Surface drainage system for dry docks in shipyards – Case study of Estaleiro Rio Grande (Technical Note)

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Abstract

This study aims to present a methodology for the design of a surface drainage system for dry docks in shipyards, taking into account the rainfall intensity at the site, the damping capacity of the hydraulic structures (drainage channels) and the pumping capacity of the pumping system. A case study of a dry dock owned by Estaleiro Rio Grande, located at the state of Rio Grande do Sul, is presented. The results obtained indicate alternatives for channel and submersible pump sizing. These pumps would be used to control the dry dock flooding after an intense rainfall event.

Keywords: shipyards, surface drainage, storm water drainage.

1. Introduction

In the 1970s, Brazil had the second largest industrial park for merchant ships worldwide, losing only to Japan. Currently, the world leadership in shipbuilding comprises Japan, China and South Korea, which are responsible for 80% of world's production (IPEA, 2014).

The industrial park for ships consists of several manufacturing sectors and assembly sites. Shipyards are possibly the most important places among them, because their configuration allows the final construction of boats that will be responsible for transporting thousands of tons of products.

Due to the type of work for which they are to be used, shipyards have specific requirements regarding their operation. Several factors affect the efficiency of shipyard operation, including the possibility of rainfall events that would flood the assembly yards. Small floods can halt the assembly line, causing costs and undesirable delays throughout the production chain.

In order to avoid halting the dry dock operations due to a rainfall event, it must be equipped with a storm water management system. This system should allow the maintenance and construction sectors to remain operational, when intense rainfall events occur. It is a common practice to install a set of drainage channels inside the dry dock to collect all

runoff into a tank, from which the flow needs to be pumped out as the dry dock elevation is lower than sea level.

In this case the drainage channels are for two purposes, namely: (a) to collect storm water and guide it to a tank and (b) to store part of the inflowing water and pump it to an area outside the dry dock.

Since these are small catchment areas, data on intense rainfall are used to determine the flows into the channels. However, in the technical literature, the sizing criteria to be adopted for that structure are not identified as regards
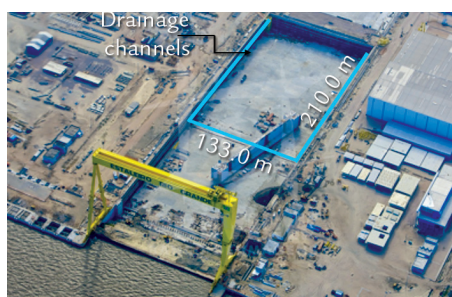
the return-period variable. Thus, an option is to perform a sensitivity analysis, adopting return-periods of 20, 50 and 100 years.

This study is for the purpose of presenting a methodology to design the drainage system project of a shipyard. The following questions must be asked: a) What is the minimum geometrical cross section of the drainage channels, so that they will have the capacity to dampen an intense rainfall event; b) How much flow must be pumped in order to, together with the action of the

drainage structures, keep the dry dock from flooding.

Several references show information about drainage system sizing. The following can be mentioned: AZEVEDO NETTO, J.M. and ALVAREZ, G.A. (1988), TUCCI, C.E.M. (1995), PORTO, R.M. (1999), TUCCI, C.E.M. (2002) BAPTISTA, M. and LARA, M. (2003), HOUGHTALEN, R.J. (2012). However, there are no studies (nationals or internationals) that present premises and criteria for the development of drainage systems in shipyard dry docks.

2. Site characteristics

The Estaleiro Rio Grande dry dock is 350.0 m long, 130.0 m high and 13.8 m deep below sea level. Its walls are 17.1 m high, including 3.3 m of free board in relation to the sea level.

Figure 1 (a) presents a view of the dry dock, where one can see the large gantry crane in operating position, with

a drilling rig platform. Figure 1 (b) also shows a view of the dry dock. In this figure the size of the work can be seen, observing the space excavated as compared to a backhoe.

Figure 2 shows a schematic drawing of the Estaleiro Rio Grande shipyard dry dock, with the positioning of the drainage

channels, for the purpose of collecting/holding storm water, installed at the bottom of the structure. The drainage system consists of 553.0 m long channels:
• Two channels 210.0 m long, sideways to the dry dock;
• One channel 133.0 m long transversally to the dry dock.

