ALTO MAIPO HYDRO POWER PROJECT

BASIC ENGINNERING

CONTRACT AM-CO304

STUDY OF HYDRAULIC AXES
MUCK DISPOSAL SITES OF COLORADO AND MAIPO RIVERS

A	05-01-2009	Approval and Comments	A. Ugarte	F. Meza	E. Woolvett	R. Bennewitz / A. Lyngra	P. Alvarado
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1. INTRODUCTION

For the accumulation of material removed from the excavation of the tunnels of Las Lajas power station, some areas on the banks of Colorado River and Maipo River have been defined as Muck Disposal sites (SAM, in Spanish). In the Colorado River downstream of Maitenes water intake, 7 muck disposal sites have been designed; in Maipo River only one site has been considered, located immediately upstream of the discharge of Las Lajas power station .

Table 1-1 shows the main data related to these sites of Muck Disposal, and in Figure 1 is the general location of these 8 works.

Table 1-1. Location of Muck Disposal Sites in Colorado and Maipo Rivers

N°	MDS	WATERWAY	DISTANCE *	COORDINATES NEAREST VERTEX TO THE WATERWAY	
			(m)	E	N
1	SAM Nº 8	COLORADO R.	2668	387.447	6.291.425
2	SAM Nº 7	COLORADO R.	4366	386.045	6.290.828
3	SAM Nº 10	COLORADO R.	12958	380.352	6.287.495
4	SAM Nº 11	COLORADO R.	13446	379.982	6.287.413
5	SAM Nº 13	COLORADO R.	14339	379.273	6.287.238
6	SAM Nº 14 A	COLORADO R.	15703	378.196	6.286.644
7	SAM Nº 14 B	COLORADO R.	15953	378.137	6.286.437
8	SAM Nº 12	MAIPO R.	-	368.240	6.284.051

*: Measured by the axis of Colorado River from Maitenes Water Intake.

Annex 1 shows schemes in plant of all sites listed in Table 1, in which you can see the position of the works regarding waterways of Colorado and Maipo Rivers.

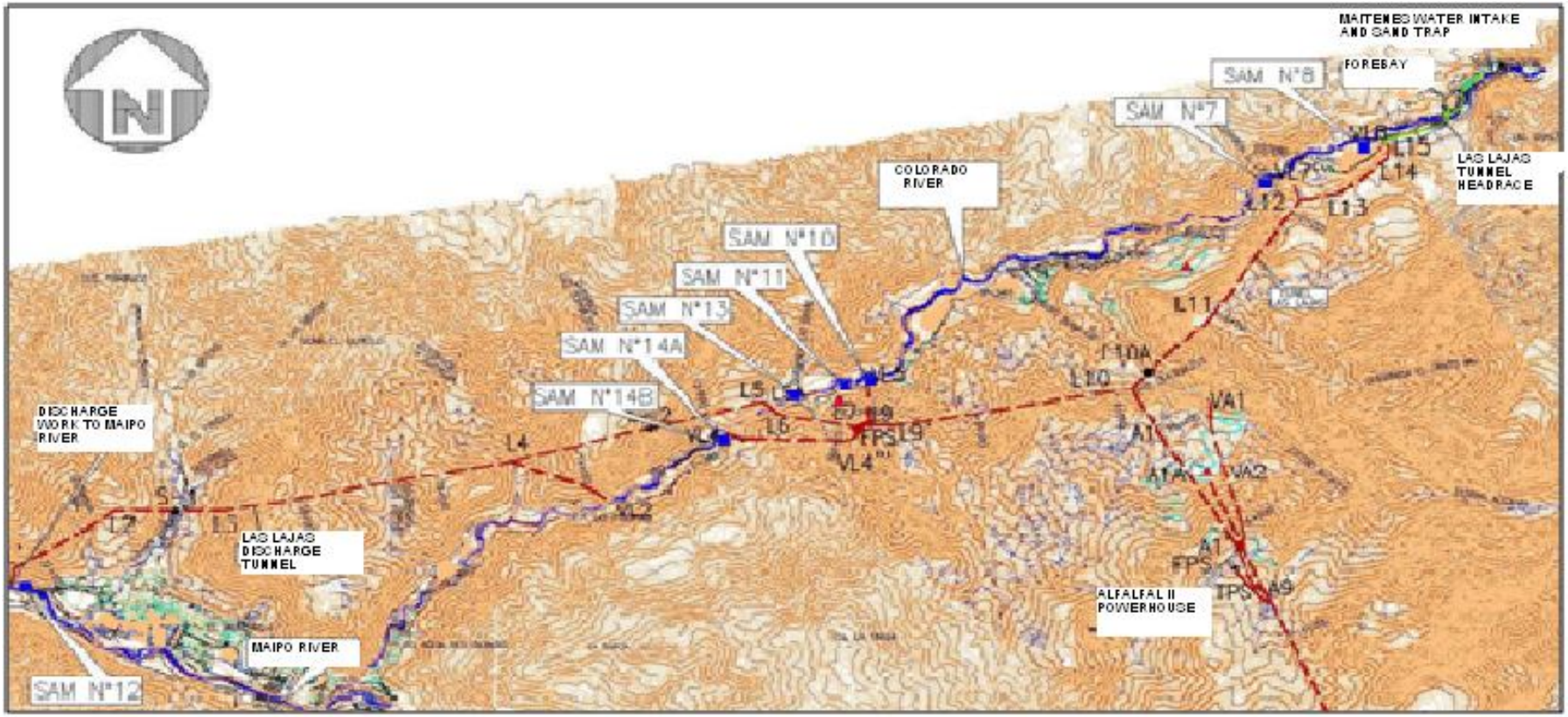

Figure 1-1. General Location of Muck Disposal Sites (MDS) in Colorado and Maipo Rivers

2. PURPOSE AND SCOPE

The purpose of this report is to present the results from calculating the hydraulic axis in Colorado and Maipo Rivers, in areas of Muck Disposal. The hydraulic levels helped define the location of the areas of material stockpile, so as not to be affected by the flooding of the river during the construction phase of Las Lajas power station.

3. BASES OF CALCULATION

3.1 Calculation of Hydraulic Axes in Natural Channels

The calculation of the hydraulic axis in a river (non-prismatic channel) corresponds to determine the free surface elevation along the waterway, based on their geometric characteristics, roughness of the bed and its banks, and its flows.

To calculate the hydraulic axis in Colorado and Maipo Rivers the program HEC-RAS 3.1.3 (2005) of U.S. Army Corps of Engineer's has been used, which solves the energy balance equation (Eq. 3.1) through the standard step method.

$$h_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = h_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad \text{(Eq.3.1)}$$

Where:

h_i	:	Height in section i
Z_i	:	Bottom elevation in section i
α_i	:	Coriolis coefficient in section i
V_i	:	Speed in section i
h_e	:	Pressure drop

In this case, water level in a section “i” is Z_{hi}:

$$Z_{hi} = h_i + Z_i \qquad \text{(Eq.3.2)}$$

Pressure drop (h_e) between two sections corresponds to the frictional loss and the loss by contraction or expansion (singular losses). The equation for the pressure drop is:

$$h_e = \langle J \rangle \cdot L + C \cdot \left| \frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g} \right| \qquad \text{(Eq.3.3)}$$

Where:

<J>	:	Average slope of the power line between two cross sections
L	:	Distance between cross sections
α_i	:	Coriolis coefficient in section i
V_i	:	Speed in section i
C	:	Pressure drop coefficient by contraction or expansion

The contraction and expansion coefficients depend on the nature of the transition. Generally, along a natural channel, transitions or geometric changes are gradual, so that high pressure drops do not occur. According to literature, for gradual transitions it is recommended, a coefficient of expansion of 0.3 and of contraction of 0.1.

For the calculation of frictional losses, the program considers the method called "Average Conveyance Equation" (average Coefficient of Hydraulic Conductivity). Its expression is:

$$< J > = \left(\frac{2Q}{K_1 + K_2} \right)^2 \qquad \text{(Eq.3.4)}$$

$$K = \frac{A \cdot R^{2/3}}{n} \qquad \text{(Eq.3.5)}$$

Where:

K_i	:	Hydraulic conductivity coefficient of section i
A	:	Runoff area
R	:	Hydraulic radius
n	:	Manning’s roughness coefficient

The slope of the power line in each section is calculated using Manning's equation.

$$Q = \frac{\sqrt{J}}{n} \cdot R^{2/3} \cdot A = \sqrt{J} \cdot K \qquad \text{(Eq.3.6)}$$

3.2 Flood Flows

3.2.1 Colorado River

The flow rates used for calculating the hydraulic axis on the Colorado River were obtained from the background of document No. 020-DC-INF-001 Definitive Basic Studies. Hydrology. Report Milestone 3. In this case there are two tranches:

- Tranche1: Between Maitenes Water Intake and confluence with Aucayes stream
- Tranche 2: Between Aucayes stream and joint with Maipo River

Sites 1 and 2 (SAM 8 and 7) are in Tranche 1, and the remainders of Colorado River are in Tranche 2.

