Proposed improvements of the drainage channels are shown in *Table VII.1.3* and *Figure VII.1.2*. Total length of the proposed channels is 12 km. Construction cost for the proposed channels is shown in *Table VII.1.3*. Total construction cost is 8.4 million soles while the cost for channels with the first priority is 5.4 million.

**(Non-structural measures)**

- formation of regulations or ordinance to prevent connection of rainwater sources (roofs etc.) to sanitary sewer system
- enhancing erosion control measures by PELT through public awareness program
- prevention of littering of drainage ways through public awareness program

**(4) Cost**

| | |
|---|---|
| Direct construction cost : | 6,700,500 S/. |
| Engineering service cost (construction x 10%): | 670,100 S/. |
| Contingency { (construction+engineering) x 15%}: | 1,105,600 S/. |
| Administration cost (construction x 1 %): | 67,000 S/. |
| **Total** | **8,543,200 S/. (not including IGV)** |

**(5) Implementation**

the year 2000: preparation, detailed design and surveys

2001 ~ 2008 : construction work

# Table VII.1.1(1) Peak Discharge Calculation By Rational Method (1/2)

| Drainage Area Name | Drainage Area ID | Sub-Catchment ID | Sub-Catchment Area (km2) | Runoff Point ID | Runoff Point Area (km2) | Runoff Coefficient, C: Sub-Catchment Ex. | Sub-Catchment Fut. | Runoff Point Ex. | Runoff Point Fut. | Inlet Lo (m) | Inlet Uppermost Catchment Slope | Inlet Ti (min) Ex. | Ti Fut. | Flow through Channel or Box Culvert: Vf (m/s) by Segment Ex. | Vf Fut. | Type* | Length of Flow, Lf (m) Segment | Lf Cumulative | Segment's, Tf (min) Ex. | Tf Fut. | Time of Concentration: Cumulative Tc (min) Ex. | Tc Fut. | Rainfall Intensity I (mm/hr): 5-Year R.P. Ex. | 5-Year Fut. | 10-Year R.P. Ex. | 10-Year Fut. | Areal Reduction r | Peak Runoff, Q (m3/s): 5-Year R.P. Ex. | 5-Year Fut. | 10-Year R.P. Ex. | 10-Year Fut. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pucara | 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 | 34.51 | 37.06 | 47.29 | 48.20 | 1.00 | 1.97 | 2.66 | 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 |
| [illegible] | 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 | 0.353 | 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 | 2.43 | 2.70 | CN | 1,064 | 1,064 | 6.74 | 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 | 0.389 | JB.B3 | 0.389 | 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 | | | | | 7.07 | 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 | 35.67 | 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 | 47.08 | 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 |
| [illegible] | PL | PL.1 | 0.254 | PL.A1 | 0.254 | 0.68 | 0.84 | 0.68 | 0.84 | 40 | 0.150000 | 0.69 | 0.69 | 2.43 | 2.50 | CN | 552 | 552 | 4.54 | 3.67 | 5.23 | 4.37 | 37.14 | 37.58 | 48.34 | 49.09 | 1.00 | 1.78 | 2.23 | 2.32 | 2.91 |
| | | PL.2 | 0.102 | PL.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 |
| | | | | PL.A | 0.356 | | | 0.67 | 0.84 | | | | | | | | | 552 | | | 5.23 | 4.37 | 37.14 | 37.58 | 48.34 | 49.09 | 1.00 | 2.48 | 3.11 | 3.23 | 4.07 |
| | | PL.3 | 0.036 | PL.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 |
| | | PL.4 | 0.053 | PL.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 |
| | | | | PL.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 |
| | | PL.5 | 0.155 | PL.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 |
| | | PL.6 | 0.160 | PL.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 |
| | | PL.7 | 0.234 | PL.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 | 52.46 | 1.00 | 1.95 | 2.26 | 2.58 | 3.00 |
| | | | | PL.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 |
| | | PL.8 | 0.046 | PL.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 |
| | | PL.9 | 0.135 | PL.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 |
| | | PL.10 | 0.409 | PL.E2 | 0.409 | 0.72 | 0.86 | 0.72 | 0.86 | 500 | 0.426000 | 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 |
| | | | | PL.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 | 16.42 |
| | | PL.11 | 0.223 | PL.F1 | 1.806 | 0.80 | 0.90 | 0.74 | 0.87 | | | | | 4.91 | 5.52 | 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 |
| | | PL.12 | 0.159 | PL.F2 | 0.159 | 0.80 | 0.90 | 0.80 | 0.90 | 500 | 0.194000 | 4.38 | 4.38 | 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 |
| | | | | PL.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 |
| | | PL.13 | 0.004 | PL.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 |
| | | PL.14 | 0.065 | PL.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 |
| | | | | PL.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 |
| | | PL.15 | 0.005 | PL.H1 | 2.039 | 0.80 | 0.90 | 0.74 | 0.87 | | | | | 3.43 | 3.86 | CK | 124 | 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 |
| | | PL.16 | 0.019 | PL.H2 | 0.019 | 0.80 | 0.90 | 0.80 | 0.90 | 185 | 0.270270 | 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 |
| | | | | PL.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 | 2.78 | 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 |
| [illegible] | CA | CA.1 | 0.524 | CA.A1 | 0.524 | 0.60 | 0.80 | 0.60 | 0.80 | 50 | 0.200000 | 0.74 | 0.74 | 2.58 | 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 | 36.21 | 36.71 | 46.80 | 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 | 41.34 | 1.00 | 3.44 | 4.77 | 4.30 | 6.01 |
| | | CA.9 | 0.417 | CA.D3a | 1.071 | 0.66 | 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 | 4.70 | 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 | 29.26 |
| | | 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 | | | | | 7.85 | 8.84 | BC | 845 | 3,401 | 1.79 | 1.59 | 24.58 | 22.00 | 28.97 | 29.87 | 35.67 | 36.99 | 0.938 | 18.91 | 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.1.1(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 | | Ls | Upstream | 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 Slope | Ex. | Fut. | Ex. | Fut. | Type* | Segment | Cumulative | Ex. | Fut. | Ex. | Fut. | Ex. | Fut. | Ex. | Fut. | r | Ex. | Fut. | Ex. | Fut. |
| | | | | CA.F2 | 0.350 | | | 0.64 | 0.82 | | | | | | | | | 890 | | | 9.53 | 8.09 | 35.83 | 35.72 | 44.88 | 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 | 34.18 | 34.94 | 43.51 | 44.72 | 1.00 | 2.73 | 3.48 | 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 | 23.09 | BC | 790 | 790 | 0.68 | 0.56 | 2.91 | 2.80 | 38.33 | 38.39 | 50.38 | 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 | 34.18 | 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 | | | 24.58 | 22.00 | 28.97 | 29.07 | 35.67 | 36.99 | 0.909 | 22.88 | 29.47 | 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 | 36.60 | 0.906 | 22.88 | 29.67 | 28.17 | 36.74 |
| Ricardo Palma | RP | RP.1 | 0.381 | RP.A | 0.381 | 0.76 | 0.88 | 0.76 | 0.88 | 1170 | 0.211966 | 8.15 | 8.15 | 4.26 | 4.94 | BC | 595 | 595 | 2.33 | 2.01 | 10.48 | 10.16 | 34.59 | 34.74 | 44.17 | 44.41 | 1.00 | 2.79 | 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 | 2.68 | 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 | 7.55 | 7.69 | 9.68 |
| 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 | 4.71 | 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 | 12.48 | 16.30 | CK | 1,462 | 1,462 | 1.95 | 1.49 | 2.98 | 2.53 | 38.29 | 38.53 | 50.32 | 50.74 | 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 | 0.385 | CH.B | 1.385 | 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 | 7.47 | 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 | | | | | 13.88 | 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 |
| Chaves | CV | CV.1 | 0.217 | CV.A | 0.217 | 0.78 | 0.89 | 0.78 | 0.89 | 520 | 0.226923 | 4.25 | 4.25 | 9.66 | 11.03 | BC | 614 | 614 | 1.06 | 0.93 | 5.31 | 5.18 | 37.09 | 37.14 | 48.27 | 48.38 | 1.00 | 1.75 | 2.00 | 2.27 | 2.60 |
| Briceño | 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 | 5.55 | 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 | 0.78 | 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 | | | | | 1.18 | 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 | 0.356757 | 1.62 | 1.61 | 2.01 | 2.33 | CN | 570 | 570 | 4.72 | 4.08 | 6.34 | 5.69 | 36.58 | 36.90 | 47.40 | 47.94 | 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 | 626 | 1,814 | 6.92 | 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 | 130 | 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 | 1.66 | 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 | 9.38 | 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 | 351 | 1,965 | 0.68 | 0.61 | 21.14 | 18.00 | 30.19 | 31.34 | 37.45 | 39.22 | 1.00 | 7.85 | 10.03 | 9.74 | 12.56 |
| | | AN.8 | 0.255 | AN.D2 | 0.255 | 0.64 | 0.82 | 0.64 | 0.82 | 100 | 0.290000 | 1.09 | 1.09 | 6.98 | 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 | 31.34 | 37.45 | 39.22 | 1.00 | 10.17 | 12.96 | 12.61 | 16.20 |
| | | AN.10 | 0.059 | 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 | 0.64 | 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 | 40.90 | 42.79 | 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 (1996) 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

