1.2.3 RAINFALL

Monthly precipitation in Puno City for the last 5 years is shown in *Table VII.1.2*. The most of the heavy rain events occurred from December to March. At present, SENAMHI weather station in Puno only records daily precipitation. The pluviographic band data is not available since 1990. For the evaluation of maximum rainwater discharge, the rainfall intensities for 5 and 10 years return periods are studied using the pluviographic band data from 1965 to 1989.

Table VII.1.2 Monthly precipitation in Puno

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1993	175.6	100.7	107.0	52.5	6.6	1.1	0.0	37.9	18.0	69.1	79.2	111.5	759.2
1994	180.0	183.1	113.3	116.2	29.9	0.4	0.0	0.0	18.3	36.6	52.6	73.2	803.6
1995	122.7	119.7	124.0	2.1	4.1	0.0	0.0	3.0	21.9	15.3	50.3	80.2	543.3
1996	252.7	130.5	60.8	76.3	0.0	0.0	2.9	12.8	0.8	10.4	88.3	118.0	753.5
1997	239.6	213.2	98.6	.88.6	0.9	0.0	0.0	21.9	108.2	30.1	62.9	44.9	908.9

Source: SENAMHI

1.2.4 OPERATION AND MAINTENANCE

Puno municipality performs silt and debris removal from the major urban drainage ways before and after the rainy season. For the each occasion, 5 personnel take part in the works for the duration of 15 to 20 days. The removed silt is transported by the dump trucks to be used as a construction material (backfill) or to the final disposal. Inspections are done after the above works and the damaged sections are repaired. If the illegal disposals of wastewater to the drainage ways were found, they are reported to EMSAPUNO.

Personnel from PELT inspect the erosion control facilities for microcuencas at the end of rainy season. The repair works for the damaged small dams are required after the major storm events.

1.2.5 FUTURE DEVELOPMENT PLANS

The following studies have been made on the drainage systems of Puno City:

1. PELT (1997) "Estudio de Factibilidad – Descontaminacion y Desarrollo de la Bahia Interior de Puno".

2. WB (1998) "Programa de Rehabilitacion y Gestion Urbana en la Republica del Peru"

PELT proposed a storm water management plan as a part of "Estudio de Factibilidad – Descontaminacion y Desarrollo de la Bahia Interior de Puno", 1997. The plan includes not only rehabilitation and expansion of the existing urban drainage system, but also erosion control measures along the existing 58 small rivers (microcuencas). The erosion control measures include installation of small dams, stabilization of banks and forestation.

World Bank funded "Programa de Rehabilitacion y Gestion Urbana en la Republica del Peru", which diagnosed the existing condition of Puno City and proposed priority projects and studies. The proposed studies include the development of a stormwater drainage master plan. The development of the master plan will take eight months with the estimated cost of US$ 435,022 (incl. I.G.V.). The proposed study includes thorough topographic survey of the area and hydraulic modeling of discharge for the fifty (50) years return period.

1.3 EVALUATION OF PRESENT CONDITIONS

At present, the major rain events flood the street in the several locations in the low-lying area of Puno City. But the flood level does not reach the top of the curb in the streets. In the past 20 years, the flood level reached the floor level of the buildings around the lake shore only when the water level of the lake went up, especially when it reached 3,813 m a.s.l. in 1986.

The street flooding takes place where the street drainage system is in sufficient or does not exist. But the natural gradient towards the lake drains rainwater within a relatively short period. Normally, the water level of the street goes down in less than 1 hour after rain events.

Silt and debris accumulation is observed in the most of the drainage ways, which requires periodical maintenance works by Puno provincial municipality.

In the small rivers (microcuencas) located on the steep hill over the city center, disposal of solid wastes, human excreta and used construction materials are frequently observed due to the insufficient solid waste collection (once a week) and the lack of sanitation facilities. Those wastes are washed away by the rain events, through urban drainage ways, reach the interior bay.

The erosion control measures initiated by PELT for the higher part of the study area over 3,850 m a.s.l. manage to control the serious erosion of the area, although the facilities require periodical maintenance works. PELT intends to extend existing facilities to the whole catchment area of the interior bay.

1.4 IDENTIFICATION OF PROBLEMS

The following problems of the existing drainage system have been found:

(1) Street flooding

Street flooding is observed mostly in low-lying area of the city. Although the flood level does not seriously obstruct the traffic so far, street drainage facilities shall be installed. Only few streets in the city have proper drainage facilities. The most of existing street drainage systems require repair and maintenance works such as dredging and cleaning of grilles.

(2) Sedimentation in the drainage ways

Sedimentation of silt and debris is observed most of the drainage ways, which reduce the hydraulic capacity of the system. Major sources of incoming silt are earth banks of small rivers, unpaved road in the steep hill and construction site scattered in the city. Sediment deposited during small storms can flush during larger storm events to the lake. They not only reduce the drainage capacity of the channels but also increase the eutrophication level of the interior bay of Puno as they are washed away to the lake by the rain events.

(3) Rainwater inflow to the sanitary sewer system

The lack of proper streets and building drainage facilities leads to the intentional and unintentional rain water discharge into the sanitary sewer system and results in surcharging and silt sedimentation in the sewer lines. Rainwater from the roof is often led to the sewage pit of buildings and ends up in the sewerage collection system. In the several places, rainwater drainage pipes or gutters are directory connected to the manholes of the sewage collection system.

(4) Water quality

The only 46% of the population are connected to the sanitary sewer system. The rest of the population dispose domestic wastewater to the streets or gutters, which ends up in the drainage ways. Combined with the solid wastes disposed in the microcuencas or drainage ways, wastewater degrades the stormwater run off quality and becomes a pollution load to the lake.

2. HYDROLOGICAL ANALYSIS

This chapter presents the results on meteo-hydrological analysis carried out during the period October 1998 to February 1999 in Peru and May to July, 1999 in Japan. Previous studies have been reviewed, raw data on meteorology and hydrology have been collected and a detailed analysis on meteo-hydrology has been carried out using the collected data.

2.1 RAINFALL ANALYSIS

2.1.1 MONITORING OF RAINFALL

Rainfall has been recorded at SENAMHI Puno station located in the Study area. Pluviographic charts, which record rainfall depth measured by a rain gage continuously, are available for the period between year 1965 and 1989. Since year 1990, use of this rain gage was discontinued and only daily rainfall readings are available.

2.1.2 PROBABILITY ANALYSIS ON ANNUAL MAXIMUM RAINFALLS

Annual maximum rainfall data at Puno station is presented in *Table VII.2.1*. The values for 15 minutes up to 24 hours represent annual maximum rainfall from compound rainfall (single or multiple) events.

Probability analysis on annual maximum short duration rainfall (from 15 minutes up to 180 minutes) and for long duration rainfall (from 3 hours up to 24 hours or daily) have been carried out using Gumbel's distribution method. The goodness of fit by Gumbel's distribution has been checked against Thomas (or Weinbull's) plotting position formula and is shown in *Figure VII.2.1*. It can be seen that Gumbel's distribution gives comparable fits with Thomas plots.

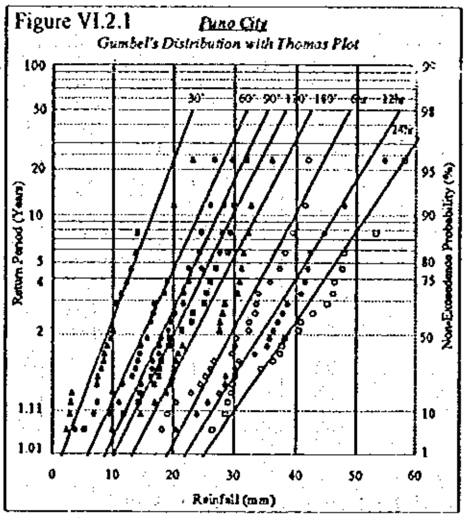


Table VII.2.1 Annual maximum rainfalls in Puno City

Year	Precipitation* (mm)							
	30 min.	60 min.	90 min.	120 min.	180 min.	6 hrs.	12 hrs.	24 hrs.
1965	10.5	18.5	21.6	27.0	31.5	41.5	44.7	46.2
1966	10.0	19.0	22.5	25.5	32.7	38.2	41.4	45.2
1967	7.4	10.0	16.6	16.9	17.0	30.4	33.3	37.7
1968	11.3	15.7	17.6	19.4	21.5	26.8	27.6	29.8
1969	10.0	16.8	21.7	25.1	28.5	30.2	30.2	30.2
1970	8.5	11.6	14.7	18.0	20.4	25.3	35.7	36.3
1971	20.0	26.1	28.3	29.9	32.2	33.9	42.3	46.4
1972	3.0	6.9	9.4	11.9	19.4	33.4	37.0	38.2
1973	9.1	24.3	28.0	29.3	30.9	32.4	40.8	40.8
1974	9.6	14.7	19.2	23.0	27.7	32.5	41.9	53.3
1975	8.6	13.8	16.3	17.6	21.5	33.6	35.3	53.3
1976	7.5	13.2	16.5	17.7	18.9	20.5	20.5	29.6
1977	3.2	7.5	11.0	14.3	19.8	26.2	36.3	37.4
1978	13.0	22.5	24.6	26.1	27.6	29.7	30.8	40.4
1980	8.1	14.5	14.5	14.5	14.6	19.1	23.9	29.1
1982	14.0	24.6	27.6	29.0	31.2	35.8	38.5	42.8
1984	2.3	14.2	19.5	21.4	28.1	42.0	54.7	58.1
1985	13.7	15.7	20.2	23.2	30.6	37.3	37.8	47.7
1986	12.3	16.3	17.7	18.0	20.8	24.5	25.7	26.5
1987	23.1	26.8	29.6	32.0	36.0	39.4	48.0	48.0
1988	2.9	3.8	5.1	5.3	9.9	18.2	28.7	28.7
1989	10.0	16.9	18.0	19.3	20.1	23.0	28.6	34.4
Maximum	23.1	26.8	29.6	32.0	36.0	42.0	54.7	58.1

* Amount represents annual maximum rainfall for compound rainfall
Data source: SENAMHI

The results of probability analysis are summarized in *Table VII.2.2.* Probable maximum rainfall intensities (60 minutes) for 2, 3, 5 and 10 year return periods are 15, 18, 21and 24 mm/hr respectively.

Table VII.2.2 Probable maximum rainfall depths (Gumbel's method)

Unit : mm

Time	Probable Rainfall Depths for Different Return Periods							
(minutes)	1.0-Yr	2-Yr	3-Yr	5-Yr	10-Yr	20-Yr	30-Yr	50-Yr
30		9.08	11.21	13.58	16.55	19.41	21.05	23.11
60	3.99	15.05	17.63	20.50	24.11	27.58	29.57	32.06
90	6.83	18.07	20.69	23.61	27.28	30.79	32.82	35.35
120	8.16	20.02	22.79	25.87	29.74	33.46	35.60	38.27
180	11.12	23.46	26.33	29.54	33.56	37.42	39.65	42.42
360	16.88	29.48	32.41	35.69	39.80	43.74	46.01	48.84
720	19.40	34.26	37.73	41.59	46.44	51.09	53.77	57.11
1440	22.31	38.52	42.30	46.51	51.80	56.88	59.80	63.45

2.1.3 INTENSITY-DURATION-FREQUENCY CURVES

Based on the results of probability analysis using collected data ranging from 1965 to 1989, IDF curves have been constructed. To facilitate runoff analysis the best fit equation for the IDF curves has been investigated against Kimijima (or Wenzel) type equation:

$$i = \frac{a}{t_d^{\,b} + c}$$

where i: rainfall intensity (mm/hr)
t_d: duration (minutes)

Since, a single curve does not represent well for rainfall duration up to 24 hours, two sets of curves have been prepared: one set for rainfall duration up to 3 hours and another set for rainfall duration from more than 3 to 24 hours. Kimijima type equation gives good fits to calculated values by Gumbel's method. The proposed IDF curves with equations up to 3 hours and from more than 3 to 24 hours are shown in *Figure VII.2.2.*