Table 3-1 shows the flood flows to the areas under study for different return periods.

Table 3-1: Flood Flows. Colorado River in Muck Disposal Sites

T	**Qmax (m^3/s)**	
(years)	**Tranche 1**	**Tranche2**
2	200	220
5	320	350
10	430	470
25	610	660
50	770	850
100	980	1,080
200	1,230	1,350

3.2.2 Maipo River

For the study in the Maipo River, the background of document No. 020-DC-INF-001 above mentioned has also been used. The results obtained from the maximum instantaneous flow series during winter season of Maipo station in El Manzano are shown in Table 3-2.

Table 3-2: Flood Flows. Maipo River in Las Lajas Discharge

T (years)	**Qmax (m^3/s)**
2	370
5	530
10	650
25	640
50	1,300
100	1,780
200	2,400

3.3 Coefficients of roughness

3.3.1 General

In this case, the Cowan method for estimating the roughness of main waterway and of the floodplain on the banks of rivers has been applied. The expression for the Manning coefficient is:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) \cdot m_5 \qquad \text{(Eq.3.7)}$$

Where:

- n_0 : Roughness coefficient as a basis for a straight, uniform and smooth channel
- n_1 : Degree of irregularity of the section
- n_2 : Variation of the cross section
- n_3 : Effect of obstructions
- n_4 : Presence of vegetation
- m_5 : Correction factor due to the effects of meanders

As a second method, the values of **n** for the main waterway were determined using the equation proposed by A. Ugarte and M. Madrid, published in the "Engineering 94. Proceedings of the 1994 Conference, Volume 1, American Society of Civil Engineers." According to this publication, the following explicit equations to estimate the Manning coefficient in granular beds may be used:

$$n = \frac{\left(10 \cdot D_{50\%}\right)^{1/6}}{21} \qquad \text{(Eq.3.8)}$$

$$n = \frac{\left(3{,}4 \cdot D_{84\%}\right)^{1/6}}{21} \qquad \text{(Eq.3.9)}$$

3.3.2 Colorado River

Colorado River in the tranche under study presents a granular bed of coarse grain and extended, with a well-defined main waterway and vegetation on its banks, which can be seen in Pictures 3-1 and 3-2.

The values obtained with the Cowan's Method are shown in the following Tables:

Table 3-3. Roughness coefficients of Colorado River according to Cowan's Method. SAM N°8

Coefficient	Right Bank	Main Waterway	Left Bank
n_0	0.028	0.028	0.028
n_1	0.010	0.005	0.005
n_2	0.005	0.005	0.005
n_3	0.010	0.000	0.000
n_4	0.005	0.005	0.025
m_5	1,000	1,000	1,000
n	0.058	0.043	0.063

Picture 3-1. Colorado River, upstream view, site area of Las Lajas Forebay.

Picture 3-2. Colorado River area between Maitenes water intake and confluence with Maipo River.

Picture 3-3.Maipo River in front of SAM N° 12. There is an old installation of aggregate extraction.

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Picture 3-4. Maipo River, in area located downstream of the Muck Disposal Site N° 12.

Table 3-4. Roughness coefficients of Colorado River according to Cowan's method. SAM N°7

Coefficient	Right Bank	Main Waterway	Left Bank
n_0	0.028	0.028	0.028
n_1	0.010	0.005	0.010
n_2	0.005	0.005	0.005
n_3	0.010	0.000	0.010
n_4	0.005	0.005	0.005
m_5	1,000	1,000	1,000
n	0.058	0.043	0.058

Table 3-5. Roughness coefficients of Colorado River according to Cowan's method SAM N° 10, 11 and 13

Coefficient	Right Bank	Main Waterway	Left Bank
n_0	0.028	0.028	0.028
n_1	0.010	0.005	0.005
n_2	0.005	0.005	0.005
n_3	0.010	0.000	0.000
n_4	0.005	0.005	0.025
m_5	1,000	1,000	1,000
n	0.058	0.043	0.063

Table 3-6. Roughness coefficients of Colorado River according to Cowan's method SAM N°14 A and 14 B

Coefficient	Right Bank	Main Waterway	Left Bank
n_0	0.028	0.028	0.028
n_1	0.010	0.005	0.010
n_2	0.005	0.005	0.005
n_3	0.010	0.000	0.010
n_4	0.005	0.005	0.005
m_5	1,000	1,000	1,000
n	0.058	0.043	0.058

For the hydraulic study of Colorado River, the grain size of the waterway at two points has been applied: Colorado in the outlet and Colorado before joining with Olivares. Table 3-7 shows the typical diameters of the waterway at the points mentioned above and the values of n by applying the equations 3.8 and 3.9.

Table 3-7. Calculated roughness coefficients

Point	$D_{50\%}$ (mm)	n ($D_{50\%}$)	$D_{84\%}$ (mm)	n ($D_{84\%}$)
Colorado in outlet	66.9	0.045	217.4	0.045
Colorado before joining with Olivares	88.8	0.047	189.5	0.044

Averaging the values of roughness coefficient of the main waterway, a n = 0.045 is obtained, which is almost equal to that obtained by applying the method of Cowan¸ and it is also consistent with values reported in the book "Roughness Characteristics of Natural channels" U.S. Geological Survey, Water Supply, Paper 1849, 1967.

3.3.3 Maipo River

Like Colorado River, Maipo River has a granular bed, as shown in Pictures 3-3 and 3-4. The results obtained for the area of SAM No. 12 are presented in the following Table:

Table 3-8. Maipo River Roughness Coefficients. Cowan's Method.

Coefficient	Right Bank	Main Waterway	Left Bank
n_0	0.028	0.028	0.028
n_1	0.010	0.005	0.010
n_2	0.005	0	0.005
n_3	0.010	0.010	0.010
n_4	0.005	0	0.005
m_5	1,000	1,000	1,000
n	0.058	0.043	0.058

For the hydraulic study of Maipo River, a grain size analysis of material from the riverbed has been applied, with the following characteristic diameters and n values calculated from equations 3.8 and 3.9.

Table 3-9. Calculated roughness coefficients

Point	$D_{50\%}$ (mm)	n ($D_{50\%}$)	$D_{84\%}$ (mm)	n ($D_{84\%}$)
Maipo in discharge Las Lajas power station	79.1	0.046	241.91	0.046

With these values, we can see that for the main waterway, the value of n is similar to that obtained with the method of Cowan; in addition, it is also consistent with the values mentioned in the book of U.S. Geological Survey mentioned above

3.3.4 Experimental values of n

As a third alternative for estimating roughness coefficients, in Table 3-10 Manning coefficient values based on field measurements made by Madrid, M. (1992) on Colorado River and Maipo River are shown.

Table 3-10. Experimental values of n in Colorado River

Waterway	Q	A	Vm	P	L	Rh	Fd	J	n measured
	(m^3/s)	(m^2)	(m/s)	(m)	(m)	(m)		(m/m)	
Colorado in Outlet	74	26.61	2.78	18.91	17.2	1.41	0.71	0.0100	0.0452
	24	15,86	1,51	16,64	15,6	0,95	0,48	0,0090	0,0607
	66,3	23,67	2,80	18,45	16,2	1,28	0,74	0,0105	0,0432
	45	20,95	2,15	17,86	16,2	1,17	0,60	0,0097	0,0510
Colorado before joining Olivares	18	12,95	1,39	32,44	32,2	0,40	0,70	0,0161	0,0495
	52,52	23,15	2,27	37,14	36,7	0,62	0,91	0,0146	0,0389
	47,9	22,42	2,14	35,60	35,1	0,63	0,85	0,0146	0,0416
	28,5	16,02	1,78	33,80	33,2	0,47	0,82	0,0160	0,0432
Maipo River in El Manzano	367.33	105.24	3.49	51.11	49.10	2.06	0.762	0.00820	0.0420
	348.49	105.49	3.30	49.02	47.40	2.15	0.707	0.00820	0.0457
	207.00	67.81	3.05	45.33	44.17	1.50	0.787	0.00800	0.0383
	183.00	62.23	2.94	46.28	44.20	1.34	0.792	0.00812	0.0373
	112.00	48.77	2.30	44.46	43.70	1.10	0.694	0.00730	0.0396
Maipo in San Alfonso	229.41	62.15	3.69	36.10	32.70	1.72	0.86	0.01540	0.0483
	195.00	59.61	3.27	33.28	30.10	1.79	0.74	0.01080	0.0469
	126.82	47.19	2.69	32.62	30.30	1.45	0.69	0.01000	0.0476
	66.50	31.07	2.14	30.70	28.20	1.01	0.65	0.01080	0.0489

Coefficients obtained in Colorado in outlet, which is the nearest area to the tranche studied, presents for the higher flow rates, values close to those determined using the semi empirical methods previously applied.

