ROWING LINE DREDGING FOR PAN AMERICAN GAMES 2007 RIO DE JANEIRO–BRAZIL

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ABSTRACT

The Rodrigo de Freitas Lagoon, simply called Lagoa (Lagoon), has been chosen to house the Pan American Games – 2007 rowing, canoe, kayak, and water skiing competitions. Especially concerning the rowing competitions, the Lagoon had to be submitted to some improvements. Although the sculling boats have a small draft, for hydrodynamics purposes, the Olympic Committee demands lanes at least 3 m below water level. After the bathymetric surveys, it was found that in order to achieve the desired depth of the rowing line; about 100.000m^3 of sediment dredging would have to be performed, in order to meet the Olympic Authority requirements.

The Lagoon is located in the center of Rio de Janeiro's south zone, close to the Ipanema beach, being on the most important sightseeing places in Rio de Janeiro. The Lagoon is also a highly sensitive environmental site, where occasionally there are serious fish kills resulting in a very strong odor. The causes are still being investigated.

- Considering the aspects of production, distance dumping sites, turbidity during dredging operation, among others, the equipments choice was fundamental to the success of the Job. Three different types of equipments were used, pneumatic system dredge, suction dredge with dustpan draghead and suction head with auger cutter (both with submerged pump).

During the dredge operation, not only bathymetry, but also turbidity, dumping dispersions, water and sediments analyses, and shoreline stability and displacement were monitored.

Key Words: Environmental dredging, open water disposal, monitoring, dustpan, auger, and pneumatic dredges.

INTRODUCTION

The City of Rio de Janeiro has been chosen to house the XV Pan American Games in July of 2007. In order to accommodate the several sport modalities, the city passed through several transformations and adaptations, not only concerning its general urbanization, but also the places for the practice of specific sports. The place chosen for the rowing, canoe, and kayak competitions was the Rodrigo de Freitas Lagoon, a highly sensitive location from the environmental point of view, which had to undergo adjustments to be adapted for the competitions.

The Pan American Games

Every 4 years a city in North, Central or South America is chosen to house the Pan American Games. In 2007 the XV Pan American Games will be realized in the City of Rio de Janeiro.

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The City of Rio de Janeiro

The City of Rio de Janeiro, former Brazilian capital, has been privileged by its natural beauty.

Figure 1. Rio de Janeiro City.

It is the second biggest city in Brazil and its main income derives from tourism, oil (80% of the Brazilian production) and also from the automobile industry in its vicinity.

The Rodrigo de Freitas Lagoon

Located in the in the heart of Rio de Janeiro's south zone, the lagoon is a sensitive environment and any proposed changes in its ecosystem raises strong protests from the society apart from the possible environmental damage that might occur.

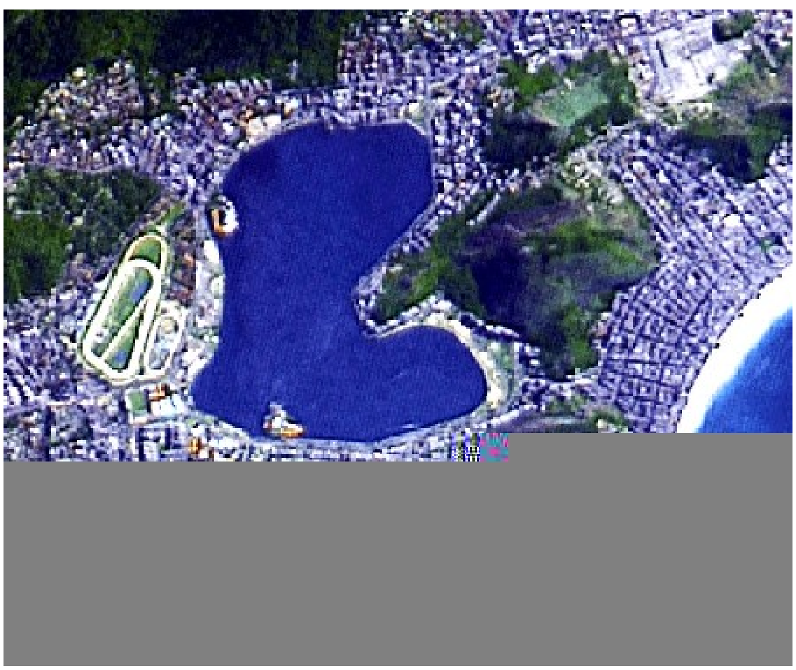


Figure 2. Lagoon aerial view.

Figure 3. Lagoon aerial view.

DREDGING OF THE RODRIGO DE FREITAS LAGOON

Main aspects of the Rodrigo de Freitas Lagoon

The Rodrigo de Freitas Lagoon possesses an area of 2,5 km² (in the past the dimensions were of 4 km²). It receives the contribution of several tributary streams and disembogues in the sea through an artificial channel ruled by a floodgate. The lands located at the Rodrigo de Freitas Lagoon's margin were formerly occupied by the Tamoio tribe. A long time ago, the lagoon was an open bay in the direction of the sea. But slowly, the Ipanema and Leblon sandbanks closed its entrance and the circulation currents responsible for water exchange ceased.

