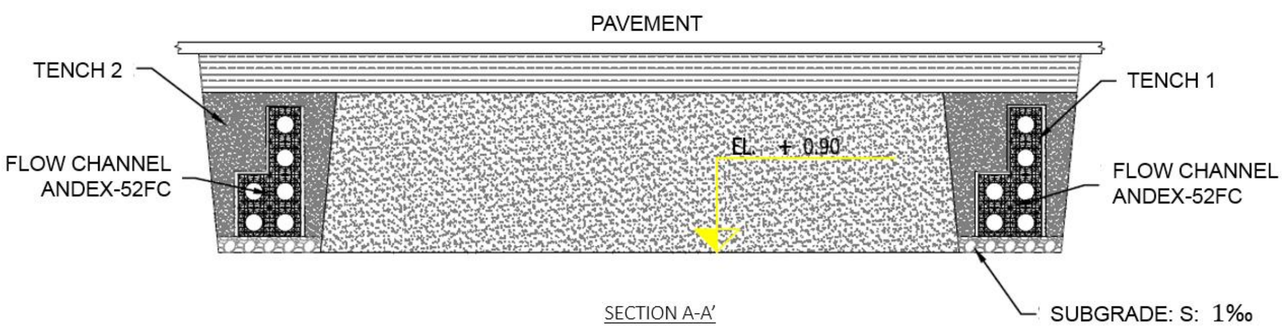

Figure 8: Scheme of ditches with double draining tanks.

3.3 Constructive process

Once the analysis carried out, the project was execute in the study area. To do this, first, a bed of gravel-shaped material was placed as a subgrade ground. Consequently, the 52FC polypropylene draining tanks lined with non-woven geotextile were placed (Figure 9-a and 9-b). These tanks were placed according to the design made, with the purpose of significantly reducing the water table. Figure 9-c and 9-d shows the longitudinal arrangement of the drainage tank systems throughout the entire project area. Finally, the draining ditches were fill with burdensome material typical of the area. These disposed draining tanks will form the foundation of the projected structures in the workplace.

Figure 9: Construction process of the draining tank system in the project area.

4. CONCLUSIONS

The use of the sub-drainage system composed of drainage tanks kept clear of supersaturation of the soil, thereby interrupting the capillary process and avoiding the loss of its resistance to cutting caused by the corrosion of the reinforcing steel when the foundations are saturated. Moreover, the adoption of this system drainage reduced by half the construction time and the cost of the project.

The draining tank system offers multiple constructive advantages, its installation is manual, it does not need skilled labor, and it avoids the dependence of heavy equipment for its installation, which is not available at any time and place. Likewise, these systems, having a high percentage of voids in volume (95% of voids), allow to obtain a greater water collection by infiltration. Consequently, a greater reduction of existing water tables is achieved.

On the other hand, draining tank systems have greater hydraulic capacity compared to conventional sub-drainage systems such as gravel and perforated pipe (French drain). In addition, these systems have the advantage of presenting high compressive strength, which allows optimal operation as a load carrier.

More diffusion is required in the centers of higher and technical studies in Peru about the versatility of technological advances in drainage systems with geosynthetics.

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