In the case of Colorado before joining with Olivares, the values of n have less scatter in the outlet. Also in Maipo River in El Manzano experimental values are similar to those calculated. This validates the assumption that for the calculation of the hydraulic axis the following hydraulic roughness coefficient values are applied:

Table 3-11. Values of n adopted

Colorado River Muck Disposals N° 8, 7, 10, 11 and 13	**n**
Main waterway	0.045
Flood plains (low vegetation)	0.055
Flood plains (abundant vegetation)	0.063
Colorado River Muck Disposals N° 14 a and 14 B	**n**
Main waterway	0.045
Flood plains (low vegetation)	0.058
Flood plains (abundant vegetation)	0.058
Maipo River Muck Disposal N° 12	**n**
Main waterway	0.045
Flood plains	0.055
Rockfill dam protection, right bank	0.030

3.4 Topographic Background

To carry out the calculations of the hydraulic axis in the two rivers, a land survey made with the Transported Laser system was made, from which transversal profiles were obtained in the study area. In Figure 1-1 you can see an overview of this survey of the study area.

3.5 Boundary conditions

To calculate the hydraulic axis it is necessary, in addition to geometric and flow data, to establish boundary conditions according to the existing hydraulic controls in the waterway analyzed.

In the case of a river runoff, boundary condition is given from downstream; but instead a stream is conditioned from upstream.

In this analysis, we have assumed a mixed runoff, i.e. two boundary conditions are required, one upstream and one downstream. The condition entered into the HEC-RAS, in both cases, was the so-called "normal height" in the program. This

requires knowing the slopes of the river, both downstream and upstream for each tranche of calculation considered.

4. RESULTS

Axis hydraulic calculations were performed for 100 and 200 years of return period, even if for the purpose of checking the position of Muck Disposal Sites values corresponding to T = 200 years were used.

4.1 Hydraulic Axis in Muck Disposal N° 8

Figure 4-1 shows a longitudinal profile with the results of the hydraulic axis on the Colorado River in the area of muck disposal called SAM No. 8, near the window VL-9. Calculations were performed for T = 100 and 200 years. The detailed results for T = 200 years is shown in Table 4-1.

Table 4-1. Results for T=200 years. Muck Disposal N° 8

X	BED LEVEL	h	ELEVATION EH	ELEVATION ENERGY	J	Vm	Froude N°
(m)	(m ASL)	(m)	(m)	(m ASL)	(m/m)	(m/s)	(m)
0	1274,45	0	1280,09	1279,00	0,000162	0,96	0,13
40	1273,00	40	1280,08	1277,32	0,000191	1,01	0,12
80	1272,19	80	1279,22	1276,69	0,003385	3,76	0,50
120	1271,10	120	1278,86	1276,17	0,003289	4,19	0,53
160	1270,07	160	1276,75	1275,97	0,011401	7,02	0,97
200	1269,18	200	1273,18	1274,15	0,046538	9,81	1,88
240	1268,66	240	1271,65	1272,53	0,059386	8,63	2,00
280	1268,00	280	1272,13	1272,14	0,016933	6,04	1,16
320	1267,30	320	1272,32	1271,18	0,007471	4,56	0,76
360	1266,21	360	1272,43	1270,38	0,003151	3,05	0,53
400	1265,31	400	1271,28	1270,08	0,007445	4,98	0,86
440	1264,26	440	1270,00	1269,63	0,012963	5,70	0,98
480	1264,00	480	1268,77	1268,94	0,019519	6,26	1,17
520	1263,08	520	1266,43	1267,16	0,044237	8,55	1,81
560	1262,22	560	1267,09	1266,77	0,011962	5,68	1,00
600	1262,00	600	1265,65	1266,02	0,024102	6,42	1,37
640	1261,03	640	1265,06	1265,29	0,019302	5,94	1,27
680	1260,52	680	1264,15	1264,44	0,021855	6,03	1,34
720	1259,80	720	1263,69	1263,74	0,016525	5,52	1,16
760	1259,00	760	1262,89	1263,12	0,018739	5,42	1,30

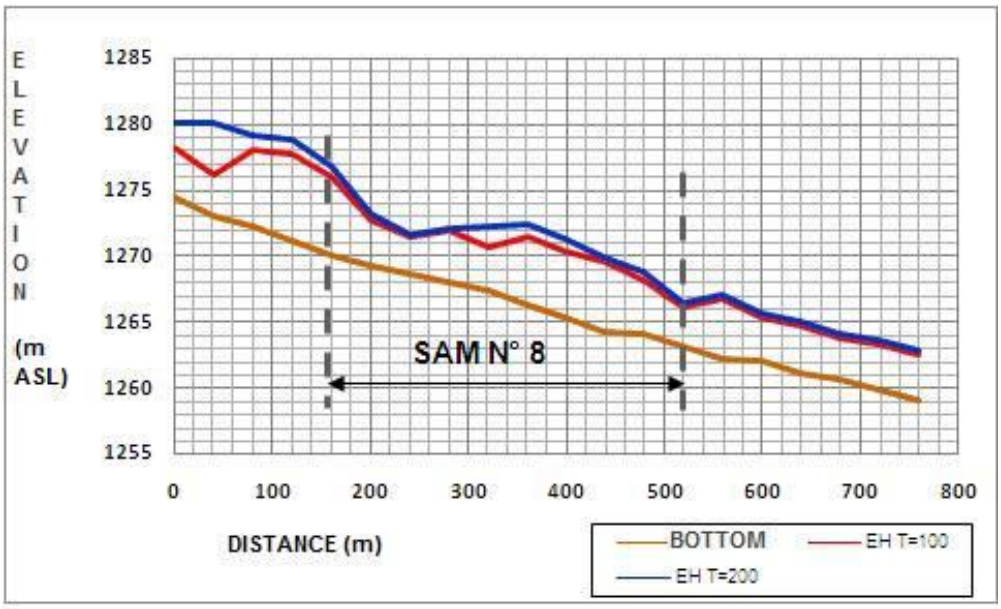


Figure 4-1. Hydraulic Axis Muck Disposal N° 8

4.2 Hydraulic axis in Muck Disposal N° 7

Figure 4-2 shows a longitudinal profile with the results of the hydraulic axis on the Colorado River in the area of Muck Disposal No. 7 near the VL-7, for the flow corresponding to T = 100 and 200 years. The detailed results for T = 200 years is shown in Table 4-2.

Table 4-2. Results for T=200 years. Muck Disposal N° 7

X	BED LEVEL	h	ELEVATION EH	ELEVATION ENERGY	J	Vm	Froude N°
(m)	(m ASL)	(m)	(m)	(m ASL)	(m/m)	(m/s)	(m)
0	1238,15	3,28	1241,43	1243,59	0,024704	6,52	1,29
50	1237,00	4,37	1241,37	1242,86	0,014041	5,41	1,00
100	1235,57	3,66	1239,23	1241,77	0,029778	7,04	1,49
150	1234,09	3,04	1237,13	1239,95	0,044009	7,44	1,66
200	1232,47	5,30	1237,77	1238,77	0,008379	4,44	0,78
250	1231,60	6,28	1237,88	1238,37	0,003275	3,11	0,50
300	1230,00	7,86	1237,86	1238,20	0,001818	2,59	0,38
350	1228,00	9,87	1237,87	1238,11	0,000879	2,18	0,28
400	1225,60	12,30	1237,9	1238,06	0,000433	1,77	0,20
450	1223,86	13,52	1237,38	1237,97	0,001779	3,38	0,41
500	1222,00	15,52	1237,52	1237,83	0,000900	2,46	0,27
550	1222,27	12,62	1234,89	1237,48	0,016576	7,13	1,00
600	1220,97	5,45	1226,42	1235,30	0,077548	13,20	2,28
650	1219,60	3,26	1222,86	1230,31	0,108823	12,09	2,62
700	1218,98	3,51	1222,49	1226,35	0,035507	8,70	1,56