# Table VII.1.2(1) Existing Capacities of Drainage Channels (1/2)

| Drainage Area | | Reach | | Runoff Point | | Type* | Channel Profile | | | Existing Cross-Section | | | | Hydraulic Properties for Existing Channel | | | | Velocity** | Discharge | 5-Year Peak Runoff | | Enough Capacity*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | ID | ID | Length (m) | ID | Area (km2) | | U/S Elevation (El., m) | D/S Elevation (El., m) | Slope | z | b (m) | y (m) | Number (nos.) | Manning's n | A (m2) | P (m) | R (m) | v (m/s) | Capacity (m3/s) | Existing (m3/s) | Future (m3/s) | Existing (Y/N) | Future (Y/N) |
| Puvar * | 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 | 3,811.28 | 0.10176 | | | | | | | | | | | 3.57 | 4.94 | | |
| Jos de la Mar | JM | JM.1 | 787 | JM.A | 0.201 | CN | 4,052.00 | 3,850.00 | 0.25683 | | | | | | | | | | | 1.22 | 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 | 1,064 | JB.A1 | 0.714 | CN | 3,994.00 | 3,838.65 | 0.14607 | 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 | | | | | | | | | | | 3.00 | 4.56 | | |
| | | JB.5 | 1,411 | JB.B3 | 0.307 | CN | 4,083.00 | 3,831.22 | 0.17850 | | | | | | | | | | | 2.30 | 3.10 | | |
| | | | | 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 | 16.63 | N | N |
| | | JB.9 | 560 | JB.D2 | 0.161 | CN | 3,880.00 | 3,821.98 | 0.10370 | 0.00 | 1.80 | 1.00 | 1 | | | | | | | 1.27 | 1.44 | | |
| | | | | 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 |
| Florid | 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 | 0.19672 | | | | | | | | | | | 1.18 | 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 | 1.00 | 1 | 0.013 | 2.70 | 5.10 | 0.53 | 8.43 | 22.76 | 7.95 | 9.49 | Y | Y |
| | | FL.10 | 577 | FL.E2 | 0.409 | BC | 3,880.00 | 3,821.31 | 0.10180 | 0.00 | 1.55 | 1.00 | 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 | 1.886 | BC | 3,821.31 | 3,815.28 | 0.00923 | 0.00 | 1.55 | 1.00 | 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 | 1.00 | 1 | 0.013 | 2.79 | 5.15 | 0.54 | 6.21 | 17.32 | 13.13 | 15.96 | 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 | 16.38 | 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 | 10.18 | 2.29 | 0.16 | 0.18 | Y | Y |
| | | | | FL.H | 2.050 | | | | | | | | | | | | | | | | | | |
| Candelaria * | CD | CD.1 | 83 | CD.A | 0.143 | BC | 3,820.76 | 3,826.39 | 0.00444 | 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 | 0.307 | BC | 3,820.39 | 3,813.36 | 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 |
| Caracoto | 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 | 8.60 | | |
| | | CA.4 | 673 | CA.B2 | 0.119 | CN | 4,082.00 | 3,900.00 | 0.27063 | | | | | | | | | | | 0.79 | 1.08 | | |
| | | | | 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 | 11.85 | Y | Y |
| | | CA.8 | 1,433 | CA.D2 | 0.654 | 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 | 5.90 | 7.86 | 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 | 0.200 | 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.1.2(2) Existing Capacities of Drainage Channels (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 z | b (m) | y (m) | Number (nos.) | 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.P2 | 0.350 | | | | | | | | | | | | | | | | | | |
| | | CA.15 | 174 | CA.P3a | 0.431 | CN | 3,873.29 | 3,835.21 | 0.21885 | | | | | | | | | | | 2.73 | 3.46 | | |
| | | CA.16 | 798 | CA.P3b | 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.P3 | 0.571 | | | | | | | | | | | | | | | | | | |
| | | CA.17 | 870 | CA.P4 | 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.P | 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 | 3.99 | 13.12 | 22.88 | 29.47 | N | N |
| Ricardo Palma | RP | RP.1 | 595 | RP.A | 0.381 | BC | 3,818.64 | 3,812.36 | 0.01055 | 0.02 | 1.00 | 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 |
| Brandes | CH | CH.1 | 1,754 | CH.A1 | 0.635 | CN | 4,254.00 | 3,871.77 | 0.21790 | | | | | | | | | | | 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 | 12.40 | 50.22 | 2.40 | 3.16 | Y | Y |
| | | | | CH.A | 0.999 | | | | | | | | | | | | | | | | | | |
| | | CH.3 | 889 | CH.B | 1.305 | BC | 3,871.77 | 3,814.13 | 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 |
| 8 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 |
| Chavez | CV | CV.1 | 634 | 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 |
| Belaunde | BR | BR.1 | 957 | BR.A | 0.158 | CN | 4,056.00 | 3,883.89 | 0.18203 | | | | | | | | | | | 0.93 | 1.27 | | |
| | | BR.2 | 796 | BR.B | 0.264 | BC | 3,889.29 | 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 Cachorro | 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 | 0.309 | 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 | 0.09434 | | | | | | | | | | | 3.33 | 4.35 | | |
| | | AN.3 | 579 | AN.B2 | 0.107 | CN | 3,980.00 | 3,870.00 | 0.24720 | | | | | | | | | | | 0.83 | 0.97 | | |
| | | | | AN.B | 0.649 | | | | | | | | | | | | | | | | | | |
| | | AN.4 | 426 | AN.C1 | 0.760 | CN | 3,870.00 | 3,840.00 | 0.04796 | | | | | | | | | | | 4.41 | 5.63 | | |
| | | AN.5 | 934 | AN.C2 | 0.434 | CN | 4,156.00 | 3,900.00 | 0.27365 | | | | | | | | | | | 2.78 | 3.63 | | |
| | | AN.6 | 723 | AN.C3 | 0.576 | CN | 3,900.00 | 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 | 4,228.00 | 3,964.29 | 0.20000 | 0.00 | 0.70 | 0.80 | 1 | 0.020 | 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 | 1.828 | BC | 3,838.02 | 3,832.06 | 0.01380 | 0.00 | 1.00 | 0.90 | 1 | 0.013 | 0.90 | 2.80 | 0.32 | 4.24 | 3.82 | 10.35 | 12.17 | N | N |
| | | AN.11 | 714 | AN.E2 | 0.601 | CN | 4,044.00 | 3,902.00 | 0.19888 | | | | | | | | | | | 3.47 | 4.72 | | |
| | | AN.12 | 1,038 | AN.E3 | 1.106 | 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 | 5.56 | 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 to 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 these channels indicate that, these channel sections have enough flow capacity even with reduced flow velocity.