Along its history, the lagoon had different names: Piraguá Lagoon – which means still water, Sacopenapan – which means heron route. It has also been called Amorim Soares Lagoon as a reference to the town councilor Amorim Soares who at least was expelled from the city in 1609 after involving himself with the illegal land buying and selling. Before escaping, the town councilor sold his land – including the lagoon area – to his son-in-law, Sebastião Fagundes Varela, who still invaded several vicinity terrains before becoming the landlord of almost the entire region. Later, Varela's 50-year-old widow, Petronilha, married Rodrigo de Freitas, a young man of only 18 years. In a love gesture, she named the Lagoon after her new husband.

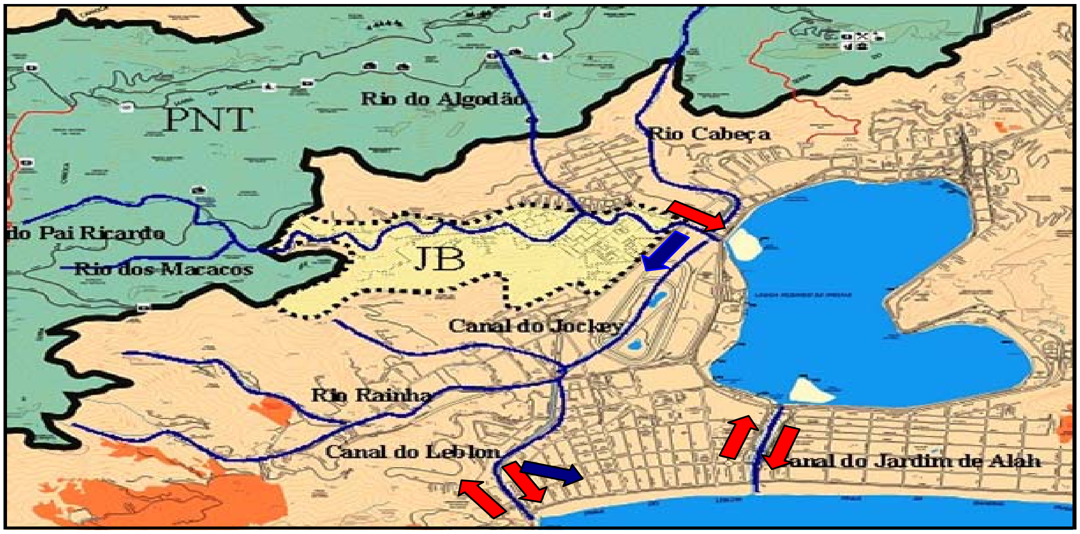


Figure 4. Lagoon, tributary streams and disemboguing.

The Rodrigo de Freitas Lagoon has its hydrographic basin basically formed by the rivers Macacos, Rainha and Cabeça, having each one of them a drainage area of 7,2 km^2, 4,3 km^2 and 1, 9 km^2, respectively.

The Lagoon's Chronic Problem

Historically, there have been numerous fish kills in the lagoon. Thousands of fish float next to the margins emitting a strong odor. The press notices it, the authorities exchange accusations among each other, biologists, engineers and inventors launch theories and solutions but, in spite of attempted solutions, the fish kills continue.

Figure 5. Fish kill.

Figure 6. Fish kill.

The fish kills are caused by a conjunction of factors, which not always occur simultaneously. Among the main villains are the adverse climatic effects that move the bottom waters, the high water temperature, the illegal discharge of sewerage and the eventual obstructions of the communication channel to the sea.

In 1808, Jonh Luccok, an english traveler, has referred himself to the Lagoon as follows: "Sometimes subject to strong wind blasts and, when occasionally the see transposes the sandbank, a lot of freshwater fish die". The repetition of these negative effects persisted without a solution up to 1844. From this date on, the search for satisfactory results by part of the public authorities transformed the mentioned biotype into a research "campus" of several experiments. In 1850, the Emperor Dom Pedro II has assigned a commission to study manners to avoid the fish kills. The fish kills in the Lagoa Rodrigo de Freitas Lagoon have been reported almost annually since 1935.
Ludwig & Selleck in 1971, computed data, which show how frequent the fish kills were:

Table 1. Ludwig & Selleck dead fish statistics.

Years	Months	Dead Fish (tons)
1954	March	--------
1963	October	--------
1964	December	70
1966	September	160
1967	July	350
1968	April	220
1968	December	128
1969	June	136
1970	January	80
1970	August	92
1970	September	5
1971	November	457

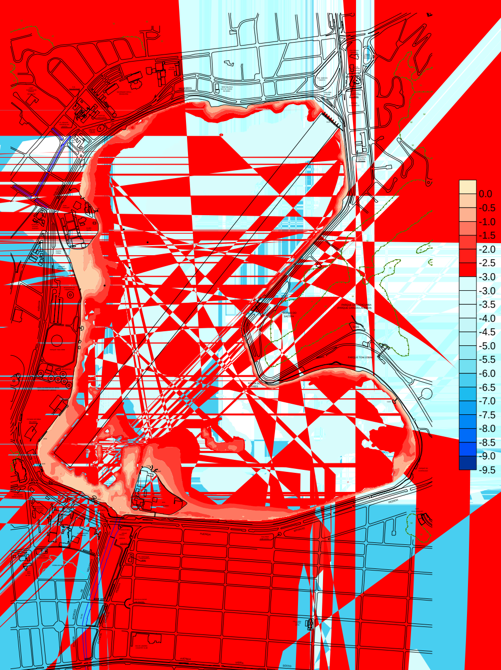
Reports and projects were issued by national scientists and from abroad, who have been active in the search of solutions for this problem, which only got worse with the disorganized urban population growth. In February of 2000, almost 100 tons of fish were removed, achieving 136 tons in February of 2001. In the beginning of February of 2002 there was another fish kill of approximately 94 tons.