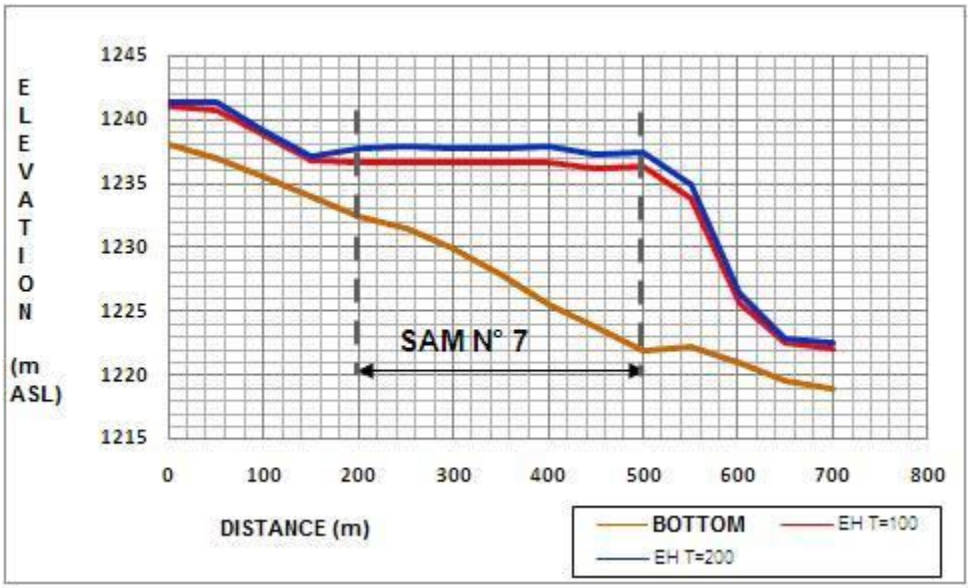


Figure 4-2. Hydraulic Axis Muck Disposal N° 7

4.3 Hydraulic axis in Muck Disposals N° 10, 11 and 13

This group of muck disposal sites is located at El Sauce. Figure 4-3 shows a longitudinal profile with hydraulic axis results in this sector of Colorado River for flows corresponding to T = 100 and 200 years. The detailed results for T = 200 years are shown in Table 4-3.

Table 4-3. Results for T=200 years. Muck Disposals El Sauce

X	BED LEVEL	h	ELEVATION EH	ELEVATION ENERGY	J	Vm	Froude N°
(m)	(m ASL)	(m)	(m)	(m ASL)	(m/m)	(m/s)	(m)
0	1072,00	5,17	1077,17	1078,55	0,009514	5,20	0,84
80	1071,00	5,01	1076,01	1077,64	0,013193	5,65	0,97
160	1070,43	4,51	1074,94	1076,54	0,014062	5,60	1,00
240	1068,86	4,00	1072,86	1075,18	0,018456	6,76	1,15
320	1067,18	3,61	1070,79	1073,38	0,027358	7,12	1,37
400	1065,06	6,31	1071,37	1072,04	0,003438	3,53	0,58
480	1064,00	7,33	1071,33	1071,76	0,001988	2,92	0,41
560	1062,75	6,63	1069,38	1071,28	0,013249	6,12	1,00
640	1062,00	2,66	1064,66	1069,09	0,057985	9,33	1,94
720	1060,62	4,72	1065,34	1067,02	0,013913	5,74	1,00
800	1058,98	4,12	1063,10	1065,49	0,024914	6,85	1,31
880	1057,38	6,40	1063,78	1064,34	0,002464	3,33	0,45
960	1056,30	5,39	1061,69	1063,80	0,013100	6,43	1,00
1040	1055,67	4,51	1060,18	1062,55	0,018379	6,81	1,16
1120	1053,83	4,55	1058,38	1061,03	0,018676	7,22	1,16
1200	1052,90	4,86	1057,76	1059,64	0,013157	6,08	1,00
1280	1051,94	5,80	1057,74	1058,51	0,004053	3,89	0,57
1360	1050,45	7,07	1057,52	1058,20	0,003113	3,65	0,50
1440	1049,00	8,19	1057,19	1057,95	0,002948	3,87	0,48
1520	1047,99	6,57	1054,56	1057,31	0,014132	7,34	1,00
1600	1046,20	4,32	1050,52	1055,34	0,039118	9,72	1,65
1680	1045,22	5,40	1050,62	1052,84	0,013614	6,60	1,00
1760	1044,00	3,63	1047,63	1051,04	0,036393	8,18	1,56
1840	1043,42	4,39	1047,81	1049,55	0,013715	5,83	1,00
1920	1040,79	4,06	1044,85	1047,88	0,028924	7,71	1,42
2000	1038,89	6,14	1045,03	1045,93	0,004984	4,21	0,63
2080	1037,00	6,02	1043,02	1045,19	0,013285	6,53	1,00
2160	1035,30	6,28	1041,58	1044,01	0,015722	6,91	1,08
2200	1033,00	3,79	1036,79	1042,61	0,053868	10,69	1,93

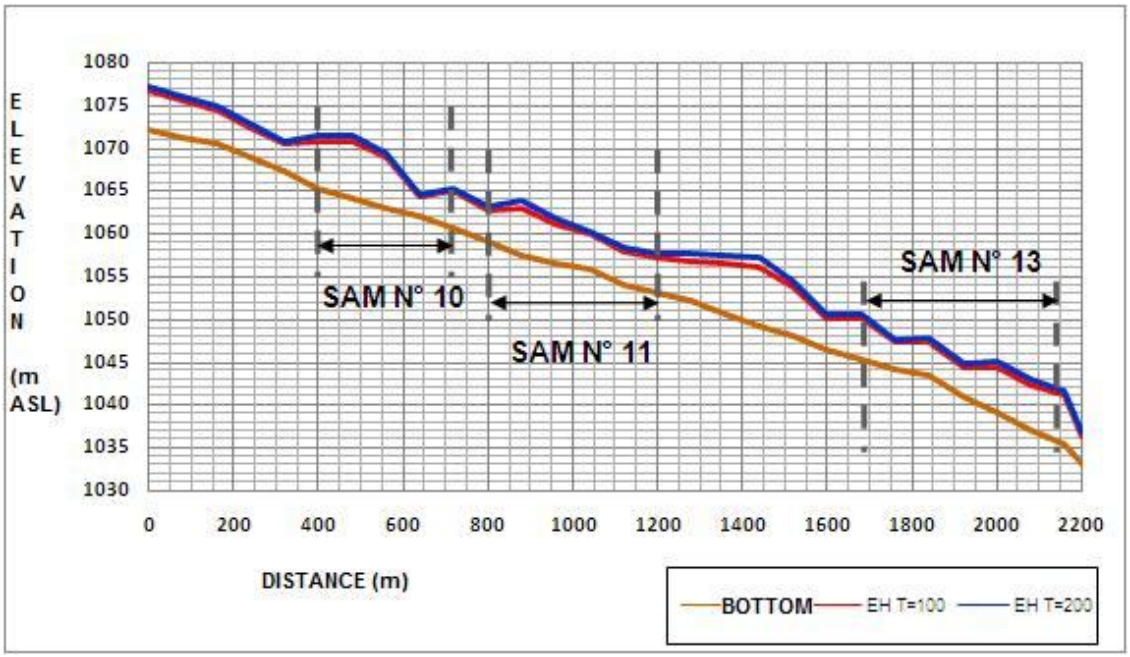


Figure 4-3. Hydraulic Axis Muck Disposals in El Sauce area

4.4 Hydraulic Axis in Muck Disposals N° 14 A and 14 B

These are the last two muck disposal sites of Colorado River. Figure 4-4 shows the longitudinal profile with the results of the hydraulic axis on Colorado River, for the flow corresponding to T = 100 and 200 years. The detailed results for T = 200 years is shown in Table 4-4.

