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Hydrological Considerations for Sizing of a Barge Discharge Pipeline Runway

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Abstract

A key element for water supply systems is the design of the water intake components. Mobile floating platforms (barges) are helpful when the hydraulic system displays substantial variations in water levels. This study presents the hydrological considerations that should be considered for the design of the barge's pipeline runway. The analysis takes into consideration the maximum and minimum water levels measured at the location. The study was carried out at the Magdalena River -Plato (Colombia) station, finding variations in water levels of between 12.3 m and 16.1 m for return periods of 25 and 100 years, respectively. This information is helpful for designers and consultants in order to design an appropriate barge pipeline runway.

Keywords: barge; pipeline runway; hydrology; variation in water levels

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1. Introduction

Barges are floating platforms used in rivers, lakes or swamps. These structures are used by drinking water supply systems to intake water from the studied hydrological system.

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Barge suppliers highlight that they are easy to handle and build on bodies of water and that the design is suitable for the project's requirements. Another significant advantage is the low cost of the barge's operation, maintenance and repair.

The water intake system consists of a pumping system with suction pipes installed on the body of water. It must be designed for the required flow and height, considering aspects related to hydraulic efficiency and maintaining the absolute pressure value below the liquid-vapor pressure (cavitation phenomenon)[1][2][3][4]. According to Title B of Colombia's Drinking Water and Basic Sanitation Regulation (RAS), floating water intake systems of this type (e. g., barges) are used when there are significant variations in the water levels of the body of water [5][6]

The barge design must consider the following elements: the pipeline runway, the staying cables, and anchoring for the structure [7, 8]. An adequate sizing of these systems is necessary to avoid failure in the intake of water supply systems. Fig. 1 displays a barge installation layout. The pipeline runway that holds the discharge pipes must be flexible to adapt to the different water levels that may arise in the hydrological system.

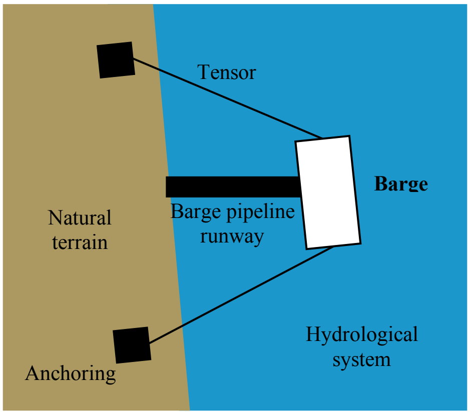

Fig. 1. The layout of a barge installation

This study presents the hydrological analysis to be considered for sizing the pipeline runway from a barge. In particular, it analyzes the water levels at the Magdalena River – Plato station (code 25027450), operated by the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM).

Nomenclature

h	Measured level (m)
f	Gumbel probability density function
α	Scale Parameter
μ	Location Parameter

2. Hydrological considerations for barge design

2.1 Information Used

The hydrological analysis is based on the records available at the hydrometric stations near the location where the water intake is to be installed. In this study, the water intake is near the Magdalena River – Plato water level monitoring station (code 25027450). San Juan Nepomuceno's (Bolívar, Colombia) is located at 35 km from the water level monitoring station (see Fig. 2).

Fig. 2. Lotion of the Magdalena River – Plato station and the intake location

Reliable records from the water level monitoring station are essential to determine the variability of the water level of the Magdalena River and consequently for the pipeline runway design.

The data analyzed included the records from November 2, 2011, to the present, including hourly water level data. For the effects of the data treatment, cleansing was performed of anomalous data. Table 1 displays, as an example, a sample data set.

Table 1. Example of hourly water level data (m) reported by IDEAM. Magdalena River – Plato station

Year	Month	Day	Time	Water level (m)
2011	11	02	11:59:00	3.21
2011	11	02	12:59:00	3.2
2011	11	02	13:59:00	3.21
2011	11	02	14:59:00	3.21
2011	11	02	15:59:00	3.21
2011	11	02	16:59:00	3.21
2011	11	02	17:59:00	3.18

2.2 Analysis of extreme water levels

Understanding the measured water levels at the Magdalena River – Plato station enables determining the water levels at the intake location. The variation in average annual levels at the Magdalena River – Plato station, with a multi-year average of 7.11 m. The months from January to April are the dry season, when lower levels of the Magdalena River are expected, whereas the months from May to December are the rainy season, with higher water levels. The lowest average measured level is in March, with 4.28 m, whereas the highest value is in November, at 9.19 m.

Analysis of variation of measured water levels was carried out to determine the differences in water levels of the Magdalena River that must be taken into consideration to design the barge pipeline runway. The analysis assessed the maximum and minimum water level points measured between 2011 and 2019, as displayed in Tables 2 and 3, respectively.

Table 2. Maximum measured water levels (m). Magdalena River - Plato station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAXIMUM
2011											4.1	5.39	5.39
2012	5.26	1.47	-0.84	1.45	2.97	2.89				4.95	5.24	5.2	5.26
2013	3.34	2.3	2.47	2.97	4.44		8.28	8.31		10.66	10.08		10.66
2014					9.54	9.38	8.58	8.26	9.04	9.9	10.71	10.69	10.71
2015	9.53	7.77	7.58	8.7	8.64	9.01	7.66	7.41	7.41	7.73	8.39	8.38	9.53
2016	5.88	5.07		6.66	7.95	8.07	7.63	7.96	8.58	9.54	10.45	11.05	11.05
2017	10.88				11.05	11.46	11.5	11.34	10.36	10.67	10.71	11.11	11.50
2018	9.99	9.19	7.44	8.57	9.83	10.19	10.05	8.82	8.91	9.94	10.58	10.47	10.58
2019	8.58	6.53	7.42	8.63	9.21	10.47	10.32	9	8.14				10.47
AVERAGE	7.64	5.39	4.81	6.16	7.95	8.78	9.15	8.73	8.74	9.06	8.78	8.90	9.46
MAXIMUM	10.88	9.19	7.58	8.70	11.05	11.46	11.50	11.34	10.36	10.67	10.71	11.11	11.50
MINIMUM	3.34	1.47	-0.84	1.45	2.97	2.89	7.63	7.41	7.41	4.95	4.10	5.20	5.26