Thus, an analysis of the Rodrigo de Freitas Lagoon's fish kill history indicates that they might even happen without the presence of mud. However, it is undeniable, that mud is one additional sink for dissolved oxygen through the decomposition of organic matter.

Alterations in the Rodrigo de Freitas Lagoon to receive the Pan American Games

Although the rowing boats, canoes, and kayaks present a small draft, the Olympic Committee requires a water depth of 3,0 meters, due to the hydrodynamic effects. Thus, there has been defined a line with 2.000 meters, 108 meters width and a 3 meters depth.

Other alterations and adaptations that are beyond the scope of this work have also been suggested, as in the case of the starting pier with a retractable system, the implantation of the Albano line, the warm up lines, the electronic arrival detection systems and of the stadium itself in order to house the spectators.


0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5

The Equipment Choice

Knowing the volume and characteristics of the material to be dredged, the dredging equipment was selected. The main focus was the choice of non-conventional equipment with environmental characteristics. For instance, dredges that already showed the inscription of being “non-polluting”. The main concern besides realizing the work within the foreseen time was, that there did not create a fish kill during the dredging works, because even if caused by unknown factors, the dredging would be held responsible by part of the environmentalists, authorities, and by the press. The equipment choice thus fell on equipment, which dredged material suction would cause the smallest resuspension of the lagoon sediment, in order not to influence the environmental balance. Thus, the dredging was performed with 3 types of equipment:

- Pneumatic type dredge;
- Suction dredge with submersible pump and drag head, dustpan type;
- Suction dredge with submersible pump, and AUGER cutter.

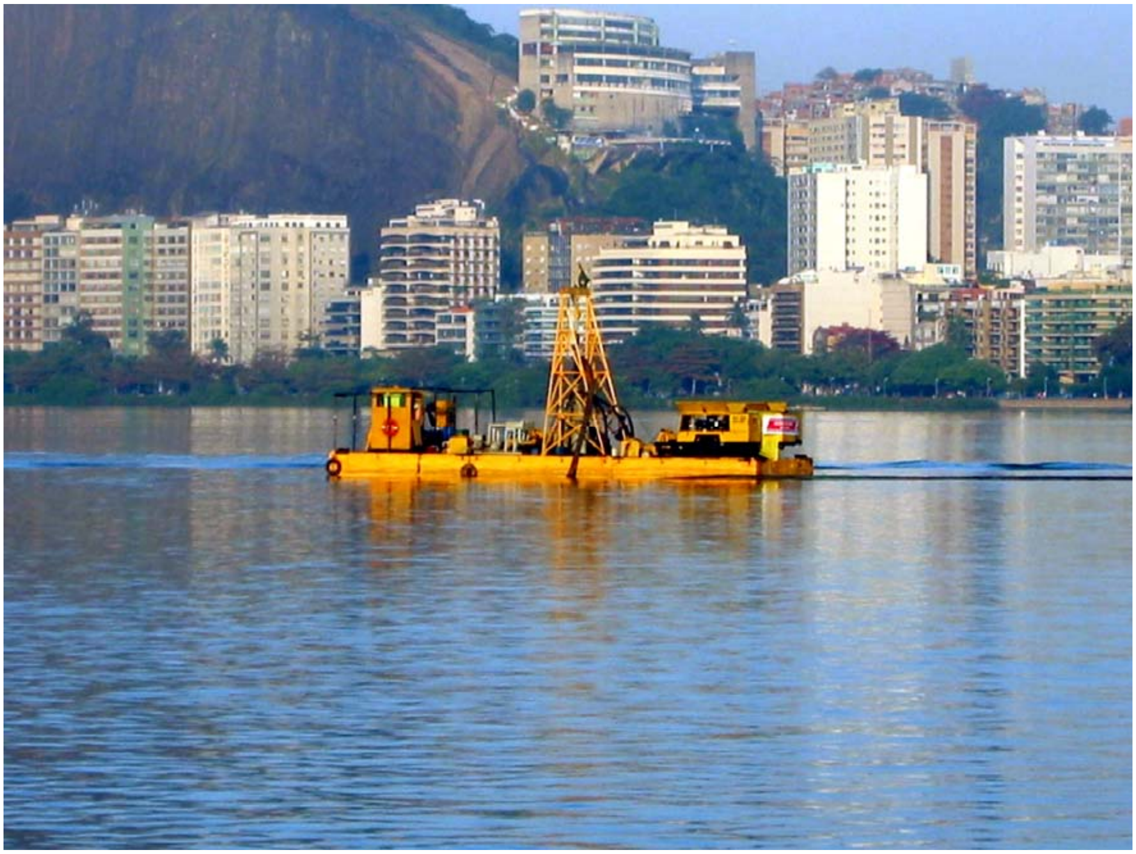


Figure 10. Pneumatic dredge.