Figure 1
(a) general view of the
Estaleiro Rio Grande dry dock and
(b) general view of the opening
of the ditch to install the dry dock.
Ref.: CEGLINSKI, J.P. (2014).

Figure 2
Positioning of the
channels in relation to the dry dock.
Ref.: BERNARDES, J. (2014).

3. Materials and methods

Rainfall intensity:

The intensity-duration-frequency (idf) equation of the city of Rio Grande, Rio Grande do Sul, was obtained from the paper presented by DAMÉ *et al.* (2006).

The adjustment obtained in this case is shown in Equation 1:

$$i = \frac{k.tr^{0,23}}{\sqrt{\left(2,25+t_{min}\right)}}$$

(1)

in which,
i s the maximum intensity of rainfall (mm/h) for a duration of t_{min};
tr is the return-period of precipita-

tion (years);
t_{min} is the duration of the rainfall event (minutes);
k is a parameter of the equation

obtained from the historical precipitation data.

Table 1 presents the intensity values for rainfall events with 20, 50 and 100 years return-periods, and several durations of precipitation.

tr (years)	t (min)	5	10	15	25	30	60	360	720	1440
20	i (mm/h)	246.69	190.29	157.08	118.92	106.77	68.74	19.51	19.51	7.07
50	i (mm/h)	304.56	234.93	193.93	146.82	131.82	84.87	24.09	14.52	8.73
100	i (mm/h)	357.20	275.54	227.45	172.19	154.60	99.54	28.25	17.03	10.24

Table 1
Maximum rainfall intensity for the city of Rio Grande.

Source: Adapted from Damé *et al.* (2006).

The channel system evaluated in this paper considered 35 durations of the incident rainfall events, ranging from 5min to 175min (2h 55min), uniformly distributed along each duration.

Drainage channels sizing:

The storage volume of the drainage channels was determined from their total length and cross section, considering a rectangular section.

Initially, in order to determine the canal section, the sectors responsible for implementing the work were consulted. Based on the dimensions of the excavation equipment they recommended that the minimum width of the canal would be 1.50 m. Likewise, the maximum depth should be in the order of 2.40 m. From these boundary conditions, three different channel heights were tested (1.00 m, 1.70 m and 2.40 m) with the same width (1.50 m) under the occurrence of rainfall events of 20, 50 and 100 years of return-period.

Table 2 shows the sections researched and the respective accumulation volumes. The canal is a total of 553.0 m long. The channels filling profiles for recurrence periods of 20, 50 and 100 year were obtained from a water balance considering the maximum rainfall intensity, the damping capacity of the channels and pumped flow.

tr (years)	Canal width* (m)	Canal height (m)	Canal volume (m³)
20	1.50	1.00	829.5
50	1.50	1.70	1410.2
100	1.50	2.40	1990.8

Table 2
Dimensions adopted for the set of drainage channels based on back time.

* Width defined by using the Caterpillar Backhoe 336 D L

Pumping power:

Pumping power in each case was obtained from equation 2:

$$Pot_b = \frac{9,81 \cdot Q \cdot H_{total}}{\eta_b}$$

(2)

In which,
Pot$_b$ is the pump power (kW);

Q is the pumping flow (m³/s);
Htotal is the manometric height (m);

η_b is the pump yield (in this study adopted as 55%).

The manometric height of the pumps was calculated by the sum of geometric height, equal to 13.8 m, and the loss of total load in the circuit, estimated as 2/3 of the pumping height, i.e., 9.20 m. Thus the manometric height considered was 22.0 m.

From the previously described conditions and ignoring channels damping, the calculated pumping power for each pumping flow is shown in Table 3. These flow values were chosen from a prelimi-nary analysis to avoid excessive dry dock flooding, which shouldn't be greater than 75 mm (3 inches) in any case but preferably lower than 10 mm, and to avoid excessively large pumps, which would result in an excessive system cost.