Table 4-4. Results for T=200 years. Muck Disposals N° 14 A and 14 B

X	BED LEVEL	h	ELEVATION EH	ELEVATION ENERGY	J	Vm	Froude N°
(m)	(m ASL)	(m)	(m)	(m ASL)	(m/m)	(m/s)	(m)
0	1025,79	7,25	1033,04	1035,68	0,012455	7,20	1,01
100	1022,80	7,85	1030,65	1033,33	0,012558	7,26	1,01
200	1019,92	8,28	1028,20	1030,86	0,012689	7,23	1,02
300	1017,23	8,35	1025,58	1028,08	0,012298	7,02	1,01
400	1014,25	7,49	1021,74	1024,91	0,017892	7,89	1,20
500	1012,07	5,08	1017,15	1021,88	0,030572	9,63	1,53
600	1009,85	6,45	1016,30	1019,35	0,018398	7,74	1,21
700	1008,94	6,09	1015,03	1017,31	0,013228	6,70	1,04
800	1008,03	5,06	1013,09	1015,25	0,012373	6,52	1,01
900	1006,71	4,13	1010,84	1013,14	0,014795	6,73	1,09
1000	1004,70	4,61	1009,31	1011,07	0,011085	5,88	0,95
1100	1002,60	5,38	1007,98	1009,79	0,010727	5,95	0,94
1200	1001,30	5,42	1006,72	1008,55	0,010285	5,99	0,92
1300	999,80	5,71	1005,51	1007,37	0,009853	6,03	0,91
1400	999,40	5,00	1004,40	1006,25	0,009251	6,02	0,88
1500	997,00	6,21	1003,21	1005,17	0,009575	6,20	0,90
1600	995,60	6,33	1001,93	1004,00	0,010183	6,37	0,93

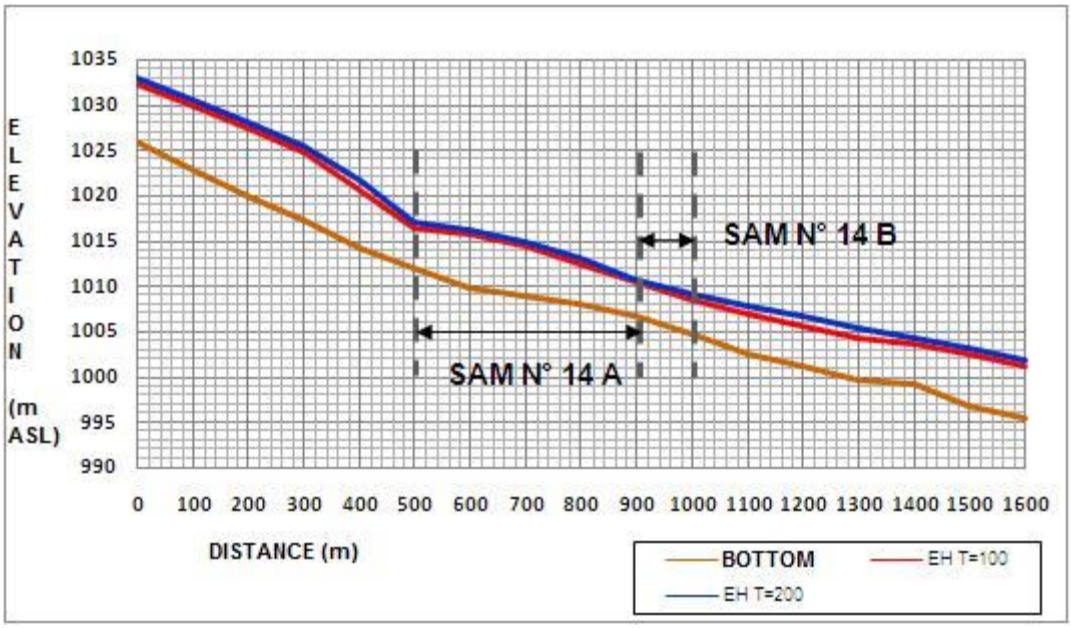


Figure 4-4. Hydraulic Axis Muck Disposals N° 14 B and 14 B

4.5 Hydraulic Axis in Muck Disposal N° 12

This muck disposal site that corresponds to Maipo River, is located in a tranche located immediately upstream of the discharge of Las Lajas power station. Figure 4-5 shows the longitudinal profile with the results of the hydraulic axis in Maipo River, for the flow corresponding to T = 100 and 200 years. The detailed results for T = 200 years is shown in Table 4-5.

Table 4-5. Results for T=200 years. Muck Disposal N° 12

X	BED LEVEL	h	ELEVATION EH	ELEVATION ENERGY	J	Vm	Froude N°
(m)	(m ASL)	(m)	(m)	(m ASL)	(m/m)	(m/s)	(m)
0	823,39	5,82	829,21	831,29	0,008961	6,29	0,89
100	822,57	6,35	828,92	830,40	0,005738	5,24	0,77
200	821,50	6,70	828,20	829,80	0,005953	5,24	0,77
300	820,64	7,05	827,69	829,24	0,005074	5,41	0,71
400	820,00	6,68	826,68	828,59	0,006580	6,02	0,81
500	819,27	5,94	825,21	827,71	0,010532	6,87	0,99
600	816,67	5,18	821,85	826,07	0,021971	9,04	1,39
700	815,26	7,31	822,57	824,59	0,007143	6,11	0,84
800	814,92	7,22	822,14	823,86	0,005857	5,68	0,75
900	814,00	6,22	820,22	822,97	0,010899	7,16	0,99
1000	813,00	7,39	820,39	821,58	0,003617	4,75	0,59
1100	813,00	7,51	820,51	821,17	0,001903	3,51	0,43
1200	812,00	8,25	820,25	820,97	0,001904	3,63	0,45
1300	811,83	6,62	818,45	820,50	0,007362	6,18	0,83
1400	811,00	7,18	818,18	819,75	0,005156	5,25	0,79
1500	811,00	6,90	817,90	819,18	0,004500	4,63	0,70

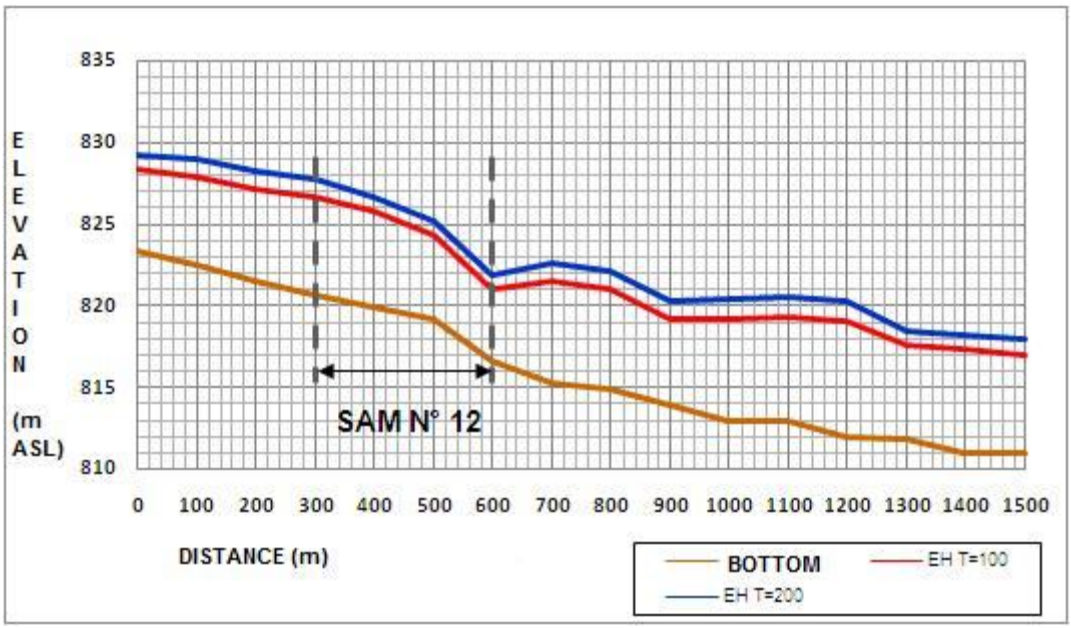


Figure 4-5. Hydraulic Axis Muck Disposal N° 12. Maipo River

5. ANALYSIS OF RESULTS AND CONCLUSIONS

With the results obtained from calculating the hydraulic axis on Colorado River and Maipo River, at various points where there are plans to install Muck Disposal sites, it was verified that these works are not affected by the levels of the river in case of flood. To this end, a check has been performed using hydraulic axis levels obtained for a return period of T = 200 years. This can be seen in Figures in Annex 2.

5.1 Colorado River

As noted, in Colorado River 7 Muck Disposal site have been projected, which are located on the banks of the river, as shown in the diagrams in Annex 1 to this Report. These sites are located on natural terrain, to appropriate levels, so that the minimum freeboards measured with regard to foundation elevation of the seven SAM are at least 2 m, assuming a 200 year flood of return period. This can be seen in Table 5-1, which presents a summary of the existing freeboards and safeguards against the seven Muck Disposal Sites in Colorado River.