Figure 11. Two "Eco Dredges" with auger cutter and dustpan draghead.

Dumping Areas

Considering the impossibility of transporting 97.000m³ from the lagoon using trucks, and due to the fact that the lagoon margin does not offer any place for the creation of a CDF (Confined Disposal Facility), the environmental authorities allowed the material disposal in regions of deep depth existing in the lagoon itself. The initially realized bathymetric survey indicated that these depressions had the capacity to hold 188.000m³, thus double the volume to be dredged. The environmental authorities, however, indicated the dredged material monitoring dispersal and characteristics in this open water disposal operation.

In case of the dispersion of contaminated sediments, we would be obliged to use a silt curtain and if the problems persisted, the dredging would be interrupted and another solution adopted for the dumping of the dredged material. The other solution that would be very expensive would be the material launching into the pump stations of the sewerage system. These pump stations would convey the material to a submarine out fall with 5km disposal in open sea. The problem of this solution is that the pump stations only support the compressing of fluid mud. As sandy material causes high wearing of the pumps, which have only been constructed to compress sewerage, these materials would have to be separated. This separation would be made via sedimentation boxes, being the material later on transported via trucks. As might be stated, an expensive process that would highly influence the dredging equipment production.

As noted in the next chapter, the disposal area monitoring achieved satisfactory results and the dredged material has been all deposited in such areas without technical or environmental problems.

The Dredging Procedure

During the dredging, some common but unforeseen situations occurred. Although the geological drilling initially performed by means of the Jet Probe system had indicated soft soils, we found more competent soils, as clay over 5 SPT strokes and even small arenite plates. The solution found was to apply a small rotation to the rowing line in order to escape from this region.

The pneumatic system only proved to be efficient for fluid clays of low strength. The dredge with a Dustpan head type had to be changed by another one with an AUGER cutter. Even with the dredges already equipped with a active cutter system of the AUGER type, there were tested several tooth angles until obtaining the maximum output regarding the soil to be dredged in the lagoon.

ENVIRONMENTAL ACCOMPANIMENT AND MONITORING

The environmental aspects and margin stability concerned us during the realization of the lagoon dredging services.

Lagoon Margin Stability

Historically, due to the displacement observations made concerning the lagoon traffic tracks, it was feared that with the realization of a dredging of such proportions, which was mostly concentrated at the extremities, i.e. next to the most significant improvements as the retention walls, roads, child parks and sporting clubs, there might be displacements that would high material prejudices and possibly require high cost engineering solutions. There were contracted consultants specialized in geotechnics. The studies consisted basically of:

- Geotechnical drilling for precise soil characterization;
- Installation of control bolts (bench marks) to monitor the displacements;
- Execution of a margin retention project with sheet piles, thus enabling the immediate problem solution in the case displacements were observed.

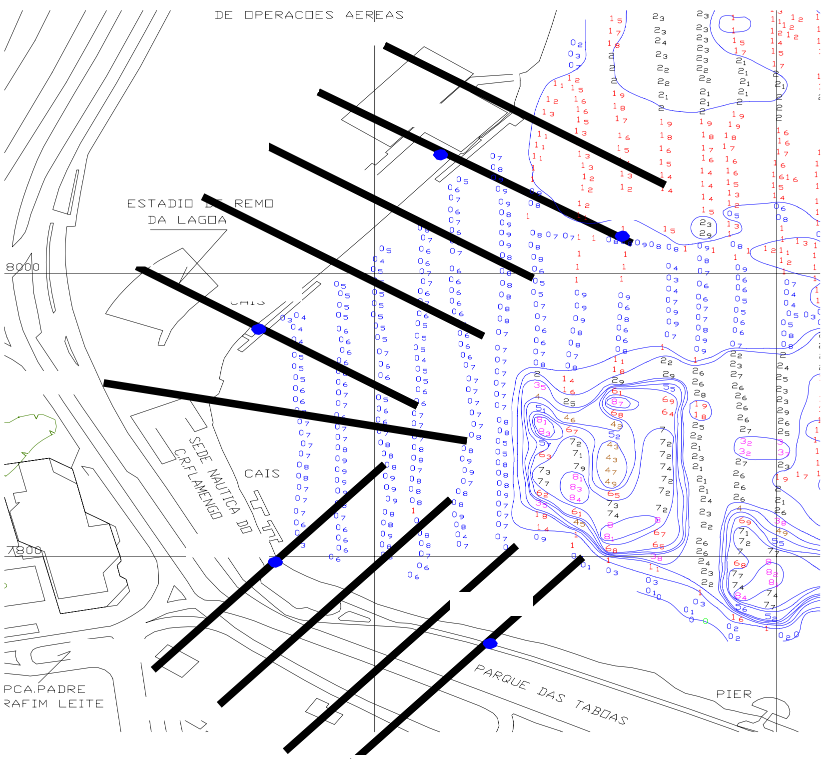


Figure 12. Top-bathymetric sections at the finish area.