Pumped flow (m³/s)	Power required by the pumps * (kW)
0.280	110
0.300	120
0.330	130
0.350	140
0.400	160

Table 3
Power required by the
pumps and pumped flow.

* This is the power required by the set of pumps. It indicates that the system may comprise
two or more pumps, depending on the flow, manufacturer or operational strategy and maintenance.

The system operation assumptions that pumps are turned on as soon as enough water height is available at the pumping intake, which would be designed and placed in such a way that it is reached from runoff almost at rainfall start. This means that power calculation considers full rainfall duration and channel storage is empty at rainfall beginning.

However, the drainage channels may behave as elements that dampen the inflows when they operate together with the submersible pumps during intense rainfall events.

This analysis was performed based on water balance simulation of the system. These simulations took into account rainfall events of 20, 50 and 100 years return-periods. It should be emphasized that, in all cases, the use of the pumping system was considered with the hypotheses of installing pumps as shown in Table 3.

The remaining volumes during the rainfall events in the channels will later be pumped until the system is completely drained.

4. Results

Figures 3 to 11 show the results of simulations for the drainage channels with a rectangular cross section and a base equal to 1.50 m (due to constructive issues and excavation equipment commonly used in carrying out these large works) and heights equal to 1.00 m, 1.70 m and 2.40 m, corresponding to storage capacities equal to 829.5 m³, 1410.2 m³ and 1990.8 m³, respectively, for different return-periods (20, 50 and 100 years). In all cases, the results of water depths and volume that overflowed onto the dry dock floor are presented. The vertical scales of these figures are the same to allow better visualization of the results.

The water depths and volumes that overflowed with positive values, shown in Figures 3 to 11, are the situations in which water overflows onto the dry dock. On the other hand, the negative values of water depth and volume indicate that the channels and pumping systems proposed have a capacity to absorb the flood event without flooding the dry dock, i.e., the channels were not completely filled during the respective rainfall event. It should be noted that the damping of the flood event was considered for each scenario studied. Besides, as a premise, it was considered that before the flood event, the channel was empty (all storage volume can be used for flood damping).

The results obtained indicate that the channels that are 1.70 m high (storage equal to 1410.2 m³) and 2.40 m (storage equal to 1990.8 m³) do not overflow in rainfall events with a return-period of up to 20 years, considering the pumping hypotheses presented in Table 3.
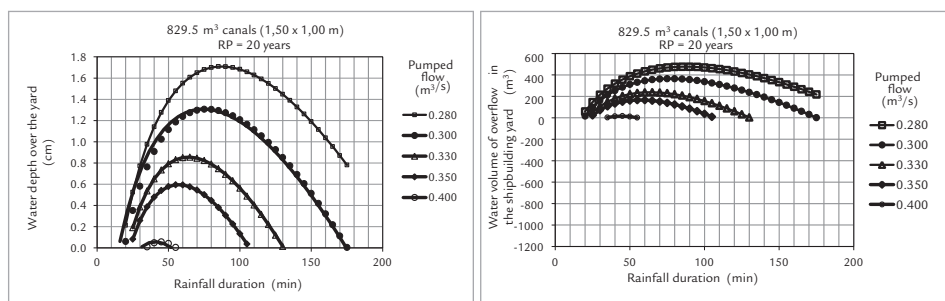

Figure 3
Water depth and overflow volume for
channels of 1.50 m x 1.00 m and rainfall
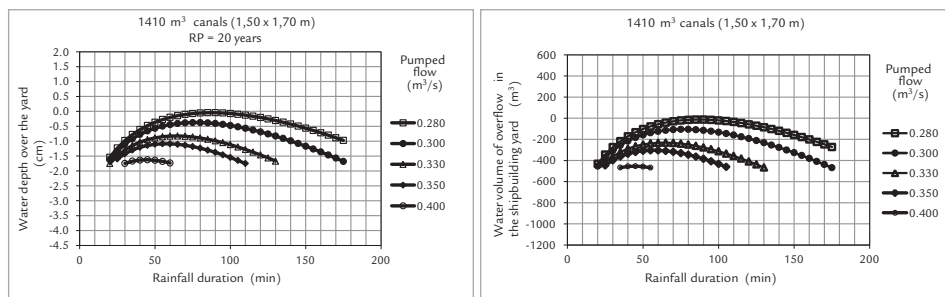events with a 20 years return-period.