Table 3. Minimum measured water levels (m). Magdalena River - Plato station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MINIMUM
2011											3.18	4.11	3.18
2012	1.46	-0.88	-1.61	-0.87	1.41	1.53				4.59	4.94	3.32	-1.61
2013	0.98	0.73	1.59	2.22	2.95		7.79	7.59		9.78	10		0.73
2014					9.38	8.57	6.81	6.41	7.49	8.69	9.86	9.55	6.41
2015	7.12	7.03	6.35	7.37	7.78	7.52	6.64	6.72	6.93	6.58	7.69	5.7	5.70
2016	4.89	4.68		6.25	6.61	7.58	7.28	7.42	7.6	8.44	9.54	10.44	4.68
2017	10.3				10.12	10.58	10.9	10.1	9.98	10.22	10.22	9.95	9.95
2018	9.18	7.34	6.13	6.99	8.53	9.85	8.75	7.94	7.86	8.9	9.91	8.58	6.13
2019	6.12	6.03	6.29	7.42	8.21	9.21	8.99	8.09	7.95				6.03
AVERAGE	5.72	4.16	3.75	4.90	6.87	7.83	8.17	7.75	7.97	8.17	8.17	7.38	4.58
MAXIMUM	10.30	7.34	6.35	7.42	10.12	10.58	10.90	10.10	9.98	10.22	10.22	10.44	9.95
MINIMUM	0.98	-0.88	-1.61	-0.87	1.41	1.53	6.64	6.41	6.93	4.59	3.18	3.32	-1.61

Based on the maximum and minimum measured levels, the differences in water levels the barge will be subject to were determined. Table 4 displays the results obtained, which indicates differences of between 1.6 m and 9.9 m. The lower part of Table 4 displays the statistical adjustments related to the different return periods, which must be considered for the barge design. The analysis was performed based on the Gumbel probability density function.

$$f(h) = \frac{1}{\alpha} exp^{\left[-\frac{h-\mu}{\alpha} - exp^{-\frac{h-\mu}{\alpha}}\right]} \tag{1}$$

Every year, the expected variation in water level is 5.1 m (for a 2.33-year return period); however, for the effects of the design, return periods of between 25 and 100 years should be used, depending on a cost/benefit analysis. Figure 3 displays the maximum water level differences that should be considered for the barge pipeline runway design.

Table 4. Statistical adjustment of extreme water level variations Magdalena River - Plato station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
2011											0.9	1.3	2.2
2012	3.8	2.4	0.8	2.3	1.6	1.4				0.4	0.3	1.9	6.9
2013	2.4	1.6	0.9	0.8	1.5		0.5	0.7		0.9	0.1		9.9
2014					0.2	0.8	1.8	1.9	1.6	1.2	0.9	1.1	4.3
2015	2.4	0.7	1.2	1.3	0.9	1.5	1.0	0.7	0.5	1.2	0.7	2.7	3.8
2016	1.0	0.4		0.4	1.3	0.5	0.4	0.5	1.0	1.1	0.9	0.6	6.4
2017	0.6				0.9	0.9	0.6	1.2	0.4	0.4	0.5	1.2	1.6
2018	0.8	1.9	1.3	1.6	1.3	0.3	1.3	0.9	1.1	1.0	0.7	1.9	4.5
2019	2.5	0.5	1.1	1.2	1.0	1.3	1.3	0.9	0.2				4.4

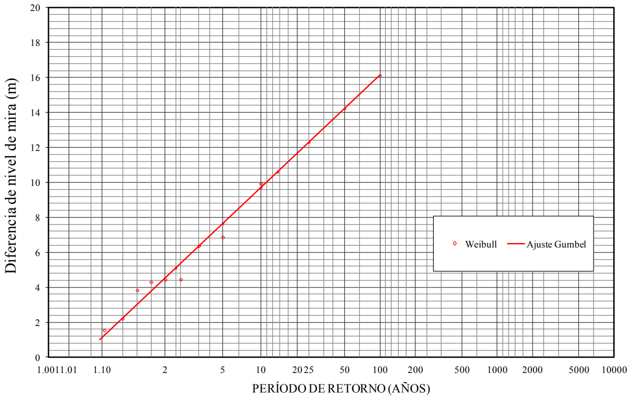

Fig. 3. The difference in annual water levels (m) for different return periods. Magdalena River - Plato station

3. Conclusions

This study has presented the hydrological considerations related to extreme water levels to which the barge pipeline runway will be subject.

The following are the conclusions of the case study at the Magdalena River – Plato station:

- The available information was collected from the Magdalena River – Plato water level monitoring station (code: 25027450) of IDEAM from 2011 to 2019.
- The barge pipeline runway should be designed for a difference in water levels of the Magdalena River associated with return periods of between 25 and 100 years, depending on the cost/benefit ratio considered in current regulations. For a 25-year return period, the maximum difference in water level for the barge pipeline runway should be 12.3 m; while for a 50-year return period, the value to be used is 14.2 m; and for a 100-year return period, the pipeline runway must be able to withstand a variation in water levels of 16.1 m.

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