Table 5-1. Elevation of EH and Freeboards. SAM Colorado River.

N°	SAM	DISTANCE *	FOUNDATION ELEVATION**	ELEVATION EH (T=200)	FREEBOARD
		(m)	(m ASL)	(m ASL)	(m)
1	SAM Nº 8	2668	1275	1272,38	2,63
2	SAM Nº 7	4366	1240	1237,87	2,13
3	SAM Nº 10	12958	1074	1069,38	4,62
4	SAM Nº 11	13446	1064	1060,94	3,07
5	SAM Nº 13	14339	1057	1044,85	12,15
6	SAM Nº 14 A	15703	1044	1015,67	28,34
7	SAM Nº 14 B	15953	1020	1009,31	10,69

*: Measured by Colorado River axis from Maitenes Water Intake

**: It corresponds to the minimum terrain elevation at the base of the Muck Disposal slope

5.2 Maipo River

Muck Disposal Site No. 12, located on the right bank of the Maipo River, is located in a former plant for the extraction of aggregates, as shown in Picture 3-3. In this place a longitudinal river defense must be built, so that the foundation elevations of dump is at least 0.50 m above the Maipo River level in flood, considering a return period of 200 years.

Based on calculations, crest elevation of this rockfill dam has been defined, which is presented in Table 5-2 and Figure 5-1 chart, which shows the longitudinal profile of the river in the defense area between 0.30 km and 0.60 km.

Table 5-2. Rockfill Dam Protection Sam 12. Right Bank of Maipo River

X	FOUNDATION ELEVATION	ELEVATION EH (T=100)	ELEVATION EH (T=200)	CREST ELEVATION. ROCKFILL DAM	REV. (T=100)	REV. (T=200)
(m)	(m ASL)	(m ASL)	(m ASL)	(m ASL)	(m)	(m)
300,00	825,00	826,56	827,69	828,50	1,94	0,81
400,00	824,50	825,74	826,68	827,50	1,76	0,82
500,00	824,50	824,26	825,21	826,00	1,74	0,79
600,00	824,00	820,96	821,85	824,00	3,04	2,15

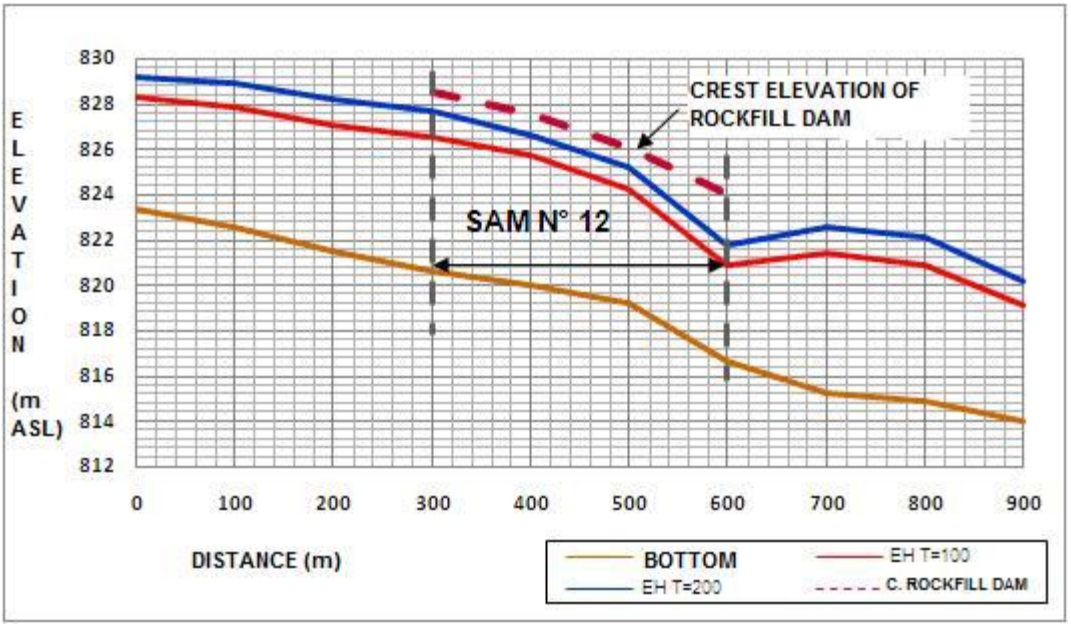


Figure 5-1. Longitudinal Profile Maipo River in front of SAM Nº 12

Figure 5-3 shows the proposed diagram for this river defense, which considers rockfill dam of two layers, with rocks of an average diameter of 1.3 m.

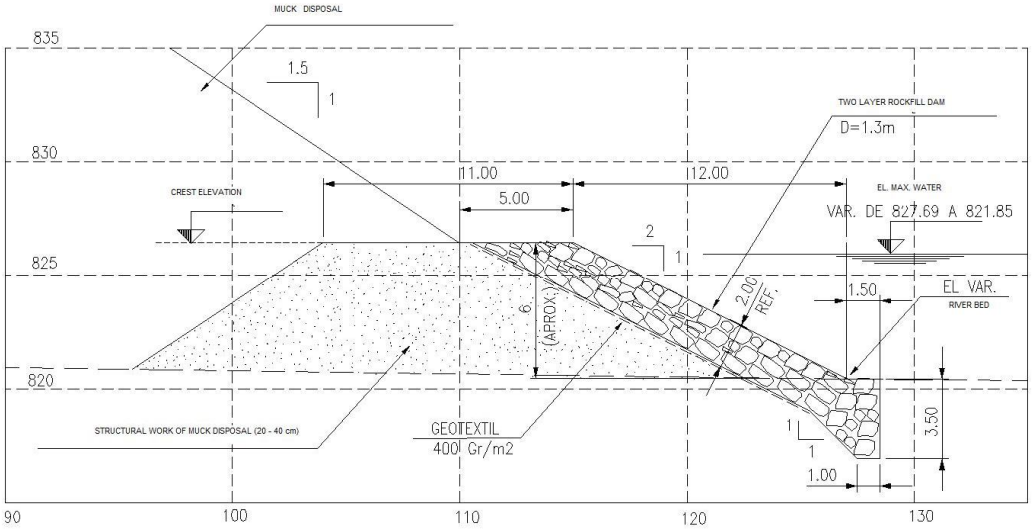
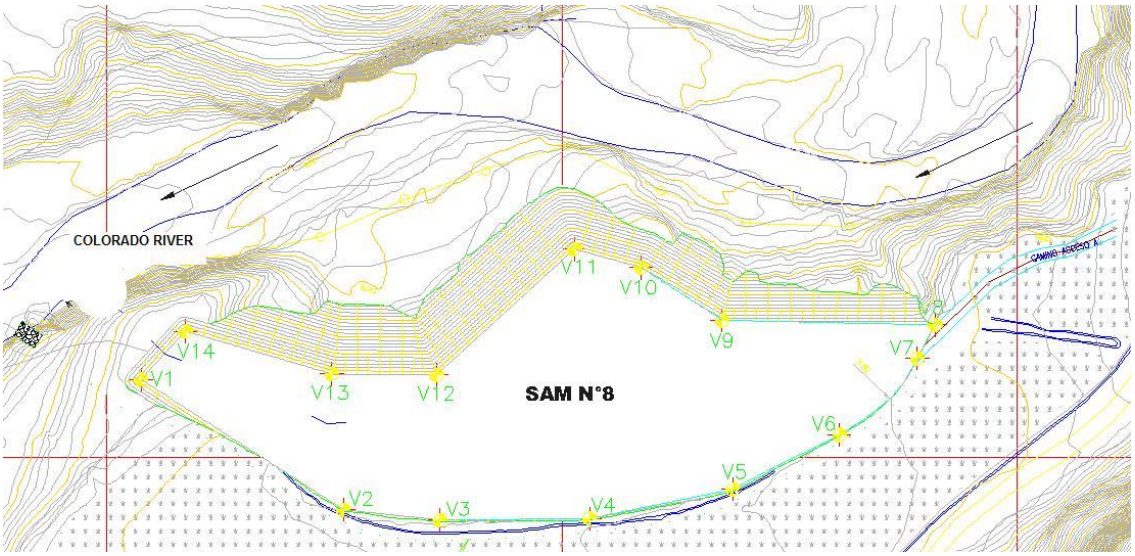