Figure 4
Water depth and overflow volume for
channels of 1.50 m x 1.70 m and rainfall
events with a 20 years return-period.

Figure 5
Water depth and overflow volume
for channels of 1.50 m x 2.40 m and
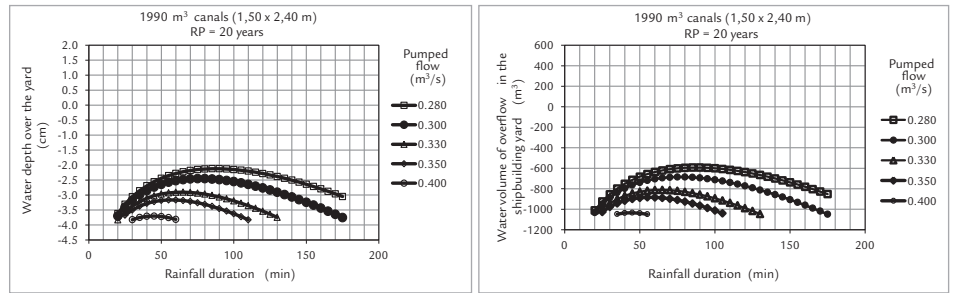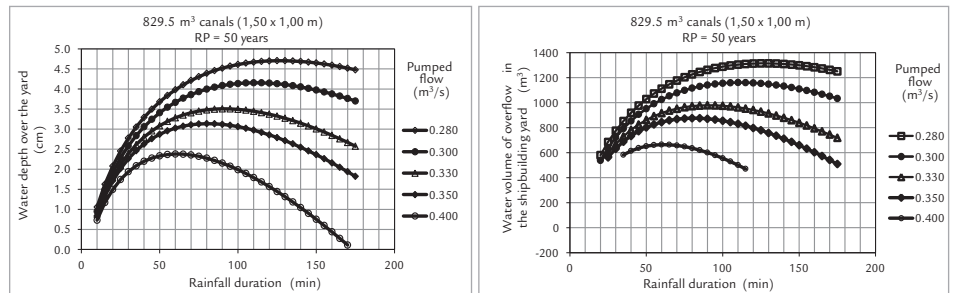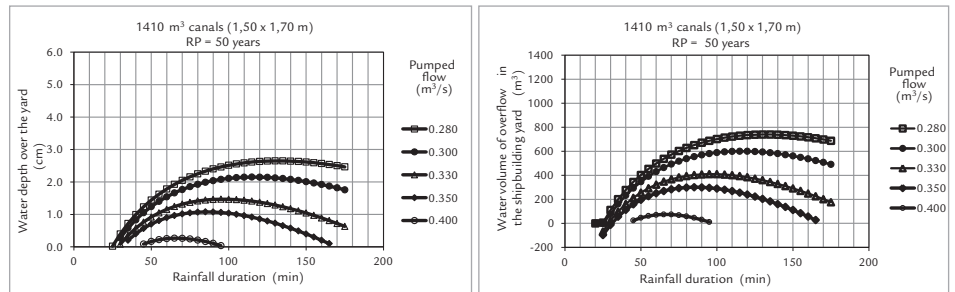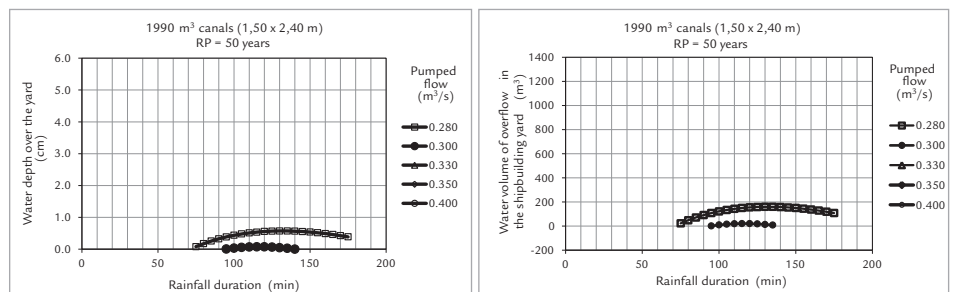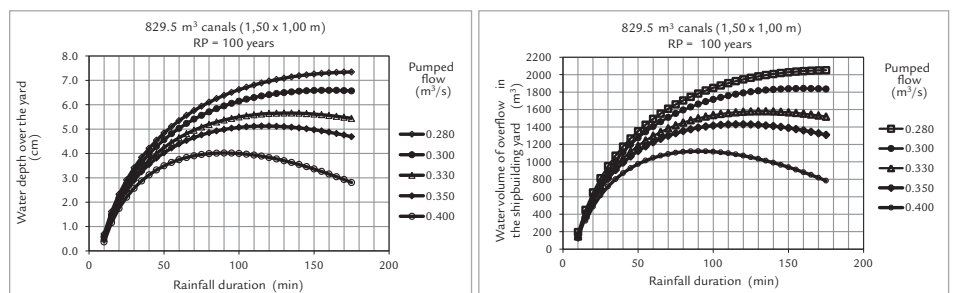rainfall events with a 20 years return-period.