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

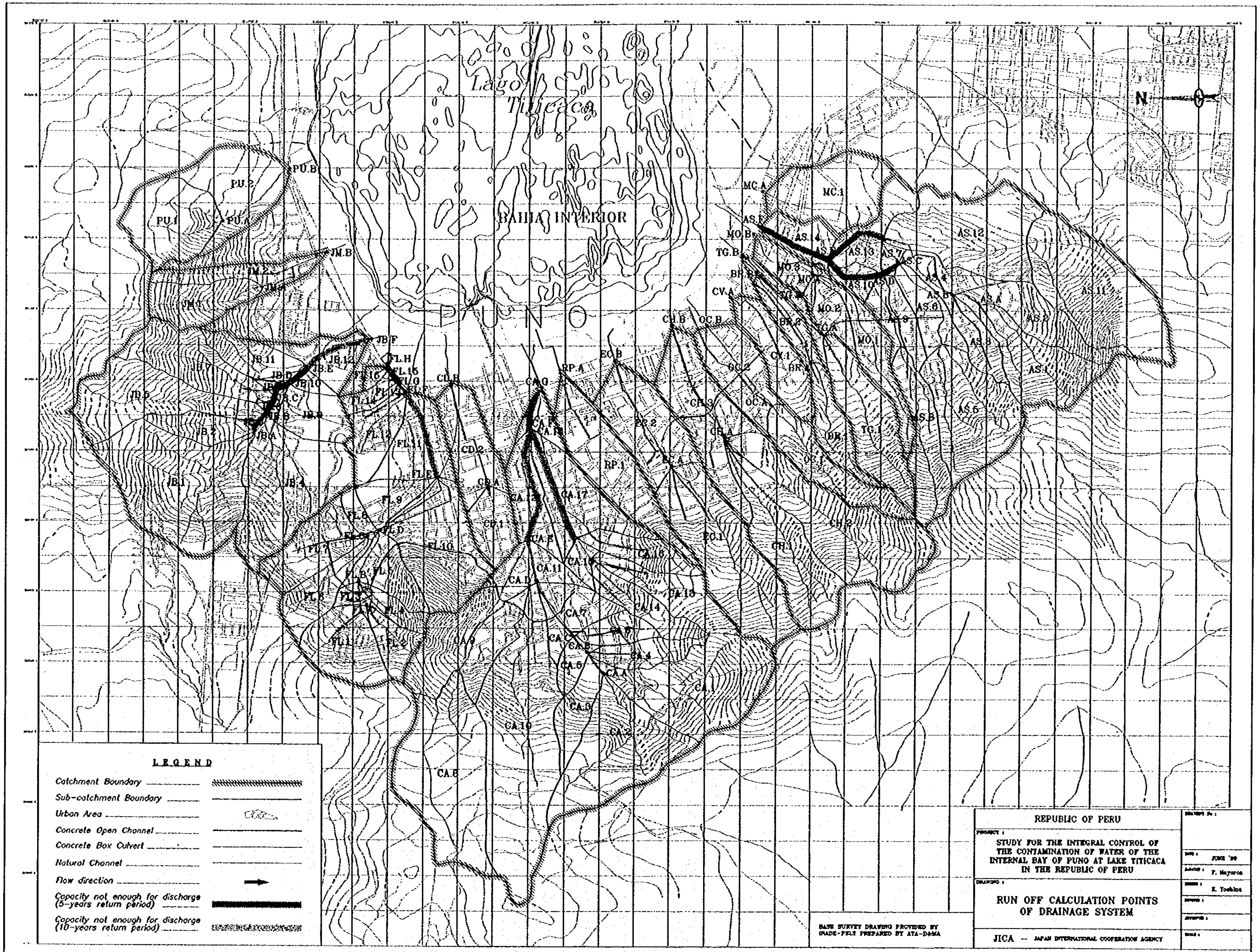


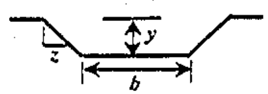

**Figure VII.1.1 Run-off Calculation Points of Drainage System**

# Table VII.1.3 Proposed improvement for the drainage channels(5-year return period)

| ID | Proposed Channel | | | | | Proposed Cross-Section | | | | Hydraulic Properties of Proposed Channel | | | | | | 5-Year Peak Runoff | | Enough Capacity | | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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.

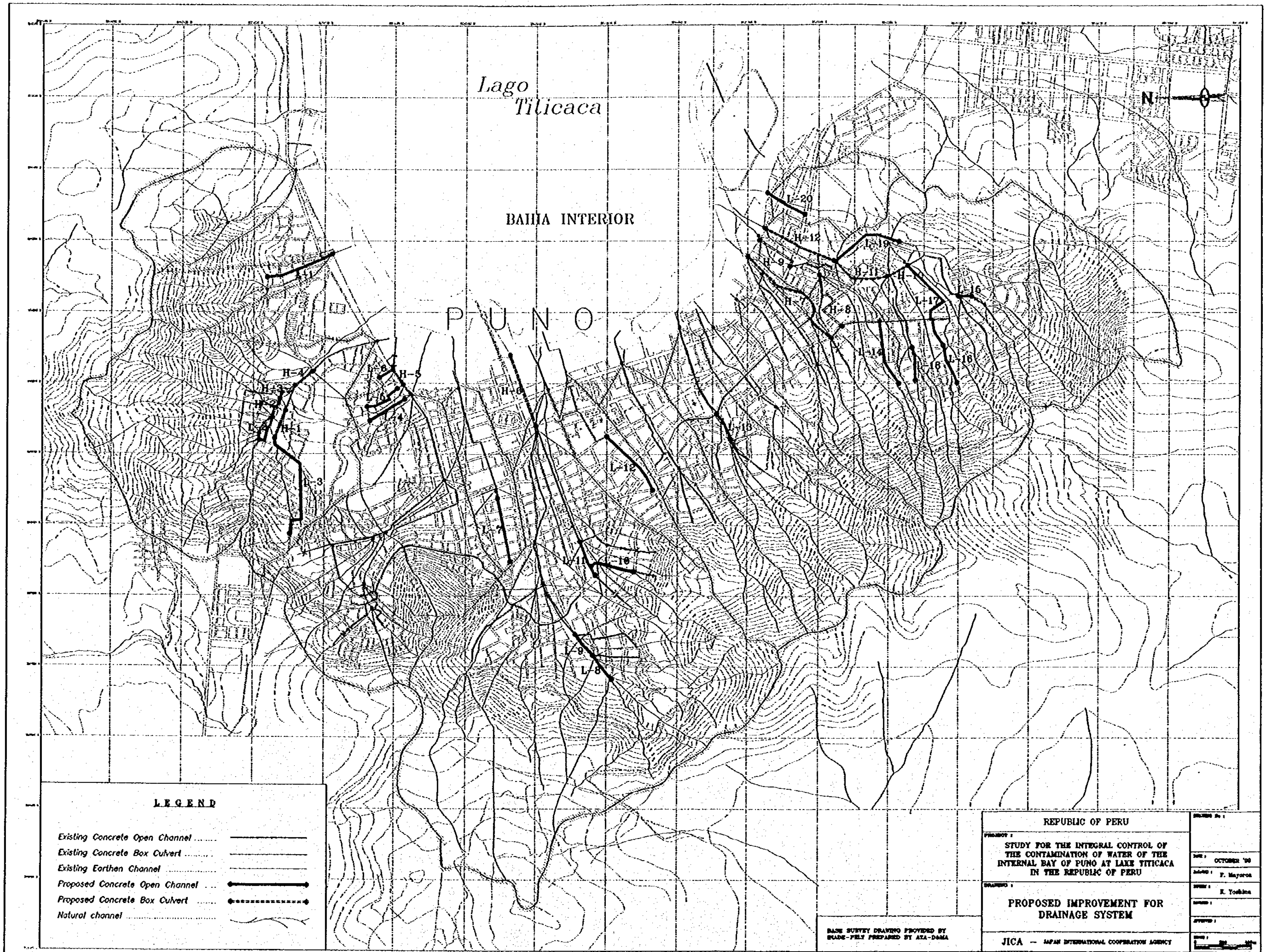



**Figure VII.1.2 Proposed improvement for the drainage channels**

## Table VII.1.4 Construction cost for the proposed 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. IN-LAKE MANAGEMENT