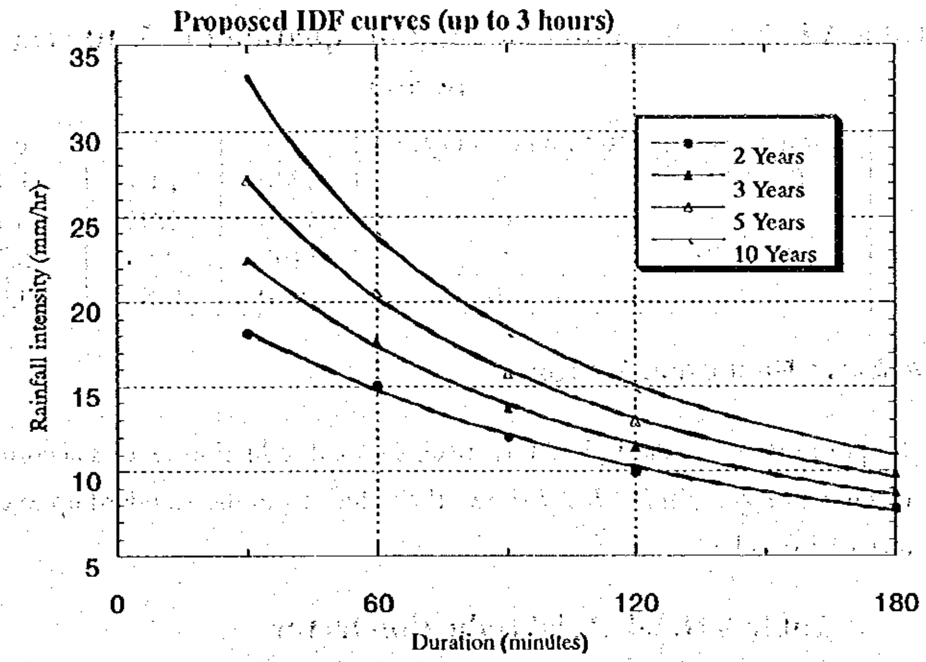


Figure VII.2.2-a Proposed IDF curves

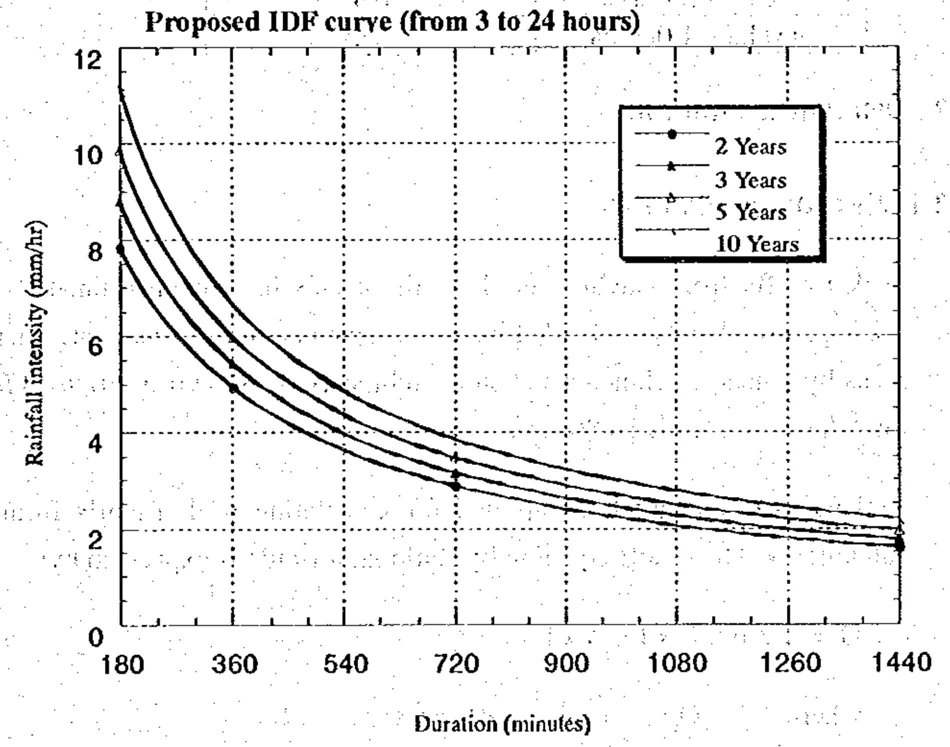


Figure VII.2.2-b Proposed IDF curves

Constants for the above equation are shown in *Table VII.2.3.*

Table VII.2.3 Constants for rainfall equation for 5, 10-year return period

Duration (min)	Return period (year)	a	b	c
0 – 180	5	3240	1.07	81.4
	10	3010	1.04	56.7
180-1440	5	1190	0.88	26.2
	10	1070	0.85	14.0

2.1.4 AREAL REDUCTION FACTOR

Proposed Peru standard (S.124.5) specifies areal reduction factors according to the catchment size. *Table VII.2.4* shows the values from the standard up to catchment size of 1,000 ha.

Table VII.2.4 Arial reduction factor (proposed Peru standard (S. 124.5))

Area	Reduction factor
≧ 200 ha	1.0
200 – 500 ha	0.9
500 ha – 1,000 ha	0.83

2.2 DISCHARGE ANALYSIS

2.2.1 METHOD OF ANALYSIS

Peak runoffs from catchments along the canals have been estimated. The total drainage area has been divided into 16 catchments and 84 sub-catchments. Basin areas by zones, catchments and sub-catchments are shown in *Figure VII.2.3.* The total drainage area is 18.86 km^2.

Rational formula has been applied for calculating peak runoffs from the sub-catchments. The runoff equation by Rational formula is expressed by:

$$Q_p = 1/3.6 \times C \times I \times A \times f$$

where Q_p: peak runoff (m^3/s)

C: runoff coefficient, depends on landuse condition as discussed later f : areal reduction factor, depends on catchment size as discussed in 2.1

A: catchment area (km^2)

Rainfall intensity, as expressed by the equations of the IDF curves is a function of time of concentration T_c, which is expressed by:

$$T_c = T_i + T_f$$

where T_I: Time of inlet and

T_f: Time of flow.

T_i is a function of hydraulic length of overland flow (L_i), catchment slope(S) and landuse condition. For overland flow without a defined channel, T_i has been estimated using Kirpich formula as shown below:

$$T_i = 0.0078 \times L^{0.77} \times S^{-0.385}$$

where L: length of natural channel / catchment (ft)

S: average watershed slope

For natural channels of which there is no information on cross-sections, Kirpich formula has applied for calculating time of flow, from which flow velocity has been estimated.

For channels with known cross-sections, Manning's formula has been applied to estimate flow velocity.

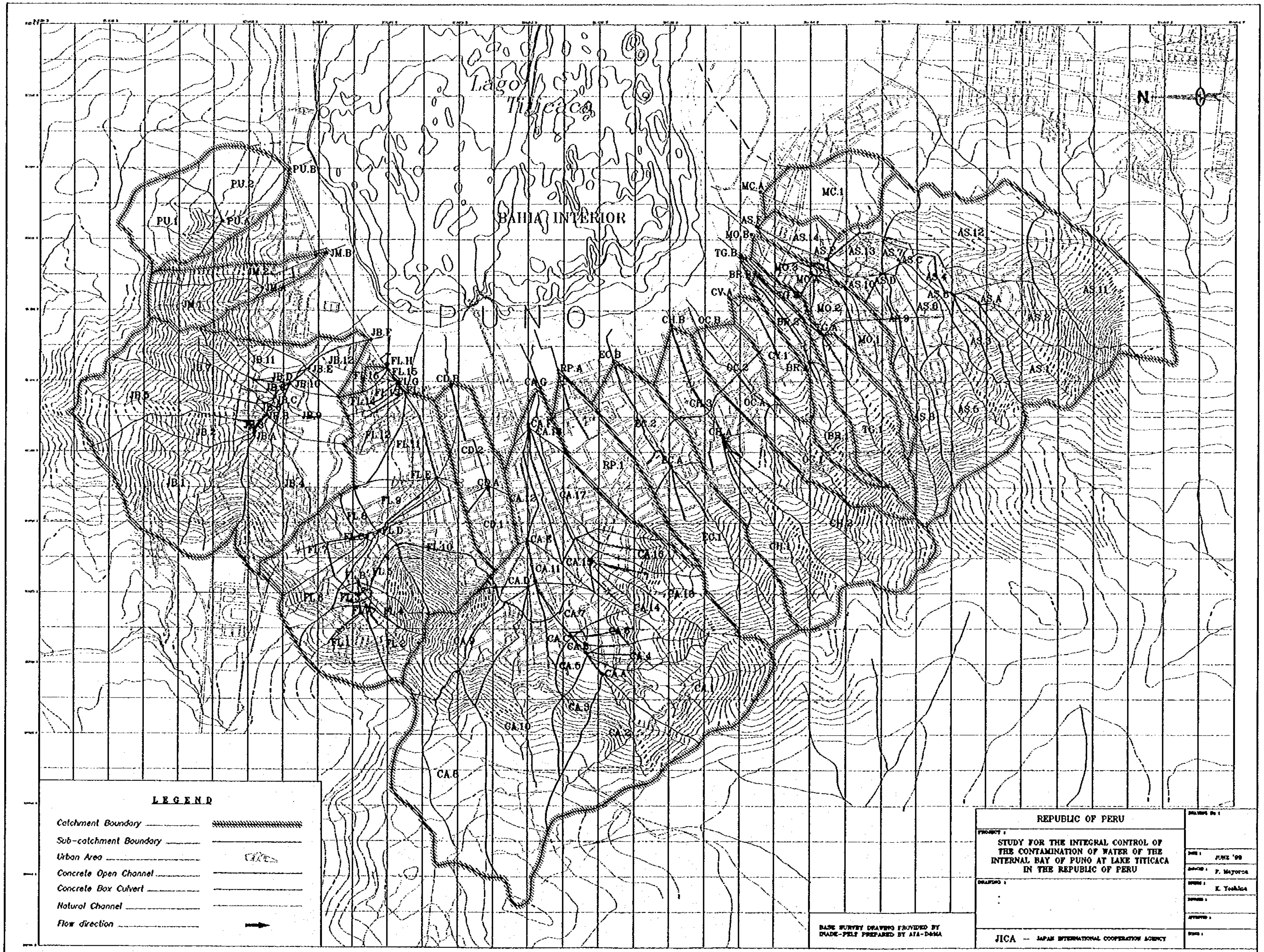


Figure VII.2.3 Division of drainage area

2.2.2 ESTIMATION OF RUNOFF COEFFICIENT

Runoff-coefficients for rational formula are dependent on the character and condition of the soil. *Table VII.2.5* presents estimated run off coefficient for urban area and hill slopes under existing (1998) and future (2025) land use. Those coefficients are chosen considering steep slope and poor vegetation of the area.

Table VII.2.5 Runoff coefficient

Year	Urban area	Hill
1998	0.8	0.6
2025	0.9	0.8

2.2.3 RETURN PERIODS

Proposed Peru Standard (S.124.5) of stormwater drainage design specified the following return periods.

Areas	Years
Residential	from 1 to 5
Commercials and high value zones	from 5 to 10
Required of special protection	50

Peak discharge is calculated for 5 and 10 years return period in this study.

2.2.4 RESULTS OF DISCHARGE ANALYSIS

Runoff calculation points of the drainage systems (having multiple catchments) are shown in *Figure VII.2.4.* Applying Rational method, peak runoffs at the calculation points have been estimated for both existing and future (2025) land use conditions for 5-and 10-years return period. The results of runoff calculations are presented in *Table VII.2.6.*

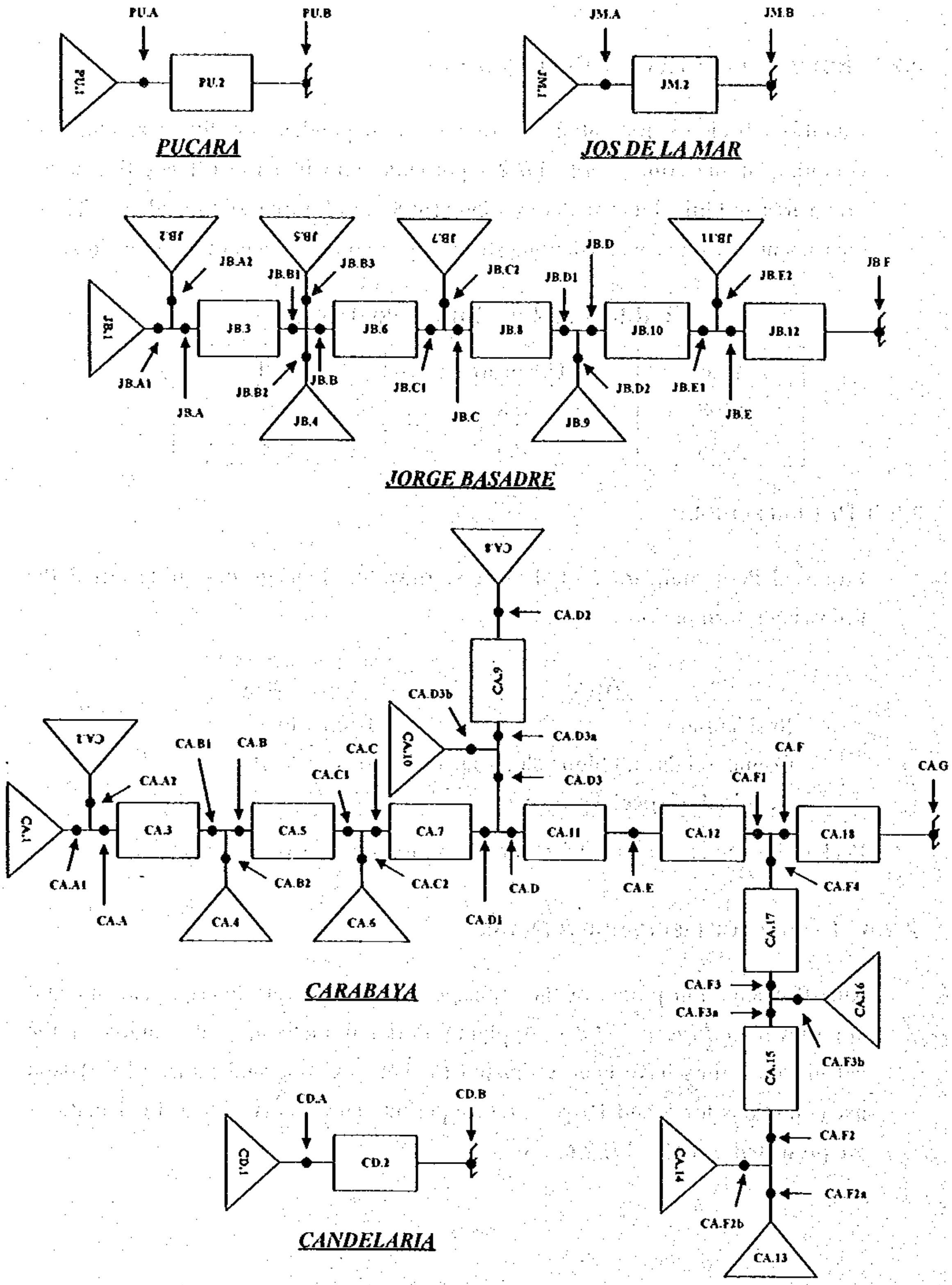


Figure VII.2.4(1) Run-off calculation points of drainage system (1/3)