Figure 6
Water depth and overflow volume
for channels of 1.50 m x 1.00 m and
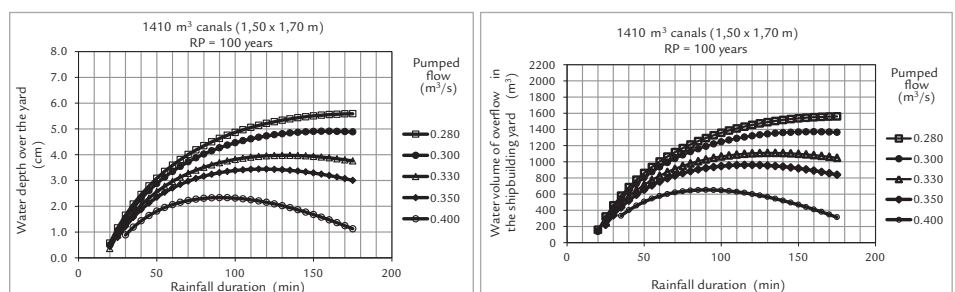rainfall events with a 50 years return-period.

Figure 7
Water depth and overflow volume
for channels of 1.50 m x 1.70 m and
rainfall events with a 50 years return-period.

Figure 8
Water depth and overflow volume
for channels of 1.50 m x 2.40 m and
rainfall events with a 50 years return-period.

Figure 9
Water depth and overflow volume for
channels of 1.50 m x 1.00 m and rainfall
events with a 100 years return-period.

Figure 10
Water depth and overflow volume for
channels of 1.50 m x 1.70 m and rainfall
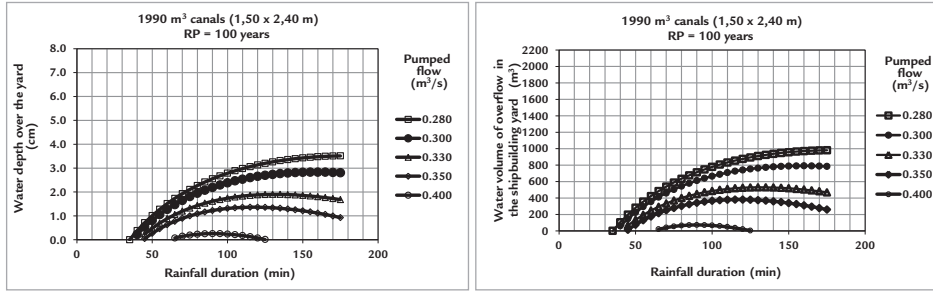events with a 100 years return-period.

Figure 11
Water depth and overflow volume for channels of 1.50 m x 2.40 m and rainfall events with a 100 years return-period.