### 2.1 TARGET AND STRATEGY

Principally the water pollution control should be focused on the measures against the external pollution loading such as sewerage or sanitary wastewater treatment. Because the external loads are the origin of pollution loads in the lake. However in-lake measures against pollution loads accumulated in the water column or in the bottom sediment should be taken when any possible measures against the external loading do not produce the expected effect on the lake water quality.

Besides the water quality improvement, natural environment should be rehabilitated to the level that used to be a few decades before. It will increase the potential of Lake Titicaca for tourism development.

Several advanced techniques have been developed and available. Dosing chemicals, bioremediation, or dilution/flushing are examples of them. Most techniques are experimental or expensive, and their effects are uncertain to apply to a full-scale water body. Dosing chemical method succeeded in some small lakes and reservoirs. However the cost will be too expensive to apply it to Puno Interior Bay, and negative effect can not be entirely denied. An experimental study on the bioremediation was carried out in Puno Interior Bay, but its effect was not clarified enough. Dilution/flushing is feasible only where large quantities of low-nutrient water are available for transport to the affected lake. It might be possible even in Puno Interior Bay if the water is transported from the Exterior Bay by widening the existing channel or by constructing another wide channel. However it will spread the problem of the Interior Bay over the whole Puno Bay, which should not be realized absolutely.

In this section, some possible measures are discussed taking the applicability to Puno Interior Bay.

## 2.2 POSSIBLE MEASURES

### (1) Removal of Duckweed (*Lemna*)

#### 1) Target and Strategy

*Lemna* is characterized as follows:

- *Lemna* is a kind of floating macrophyte with an average length of 2 millimeters.
- It lives under a wide range of temperature from 8 to 45 degrees (°C).
- It increases through two types of reproduction process, one is a sexual reproduction and the other is a vegetative or asexual reproduction.
- The reproduction cycle is rather short; approximately a month.

Removal/harvest of *Lemna* from the lake surface is a simple and direct measure. It will contribute to reducing not only *Lemna* from the lake surface but also nutrients from the lake.

The required operational processes are as follows:

- Removal/Harvest
- Transportation
- Disposal or Utilization

"The Multisectorial Committee for the Environmental Improvement of Puno Interior Bay of Lake Titicaca" campaigned for the cleaning and the removal of *Lemna* in October and November 1998. The contents of the program is summarized below.

- The multisectorial committee executed three (3) times of campaign for cleaning and harvest of the *Lemna*.
- About 500 peoples of the public and private sectors participated in each campaign.

- It is said that approximately 1,560 cubic meters of *Lemna* was removed from the lake through the campaign.

- The removed *Lemna* was transported to the experimental farmland of UNA expecting a utilization for compost.

## 2) Proposed plan

### a. Target area

Mainly, the western part of Puno Interior Bay

### b. Method

Two types of programs for the removal of *Lemna* are considered as follows.

- The same manner that was carried out in October and November 1998 through the campaign organized or supported by multisectors.

- Regular removal of *Lemna* by a competent organization.

The regular removal method is proposed from the following points of view (*Table VII.2.1*).

- To prevent the dead *Lemna* from precipitating and accumulating on the lake bottom.

- To keep the *Lemna* from spreading over the lake surface.

*Lemna* should be removed at least once a month taking the reproduction cycle of *Lemna* into account. For the promotion of environmental awareness, it would be preferable that the removal work should be done by citizen's participation. However, the citizens may be unwilling to walk into the contaminated water through the painful experiences of the last campaigns in 1998. Therefore an aquaphyte harvesting equipment installed on a low-draft barge is proposed for the removal of Lemna until the water quality will be improved to some extent. The frequency is summarized as follows:

- once a month (1 time = 5 days)
- totally 12 times a year (= 60 days)

After the year 2009, it is proposed to continue the removal work by a harvest campaign operated by citizen's voluntary participation, even if *Lemna* will be significantly reduced. Such campaign will enhance the citizen's awareness and understanding of the environmental administration. The frequency is as follows:

- three times a year (1 time = 2 days)
- totally 6 days

**c. Required number of the staff**

Required number is shown in *Table VII.2.2.*

| | | | |
|---|---|---|---|
| - Permanent staff: | 36 man-months/year | (2000~2008) |
| | 3 man-months/year | (2009~2025) |
| - Temporary staff: | 120 man-days/year | (2000~2008) |
| | 30 man-days/year | (2009~2025) |

**d. Removal volume**

The harvesting capacity of the equipment is around 30~40 t/day, which amounts to 1,800~2,400 m$^3$/year. This amount is twice as much as the quantity of 900 tons (=1,500 m$^3$) which was removed by the short-term campaign in October and November 1998. It is said that about 5,000 tons of *Lemna* spreads over the surface of Puno Interior Bay in the last few years. Then 40~50% of spreading *Lemna* can be removed by this way if reproduction process is not considered. It would not be impossible to remove all *Lemna* if the harvesting quantity is expanded. However, a rapid decrease of *Lemna* may result in a rapid increase of phytoplankton which causes algal bloom. Therefore it is proposed to remove *Lemna* moderately and carefully.

**e. Disposal of removed *Lemna***

It is expected that the *Lemna* can be utilized as a compost for agriculture. According to the study of Research Center and Farmer Production of UNA of Puno, nine (9) tons of *Lemna* can be spread over a hectare of potato field.

#### f. Required equipment

| | | |
|---|---|---|
| - Low-draft aquaphyte harvester : | 1 unit | (2000~2008) |
| | 0 unit | (2009~2025) |
| - Boat for support: | 24 boats/year | (2000~2008) |
| (for removal and support) | 36 boats/year | (2009~2025) |
| - Truck for disposal of *Lemna* : | 48 vehicles/year | (2000~2008) |
| | 6 boats/year | (2009~2025) |

### 3) Cost

The costs necessary for operation and maintenance are estimated as shown in *Table VII.2.3*.