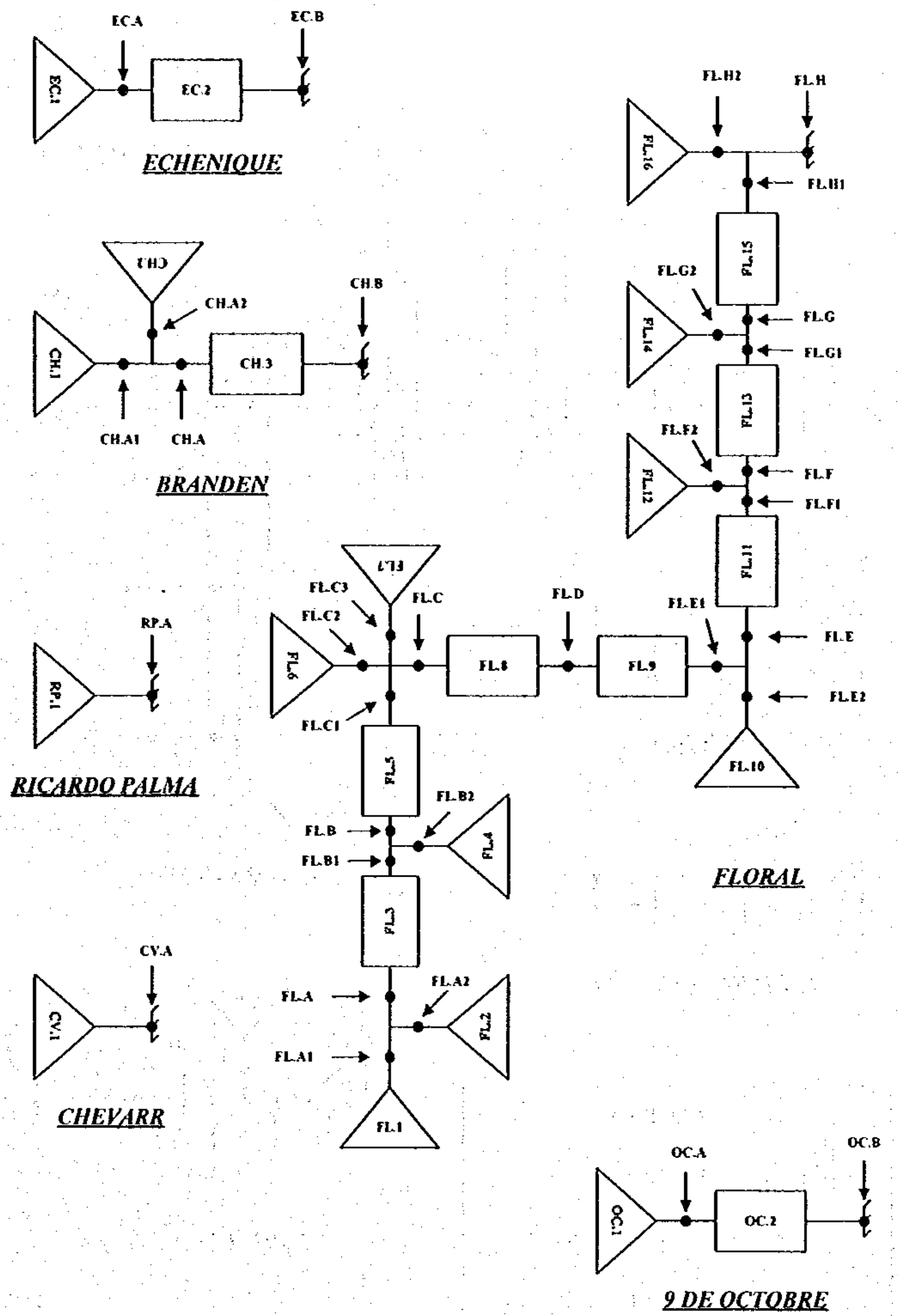


Figure VII.2.4(2) Run-off calculation points of drainage system (2/3)

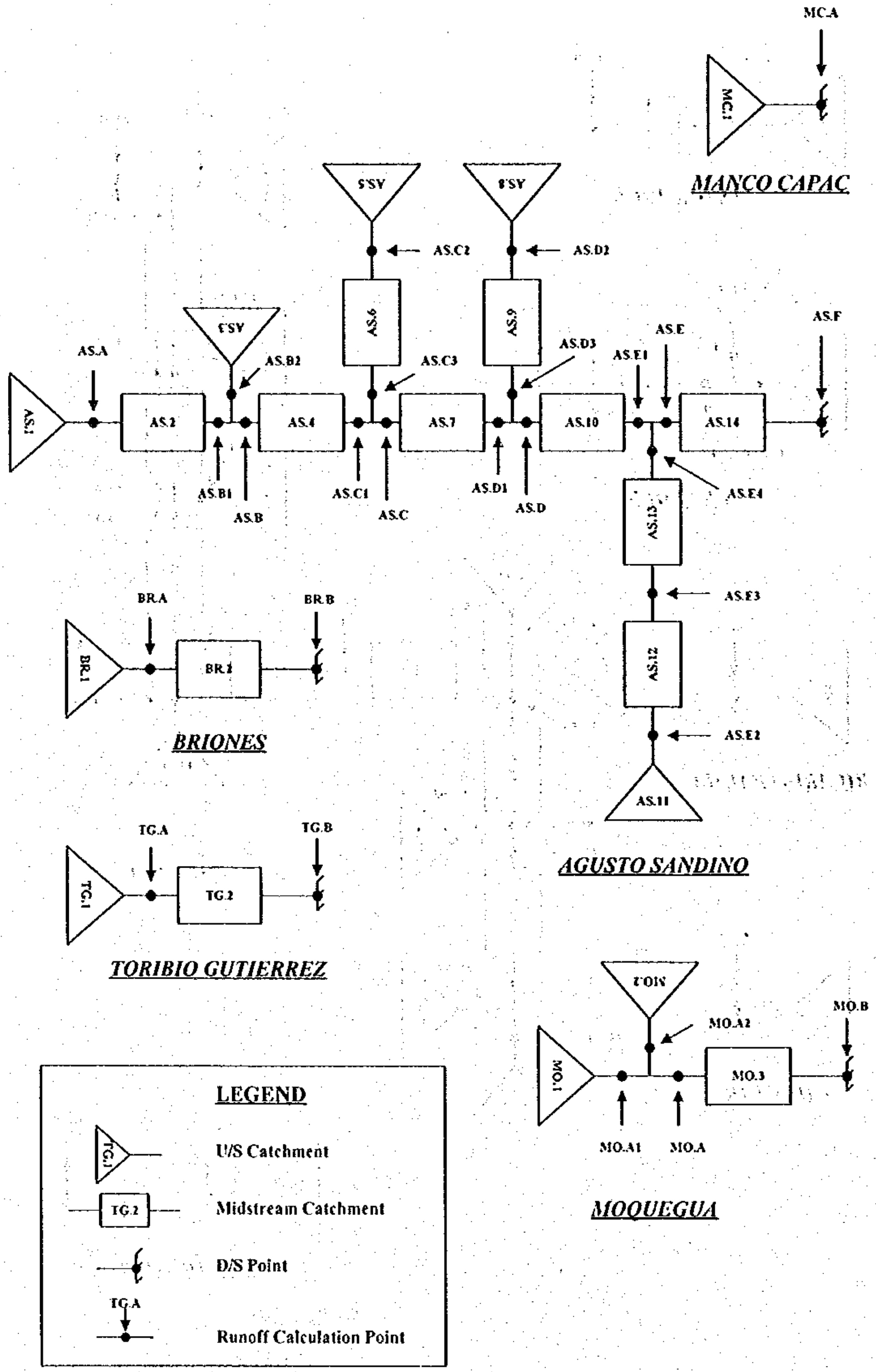


Figure VII.2.4(3) Run-off calculation points of drainage system (3/3)

Table VII.2.6(1) Peak discharge calculation by rational method (1/2)