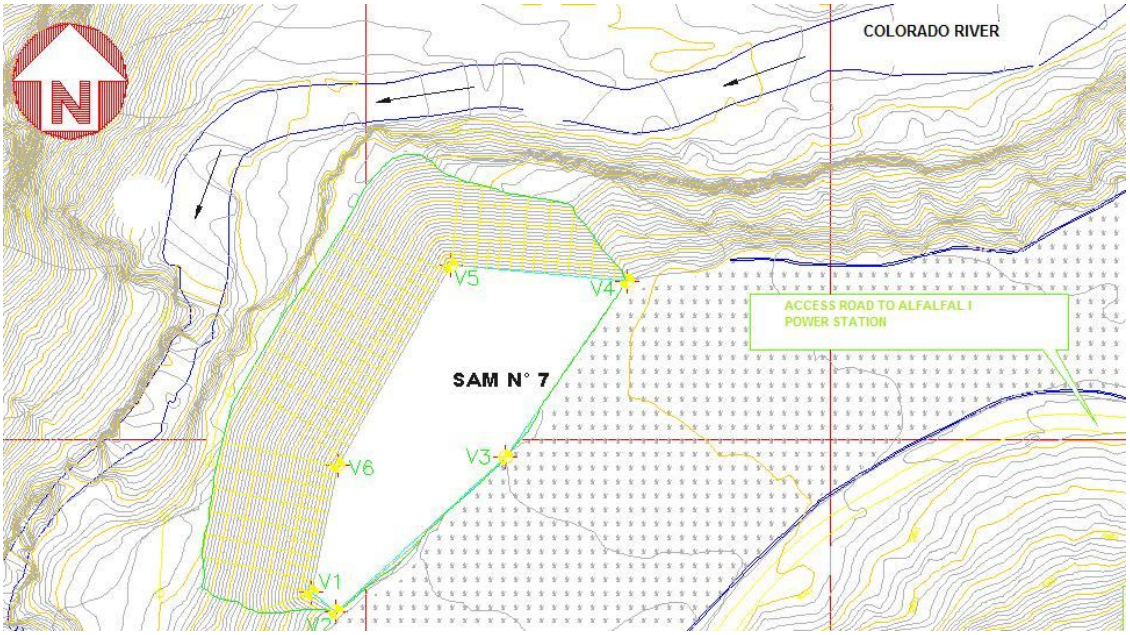
Figure5-2. Rockfill dam diagram SAM 12. Right Bank of Maipo River