Procurement of harvester : S/.378,000 Soles

Personnel expenses : S/.225,000 Soles

Rental fee (boat, vehicle, etc.) : S/.188,600 Soles

Administration cost (1% of personnel expenses) :S/.2,300 Soles

Total : S/.793,800 Soles (not including IGV)

### 4) Implementation

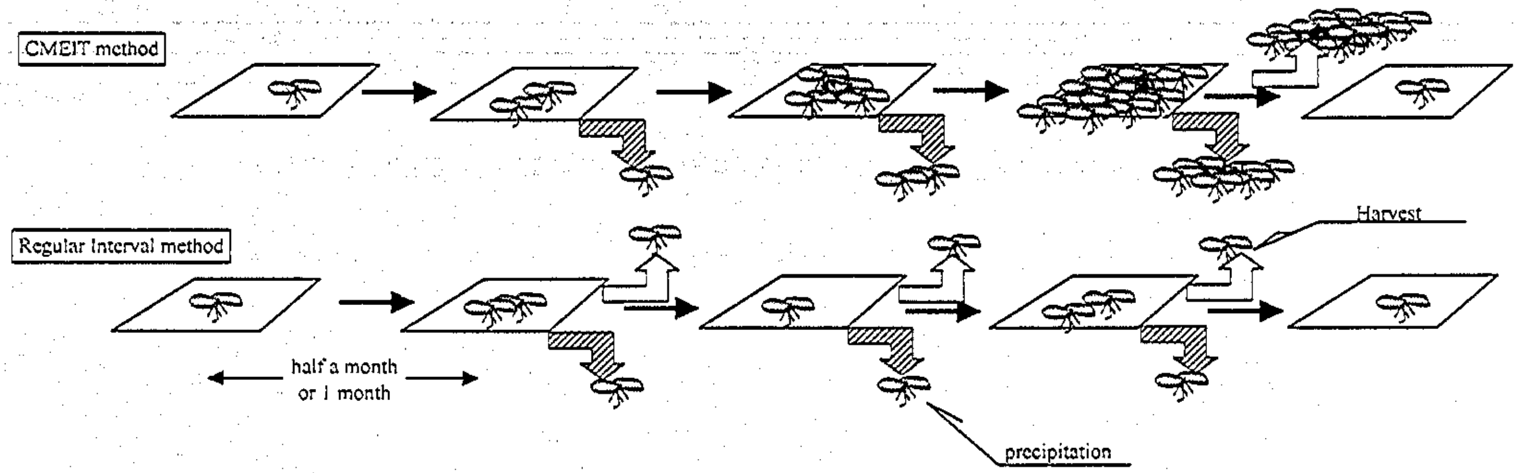
It is expected that the spread of *Lemna* will be significantly reduced by the year 2008 through the improvement of sewerage systems in Puno City. Therefore the regular removal of *Lemna* should be carried out from 2000 until 2008.

However *Lemna* may not die out nor completely disappear from Puno Interior Bay. It may be needed to occasionally remove *Lemna* even after 2008. In that case, the removal should be carried out by a harvest campaign.

# Table VII.2.1 Comparison of Removal/Harvest Manners

| Items | | CMEITmethod | Regular Interval method |
|---|---|---|---|
| Type of method | | Intensive programme | Regular and short interval programme |
| Organization | | Multi-sectors | Single competent organization |
| Budget | | Own expenses and voluntary contribution from public and private sectors | Own budget |
| Scale | | Large scale ( In the previous program in 1998, the participants were approximately 500 persons.) | small scale ( less than 30 persons ) |
| Frequency | | 1 to 3 times a year | 1 to 2 times a month |
| Removal volume | | Large volume<br>approximately 1,550 m3 by an occasional removal as the previous practice in 1998 | small volume<br>approximately 5 m3 for a time of removal/harvest |
| Efficiency | Removal of Nutrients | **CMEITmethod** >> Regular Interval method<br>The volume of removed Lemna by the CMEITmethod is larger than that by the Regular Interval method. | |
| | Accumulation of Organic Sediment | CMEITmethod >> **Regular Interval method**<br>The interval of the removal by the CMEITmethod is longer than that by the Regular Interval method, while the reproduction cycle of Lemna is rather short (about a month). | |
| | Improvement of Scenic View | CMEITmethod << **Regular Interval method** | |
| | Effects of Campaign on the Citizens | **CMEITmethod** << Regular Interval method | |

Note : CMEIT method is the same as previous program by "the Multisectorial Committee for the Environmental Improvement of Puno Interior Bay of Lake Titicaca".



## Table VII.2.2 Required Number of Staff for Removal of *Lemna*

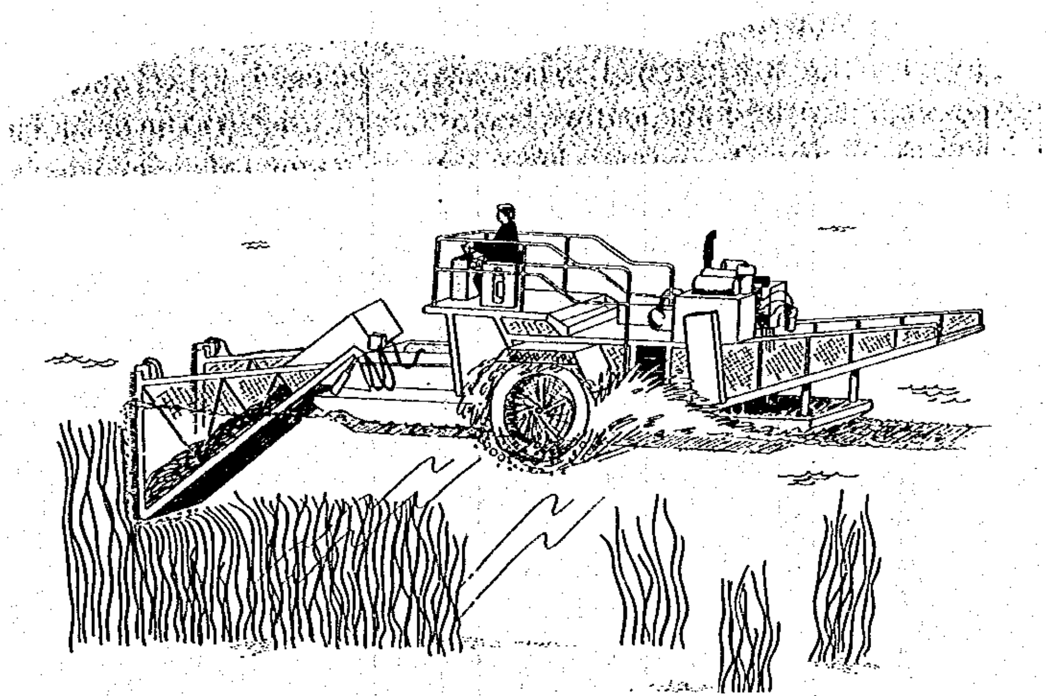
< Removal of Lemna >

unit : man-month

| Permanent Staff | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | ~ | 2015 | ~ | 2025 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project term | ←→ | | | | | | | | | ←→ | | | | | |
| Chief | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Technician (Operator) | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | - | - | - | - | - | 108 |
| Labor | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 3 | 3 | 3 | 3 | 3 | 267 |
| Total | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 3 | 3 | 3 | 3 | 3 | 324 |

unit : man-day

| Temporary Staff | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | ~ | 2015 | ~ | 2025 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labor | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 30 | 30 | 30 | 30 | 30 | 1590 |



**Low-draft Aquaphyte Harvester**

Source: Cooke, G.D., Welch, E.B., Peterson, S.A., and Newroth, P.R. 1993. Restoration and Management of Lakes and Reservoirs. 2[nd] ed. ISBN 0-87371-397-4. Lewis Publisheds, U.S. pp548

## Table VII.2.3 Cost Estimation for Removal of *Lemna*

**Operation and Maintenance**

unit : Soles

| Items | | Quantity | Foreign currency | Local currency | Foreign C. | Local C. | Total |
|---|---|---|---|---|---|---|---|
| Personnel expenses | Chief | 0 man-months | - | 1,200 soles/man-month. | 0 | 0 | 0 |
| | Technician | 108 man-months | - | 800 soles/man-month. | 0 | 86,400 | 86,400 |
| | Labor ( Permanent) | 267 man-months | - | 400 soles/man-month. | 0 | 106,800 | 106,800 |
| | Labor (Temporary) | 1590 man-days | - | 20 soles/man-day. | 0 | 31,800 | 31,800 |
| Sub-total | | | | | 0 | 225,000 | 225,000 |
| Boat with engine | | 102 boat-days | - | 100 soles/boat-day | 0 | 10,200 | 10,200 |
| Boat without engine | | 726 boat-days | - | 25 soles/boat-day | | 18,150 | 18,150 |
| Transportation | | 534 vehicles-days | - | 300 soles/vehicle-day | 0 | 160,200 | 160,200 |
| Others (personnel expenses x 1 %) | | 1 set | - | | 0 | 2,250 | 2,250 |
| Sub-total | | | | | 0 | 190,800 | 190,800 |
| Total | | | | | 0 | 415,800 | 415,800 |

## (2) Removal or Cover of Bottom Sediment

### 1) Target and Strategy

Dredging is a popular method to remove nutrient-rich bottom sediment, and sediment cover is also popular to prevent nutrients from releasing or re-suspending from the bottom.