Drainage Area		Sub-Catchment		Runoff Point		Runoff Coefficient, C				Inlet				Flow through Channel or Box Culvert							Time of Concentration		Rainfall Intensity I (mm/hr)				Areal Reduction	Peak Runoff, Q (m3/s)			
Name	ID	ID	Area	ID	Area	Sub-Catchment		Runoff Point		Lo	Upper-most	Ti (min)		Vf (m/s) by Segment		Length of Flow, Lf (m)			Segment's, Tf (min)		Cumulative Tc (min)		5-Year R.P.		10-Year R.P.		Reduction	5-Year R.P.		10-Year R.P.	
			(km2)		(km2)	Ex.	Fut.	Ex.	Fut.	(m)	Catchment Slope	Ex.	Fut.	Ex.	Fut.	Type*	Segment	Cumulative	Ex.	Fut.	Ex.	Fut.	Ex.	Fut.	Ex.	Fut.	f	Ex.	Fut.	Ex.	Fut.
Pucar*	PU	PU.1	0.32	PU.A	0.324	0.60	0.80	0.60	0.80	170	0.147059	2.13	2.13	2.36	3.14	CN	615	615	4.35	3.26	6.48	5.39	36.51	37.06	47.29	48.20	1.00	1.97	2.46	2.55	3.47
		PU.2	0.32	PU.B	0.642	0.60	0.80	0.60	0.80					1.57	2.09	CN	636	1,251	6.76	5.07	13.24	10.46	33.35	34.60	42.23	44.18	1.00	3.57	4.94	4.52	6.31
Jose de la Mar	JM	JM.1	0.201	JM.A	0.201	0.60	0.80	0.60	0.80	75	0.213333	0.98	0.98	2.35	3.13	CN	787	787	5.58	4.18	6.56	5.16	36.47	37.17	47.22	48.39	1.00	1.22	1.66	1.58	2.16
		JM.2	0.151	JM.B	0.352	0.70	0.85	0.64	0.82					1.30	1.58	CN	585	1,371	7.48	6.16	14.03	11.32	33.01	34.21	41.70	43.56	1.00	2.08	2.75	2.63	3.51
Jorge Basadre	JB	JB.1	0.714	JB.A1	0.714	0.60	0.80	0.60	0.80	50	0.020000	1.79	1.79	2.03	2.70	CN	1,064	1,064	8.74	6.56	10.53	8.34	34.57	35.60	44.14	45.79	1.00	4.11	5.65	5.25	7.27
		JB.2	0.118	JB.A2	0.118	0.60	0.80	0.60	0.80	120	0.283333	1.26	1.26	2.14	2.85	CN	751	751	5.85	4.39	7.11	5.65	36.20	36.92	46.77	47.98	1.00	0.71	0.97	0.92	1.26
				JB.A	0.833			0.60	0.80									1,502			10.53	8.34	34.57	35.60	44.14	45.79	1.00	4.80	6.59	6.13	8.47
		JB.3	0.005	JB.B1	0.837	0.80	0.90	0.60	0.80					7.17	8.07	CC	122	1,624	0.28	0.25	10.81	8.59	34.44	35.48	43.93	45.59	1.00	4.82	6.61	6.14	8.49
		JB.4	0.533	JB.B2	0.533	0.74	0.87	0.74	0.87	30	0.166667	0.53	0.53	2.02	2.38	CN	1,182	1,182	9.75	8.29	10.28	8.82	34.68	35.37	44.32	45.42	1.00	3.80	4.56	4.86	5.86
		JB.5	0.309	JB.B3	0.309	0.62	0.81	0.62	0.81	60	0.083333	1.19	1.19	2.34	3.05	CN	1,411	1,411	10.06	7.70	11.24	8.89	34.24	35.34	43.62	45.37	1.00	2.30	3.10	2.92	3.97
				JB.B	1.760			0.65	0.82									1,624			10.81	8.82	34.44	35.37	43.93	45.42	1.00	10.90	14.24	13.90	18.29
		JB.6	0.015	JB.C1	1.775	0.80	0.90	0.65	0.82					7.47	7.95	BC	145	1,769	0.34	0.30	11.15	9.13	34.28	35.22	43.68	45.18	1.00	10.97	14.32	13.97	18.37
		JB.7	0.291	JB.C2	0.291	0.64	0.82	0.64	0.82	200	0.145000	2.42	2.42	2.40	3.07	CN	1,093	1,093	7.59	5.93	10.01	8.35	34.81	35.59	44.51	45.78	1.00	1.80	2.36	2.31	3.04
				JB.C	2.067			0.65	0.82									1,769			11.15	9.13	34.28	35.22	43.68	45.18	0.998	12.71	16.62	16.20	21.32
		JB.8	0.012	JB.D1	2.079	0.80	0.90	0.65	0.82					5.92	6.66	BC	170	1,939	0.48	0.43	11.63	9.55	34.07	35.02	43.34	44.86	0.997	12.72	16.63	16.20	21.32
		JB.9	0.161	JB.D2	0.161	0.80	0.90	0.80	0.90	90	0.033333	2.31	2.31	1.53	1.72	CN	560	560	6.08	5.41	8.39	7.71	35.57	35.90	45.75	46.29	1.00	1.27	1.44	1.63	1.86
				JB.D	2.240			0.66	0.83									1,939			11.63	9.55	34.07	35.02	43.34	44.86	0.992	13.86	17.93	17.63	22.97
		JB.10	0.042	JB.E1	2.282	0.80	0.90	0.66	0.83					4.25	4.78	BC	229	2,168	0.90	0.80	12.53	10.35	33.67	34.65	42.71	44.27	0.991	13.99	18.08	17.75	23.09
		JB.11	0.133	JB.E2	0.133	0.70	0.85	0.70	0.85	160	0.318750	1.51	1.51	1.95	2.36	CN	755	755	6.47	5.33	7.97	6.83	35.78	36.33	46.08	47.00	1.00	0.92	1.14	1.19	1.47
				JB.E	2.414			0.66	0.83									2,168			12.53	10.35	33.67	34.65	42.71	44.27	0.986	14.78	19.07	18.76	24.36
		JB.12	0.149	JB.F	2.563	0.80	0.90	0.67	0.84					5.54	6.23	BC	506	2,674	1.52	1.35	14.05	11.70	33.00	34.03	41.69	43.29	0.981	15.49	19.88	19.57	25.28
Floral	FL	FL.1	0.254	FL.A1	0.254	0.68	0.84	0.68	0.84	40	0.150000	0.69	0.69	2.03	2.50	CN	552	552	4.54	3.67	5.23	4.37	37.14	37.50	48.34	49.09	1.00	1.78	2.23	2.32	2.91
		FL.2	0.102	FL.A2	0.102	0.66	0.83	0.66	0.83	100	0.220000	1.21	1.21	2.06	2.60	CN	469	469	3.79	3.01	5.00	4.22	37.25	37.65	48.54	49.21	1.00	0.70	0.89	0.91	1.16
				FL.A	0.356			0.67	0.84									552			5.23	4.37	37.14	37.50	48.34	49.09	1.00	2.48	3.11	3.23	4.07
		FL.3	0.036	FL.B1	0.392	0.80	0.90	0.69	0.84					1.42	1.59	CN	180	732	2.12	1.88	7.35	6.25	36.08	36.62	46.58	47.48	1.00	2.69	3.36	3.48	4.36
		FL.4	0.053	FL.B2	0.053	0.70	0.85	0.70	0.85	70	0.242857	0.88	0.88	2.41	2.92	CN	556	556	3.85	3.17	4.73	4.05	37.39	37.74	48.76	49.36	1.00	0.39	0.47	0.50	0.62
				FL.B	0.445			0.69	0.84									732			7.35	6.25	36.08	36.62	46.58	47.48	1.00	3.07	3.82	3.96	4.95
		FL.5	0.155	FL.C1	0.600	0.70	0.85	0.69	0.85					1.50	1.82	CN	392	1,124	4.37	3.60	11.72	9.84	34.03	34.88	43.28	44.64	1.00	3.92	4.92	4.98	6.29
		FL.6	0.160	FL.C2	0.160	0.74	0.87	0.74	0.87	60	0.033333	1.69	1.69	2.14	2.51	CN	813	813	6.33	5.39	8.02	7.07	35.75	36.21	46.04	46.80	1.00	1.18	1.40	1.52	1.81
		FL.7	0.234	FL.C3	0.234	0.76	0.88	0.76	0.88	0		0.00	0.00	16.73	19.38	BC	791	791	0.79	0.68	0.79	0.68	39.42	39.48	52.36	52.44	1.00	1.95	2.26	2.58	3.00
				FL.C	0.994			0.71	0.86									1,124			11.72	9.84	34.03	34.88	43.28	44.64	1.00	6.72	8.26	8.54	10.57
		FL.8	0.046	FL.D	1.040	0.80	0.90	0.72	0.86					12.47	14.03	BC	115	1,239	0.15	0.14	11.87	9.98	33.96	34.82	43.17	44.54	1.00	7.05	8.65	8.97	11.06
		FL.9	0.135	FL.E1	1.175	0.80	0.90	0.73	0.86					8.43	9.48	BC	591	1,830	1.17	1.04	13.04	11.02	33.44	34.34	42.36	43.78	1.00	7.95	9.69	10.07	12.35
		FL.10	0.409	FL.E2	0.409	0.72	0.86	0.72	0.86	500	0.424000	3.24	3.24	16.31	19.48	BC	577	577	0.59	0.49	3.83	3.73	37.85	37.90	49.56	49.65	1.00	3.09	3.70	4.05	4.85
				FL.E	1.584			0.73	0.86									1,830			13.04	11.02	33.44	34.34	42.36	43.78	1.00	10.68	13.04	13.53	16.62
		FL.11	0.223	FL.F1	1.886	0.80	0.90	0.74	0.87					4.91	5.53	BC	654	2,483	2.22	1.97	15.26	12.99	32.49	33.46	40.90	42.40	1.00	11.99	14.57	15.09	18.46
		FL.12	0.159	FL.F2	0.159	0.80	0.90	0.80	0.90	500	0.194000	4.30	4.30	14.22	16.00	BC	356	356	0.42	0.37	4.80	4.75	37.35	37.38	48.71	48.75	1.00	1.32	1.49	1.72	1.94
				FL.F	1.966			0.74	0.87									2,483			15.26	12.99	32.49	33.46	40.90	42.40	1.00	13.13	15.90	16.53	20.14
		FL.13	0.004	FL.G1	1.969	0.80	0.90	0.74	0.87					6.21	6.99	BC	92	2,575	0.25	0.22	15.50	13.21	32.39	33.37	40.75	42.25	1.00	13.13	15.90	16.53	20.14
		FL.14	0.065	FL.G2	0.065	0.70	0.85	0.70	0.85	220	0.113636	2.86	2.86	8.20	9.95	BC	289	289	0.59	0.48	3.45	3.35	38.05	38.10	49.90	49.99	1.00	0.48	0.59	0.63	0.77
				FL.G	2.035			0.74	0.87									2,575			15.50	13.21	32.39	33.37	40.75	42.25	0.999	13.52	16.38	17.00	20.74
		FL.15	0.005	FL.H1	2.039	0.80	0.90	0.74	0.87					3.43	3.86	CK	126	2,700	0.61	0.54	16.11	13.75	32.14	33.13	40.37	41.88	0.999	13.52	16.38	17.00	20.74
		FL.16	0.019	FL.H2	0.019	0.80	0.90	0.80	0.90	195	0.279270	1.79	1.79	10.18	11.46	BC	73	73	0.12	0.11	1.91	1.90	38.85	38.85	51.30	51.32	1.00	0.16	0.18	0.22	0.24
				FL.H	2.058			0.74	0.87									2,700			16.11	13.75	32.14	33.13	40.37	41.88	0.998	13.57	16.45	17.04	20.79
Candelaria*	CD	CD.1	0.143	CD.A	0.143	0.80	0.90	0.80	0.90	520	0.105769	5.71	5.71	2.47	2.70	BC	83	83	0.56	0.50	6.27	6.20	36.61	36.64	47.46	47.51	1.00	1.16	1.31	1.50	1.69
		CD.2	0.244	CD.B	0.387	0.80	0.90	0.80	0.90					3.41	3.84	BC	825	908	4.03	3.58	10.29	9.78	34.68	34.91	44.31	44.69	1.00	2.98	3.37	3.81	4.32
Carabaya	CA	CA.1	0.524	CA.A1	0.524	0.60	0.80	0.60	0.80	50	0.300000	0.74	0.74	2.50	3.33	CN	1,270	1,270	8.47	6.35	9.21	7.09	35.18	36.21	45.12	46.79	1.00	3.07	4.21	3.94	5.44
		CA.2	0.499	CA.A2	0.499	0.60	0.80	0.60	0.80	300	0.040000	5.43	5.43	2.22	2.96	CN	1,161	1,161	8.72	6.54	14.16	11.97	32.96	33.91	41.62	43.10	1.00	2.74	3.76	3.46	4.78
				CA.A	1.023			0.60	0.80									1,270			14.16	11.97	32.96	33.91	41.62	43.10	1.00	5.62	7.71	7.09	9.80
		CA.3	0.141	CA.B1	1.164	0.62	0.81	0.60	0.80					1.33	1.73	CN	175	1,445	2.20	1.68	16.35	13.66	32.04	33.17	40.22	41.95	1.00	6.24	8.60	7.83	10.87
		CA.4	0.119	CA.B2	0.119	0.66	0.83	0.66	0.83	260	0.303846	2.23	2.23	2.31	2.91	CN	673	673	4.84	3.85	7.07	6.08	36.31	36.71	46.90	47.62	1.00	0.79	1.00	1.02	1.30
				CA.B	1.283			0.61	0.80									1,445			16.35	13.66	32.04	33.17	40.22	41.95	1.00	6.94	9.50	8.71	12.02
		CA.5	0.064	CA.C1	1.347	0.72	0.86	0.61	0.81					9.88	11.80	CK	163	1,608	0.27	0.23	16.63	13.89	31.93	33.07	40.05	41.79	1.00	7.32	9.98	9.18	12.61
		CA.6	0.097	CA.C2	0.097	0.70	0.85	0.70	0.85	120	0.266667	1.29	1.29	2.44	2.96	CN	554	554	3.78	3.11	5.07	4.41	37.21	37.56	48.47	49.05	1.00	0.70	0.86	0.91	1.12
				CA.C	1.443			0.62	0.81									1,608			16.63	13.89	31.93	33.07	40.05	41.79	1.00	7.92	10.73	9.94	13.56
		CA.7	0.169	CA.D1	1.612	0.80	0.90	0.64	0.82					4.02	4.52	BC	492	2,100	2.04	1.81	18.67	15.70	31.12	32.31	38.83	40.62	1.00	8.89	11.85	11.09	14.90
		CA.8	0.654	CA.D2	0.654	0.60	0.80	0.60	0.80	335	0.047761	5.52	5.52	1.99	2.65	CN	1,433	1,433	12.03	9.02	17.55	14.54	31.56	32.79	39.49	41.36	1.00	3.44	4.77	4.30	6.03
		CA.9	0.417	CA.D3a	1.071	0.64	0.83	0.62	0.81					19.64	24.70	BC	814	2,247	0.69	0.55	18.24	15.09	31.29	32.56	39.08	41.01	1.00	5.80	7.86	7.25	9.90
		CA.10	0.888	CA.D3b	0.888	0.64	0.82	0.64	0.82	840	0.042857	11.69	11.69	2.46	3.15	CN	1,562	1,562	10.60	8.27	22.29	19.96	29.77	30.63	36.84	38.10	1.00	4.79	6.19	5.81	7.70
				CA.D3	1.959			0.63	0.82									2,247			22.29	19.96	29.77	30.63	36.84	38.10	1.00	10.22	13.59	12.65	16.90
				CA.D	3.571			0.63	0.82									2,247			22.29	19.96	29.77	30.63	36.84	38.10	0.948	17.74	23.52	21.96	29.24
		CA.11	0.130	CA.E	3.701	0.80	0.90	0.64	0.82					10.28	11.56	BC	310	2,557	0.50	0.45	22.79	20.41	29.59	30.46	36.58	37.85	0.943	18.36	24.22	22.70	30.10
		CA.12	0.173	CA.F1	3.874	0.80	0.90	0.65	0.82					7.05	8.84	BC	845	3,401	1.79	1.59	24.58	22.00	28.97	29.87	35.67	36.99	0.938	18.93	24.82	23.29	30.73
		CA.13	0.208	CA.F2a	0.208	0.64	0.82	0.64	0.82	380	0.313158	2.95	2.95	2.27	2.91	CN	898	898	6.58	5.13	9.53	8.09	35.03	35.72	44.88	45.99	1.00	1.29	1.69	1.66	2.17
		CA.14	0.150	CA.F2b	0.150	0.64	0.82	0.64	0.82	240	0.370833	1.94	1.94	2.33	2.98	CN	802	802	5.74	4.48	7.68	6.42	35.92	36.54	46.31	47.33	1.00	0.96	1.25	1.24	1.62

Table VII.2.6(2) Peak discharge calculation by rational method (2/2)