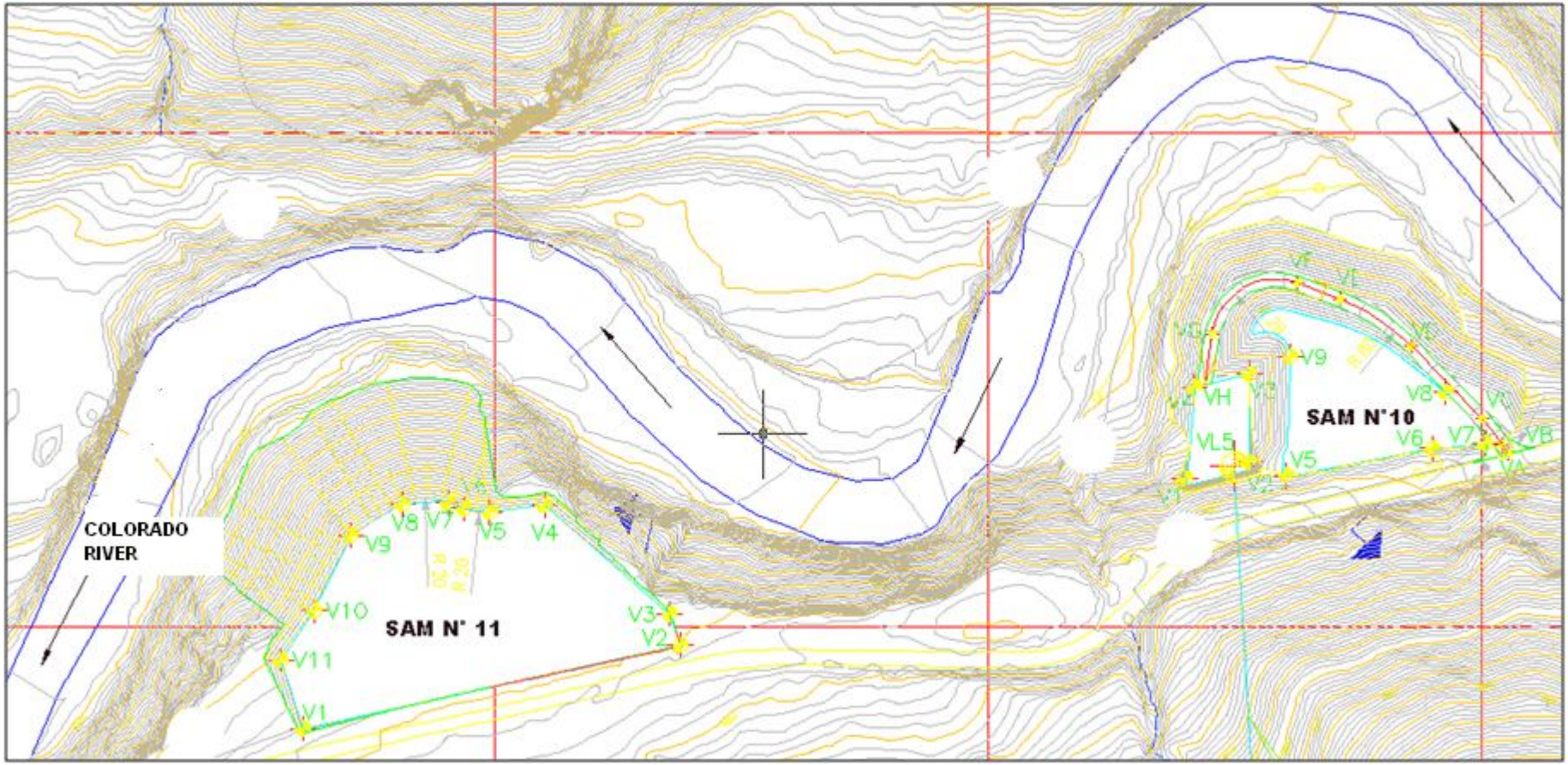
ANNEX 1

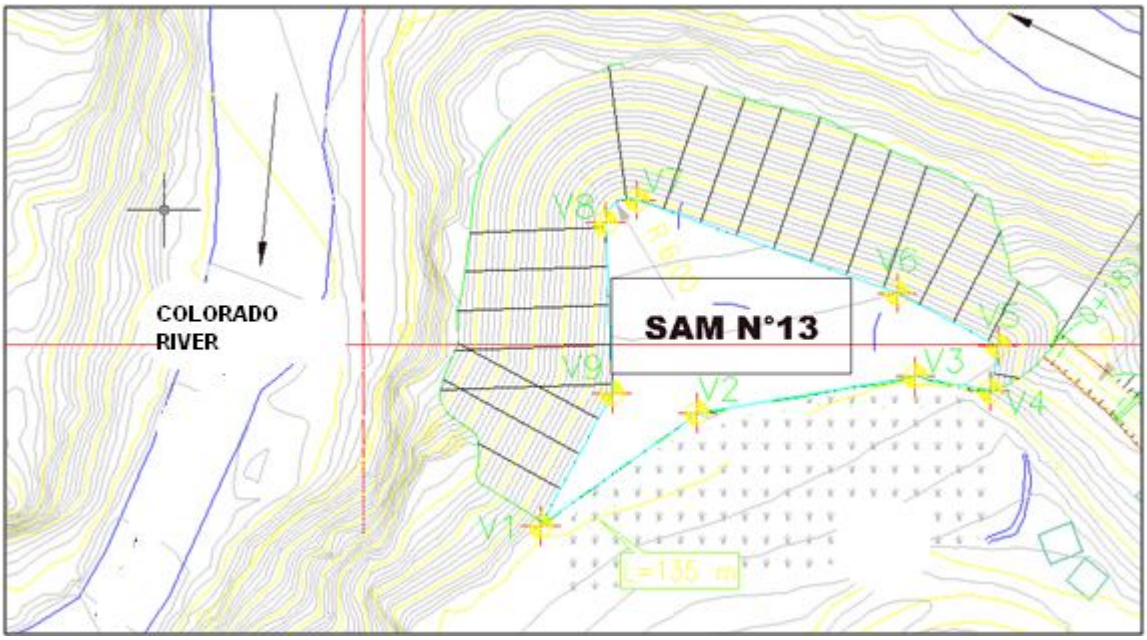
LOCATION IN PLANT
MUCK DISPOSAL SITES

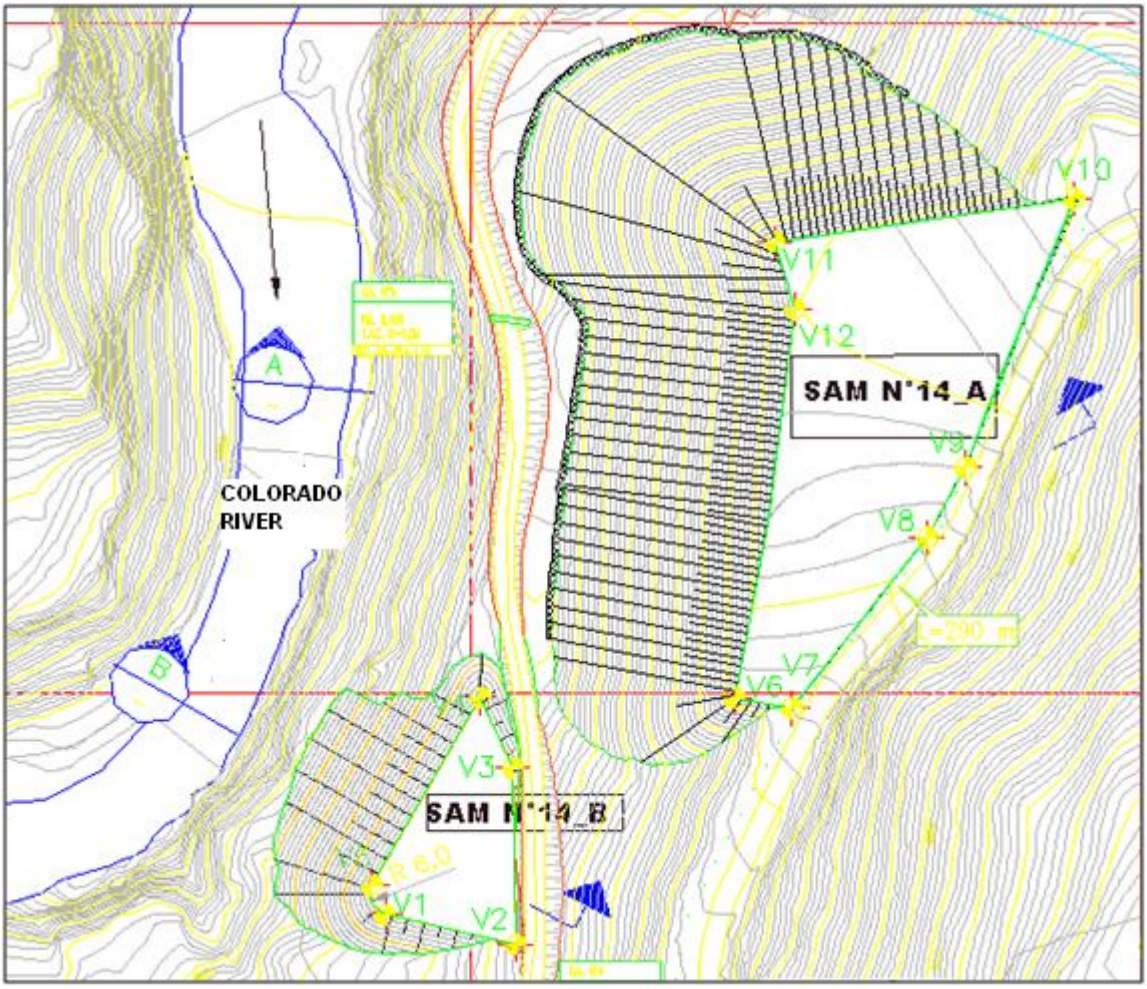
COLORADO AND MAIPO RIVERS

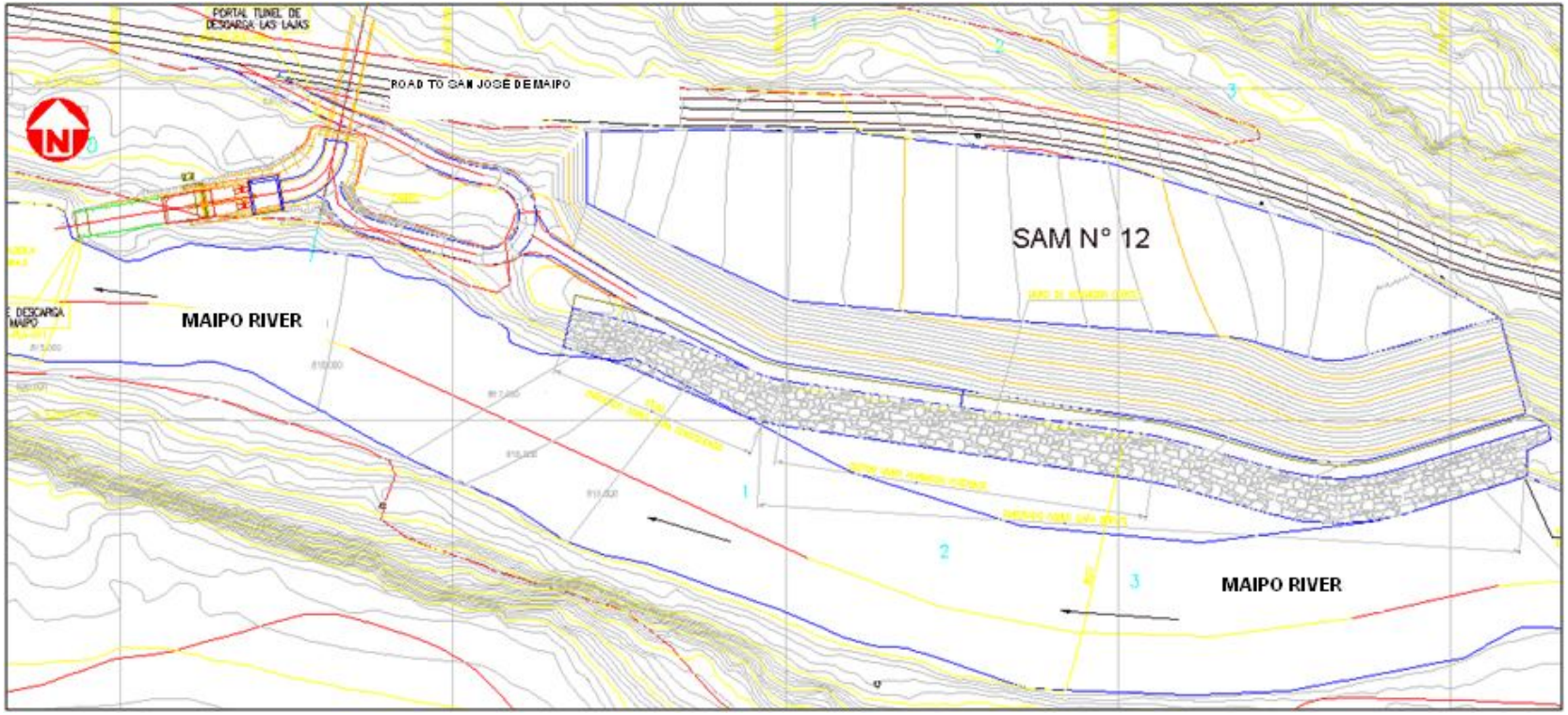

COLORADO RIVER
V11
V10
V9
V14
V1
V13
V12
SAM N°8
V7
V6
V5
V2
V3
V4


N
COLORADO RIVER
V5
V4
ACCESS ROAD TO ALFALFAL I
POWER STATION
SAM N° 7
V3
V6
V1
V2


COLORADO
RIVER
SAM N° 11
SAM N°10
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
VH
VL5


COLORADO
RIVER
SAM N°13
V1
V2
V3
V4
V5
V6
V7
V8
V9
L=135 m


COLORADO
RIVER
SAM N°14_A
SAM N°14_B
A
B
V1
V2
V3
V6
V7
V8
V9
V10
V11
V12
L=200 m


PORTAL TUNEL DE DESCARGA LAS LAJAS
ROAD TO SAN JOSE DE MAIPO
N
SAM N° 12
MAIPO RIVER
MAIPO RIVER