When properly conducted, sediment removal or cover is an effective lake management technique. In general, shallow eutrophic lakes frequently are susceptible to periodic nutrient gains from the sediment. In some lakes, phosphorous loading from sediment is about 30 to 50 % of the total loading. The sediment loading portion of the total loading increases following the reduction of the external loading portion. Sometimes nutrients loaded from the sediment are sufficient to cause eutrophic events such as an outbreak of *Lemna* or a large algal blooms, which slows down the expected rate of lake water quality improvement. In such case, the sediment removal or cover should be implemented to reduce the rate of internal nutrient loading.

The survey results of this Study suggest high organic matter content of the bottom sediment which was taken from the surface layer close to the western shore. Therefore the sediment removal or cover should be focused on the bottom surface along the western shore.

The method shall be selected with special care not to disturb the sediment or resuspend pollution loads from the bottom. Especially the dredging work needs special equipment and skilled operators.

### 2) Possible Techniques

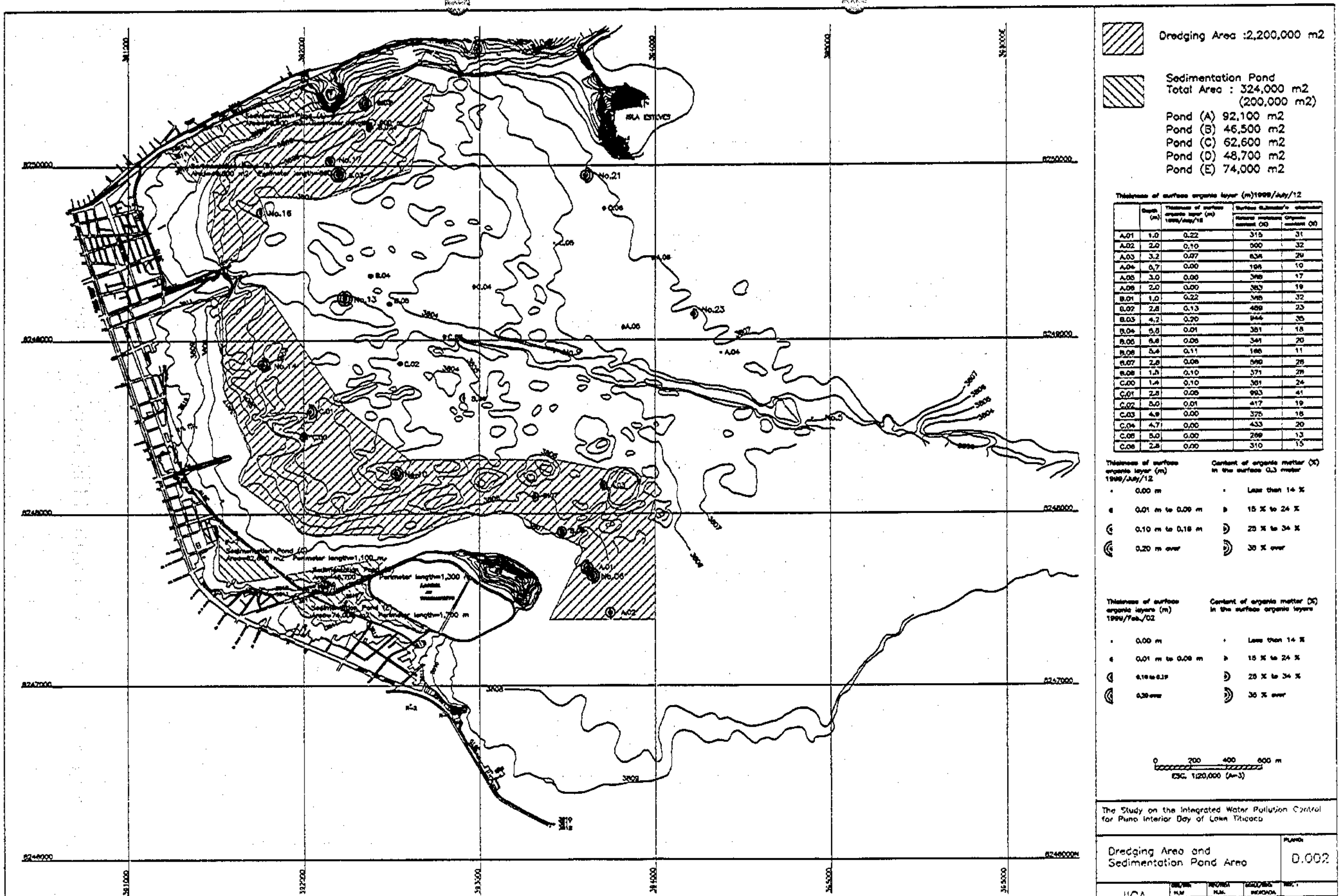
Dredging or cover shall be focused on the area where the surface sediment has an organic content (IL) of 20 % or more. The target area corresponds to the area where the water depth is smaller than 3.5 m and the equipment can be operated.

Planning conditions for possible techniques are as follows;

### a. Dredging

Dredging work requires a temporary disposal site for the dredged sediment, which significantly effects the project cost. Suitable area for the disposal site should be the inundation area along the shore. According to the PELT's ecotourism development plan, the site has been proposed at the area where no structures will be built in the future.

The areas for the sediment dredging and the temporary disposal sites (sedimentation ponds) are shown in *Figure VII.2.1.* The conceptual figures of the dredging work and the temporary disposal sites (sedimentation ponds) are shown in *Figure VII.2.2* and *Figure VII.2.3.*




Thickness of surface organic layer (m)1999/July/12

| | Depth (m) | Thickness of surface organic layer (m) 1999/July/12 | Surface Sediment's character: Natural moisture content (%) | Organic content (%) |
|---|---|---|---|---|
| A.01 | 1.0 | 0.22 | 315 | 31 |
| A.02 | 2.0 | 0.10 | 600 | 32 |
| A.03 | 3.2 | 0.07 | 634 | 29 |
| A.04 | 0.7 | 0.00 | 196 | 10 |
| A.05 | 3.0 | 0.00 | 398 | 17 |
| A.06 | 2.0 | 0.00 | 383 | 19 |
| B.01 | 1.0 | 0.22 | 398 | 32 |
| B.02 | 2.8 | 0.13 | 489 | 23 |
| B.03 | 4.2 | 0.20 | 944 | 35 |
| B.04 | 5.8 | 0.01 | 381 | 18 |
| B.05 | 6.6 | 0.06 | 341 | 20 |
| B.06 | 5.4 | 0.11 | 166 | 11 |
| B.07 | 2.8 | 0.06 | 590 | 28 |
| B.08 | 1.5 | 0.10 | 371 | 29 |
| C.00 | 1.4 | 0.10 | 381 | 24 |
| C.01 | 2.8 | 0.05 | 993 | 41 |
| C.02 | 5.0 | 0.01 | 417 | 19 |
| C.03 | 4.9 | 0.00 | 375 | 18 |
| C.04 | 4.7 | 0.00 | 433 | 20 |
| C.05 | 5.0 | 0.00 | 269 | 13 |
| C.06 | 2.8 | 0.00 | 310 | 15 |