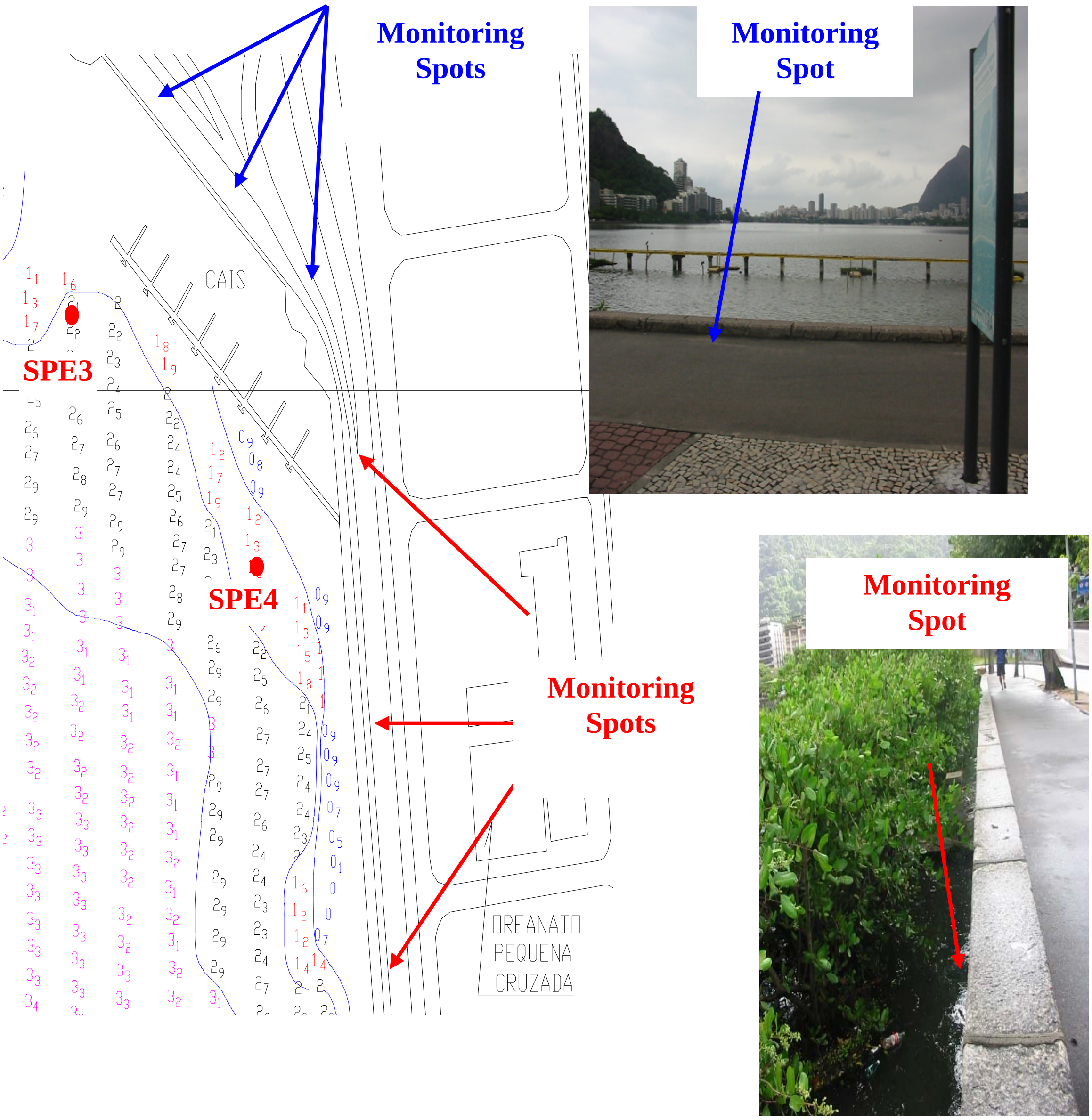


Figure. 13. Drilling and monitoring spot location at starting.

Margin Stability Conclusion

The presence of sandy soils, especially at the finish area, where the volume to be removed was much higher than in the starting area, maintained the slope stable, not altering the bolt position and thus not dislocating by means of pressure any lagoon margin.

Environmental Monitoring

According to **CONAMA's Resolution No. 344**, and in view of the area and volume to be dredged, collection of sediment sampling was required before the dredging could proceed in order to evaluate the impacts in the water quality, as well as to indicate mitigating solutions. The analyzed sediment is shown in Table 2. With the aim of accompanying the dredging activity, two types of water quality monitoring were performed at 5 (five) locations in the lagoon spots, one spot next to the disposal trench and others at historical data spots. The monitoring was performed before and during the dredging.

Parameters monitored before the dredging included:

- Turbidity,
- Temperature,
- Salinity,
- dissolved Oxygen,
- BOD (biochemical oxygen demand),
- Nitrogenated Series,
- Phosphorated Series, and
- Non-filtered Residue (RNFT).