The results shown in Figures 3 to 11 are summarized in Tables 4 to 6 for a pumped flow of 0.28 m³/s and 7 to 9 for pumped flow of 0.40 m³/s.

The analysis of Tables 4 to 6 shows that none of the channels have a water depth of less than 10 mm over the dry dock for a pumped flow of 0.28 m³/s and considering a 100-year return-period. This 10 mm reference was taken as equivalent to half the height of a roller wheel of a small cart, typical of tool benches and small welding machines. Besides, this water surface is not enough to cover small tools, such as screw drivers and wrenches, and damage them.

On the other hand, Tables 7 and 9 show that storage of 1990.8 m³ (1.5 m x 2.4 m channel section) was needed for a pumped flow of 0.40 m³/s so that the water depth over the dry dock would not be higher than 10 mm from a rainfall event of 100 years return-period.

Pumped flow = 0.28 m³/s		
rp(years)	Water depths(cm)	Volumes overflown (m³)
20	1.7	477
50	4.7	1314
100	7.3	2051

TH – There is not

Table 4
1.50 m x 1.00 m (V=829.5 m³) channel.

Pumped flow = 0.28 m³/s		
rp (years)	Water depths (cm)	Volumes of overflow (m³)
20	TH	TH
50	2.6	740
100	5.6	1561

TH – There is not

Table 5
1.50 m x 1.70 m (V=1410.2 m³) channel.

Pumped flow = 0.28 m³/s		
rp (years)	Water depths (cm)	Volumes of overflow (m³)
20	NH	NH
50	0.6	160
100	3.5	981

TH – There is not

Table 6
1.50 m x 2.40 m (V=1990 m³) canal.

Pumped flow = 0.40 m³/s		
rp (years)	Water depths (cm)	Volumes of overflow (m³)
20	0.1	16
50	2.4	664
100	4.0	1122

TH – There is not

Table 7
1.50 m x 1.00 m (V=829.5 m³) canal.

Pumped flow = 0.40 m³/s		
rp (years)	Water depths (cm)	Volumes of overflow (m³)
20	NH	NH
50	0.3	74
100	2.3	652

Table 8
1.50 m x 1.70 m (V=1410 m³) canal.

TH – There is not

Pumped flow = 0.40 m³/s		
rp (years)	Water depths (cm)	Volumes of overflow (m³)
20	NH	NH
50	NH	NH
100	NH	NH

Table 9
1.50 m x 2.40 m (V=1990m³) canal.

TH – There is not

5. Discussions

The analyses performed indicate that, for the same pumping system, the channel dimensions should be about 60 % increased while the annual risk of overflow is reduced about 5 times when rainfall events sized with a 100-year return-period are used, compared to the same system sized for rainfall events with a 20-year return-period.

On a 20-year horizon, estimated as these facilities lifetime, the probability of occurrence of overflow of a flume sized for a 20 year return-period for events is 64%, 3.5 times greater compared to the probability of failure of the structure sized for 100 year return-period events (18 %).

Thus, it is recommended for structures of the size of the Estaleiro Rio Grande dry dock:

• To size the channels and pumps system for rainfall events with a 100 year return-period;

• To adopt channels with a mean depth of 2.40 m and a width of 1.50 m;

• To use submersible pumps to drain storm water, prepared to pump up to 0.40 m³/s.

The authors also recommend that the maximum water depth accepted within the dry dock should not exceed 10 mm.

Finally, in general, it is suggested to use a parallel pump array to allow modulating flow when less intense rainfall events occur, and thus reduce the number of pumping starts and extend the useful life of the pumps.

6. Conclusions and recommendations

The decision regarding the size of the pumping system and drainage/storage channels of a dry dock must be ruled by a set of premises and basic criteria that should be spelled out at the beginning of the project.

When developing an engineering solution, it is necessary to consider the hypothetical cost of paralyzing the activities of a dry dock, because this might cost more than implementing the respective drainage system (including installing the channels and pumping devices).

The incremental costs inherent to reducing the probability of occurrence of overflows may become very low, depending on the magnitude of the costs of stopping and repairing the damage caused.

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