**Figure VII.2.1 Proposed Areas for Sediment Dredging and Temporary Disposal Sites**

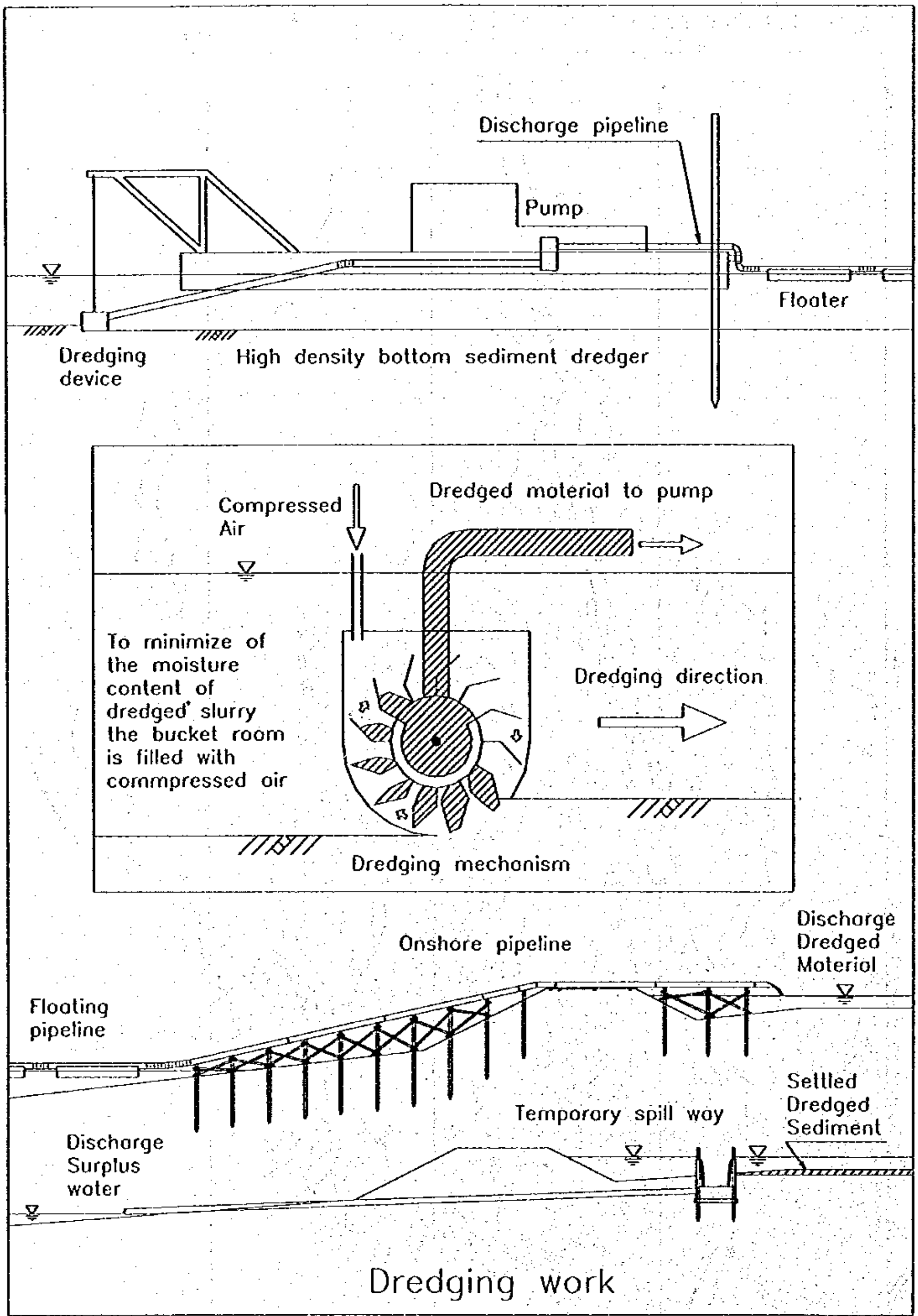



**Figure VII.2.2 Conceptual Figure of Dredging Work**

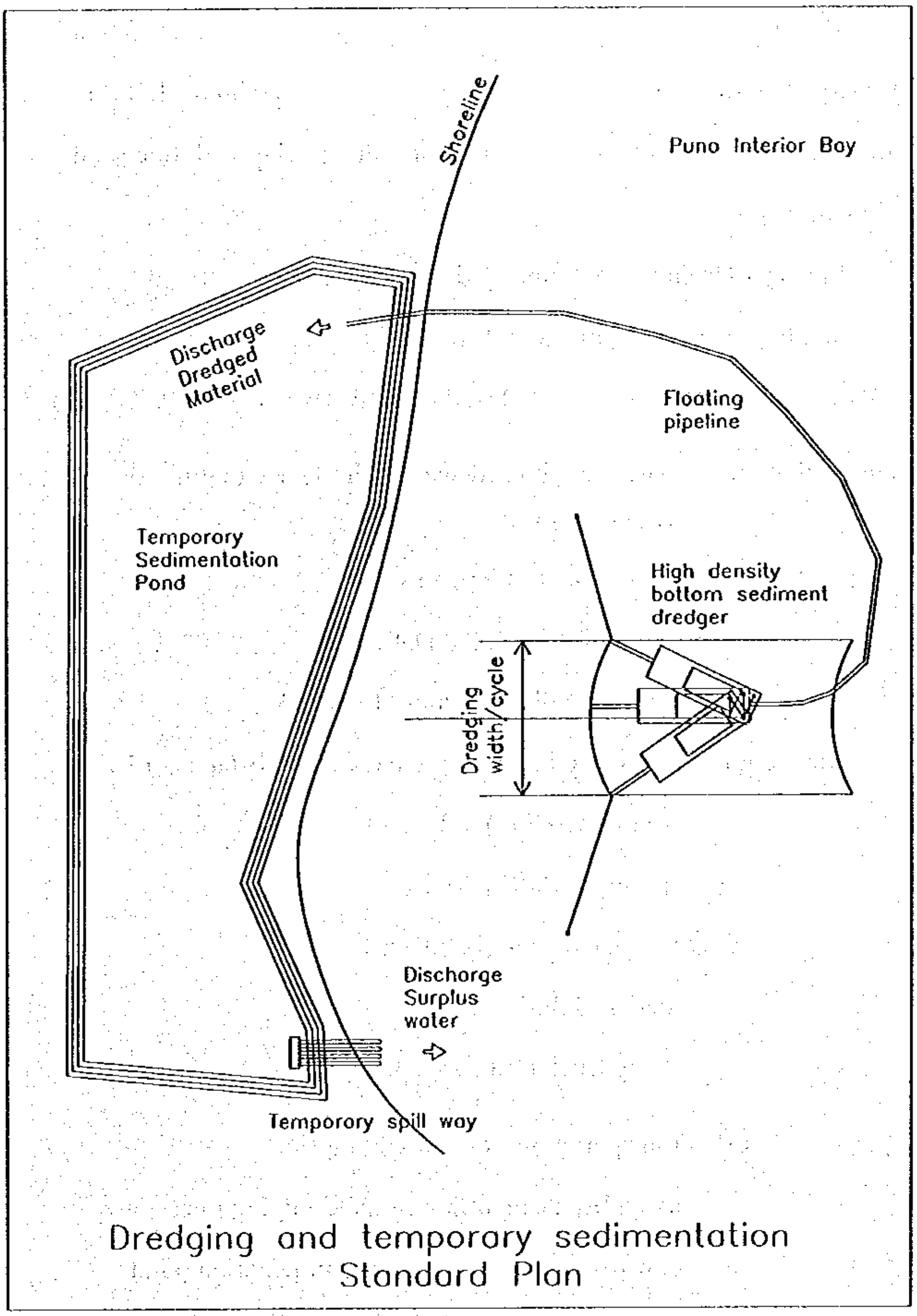



**Figure VII.2.3 Conceptual Figure of Temporary Disposal Site**

Dredging Area : 2,200,000 $m^2$ (see *Figure VII.2.1*)