Intensely monitored parameter during the dredging included:

- Turbidity,
- Temperature,
- Salinity, and
- Dissolved Oxygen.

In the following are presented tables with the data of the analyzed spots before and after dredging. The spots RF 02 and RF 00 are located in the dredging area.

Figure 14. Water monitoring locations.

Table 2. Water analyses before dredging

Parameters	SAMPLE SPOTS															
	RF00				RF02				RF04				RF05			
	Quantity	mín	med	máx	Quantity	mín	med	máx	Quantity	mín	med	máx	Quantity	mín	med	máx
Nitrogênio Kjeldahl (mg N/L)	11	<0,15	1,4	2,0	13	0,35	1,0	2,0	13	<0,15	1,2	2,0	13	0,25	1,4	2,2
Nitrato (mg N/L)	10	<0,01	0,02	0,60	12	<0,01	0,01	0,07	12	<0,01	0,02	0,05	12	<0,01	0,02	0,03
Nitrito (mg N/L)	11	<0,001	0,003	0,01	13	<0,001	0,002	0,003	13	<0,001	0,002	0,004	13	<0,001	0,001	0,01
Nitrogênio Amoniacal (mg N/L)	11	<0,01	0,04	0,20	13	<0,01	0,02	0,25	13	<0,01	0,02	0,08	13	<0,01	0,01	0,04
Fósforo total (mg P/L)	10	0,10	0,15	0,20	13	0,06	0,10	0,40	13	0,10	0,15	0,20	13	0,09	0,10	0,20
Orto Fosfato dissolvido (mg P/L)	11	<0,01	<0,01	0,20	13	<0,01	0,02	0,20	13	<0,01	<0,01	0,04	13	<0,01	<0,01	0,03
DBO (mg/L)	11	<2	4,1	6,2	13	2,4	3,8	6,4	13	<2	3,8	6,8	13	<2	3,6	4,8
RNFT (mg/L)	11	18	27	50	13	18	28	36	13	18	30	48	13	16	26	40

According to Table 2, BDO is stable, indicating a reduction in the contribution from organic matter.

Table 3. Sediment analyses before dredging

PONTO	CAMADAS	NKJELDAHL	UMIDADE	ALUMINIO T	CROMO	MANGANES	FERRO	NÍQUEL	COBRE	CÁDMIO	MERCURIO T	CHUMBO
		(mg N/g)	(%)	(mg Al/kg)	(mgCr/kg)	(mgMn/kg)	(mgFe/kg)	(mgNi/kg)	(mgCu/kg)	(mg Cd/kg)	(ug Hg/g)	(mgPb/kg)
Nivel 1					**81**			**20,9**	**34**	**1,2**	**0,15**	**46,7**
Nível 2		**4.800**			**370**			**51,6**	**270**	**9,6**	**0,71**	**218**
RF-04	0,0 - 0,1	2.200	74,4	5.000	30	10	16.000	< 5	30	< 1	0,25	30
	0,1 - 0,2	3.200	77,2	10.000	20	10	17.000	< 5	60	< 1	0,80	100
	0,2 - 0,3	3.200	71	10.000	50	22	17.000	< 5	70	< 1	0,05	50
	0,3 - 0,4	3.200	72,4	7.000	50	16	18.000	< 5	10	< 1	0,50	10
	0,4 - 0,5	1.600	72,4	7.500	30	12	18.000	7	10	< 1	0,05	10
	0,5 - 0,6	1.200	59,7	8.500	< 10	8	16.000	< 5	10	< 1	0,05	< 10
	0,6 - 0,7	600	43	3.800	10	5	11.000	< 5	8	< 1	< 0,05	< 10
RF-02	0,0 - 0,1	3.028	88,9	9.000	10	250	14.000	< 5	100	< 1	0,50	120
	0,1 - 0,2	2.023	79,8	8.000	30	180	16.000	< 5	100	< 1	0,70	180
	0,2 - 0,3	2.560	76,5	7.000	20	140	18.000	< 5	120	< 1	1,00	240
	0,3 - 0,4	3.514	60,8	7.000	30	120	18.000	< 5	12	< 1	1,00	220
	0,4 - 0,5	2.250	56,2	7.000	20	180	19.000	< 5	100	< 1	1,20	280
	0,5 - 0,6	2.260	55,3	7.500	10	200	18.000	< 5	60	< 1	1,00	140
	0,6 - 0,7	2.150	57,9	6.000	10	160	17.000	< 5	70	< 1	0,80	140

At dredging depths of 3 meters which correspond to a maximum 1.5 meter of sediment, all parameters analyzed meet CONAMA Resolution 344 which governs dredged material.

Table 4 shows that during dredging, the DO, salinity, temperature and turbidity parameters at points RF02 and RF04 remained similar to points RF00 and RF05, which are some distance from the dredging and final dumping area. This shows that dredging does not alter water quality monitoring parameters.

Table 4. Water analyses during dredging.