Drainage Area		Sub-Catchment		Runoff Point		Runoff Coefficient, C				Inlet				Flow through Channel or Box Culvert									Time of Concentration		Rainfall Intensity I (mm/hr)				Areal Reduction	Peak Runoff, Q (m3/s)			
Name	ID	ID	Area	ID	Area	Sub-Catchment		Runoff Point		Lo	Uppermost	Ti (min)		Vf (m/s) by Segment		Length of Flow, Lf (m)			Segment's, Tf (min)		Cumulative Tc (min)		5-Year R.P.		10-Year R.P.			5-Year R.P.		10-Year R.P.	
			(km2)		(km2)	Ex.	Fut.	Ex.	Fut.	(m)	Catchment Shape	Ex.	Fut.	Ex.	Fut.	Type*	Segment	Cumulative	Ex.	Fut.	Ex.	Fut.	Ex.	Fut.	Ex.	Fut.	f	Ex.	Fut.	Ex.	Fut.
				CA.F2	0.350			0.64	0.82									990			9.53	8.09	35.03	35.72	44.80	45.99	1.00	2.23	2.91	2.85	3.75
		CA.15	0.073	CA.F3a	0.431	0.80	0.90	0.67	0.83					1.56	1.76	CN	174	1,072	1.86	1.65	11.39	9.74	34.10	34.94	43.51	44.72	1.00	2.73	3.40	3.47	4.46
		CA.16	0.141	CA.F3b	0.141	0.70	0.85	0.70	0.85	150	0.100000	2.24	2.24	19.67	23.89	BC	790	790	0.68	0.56	2.91	2.80	38.33	38.39	50.30	50.49	1.00	1.05	1.27	1.30	1.60
				CA.F3	0.571			0.68	0.84									1,072			11.39	9.74	34.10	34.94	43.51	44.72	1.00	3.66	4.64	4.66	5.95
		CA.17	0.296	CA.F4	0.867	0.80	0.90	0.72	0.86					5.75	6.47	BC	870	1,942	2.52	2.24	13.91	11.98	33.06	33.91	41.78	43.10	1.00	5.72	7.01	7.22	8.92
				CA.F	4.741			0.66	0.83									3,401			24.50	22.00	28.97	29.87	35.67	36.99	0.989	22.80	29.67	28.17	36.74
		CA.18	0.066	CA.G	4.807	0.80	0.90	0.66	0.83					3.98	4.47	BC	304	3,705	1.27	1.13	25.86	23.13	28.54	29.47	35.05	36.40	0.986	22.80	29.67	28.17	36.74
Ricardo Palma	RP	RP.1	0.301	RP.A	0.301	0.76	0.80	0.76	0.80	1170	0.211966	8.15	8.15	4.26	4.94	BC	598	598	2.33	2.01	10.48	10.16	34.59	34.74	44.17	44.41	1.00	2.78	3.23	3.55	4.13
Echenique *	EC	EC.1	0.578	EC.A	0.578	0.64	0.82	0.64	0.82	130	0.253846	1.40	1.40	2.60	3.33	CN	1,404	1,404	8.99	7.02	10.40	8.42	34.63	35.56	44.23	45.73	1.00	3.56	4.68	4.54	6.02
		EC.2	0.337	EC.B	0.915	0.80	0.90	0.70	0.85					11.37	12.79	BC	895	2,299	1.31	1.17	11.71	9.59	34.03	35.01	43.29	44.83	1.00	6.04	7.58	7.69	9.60
Brandes	CH	CH.1	0.635	CH.A1	0.635	0.62	0.81	0.62	0.81	40	0.150000	0.95	0.95	2.65	3.47	CN	1,754	1,754	11.01	8.43	11.96	9.38	33.92	35.10	43.11	44.99	1.00	3.71	5.01	4.73	6.43
		CH.2	0.364	CH.A2	0.364	0.62	0.81	0.62	0.81	80	0.212500	1.03	1.03	12.40	16.30	CK	1,462	1,462	1.95	1.49	2.98	2.53	38.29	38.53	50.32	50.76	1.00	2.40	3.16	3.16	4.16
				CH.A	0.999			0.62	0.81									1,754			11.96	9.38	33.92	35.10	43.11	44.99	1.00	5.84	7.89	7.42	10.11
		CH.3	0.305	CH.B	1.305	0.80	0.90	0.67	0.84					11.96	13.46	BC	889	2,643	1.24	1.10	13.20	10.48	33.37	34.59	42.26	44.17	1.00	8.60	11.11	10.89	14.19
9 de Octubre	OC	OC.1	0.254	OC.A	0.254	0.60	0.80	0.60	0.80	520	0.355769	3.58	3.58	7.67	10.22	CK	863	863	1.87	1.41	5.45	4.98	37.02	37.26	48.15	48.55	1.00	1.56	2.10	2.03	2.74
		OC.2	0.244	OC.B	0.498	0.80	0.90	0.70	0.85					13.80	15.61	BC	774	1,636	0.93	0.83	6.38	5.81	36.56	36.84	47.37	47.84	1.00	3.53	4.33	4.57	5.62
[illegible]	CV	CV.1	0.217	CV.A	0.217	0.78	0.89	0.78	0.89	520	0.226923	4.25	4.25	9.64	11.03	BC	614	614	1.06	0.93	5.31	5.18	37.09	37.16	48.27	48.38	1.00	1.75	2.00	2.27	2.60
[illegible]	BR	BR.1	0.158	BR.A	0.158	0.60	0.80	0.60	0.80	220	0.363636	1.83	1.83	2.15	2.87	CN	957	957	7.40	5.56	9.23	7.38	35.17	36.06	45.10	46.55	1.00	0.93	1.27	1.19	1.64
		BR.2	0.106	BR.B	0.264	0.80	0.90	0.68	0.84					11.52	12.96	BC	796	1,753	1.15	1.02	10.38	8.40	34.63	35.57	44.24	45.74	1.00	1.73	2.19	2.21	2.82
Toribio Gutierrez *	TG	TG.1	0.347	TG.A	0.347	0.60	0.80	0.60	0.80	220	0.404545	1.76	1.76	27.32	36.43	BC	1,287	1,287	0.79	0.59	2.54	2.34	38.52	38.62	50.72	50.90	1.00	2.23	2.98	2.94	3.93
		TG.2	0.071	TG.B	0.418	0.80	0.90	0.63	0.82					1.20	1.35	CN	892	2,179	12.37	11.00	14.91	13.34	32.64	33.31	41.12	42.16	1.00	2.40	3.16	3.03	4.00
Moquegua	MO	MO.1	0.194	MO.A1	0.194	0.72	0.86	0.72	0.86	140	0.457143	1.18	1.18	2.20	2.63	CN	1,449	1,449	10.99	9.20	12.17	10.38	33.82	34.64	42.96	44.24	1.00	1.31	1.61	1.67	2.05
		MO.2	0.105	MO.A2	0.105	0.80	0.90	0.80	0.90	0		0.00	0.00	1.73	1.95	CN	440	440	4.23	3.76	4.23	3.76	37.64	37.89	49.20	49.62	1.00	0.87	0.99	1.14	1.30
				MO.A	0.299			0.75	0.87									1,449			12.17	10.38	33.82	34.64	42.96	44.24	1.00	2.10	2.51	2.67	3.21
		MO.3	0.100	MO.B	0.399	0.80	0.90	0.76	0.88					0.59	0.66	CN	549	1,998	15.59	13.85	27.76	24.24	27.92	29.09	34.17	35.84	1.00	2.35	2.84	2.88	3.50
Augusto Sandino *	AN	AN.1	0.309	AN.A	0.309	0.64	0.82	0.64	0.82	190	0.252632	1.88	1.88	2.44	3.12	CN	977	977	6.68	5.22	8.56	7.10	35.49	36.20	45.62	46.78	1.00	1.95	2.55	2.50	3.29
		AN.2	0.232	AN.B1	0.541	0.66	0.83	0.65	0.82					1.10	1.49	CN	212	1,189	2.98	2.37	11.54	9.47	34.11	35.06	43.40	44.93	1.00	3.33	4.35	4.23	5.57
		AN.3	0.107	AN.B2	0.107	0.76	0.88	0.76	0.88	185	0.354757	1.61	1.61	2.01	2.33	CN	570	570	4.72	4.08	6.34	5.69	36.58	36.90	47.40	47.98	1.00	0.83	0.97	1.07	1.26
				AN.B	0.649			0.67	0.83									1,189			11.54	9.47	34.11	35.06	43.40	44.93	1.00	4.10	5.27	5.22	6.75
		AN.4	0.111	AN.C1	0.760	0.80	0.90	0.69	0.84					1.17	1.31	CN	424	1,814	8.92	7.93	20.46	17.39	30.44	31.62	37.82	39.58	1.00	4.41	5.63	5.48	7.04
		AN.5	0.434	AN.C2	0.434	0.64	0.82	0.64	0.82	120	0.333333	1.19	1.19	2.51	3.21	CN	936	936	6.22	4.85	7.41	6.04	36.05	36.73	46.53	47.65	1.00	2.78	3.63	3.59	4.71
		AN.6	0.143	AN.C3	0.576	0.80	0.90	0.68	0.84					1.49	1.68	CN	723	1,659	8.07	7.18	15.48	13.22	32.40	33.36	40.76	42.24	1.00	3.52	4.49	4.43	5.68
				AN.C	1.336			0.68	0.84									1,814			20.46	17.39	30.44	31.62	37.82	39.58	1.00	7.72	9.88	9.59	12.37
		AN.7	0.029	AN.D1	1.365	0.80	0.90	0.69	0.84					3.68	4.14	CC	151	1,965	0.68	0.61	21.14	18.00	30.19	31.38	37.45	39.22	1.00	7.85	10.03	9.74	12.54
		AN.8	0.255	AN.D2	0.255	0.64	0.82	0.64	0.82	180	0.290000	1.09	1.09	6.90	8.95	CK	1,294	1,294	3.09	2.41	4.18	3.50	37.67	38.02	49.25	49.86	1.00	1.71	2.21	2.23	2.90
		AN.9	0.141	AN.D3	0.396	0.80	0.90	0.70	0.85					7.87	8.85	BC	580	1,874	1.23	1.09	5.40	4.59	37.05	37.46	48.19	48.89	1.00	2.84	3.50	3.70	4.57
				AN.D	1.761			0.69	0.84									1,965			21.14	18.00	30.19	31.38	37.45	39.22	1.00	10.17	12.96	12.61	16.20
		AN.10	0.057	AN.E1	1.820	0.80	0.90	0.69	0.85					4.24	4.77	BC	432	2,397	1.70	1.51	22.84	19.51	29.57	30.80	36.55	38.35	1.00	10.35	13.17	12.79	16.40
		AN.11	0.601	AN.E2	0.601	0.60	0.80	0.60	0.80	765	0.400000	4.60	4.60	2.08	2.78	CN	714	714	5.71	4.28	10.31	8.89	34.67	35.34	44.29	45.37	1.00	3.47	4.72	4.44	6.06
		AN.12	0.505	AN.E3	1.106	0.60	0.80	0.60	0.80					1.49	1.99	CN	1,038	1,752	11.61	8.71	21.93	17.60	29.90	31.54	37.03	39.46	1.00	5.51	7.75	6.83	9.70
		AN.13	0.164	AN.E4	1.271	0.70	0.85	0.61	0.81					4.67	5.60	CC	472	2,223	1.68	1.38	23.61	18.98	29.30	31.00	36.16	38.65	1.00	6.34	8.82	7.82	11.00
				AN.E	3.091			0.66	0.83									2,397			23.61	19.51	29.30	30.80	36.16	38.35	0.964	15.99	21.14	19.73	26.33
		AN.14	0.129	AN.F	3.220	0.72	0.86	0.66	0.83					5.58	6.66	BC	552	2,949	1.65	1.38	25.26	20.89	28.74	30.28	35.34	37.58	0.959	16.32	21.59	20.07	26.80
Manco Capac	MC	MC.1	0.352	MC.A	0.352	0.66	0.83	0.66	0.83	90	0.111111	1.45	1.45	0.87	1.09	CN	721	721	13.81	10.98	15.26	12.43	32.49	33.71	40.98	42.78	1.00	2.10	2.73	2.64	3.47

Note : Kirpich Formula has been applied : - for calculating overland flow velocity which has been used in calculating inlet time, Ti and
- for calculating velocity of flow through natural channel which has been used in calculating flow time, Tf

Nomenclature: Ex. => Under existing (1998) condition; Fut. => Under future (2025) condition

* Type of Channel: BC => Concrete box culvert; Manning's roughness coefficient, n = 0.013
CC => Concrete open channel; Manning's roughness coefficient, n = 0.015
CK => Earthen channel; Manning's roughness coefficient, n = 0.030
CN => Natural channel; Overland flow expressed by Kirpich Formula

2.2.5 EVALUATION OF EXISTING CHANNEL CAPACITY

Discharge capacity of the existing concrete channels are calculated using Manning's formula. The results are shown in *Table VII.2.7*. *Table*VI*I.2.7* also presents comparison between peak discharge for the present land use and the above discharge capacity of the channels. The channel capacity was examined for 5-and 10-year return period. *Figure VII.2.5* illustrates channels that do not have enough capacity to carry peak discharges for 5 and 10-year return periods. The drainage channel runs through Ave. Choquehuanco – Ave. Carabaya (discharge points CA.C – CA.G) does not have enough capacity for peak discharges for 5 and 10-year return periods. This coincides with he JICA team observation of street flooding around the point (CA.E) during the heavy rain events in February 1999.

Table VII.2.7(1) Existing capacity of drainage channels (1/2)

Drainage Area Name	Drainage Area ID	Reach ID	Reach Length (m)	Runoff Point ID	Runoff Point Area (km2)	Type*	Channel Profile U/S Elevation (El., m)	Channel Profile D/S Elevation (El., m)	Channel Profile Slope	Existing Cross-Section s	Existing Cross-Section b (m)	Existing Cross-Section y (m)	Existing Cross-Section Number (nos.)	Hydraulic Properties for Existing Channel Manning's n	A (m2)	P (m)	R (m)	Velocity** v (m/s)	Discharge Capacity (m3/s)	5-Year Peak Runoff Existing (m3/s)	5-Year Peak Runoff Future (m3/s)	Enough Capacity*** Existing (Y/N)	Enough Capacity*** Future (Y/N)
Pucara	PU	PU.1	615	PU.A	0,324	CN	4,060,00	3,876,00	0,29919											1,97	2,66		
		PU.2	636	PU.B	0,642	CN	3,876,00	3,811,20	0,10176											3,57	4,94		
Jua de la Mar	JM	JM.1	797	JM.A	0,201	CN	4,052,00	3,850,00	0,25343											1,32	1,66		
		JM.2	585	JM.B	0,353	CN	3,850,00	3,811,20	0,06624											2,00	2,75		
Jorge Basadre	JB	JB.1	1,044	JB.A1	0,714	CN	3,994,00	3,838,65	0,14887	0,00	0,90	0,80	1							4,11	5,65		
		JB.2	751	JB.A2	0,118	CN	3,994,00	3,838,65	0,20686											0,71	0,97		
				JB.A	0,833																		
		JB.3	122	JB.B1	0,837	CC	3,838,65	3,831,22	0,06090	0,00	0,90	0,80	1	0,015	0,72	2,50	0,29	7,17	5,17	4,82	6,61	Y	N
		JB.4	1,182	JB.B2	0,533	CN	3,992,00	3,831,22	0,13602											3,50	4,56		
		JB.5	1,411	JB.B3	0,389	CN	4,083,00	3,831,22	0,17850											2,30	3,18		
				JB.B	1,760																		
		JB.6	145	JB.C1	1,775	BC	3,831,22	3,824,80	0,04443	0,00	0,90	0,80	1	0,013	0,72	2,50	0,29	7,07	5,09	10,97	14,32	N	N
		JB.7	1,093	JB.C2	0,291	CN	4,068,00	3,824,80	0,22251											1,80	2,36		
				JB.C	2,067																		
		JB.8	170	JB.D1	2,079	BC	3,824,80	3,821,98	0,01659	0,00	1,50	1,20	1	0,013	1,80	3,90	0,46	5,92	10,65	12,72	16,43	N	N
		JB.9	560	JB.D2	0,161	CN	3,880,00	3,821,98	0,10370	0,00	1,00	1,00	1							1,27	1,64		
				JB.D	2,240																		
		JB.10	229	JB.E1	2,282	BC	3,821,98	3,820,36	0,00707	0,00	1,80	1,30	1	0,013	2,34	4,40	0,53	4,25	9,94	13,99	18,00	N	N
		JB.11	755	JB.E2	0,133	CN	3,942,00	3,820,36	0,16111											0,92	1,14		
				JB.E	2,414																		
		JB.12	506	JB.F	2,563	BC	3,820,36	3,812,96	0,01462	0,00	1,70	1,00	2	0,013	1,70	3,70	0,46	5,54	18,83	15,49	19,88	Y	N
Floral	FL	FL_1	552	FL_A1	0,254	CN	4,034,00	3,915,00	0,21578											1,78	2,23		
		FL_2	469	FL_A2	0,102	CN	4,032,00	3,915,00	0,24947											0,70	0,89		
				FL_A	0,356																		
		FL_3	180	FL_B1	0,392	CN	3,915,00	3,885,00	0,16667											2,69	3,36		
		FL_4	556	FL_B2	0,053	CN	4,072,00	3,885,00	0,33633											0,39	0,47		
				FL_B	0,445																		
		FL_5	392	FL_C1	0,600	CN	3,885,00	3,837,88	0,12020											3,92	4,92		
		FL_6	813	FL_C2	0,160	CN	4,010,00	3,850,00	0,19692											1,10	1,40		
		FL_7	791	FL_C3	0,234	BC	4,000,00	3,850,00	0,18975	0,00	1,00	1,20	1	0,013	1,20	3,40	0,35	16,73	20,00	1,95	2,26	Y	Y
				FL_C	0,994																		
		FL_8	115	FL_D	1,040	BC	3,850,00	3,837,88	0,10539	0,00	1,00	1,20	1	0,013	1,20	3,40	0,35	12,47	14,97	7,05	8,65	Y	Y
		FL_9	591	FL_E1	1,175	BC	3,837,88	3,821,31	0,02804	0,00	1,50	1,80	1	0,013	2,70	5,10	0,53	8,43	22,76	7,95	9,69	Y	Y
		FL_10	577	FL_E2	0,409	BC	3,880,00	3,821,31	0,10180	0,00	1,55	1,80	1	0,013	2,79	5,15	0,54	16,31	45,51	3,09	3,70	Y	Y
				FL_E	1,584																		
		FL_11	654	FL_F1	1,906	BC	3,821,31	3,815,28	0,00923	0,00	1,55	1,80	1	0,013	2,79	5,15	0,54	4,91	13,70	11,99	14,57	Y	N
		FL_12	356	FL_F2	0,159	BC	3,863,71	3,815,28	0,13604	0,00	1,10	1,00	1	0,013	1,10	3,10	0,35	14,22	15,64	1,32	1,49	Y	Y
				FL_F	1,966																		
		FL_13	92	FL_G1	1,969	BC	3,815,28	3,813,93	0,01475	0,00	1,55	1,80	1	0,013	2,79	5,15	0,54	6,21	17,32	13,13	15,90	Y	Y
		FL_14	289	FL_G2	0,065	BC	3,826,99	3,813,93	0,04519	0,00	1,10	1,00	1	0,013	1,10	3,10	0,35	8,20	9,02	0,48	0,59	Y	Y
				FL_G	2,035																		
		FL_15	126	FL_H1	2,039	CE	3,813,93	3,811,92	0,01602	0,50	1,55	1,60	1	0,030	3,76	5,13	0,73	3,43	12,90	13,52	16,30	N	N
		FL_16	73	FL_H2	0,019	BC	3,826,56	3,811,92	0,20055	0,00	0,50	0,45	1	0,013	0,23	1,40	0,16	16,18	2,29	0,16	0,18	Y	Y
				FL_H	2,058																		
Candelaria	CD	CD.1	83	CD.A	0,143	BC	3,820,76	3,820,39	0,00446	0,00	1,00	1,00	1	0,013	1,00	3,00	0,33	2,47	2,47	1,16	1,31	Y	Y
		CD.2	825	CD.B	0,387	BC	3,820,39	3,813,34	0,00852	0,00	1,00	1,00	1	0,013	1,00	3,00	0,33	3,41	3,41	2,98	3,37	Y	Y
Carabaya	CA	CA.1	1,270	CA.A1	0,524	CN	4,212,00	3,925,00	0,22598											3,07	4,21		
		CA.2	1,161	CA.A2	0,499	CN	4,128,00	3,925,00	0,17492											2,74	3,76		
				CA.A	1,023																		
		CA.3	175	CA.B1	1,164	CN	3,925,00	3,900,00	0,14286											6,24	8,48		
		CA.4	473	CA.B2	0,119	CN	4,028,00	3,900,00	0,27063											0,79	1,00		
				CA.B	1,283																		
		CA.5	163	CA.C1	1,347	CE	3,900,00	3,843,00	0,34969	0,00	1,10	1,00	1	0,030	1,10	3,10	0,35	9,88	10,87	7,32	9,98	Y	Y
		CA.6	554	CA.C2	0,097	CN	4,036,00	3,843,00	0,34869											0,70	0,86		
				CA.C	1,443																		
		CA.7	492	CA.D1	1,612	BC	3,843,00	3,840,35	0,00539	0,00	2,00	1,50	1	0,013	3,00	5,00	0,60	4,02	12,05	8,89	11,05	Y	Y
		CA.8	1,433	CA.D2	0,454	CN	4,140,00	3,974,00	0,11584											3,44	4,77		
		CA.9	814	CA.D3a	1,071	BC	3,974,00	3,840,35	0,16429	0,00	2,00	1,00	1	0,013	2,00	4,00	0,50	19,64	39,28	5,80	7,36	Y	Y
		CA.10	1,562	CA.D3b	0,888	CN	4,128,00	3,829,42	0,19115											4,70	6,19		
				CA.D3	1,959																		
				CA.D	3,571																		
		CA.11	310	CA.E	3,701	BC	3,840,35	3,829,42	0,03526	0,00	2,00	1,50	1	0,013	3,00	5,00	0,60	10,28	30,83	18,36	24,22	Y	Y
		CA.12	845	CA.F1	3,874	BC	3,829,42	3,812,02	0,02060	0,00	2,00	1,50	1	0,013	3,00	5,00	0,60	7,85	23,56	18,91	24,82	Y	N
		CA.13	898	CA.F2a	0,208	CN	4,069,00	3,873,29	0,21794											1,29	1,69		
		CA.14	802	CA.F2b	0,150	CN	4,072,00	3,873,29	0,24777											0,96	1,25		

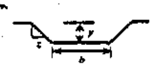
Table VII.2.7(2) Existing capacity of drainage system (2/2)

Drainage Area Name	Drainage Area ID	Reach ID	Reach Length (m)	Runoff Point ID	Runoff Point Area (km2)	Type*	Channel Profile U/S Elevation (El., m)	Channel Profile D/S Elevation (El., m)	Slope	Existing Cross-Section s	b (m)	y (m)	Number (nos.)	Hydraulic Properties for Existing Channel Manning's n	A (m2)	P (m)	R (m)	Velocity** v (m/s)	Discharge Capacity (m3/s)	5-Year Peak Runoff Existing (m3/s)	5-Year Peak Runoff Future (m3/s)	Enough Capacity*** Existing (Y/N)	Enough Capacity*** Future (Y/N)
				CA.F2	0.358																		
		CA.15	174	CA.F3a	0.431	CN	3,873.29	3,835.21	0.21885											2.73	3.48		
		CA.16	798	CA.F3b	0.141	BC	4,052.00	3,835.21	0.27167	0.00	1.00	1.10	1	0.013	1.10	3.20	0.34	19.67	21.64	1.05	1.27	Y	Y
				CA.F3	0.571																		
		CA.17	870	CA.F4	0.867	BC	3,835.21	3,815.02	0.02321	0.00	1.00	1.10	1	0.013	1.10	3.20	0.34	5.75	6.33	5.72	7.01	Y	N
				CA.F	4.741																		
		CA.18	304	CA.G	4.807	BC	3,815.02	3,813.53	0.00490	0.00	3.00	1.10	1	0.013	3.30	5.20	0.63	3.98	13.12	22.88	29.67	N	N
Ricardo Palma	RP	RP.1	595	RP.A	0.301	BC	3,818.64	3,812.36	0.01055	0.02	1.30	0.70	1	0.013	1.27	3.20	0.40	4.26	5.40	2.78	3.23	Y	Y
Echenique	EC	EC.1	1,404	EC.A	0.578	CN	4,192.00	3,860.00	0.23647											3.56	4.68		
		EC.2	895	EC.B	0.915	BC	3,860.00	3,812.01	0.05362	0.00	1.90	1.10	1	0.013	2.09	4.10	0.51	11.37	23.76	6.04	7.55	Y	Y
Branden	CH	CH.1	1,754	CH.A1	0.635	CN	4,254.00	3,871.77	0.21798											3.71	5.01		
		CH.2	1,462	CH.A2	0.364	CE	4,208.00	3,871.77	0.23006	0.33	1.00	2.30	1	0.030	4.03	5.84	0.69	12.48	50.22	2.60	3.16	Y	Y
				CH.A	0.999																		
		CH.3	889	CH.B	1.385	BC	3,871.77	3,814.11	0.06486	0.00	1.40	1.50	1	0.013	2.10	4.40	0.48	11.96	25.13	8.60	11.11	Y	Y
9 de Octubre	OC	OC.1	863	OC.A	0.254	CE	4,070.00	3,887.50	0.21159	0.50	0.70	0.80	1	0.030	0.88	2.49	0.35	7.67	6.75	1.56	2.10	Y	Y
		OC.2	774	OC.B	0.498	BC	3,887.50	3,813.05	0.09625	0.00	1.20	1.70	2	0.013	2.04	4.60	0.44	13.88	56.62	3.53	4.33	Y	Y
Chocuito	CV	CV.1	614	CV.A	0.217	BC	3,840.31	3,812.50	0.04529	0.00	1.30	1.50	1	0.013	1.95	4.30	0.45	9.66	18.84	1.75	2.00	Y	Y
Bolívar	BR	BR.1	957	BR.A	0.158	CN	4,058.00	3,883.89	0.18203											0.93	1.27		
		BR.2	796	BR.B	0.264	BC	3,889.39	3,812.10	0.09710	0.00	1.00	1.00	1	0.013	1.00	3.00	0.33	11.52	11.52	1.73	2.19	Y	Y
Toribio Gutierrez	TG	TG.1	1,287	TG.A	0.347	BC	4,170.00	3,849.23	0.24924	0.00	2.00	1.50	1	0.013	3.00	5.00	0.60	27.32	81.96	2.23	2.98	Y	Y
		TG.2	892	TG.B	0.418	CN	3,849.23	3,812.10	0.04165											2.40	3.16		
Moquegua	MO	MO.1	1,449	MO.A1	0.194	CN	4,034.00	3,817.00	0.14976											1.31	1.61		
		MO.2	440	MO.A2	0.105	CN	3,889.39	3,817.00	0.16452											0.87	0.99		
				MO.A	0.299																		
		MO.3	549	MO.B	0.399	CN	3,817.00	3,812.24	0.00867											2.35	2.84		
Augusto Sandino	AN	AN.1	977	AN.A	0.349	CN	4,132.00	3,890.00	0.24770											1.95	2.55		
		AN.2	212	AN.B1	0.541	CN	3,890.00	3,870.00	0.09456											3.33	4.35		
		AN.3	570	AN.B2	0.107	CN	3,988.00	3,870.00	0.20720											0.83	0.97		
				AN.B	0.649																		
		AN.4	626	AN.C1	0.760	CN	3,870.00	3,840.00	0.04796											4.61	5.63		
		AN.5	936	AN.C2	0.434	CN	4,156.00	3,990.00	0.27365											2.78	3.63		
		AN.6	723	AN.C3	0.576	CN	3,990.00	3,840.00	0.08299											3.52	4.49		
				AN.C	1.336																		
		AN.7	151	AN.D1	1.365	CC	3,840.00	3,838.02	0.01316	0.00	1.00	1.00	1	0.015	1.00	3.00	0.33	3.68	3.68	7.85	10.03	N	N
		AN.8	1,294	AN.D2	0.255	CE	4,236.00	3,964.29	0.20980	0.00	0.70	0.80	1	0.030	0.56	2.30	0.24	6.98	3.91	1.71	2.21	Y	Y
		AN.9	580	AN.D3	0.396	BC	3,964.29	3,838.02	0.04529	0.00	1.00	1.00	1	0.013	1.00	3.00	0.33	7.87	7.87	2.84	3.50	Y	Y
				AN.D	1.761																		
		AN.10	432	AN.E1	1.820	BC	3,838.02	3,832.06	0.01380	0.06	1.00	0.90	1	0.013	0.90	2.80	0.32	4.24	3.82	10.35	13.17	N	N
		AN.11	714	AN.E2	0.601	CN	4,044.00	3,902.00	0.19888											3.47	4.72		
		AN.12	1,030	AN.E3	1.166	CN	3,902.00	3,833.00	0.06651											5.51	7.75		
		AN.13	472	AN.E4	1.271	CC	3,833.00	3,822.97	0.02127	0.00	1.00	1.00	1	0.015	1.00	3.00	0.33	4.47	4.47	6.34	8.82	N	N
				AN.E	3.091																		
		AN.14	552	AN.F	3.220	BC	3,822.97	3,812.24	0.01944	0.00	1.20	1.00	1	0.013	1.20	3.20	0.38	5.58	6.69	16.32	21.59	N	N
Manco Capac	MC	MC.1	721	MC.A	0.352	CN	3,827.00	3,812.24	0.02047											2.10	2.73		

*: Represents channel along the main course of flow. Length of channel can be different from reach length which has been used for runoff calculation.

**: Peruvian design standard specifies maximum flow velocity through concrete channel be 10.0 m/s. For those channels having flow velocity exceeding 10.0 m/s, actual flow velocity might be lower than the velocity shown in the table due to presence of drop structure. This couldn't be verified due to insufficient data. However, separate calculation with reduced flow velocity of 10.0 m/s for those channels indicate that, those channel sections have enough flow capacity even with reduced flow velocity.

***: No evaluation has been made on existing capacities of natural channels.



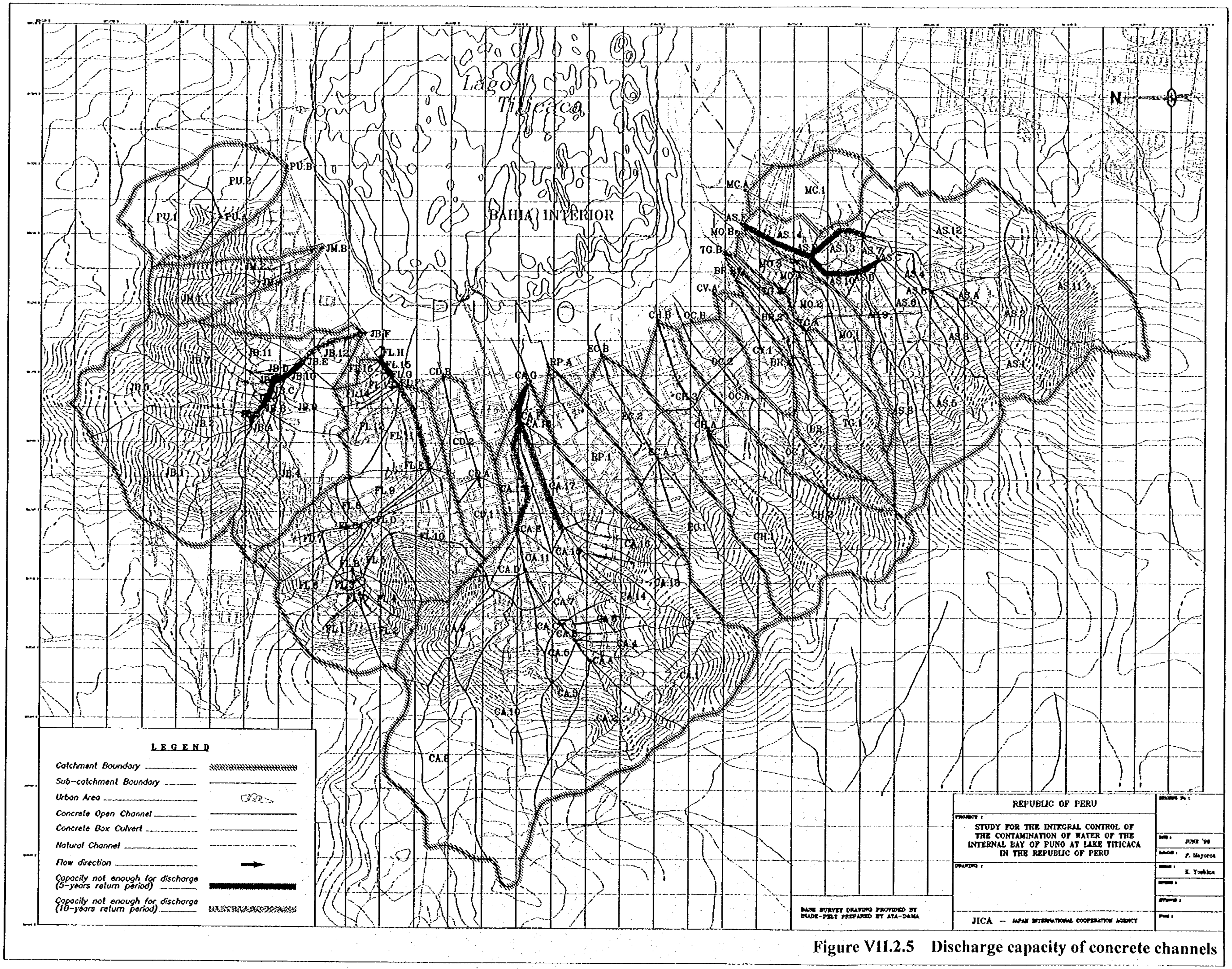


Figure VII.2.5 Discharge capacity of concrete channels

2.2.6 FLOW VELOCITY OF NATURAL CHANNELS

Maximum permissible flow velocities, which do not cause scour, for unlined channels, are shown in *Table VII.2.8*. Bed materials of natural channels in Puno City are fire sand or silts. If flow velocity exceeds 0.75 m/s, channels are subject to scour, for which erosion control measures are required. *Figure VII.2.6* shows natural channels where flow velocity exceeds the maximum permissible velocities. PELT has installed flow control structures, such as small (check) dams for various natural channels shown in *Figure VII.1.2*. Erosion control measures shall be extended to all the other natural channels.