Estação da Lagoa	Prof. (m)	OD - mg/L				Salinidade - (0/00)				Temperatura - (°C)				Disco Secchi - (m)			
		N	mínimo	mediana	máximo	N	mínimo	mediana	máximo	N	mínimo	mediana	máximo	N	mínimo	mediana	máximo
RF00	0,0	9	4,96	7,98	14,,69	9	12,1	12,2	13,2	9	21,8	23,6	24,8	9	0,40	0,50	0,60
	0,5	9	4,63	5,96	14,46	9	12,1	12,2	13,2	9	21,8	23,4	24,7				
	1,0	9	4,18	6,23	14,19	9	12,1	12,4	13,2	9	21,7	23,3	24,6				
	1,5	9	2,44	5,78	12,75	9	12,2	12,4	13,2	9	21,4	23,1	24,5				
	2,0	9	2,12	4,68	11,18	9	12,2	12,4	13,2	9	21,3	23,1	24,5				
	2,5	9	1,91	3,89	7,94	9	12,2	12,4	13,2	9	21,2	23,0	24,5				
	3,0	9	0,38	2,69	6,48	9	12,2	12,4	13,6	9	21,2	22,9	24,5				
	3,5	9	0,00	0,00	4,09	9	12,4	13,5	21,9	9	21,2	23,0	24,5				
	4,0	9	0,00	0,00	0,00	6	12,6	19,0	22,1	6	22,6	23,0	24,4				
	4,5																
RF02	0,0	9	2,84	9,64	9,64	9	12,1	12,3	12,4	9	21,9	22,9	24,8	9	0,40	0,50	0,60
	0,5	9	2,79	9,58	9,58	9	12,1	12,3	12,4	9	21,9	22,9	24,8				
	1,0	9	1,78	9,52	9,52	9	12,1	12,4	12,4	9	21,5	22,8	24,7				
	1,5	9	1,28	8,46	8,46	9	12,1	12,4	12,4	9	21,3	22,8	24,6				
	2,0	9	0,71	8,32	8,32	9	12,2	12,4	12,4	9	21,3	22,8	24,6				
	2,5	9	00,0	7,76	7,76	9	12,2	12,4	12,9	9	21,5	22,8	24,6				
	3,0	9	00,0	6,84	6,84	9	12,2	12,5	19,7	9	21,8	22,8	24,6				
	3,5	9	00,0	2,69	2,69	9	12,3	13,2	22,7	9	22,0	23,1	24,5				
	4,0	6	00,0	0,00	0,00	6	12,4	16,8	23,4	6	22,9	23,5	24,5				
	4,5																
RF04	0,0	9	4,22	11,69	11,69	9	12,1	12,4	12,4	9	21,9	23,9	24,6	9	0,40	0,50	0,60
	0,5	9	3,88	11,53	11,53	9	12,2	12,4	12,4	9	22,0	23,8	24,6				
	1,0	9	2,09	10,16	10,16	9	12,2	12,4	12,4	9	21,8	23,7	24,5				
	1,5	9	1,41	8,02	8,02	9	12,2	12,4	12,4	9	21,2	23,6	24,4				
	2,0	9	0,00	6,22	6,22	9	12,2	12,4	12,4	9	21,2	23,4	24,4				
	2,5	9	0,00	5,96	5,96	9	12,2	12,4	12,6	9	21,1	23,0	24,4				
	3,0	9	0,00	1,44	1,44	9	12,2	12,4	17,9	9	21,1	22,9	24,4				
	3,5	4	0,00	0,00	0,00	9	12,2	12,7	24,1	9	21,2	23,0	24,4				
	4,0					4	13,5	16,4	23,0	5	22,2	23,2	24,4				
	4,5																
RF05	0,0	9	4,68	9,89	9,89	9	12,2	12,4	12,3	9	21,4	23,9	25,1	9	0,40	0,50	0,60
	0,5	9	4,62	9,78	9,78	9	12,2	12,4	12,3	9	21,5	23,6	24,8				
	1,0	9	3,82	10,16	10,16	9	12,2	12,4	12,3	9	21,2	23,0	24,6				
	1,5	9	3,65	9,74	9,74	9	12,2	12,4	12,3	9	21,1	23,0	24,4				
	2,0	9	3,26	9,52	0,52	9	12,2	12,4	12,4	9	20,9	23,0	24,5				
	2,5	9	1,84	8,12	8,12	9	12,2	12,4	12,5	9	20,9	23,0	24,5				
	3,0	9	0,00	5,27	5,27	9	12,2	12,4	18,8	9	20,9	23,0	24,5				
	3,5	6	0,00	2,26	2,26	6	12,4	12,7	22,8	1	20,9	23,2	24,5				
	4,0	1	0,00	0,00	0,00	1	21,4	21,4			23,3	23,3	23,3				
	4,5																

Table 5 – Water analyses before dredging in dumping places.

Estação da Lagoa	*Prof.(m)*	OD - mg/L				Salinidade - (0/00)				Temperatura - (°C)				Disco Secchi - (m)			
		N	minimo	mediana	máximo	N	minimo	mediana	máximo	N	minimo	mediana	máximo	N	minimo	mediana	máximo
Cava 1	0,0	5	4,08	7,79	10,80	5	7,0	8,5	11,9	5	22,4	29,5	31,6	4	0,40	0,50	0,80
	0,5	5	3,69	7,26	10,10	5	7,0	8,5	11,9	5	22,5	29,5	31,3				
	1,0	5	3,62	6,86	9,63	5	7,1	8,5	12,1	5	22,4	29,1	31,2				
	1,5	5	3,47	6,27	8,95	5	7,3	8,6	12,4	5	22,4	29,0	31,0				
	2,0	5	2,10	6,00	8,90	5	7,5	8,6	12,8	5	22,4	28,8	31,0				
	2,5	5	0,98	5,22	8,57	5	7,7	8,6	14,3	5	22,3	28,9	31,0				
	3,0	5	0,29	4,83	8,11	5	7,7	8,6	21,0	5	22,2	29,0	30,9				
	3,5	5	0,00	3,73	7,19	5	7,8	8,8	23,1	5	22,7	28,9	30,9				
	4,0	5	0,00	1,90	7,03	5	7,9	10,9	23,5	5	24,6	28,8	31,3				
	4,5	5	0,00	1,63	5,60	5	7,9	20,1	23,8	5	24,9	28,2	31,1				
	5,0	5	0,00	1,60	5,09	5	7,9	23,6	24,7	5	25,4	27,4	30,4				
	5,5	4	0,00	1,55	2,61	4	8,4	24,0	24,9	4	25,1	26,7	29,3				
	6,0	4	0,00	1,55	2,34	4	21,9	24,5	25,9	4	25,1	26,2	28,5				
	7,0	4	0,00	1,51	2,33	4	23,5	25,6	27,5	4	25,1	25,6	27,6				
	8,0	4	0,00	1,51	2,32	4	24,8	26,3	27,5	4	24,9	25,4	26,6				
	8,5	4	0,00	1,49	2,30	4	26,0	26,4	26,9	4	25,0	25,4	26,6				
	9,0	3	1,25	1,34	2,31	3	19,9	24,8	26,5	3	25,3	25,8	26,3				
Cava 2	0,0	5	4,06	7,69	10,74	5	7,0	8,6	11,9	5	22,4	29,5	31,6	3	0,40	0,50	0,80
	0,5	5	3,72	7,44	10,22	5	7,0	8,6	11,9	5	22,4	29,2	31,4				
	1,0	5	3,66	6,89	9,60	5	7,1	8,6	12,0	5	22,5	29,1	31,2				
	1,5	5	3,58	6,43	9,32	5	7,2	8,6	12,3	5	22,4	28,9	31,0				
	2,0	5	2,16	6,04	8,87	5	7,3	8,6	12,5	5	22,3	28,8	31,0				
	2,5	5	0,96	5,40	8,57	5	7,5	8,6	18,4	5	22,4	28,7	31,0				
	3,0	5	0,33	4,53	8,31	5	7,7	8,7	22,0	5	22,6	28,7	30,9				
	3,5	5	0,00	3,89	7,26	5	7,8	9,0	23,2	5	22,8	28,6	30,8				
	4,0	5	0,00	2,25	5,77	5	7,9	10,1	23,4	5	24,2	28,5	31,0				
	4,5	5	0,00	1,71	3,98	5	7,9	19,9	23,8	5	24,8	28,0	31,2				
	5,0	5	0,00	1,63	3,16	5	7,9	23,4	24,2	5	25,1	27,2	29,8				
	5,5	4	0,00	1,54	3,01	4	8,3	24,0	24,9	4	25,1	26,9	29,9				
	6,0	4	0,00	1,54	2,36	4	22,0	24,6	26,4	4	25,0	26,2	28,4				
	7,0	4	0,00	1,50	2,34	4	24,1	25,7	26,8	4	25,0	25,7	27,3				
	8,0	4	0,00	1,50	2,30	4	24,9	26,3	26,8	4	24,8	25,4	26,8				
	8,5	4	0,03	1,57	2,28	4	26,0	26,4	26,8	4	25,0	25,4	26,7				

At holes 1 and 2, the DO was monitored before dredging, finding that at a depth of over 3.5 meters, the values measured (over 6 months) indicates DO below 2 mg/l, representing an environment unfavorable to marine fauna, indicating that dredged material dumping at these locations would have no impact on the Rodrigo de Freitas Lake ecosystem.

SUMMARY AND CONCLUSION

We might come to the following conclusions on the performed service:

- The Lagoon is a sensitive environment of great cultural and economic importance for the City of Rio de Janeiro.
- In view of its localization, the Lagoon has been chosen to house the aquatic sports at the XV Pan American Games, having however to be submitted to some adaptations.
- Historically, ecological disasters in the Lagoon, causing fish kills with negative repercussion to its geographic situation.
- The dredging and disposal of roughly 100.000 m³ inside the lagoon is a concerning factor, for if there would occur a fish mortality simultaneously to the service execution, most probably although not obligatorily, the dredging would be the great responsible.
- The choice of the dumping places has shown to be technically and economically feasible.
- The choice of dredging equipment with the label "ecological" has proven to be correct, although we do not have registers if the conventional equipment would cause environmental alteration in the Lagoon.
- A fish kill did not take place during the dredging period.
- The Lagoon margins have behaved in a stable way from the geological point of view.
- The dredging did not cause any exceedences of water quality parameters.

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