Table VII.2.8 Maximum permissible velocities recommended by Fortier and Scobey (For straight channels of small slope, after aging).

Material	Water Transporting Colloidal Silts V, m/s
Fine sand, colloidal	0.75
Sand loam, noncolloidal	0.75
Alluvial silts, noncolloidal	1.05
Alluvial silts, collidal	1.50
Fine gravel	1.50
Cobbles and shingles	1.65
Coarse gravel, noncolloidal	1.80
Concrete sewer*2	3.00

*The Fortier and Scobey values were recommended for use in 1926 by the Sp Committee on Irrigation Research of the American Society of Civil Engineers.

*2 JICA Study team (1999)

Source: ASCE/WEF (1992)

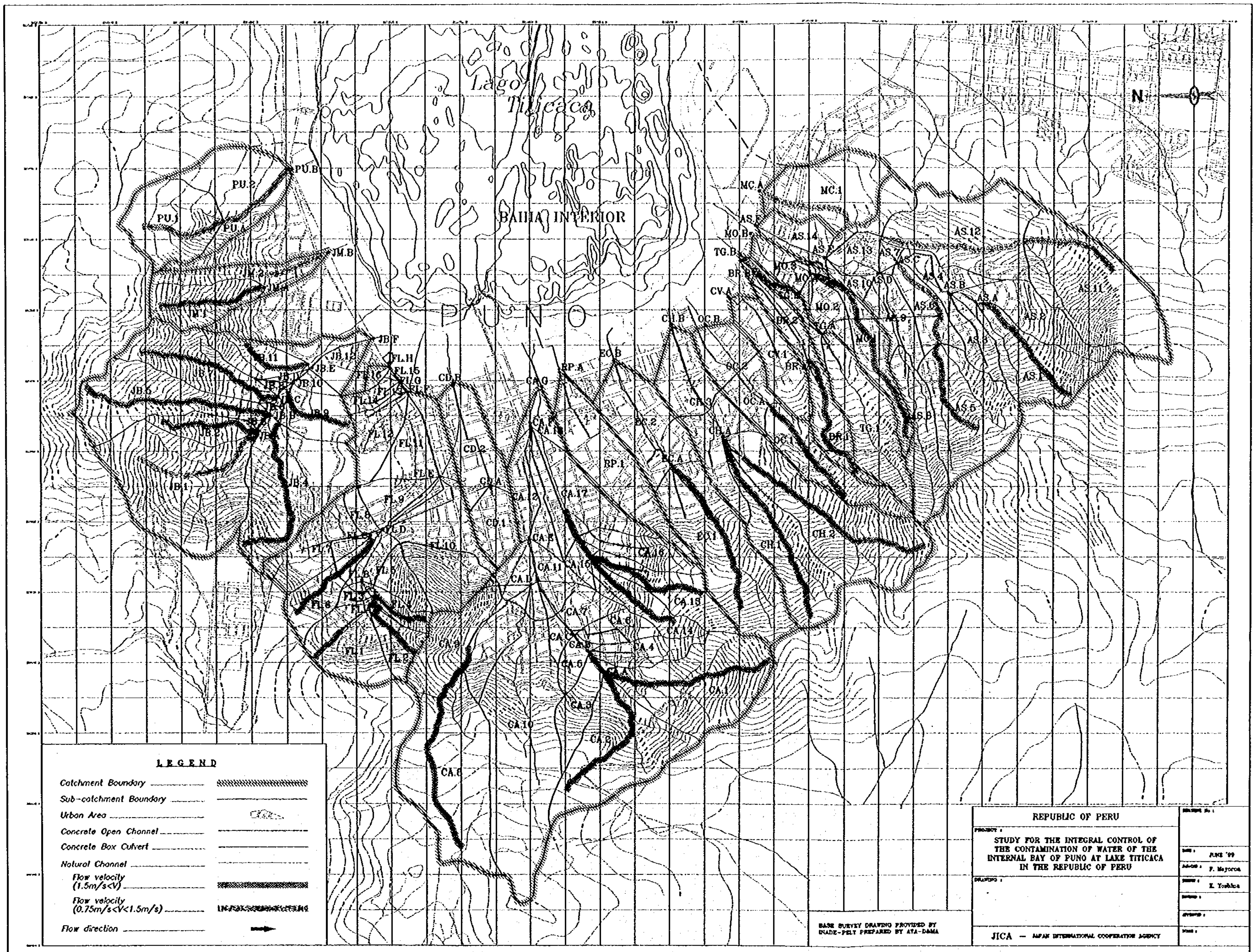


Figure VII.2.6 Flow velocity of natural channels

3. MEASURES FOR DRAINAGE IMPROVEMENT

3.1 TARGET

3.1.1 TARGET OF DRAINAGE IMPROVEMENT

From the results of the problem identification in Section 1.3, the following targets are set for drainage improvement plan.

- control of street flooding
- reduction of sediment and contaminant inflow to the interior bay of Puno
- prevention of rainwater inflow to sanitary sewer system

Target Year: Year 2025

3.1.2 STRATEGY

The following strategy is adopted for development of drainage improvement plans.

- maximum use of natural drainage ways and existing channels to minimize cost
- expanding the erosion and scour control measures to all the natural channels
- construction of detention basin to improve water quality and sediment trapping

The safety and cost effectiveness of preserving natural drainage to serve as "out fall" for street discharges is well recognized. Transferring the problem from one drainage basin to another should be avoided.

3.2 PROPOSED MEASURES

3.2.1 STRUCTURAL MEASURES

(1) Capacity improvement of the existing drainage system

a) Enlargement and lining of existing channels

Enlargement of existing channel cross-sections that have poor flow capacity for the future requirement shall be improved by widening and lining, which include improvement of possible bottlenecks, such as bridges and culverts.

b) Construction of additional drainage ways

This option is only considered where enlargement of existing channels is not possible or enlarged capacity of the channels can not carry the design flow.

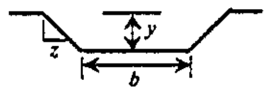
c) Construction of check dams and drop structures to control flow velocity and sediment

As discussed in Section 2.2, flow velocities in the most of natural channels exceed permissible limits for erosion and scour. Channel slope modification, such as check dams and drop structure shall be considered. These structures have been installed by INADE-PELT. This effort will be extended to all the natural channels where velocity reduction is required.

Proposed improvements of the drainage channels are shown in *Table.VII.3.1.* Those channels are also shown in *Figure VII.3.1.* Total length of the proposed channels is 12 km. Construction cost for the proposed channels is calculated using the same condition applied for the sewerage system. The results are shown in *Table VII.3.2.* Total construction cost is 8.4 million soles while the cost for channels with the first priority is 5.4 million.

Table VII.3.1 Proposed improvement of drainage channels

Proposed Channel						Proposed Cross-Section				Hydraulic Properties of Proposed Channel						5-Year Peak Runoff		Enough Capacity		Comment
ID	Priority Level	Reach Location	Type	Length (m)	Slope	z	b (m)	y (m)	Number (nos.)	Manning's n	A (m2)	P (m)	R (m)	Velocity (m/s)	Capacity (m3/s)	Existing (m3/s)	Future (m3/s)	Existing (Y/N)	Future (Y/N)	
L-1	2	JM.2	CC	570	0.06624	0.0	0.70	0.65	1	0.015	0.46	2.00	0.23	6.39	2.91	2.08	2.75	Y	Y	U
L-2	2	JB.3	CC	240	0.06090	0.0	0.60	0.50	1	0.015	0.30	1.60	0.19	5.39	1.62	-	1.44	Y	Y	A
L-3	2	JB.4	CC	870	0.13602	0.0	0.75	0.65	1	0.015	0.49	2.05	0.24	9.44	4.60	3.80	4.56	Y	Y	N
H-1	1	JB.6	CC	220	0.04443	0.0	0.95	0.80	1	0.015	0.76	2.55	0.30	6.27	4.77	3.80	4.56	Y	Y	U
H-2	1		BC	160	0.04443	0.0	0.85	0.80	1	0.013	0.68	2.45	0.28	6.90	4.69	2.07	4.67	Y	Y	A
H-3	1	JB.8	CC	170	0.01659	0.0	1.20	1.10	1	0.015	1.32	3.40	0.39	4.57	6.03	2.07	5.98	Y	Y	U
H-4	1	JB.10	BC	170	0.00707	0.0	1.60	1.30	1	0.013	2.08	4.20	0.50	4.05	8.42	4.05	8.14	Y	Y	A
L-4	2	FL.12	CC	300	0.13604	0.0	0.50	0.45	1	0.015	0.23	1.40	0.16	7.27	1.64	1.32	1.49	Y	Y	U
L-5	2	FL.14	CC	300	0.04519	0.0	0.45	0.40	1	0.015	0.18	1.25	0.14	3.89	0.70	0.48	0.59	Y	Y	U
H-5	1	FL.15	CC	140	0.01602	0.5	1.50	1.30	1	0.015	2.80	4.41	0.63	6.23	17.41	13.52	16.38	Y	Y	U
L-6	2	FL.16	CC	120	0.20055	0.0	0.25	0.15	1	0.015	0.04	0.55	0.07	4.98	0.19	0.16	0.18	Y	Y	U
L-7	2	CD.1	CC	480	0.00446	0.0	0.90	0.80	1	0.015	0.72	2.50	0.29	1.94	1.40	1.16	1.31	Y	Y	N
L-8*	2	CA.3	CC	230	0.09000	0.0	1.05	0.90	1	0.015	0.95	2.85	0.33	9.58	9.05	6.24	8.60	Y	Y	U
L-9*	2	CA.5	CC	200	0.09000	0.0	1.10	0.95	1	0.015	1.05	3.00	0.35	9.90	10.35	7.32	9.98	Y	Y	U
L-10	2	CA.13	CC	330	0.21794	0.0	0.50	0.40	1	0.015	0.20	1.30	0.15	8.94	1.79	1.29	1.69	Y	Y	U, N
L-11*	2	CA.15	CC	270	0.14000	0.0	0.70	0.60	1	0.015	0.42	1.90	0.22	9.12	3.83	2.73	3.48	Y	Y	N
H-6	1	CA.18	BC	560	0.00490	0.0	1.80	1.50	3	0.013	2.70	4.80	0.56	3.67	29.72	22.88	29.67	Y	Y	N
L-12	2	RP.1	CC	530	0.01055	0.0	1.10	0.90	1	0.015	1.00	2.90	0.35	3.37	3.38	2.78	3.23	Y	Y	N
L-13	2	CH.3	CC	220	0.06486	0.0	1.20	1.05	1	0.015	1.26	3.30	0.38	8.94	11.26	8.60	11.11	Y	Y	U
H-7	1	TG.2	CC	940	0.04165	0.0	0.85	0.70	1	0.015	0.60	2.25	0.26	5.61	3.34	2.40	3.16	Y	Y	U
L-14	2	MO.1	CC	490	0.14976	0.0	0.50	0.45	1	0.015	0.23	1.40	0.16	7.63	1.72	1.31	1.61	Y	Y	N
H-8	1	MO.2	CC	580	0.16452	0.0	0.45	0.35	1	0.015	0.16	1.15	0.14	7.18	1.13	0.87	0.99	Y	Y	N
H-9	1	MO.3	CC	330	0.00867	0.0	1.10	0.90	1	0.015	0.99	2.90	0.34	3.03	3.00	2.35	2.84	Y	Y	N
L-15	2	AS.2	CC	100	0.09456	0.0	0.90	0.80	1	0.015	0.72	2.50	0.29	8.94	4.51	3.33	4.35	Y	Y	N
L-16*	2	AS.5	CC	300	0.17000	0.0	0.70	0.55	1	0.015	0.39	1.80	0.21	9.83	3.78	2.78	3.63	Y	Y	N
L-17	2	AS.6	CC	790	0.08299	0.0	0.85	0.70	1	0.015	0.60	2.25	0.26	7.91	4.71	3.52	4.49	Y	Y	N
H-10	1	AS.7	CC	180	0.01316	0.5	1.30	1.10	1	0.015	2.04	3.76	0.54	5.08	10.34	7.85	10.03	Y	Y	U
L-18*	2	AS.8	CC	240	0.23000	0.0	0.55	0.45	1	0.015	0.25	1.45	0.17	9.84	2.43	1.71	2.21	Y	Y	U
H-11	1	AS.10	BC	460	0.01380	0.0	1.20	0.90	2	0.013	1.08	3.00	0.36	4.57	9.88	6.53	9.36	Y	Y	A
L-19	2	AS.13	CC	560	0.02127	0.0	1.35	1.20	1	0.015	1.62	3.75	0.43	5.56	9.00	6.34	8.82	Y	Y	U
H-12	1	AS.14	BC	560	0.01944	0.0	1.30	1.00	2	0.013	1.30	3.30	0.39	5.76	14.98	9.63	14.90	Y	Y	A
L-20	2	MC.1	CC	320	0.02047	0.0	0.90	0.75	1	0.015	0.68	2.40	0.28	4.09	2.76	2.10	2.73	Y	Y	N



* : May require construction of drop structure.

Nomenclature : U => Upgrading of existing channel
A => Addition to existing channel
N => New channel

Note : Existing concrete channels in reaches JB.12, FL.11, CA.12 and CA.17 have enough capacities under existing landuse condition and in combination with natural channels, can be considered to have enough capacities even under future landuse condition.

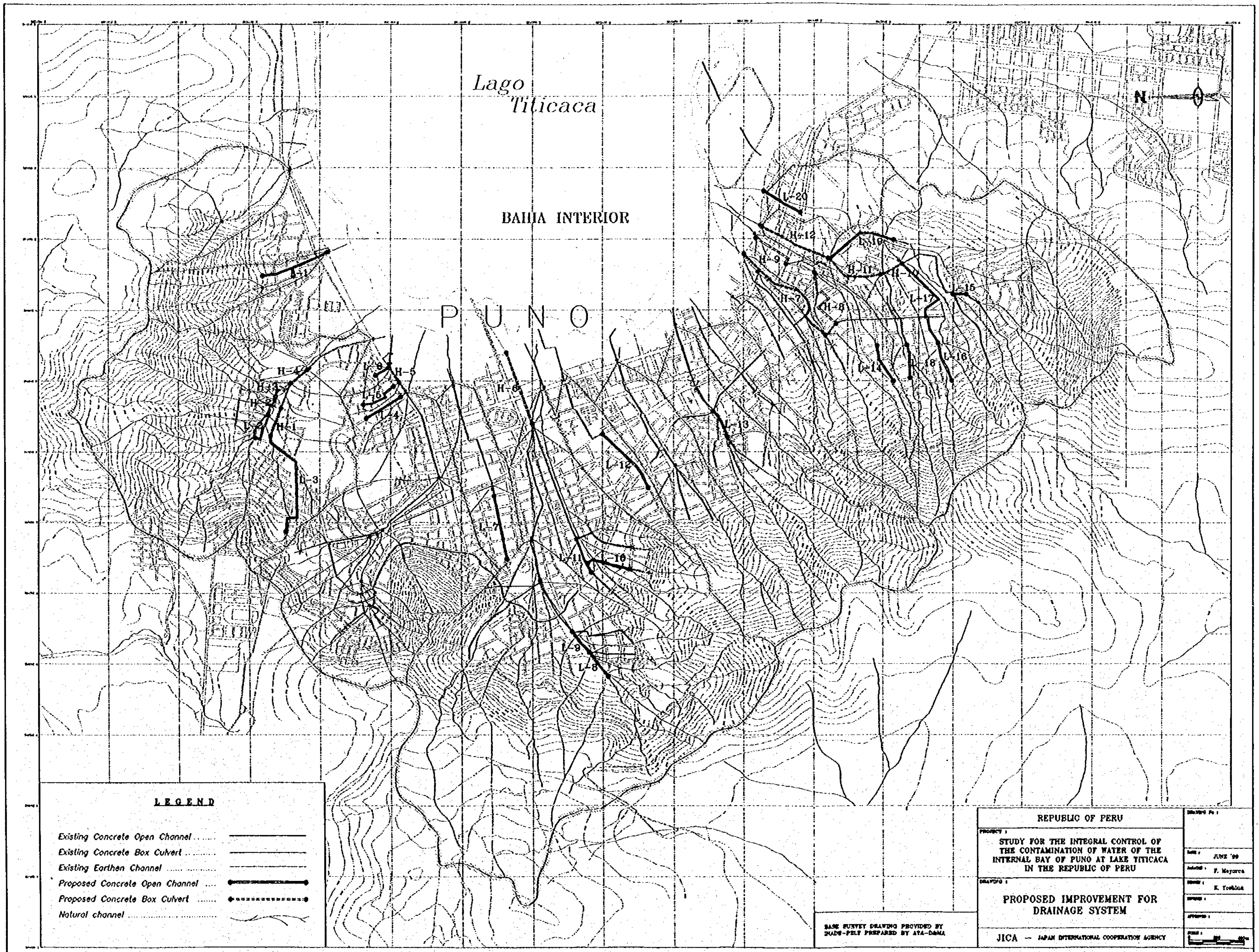


Figure VII.3.1 Proposed improvement for drainage system

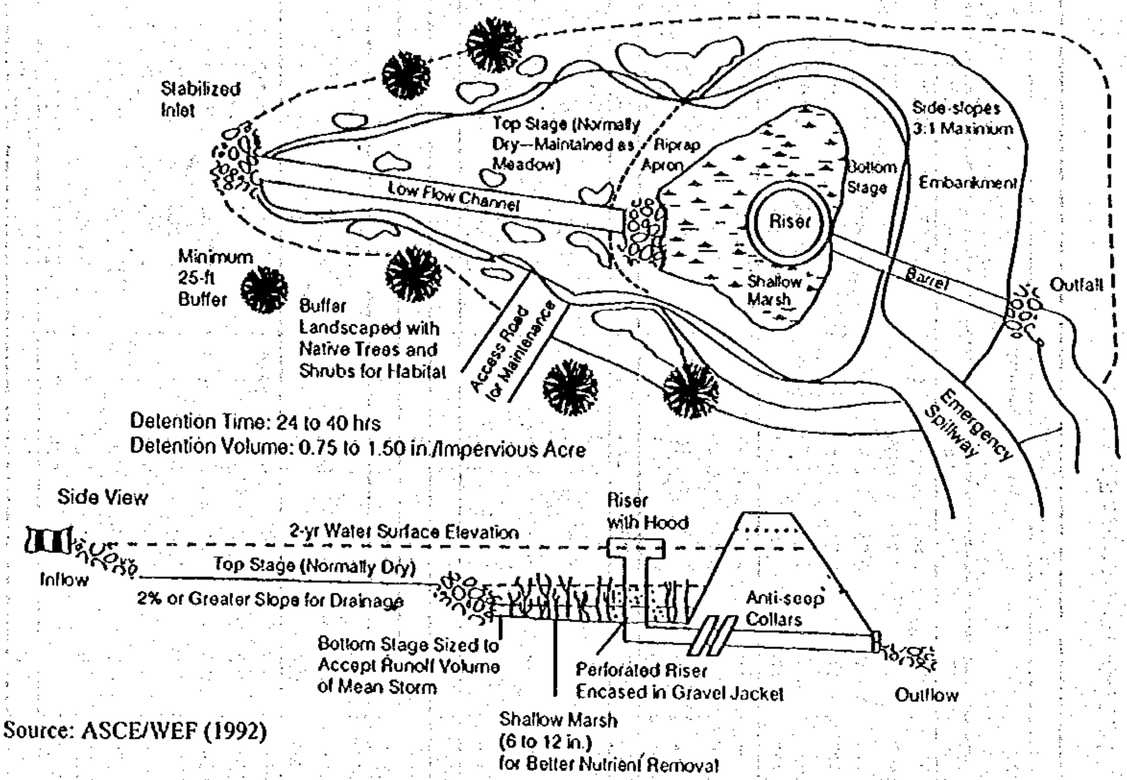
Table VII.3.2 Construction cost for proposed drainage channels

Proposed Channel						Proposed Cross-Section				Construction cost				
ID	Priority Level	Reach Location	Type	Length (m)	Slope	z	b (m)	y (m)	Number (nos.)	Direct cost (soles)	GG&U 25%	Sub-total (soles)	IGV 18%	Total (soles)
L-1	2	JM.2	CC	570	0.06624	0.0	0.70	0.65	1	132,454	33,113	165,567	29,802	195,369
L-2	2	JB.3	CC	240	0.06090	0.0	0.60	0.50	1	45,176	11,294	56,470	10,165	66,635
L-3	2	JB.4	CC	870	0.13602	0.0	0.75	0.65	1	205,324	51,331	256,655	46,198	302,853
H-1	1	JB.6	CC	220	0.04443	0.0	0.95	0.80	1	63,409	15,852	79,262	14,267	93,529
H-2	1		BC	160	0.04443	0.0	0.85	0.80	1	67,619	16,905	84,524	15,214	99,738
H-3	1	JB.8	CC	170	0.01659	0.0	1.20	1.10	1	80,062	20,015	100,077	18,014	118,091
H-4	1	JB.10	BC	170	0.00707	0.0	1.60	1.30	1	149,451	37,363	186,814	33,627	220,441
L-4	2	FL.12	CC	300	0.13604	0.0	0.50	0.45	1	50,692	12,673	63,365	11,406	74,771
L-5	2	FL.14	CC	300	0.04519	0.0	0.45	0.40	1	45,997	11,499	57,496	10,349	67,845
H-5	1	FL.15	CC	140	0.01602	0.5	1.50	1.30	1	78,560	19,640	98,200	17,676	115,876
L-6	2	FL.16	CC	120	0.20055	0.0	0.25	0.15	1	9,549	2,387	11,936	2,148	14,084
L-7	2	CD.1	CC	480	0.00446	0.0	0.90	0.80	1	136,558	34,139	170,697	30,726	201,423
L-8*	2	CA.3	CC	230	0.09000	0.0	1.05	0.90	1	73,834	18,459	92,293	16,613	108,905
L-9*	2	CA.5	CC	200	0.09000	0.0	1.10	0.95	1	67,507	16,877	84,384	15,189	99,573
L-10	2	CA.13	CC	330	0.21794	0.0	0.50	0.40	1	51,740	12,935	64,675	11,641	76,316
L-11*	2	CA.15	CC	270	0.14000	0.0	0.70	0.60	1	59,400	14,850	74,251	13,365	87,616
H-6	1	CA.18	BC	560	0.00490	0.0	1.80	1.50	3	1,669,272	417,318	2,086,590	375,586	2,462,176
L-12	2	RP.1	CC	530	0.01055	0.0	1.10	0.90	1	172,151	43,038	215,188	38,734	253,922
L-13	2	CH.3	CC	220	0.06486	0.0	1.20	1.05	1	100,334	25,083	125,417	22,575	147,992
H-7	1	TG.2	CC	940	0.04165	0.0	0.85	0.70	1	240,406	60,102	300,508	54,091	354,599
L-14	2	MO.1	CC	490	0.14976	0.0	0.50	0.45	1	82,797	20,699	103,496	18,629	122,125
H-8	1	MO.2	CC	580	0.16452	0.0	0.45	0.35	1	81,887	20,472	102,359	18,425	120,783
H-9	1	MO.3	CC	330	0.00867	0.0	1.10	0.90	1	107,188	26,797	133,985	24,117	158,103
L-15	2	AS.2	CC	100	0.09456	0.0	0.90	0.80	1	19,915	4,979	24,893	4,481	29,374
L-16*	2	AS.5	CC	300	0.17000	0.0	0.70	0.55	1	62,293	15,573	77,866	14,016	91,882
L-17	2	AS.6	CC	790	0.08299	0.0	0.85	0.70	1	202,044	50,511	252,555	45,460	298,014
H-10	1	AS.7	CC	180	0.01316	0.5	1.30	1.10	1	86,553	21,638	108,192	19,474	127,666
L-18*	2	AS.8	CC	240	0.23000	0.0	0.55	0.45	1	41,393	10,348	51,741	9,313	61,055
H-11	1	AS.10	BC	460	0.01380	0.0	1.20	0.90	2	473,209	118,302	591,511	106,472	697,984
L-19	2	AS.13	CC	560	0.02127	0.0	1.35	1.20	1	288,860	72,215	361,075	64,993	426,068
H-12	1	AS.14	BC	560	0.01944	0.0	1.30	1.00	2	627,873	156,968	784,842	141,272	926,113
L-20	2	MC.1	CC	320	0.02047	0.0	0.90	0.75	1	87,023	21,756	108,779	19,580	128,359
													Total cost (S/.)	**8,349,282**

* : May require construction of drop structure.

(2) Construction of wet detention basins

The existing drainage ways carry untreated domestic wastewater and sediment to the interior bay, which aggravate the eutrophic condition of the lake. Wet detention basins will be built for water quality and sediment control. *Figure VII.3.2* illustrates typical design schematic of a wet detention basin.



Source: ASCE/WEF (1992)

Figure VII.3.2 Extended detention pond design feature (Schueler, 1987)

The removal of storm water pollutants in the detention basin is accomplished by a number of processes such as:

- gravity settling (sediment removal)
- chemical flocculation: heavier sediment particles overtake and coalesce with smaller particles to form larger particles
- biological removal of dissolved pollutants: uptake by aquatic plans or micro-organisms

Bar screens or trash racks placed at the inlet or outlet of the basin will remove solid wastes carried by the storm water.

The detention basins will be constructed in the flood area along the interior bay as a temporary structure until tourism and commercial developments make use of the area. The detention basin can be designed for aesthetic enhancement, usually viewed as an amenity. The design procedure is explained in the DATA BOOK.

(3) Installation of proper street drainage

Street flooding is observed frequently in Puno City after the rain events. The storm sewer system may begin at the locations where specified street carrying capacity is exceeded. Design of the street drainage system requires street grades and cross-sections, which is not available for this study. Detailed topographic survey such as one proposed by World Bank study (1998) is necessary for this purpose.

(4) Separation of drainage ways and sanitary sewer system

The sanitary sewer system in Puno City is a separate system, which is not supposed to receive storm water. As extreme inflow to the sewerage system is recorded after the rain event, devised or unintentional connections of drainage ways to the sanitary sewer system are suspected. Thorough inspection of drainage ways is required to eliminate these connections.

3.2.2 NON-STRUCTURAL MEASURES

(1) Public awareness program for proper use of drainage system

Improper use of drainage system, such as disposal of solid wastes and connection of sanitary sewer, badly affects the quality of discharge from drainage system to the interior bay of Puno. Public awareness program is essential to promote proper use of drainage system. The program shall include:

- prevention of public littering and waste disposal to drainage ways
- prevention of illicit or cross connection with sanitary sewer

- promotion of public participation to erosion and scour control program initiated by PELT

(2) Introduction and enforcement of regulations for drainage system use

Appropriate regulations shall be introduced to prevent improper use of drainage ways, such as illicit disposal of solid wastes. Regulations shall also prevent connection of rainwater sources (roofs etc.) to the sanitary sewer system.