Dredging thickness : 0.30 m

Dredging volume : 660,000 $m^3$

Water depth: 1.3 ~ 3.5 m

Discharge length: maximum 1,500 m

Nature of the sediment : organic silt and clay with fine sand

Sediment disposal:

Primary : Drying up at tempory disposal area

Finally : Disposition to agricultural land or forestry land

Temporary disposal area : 324,000 $m^2$ (effective area : 200,000 $m^2$ )

Main Equipment : portable high-density dredger (Turn bucket type 100$m^3$/hr.) x 1

anchor boat (3t 60PS) x 1

transport boat (FRP D50PS) x1

discharge pipe (300mm, L=5.5m) x 300

* fleet equipment : carry-in and carry-back from/to Japan or Europe

backhoe (0.7$m^3$) x 2

generator (50KVA) x 1

marsh backhoe (0.4$m^3$) x 1

loader (3.3$m^3$) x 1

dump truck (10$m^3$) x 10

Appurtenant work : transportation of the dredging fleet

assembly/dismantling of the dredging fleet

construction of temporary sedimentation pond

construction of temporary spill way

construction of discharge pipeline

construction of temporary jetty

Contractor : Foreign contractor

Construction Period : 2009 ~ 2014

**b. Sediment Cover**

According to the field reconnaissance, three alternatives were studied. Major differences among them are what material is used for covering the sediment and where the material is obtained. Possible covering materials are as follows:

| | |
|---|---|
| Cutimbo River Sand : | The sand of Cutimbo river which is distributed near the Cutimbo bridge about 21 km from Puno City. Exploitable volume is limited and it is required to use the sand sieved from gravel-mixture material. |
| Charcas Beach Sand : | Charcas beach sand which is fine and unnecessary to be sieved. It can be taken from the barge by the sand pump and transported by the hopper barge. |
| Puno Interior Bay Sand : | Silty sand which is distributed along the navigation channel. |

*Case 1 (Cutimbo River Sand)*

The covering work consists of four processes; excavation of the sand, onshore transportation, offshore transportation and sprinkling the sand. The maximum total length of offshore transportation by floating pipeline is restricted by the total loss of water head due to the friction in the pipeline. Consequently 500 m is the economically maximum discharge length.

The areas for the sediment cover is shown in *Figure VII.2.4*. The conceptual figures of the covering work is shown in *Figure VII.2.5*.

| | |
|---|---|
| Sediment Covering Area : | 2,100,000 $m^2$ (see *Figure VII.2.4*) |
| Covering thickness : | 0.30 m |
| Covering volume : | 630,000 $m^3$ |

Main Equipment :

[excavation] loader (3.3m³) x 2, sorting machine (1/2 inch mesh screen) x 1

[onshore transportation] dump truck (15m³) x 10

[offshore transportation] hopper (100m³) x 1, generator (300KVA) x 1, sand pump (180KW) x 1, water pump (22KW) x 1, stirrer machine (22KW) x 1, discharge pipe (200mm, steel) x 200, flexible pipe (200mm, rubber sleeve) x 200

[sprinkling] barge (Unifloat UF-1A) x 7, barge (Unifloat UF-1AS) x 2, spad (350mm, L=10m) x 2, winch (15KW 1.8t) x 2, generator (50KVA) x 1, sprinkling pipe

* after completion of the work, the fleet has no remaining value and scrap.

Appurtenant Work: temporary jetty

Contractor : Peruvian contractor

Construction Period : 2009 ~ 2020

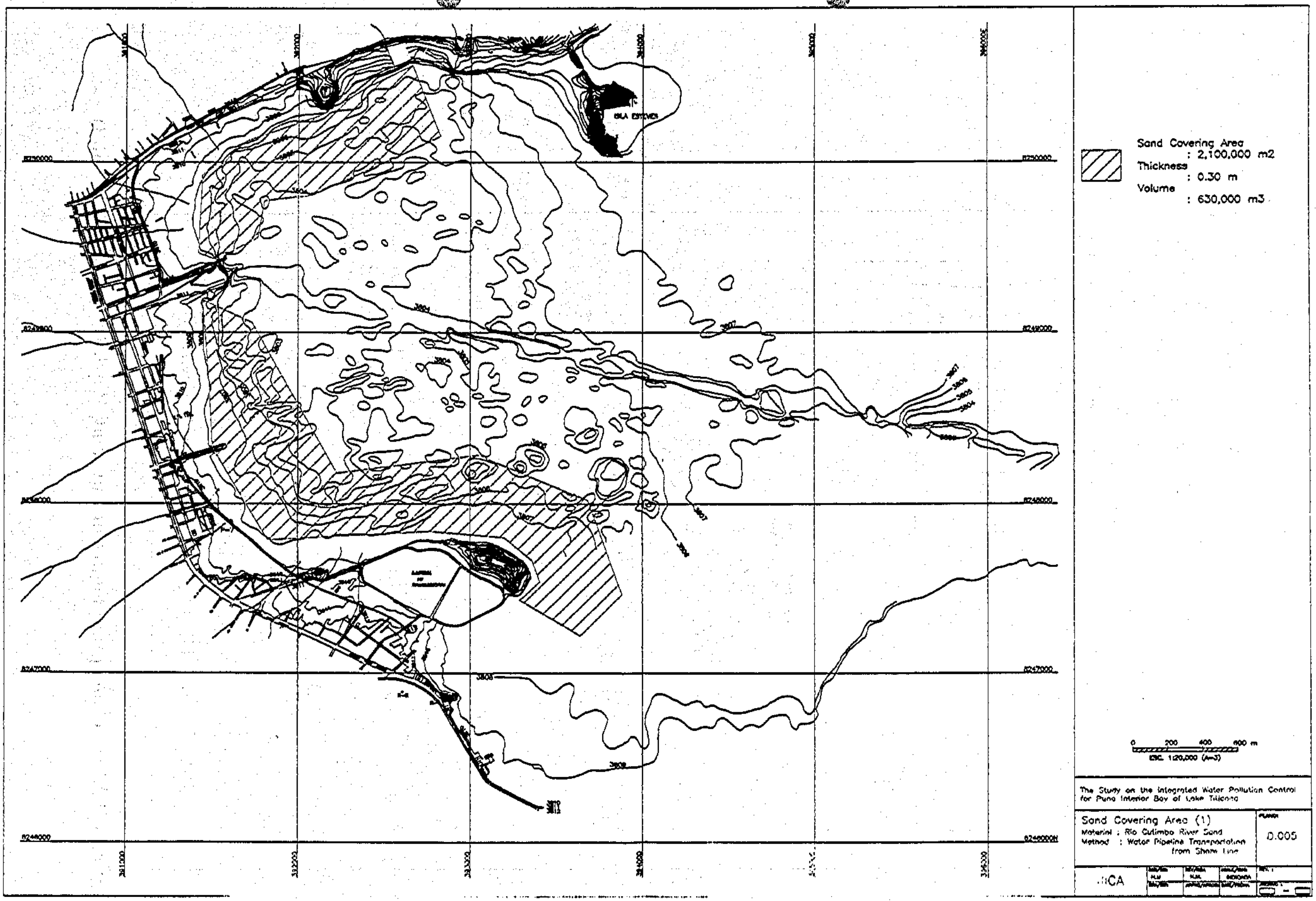



Figure VII.2.4 Proposed Areas for Sediment Cover (Cutimbo River Sand)

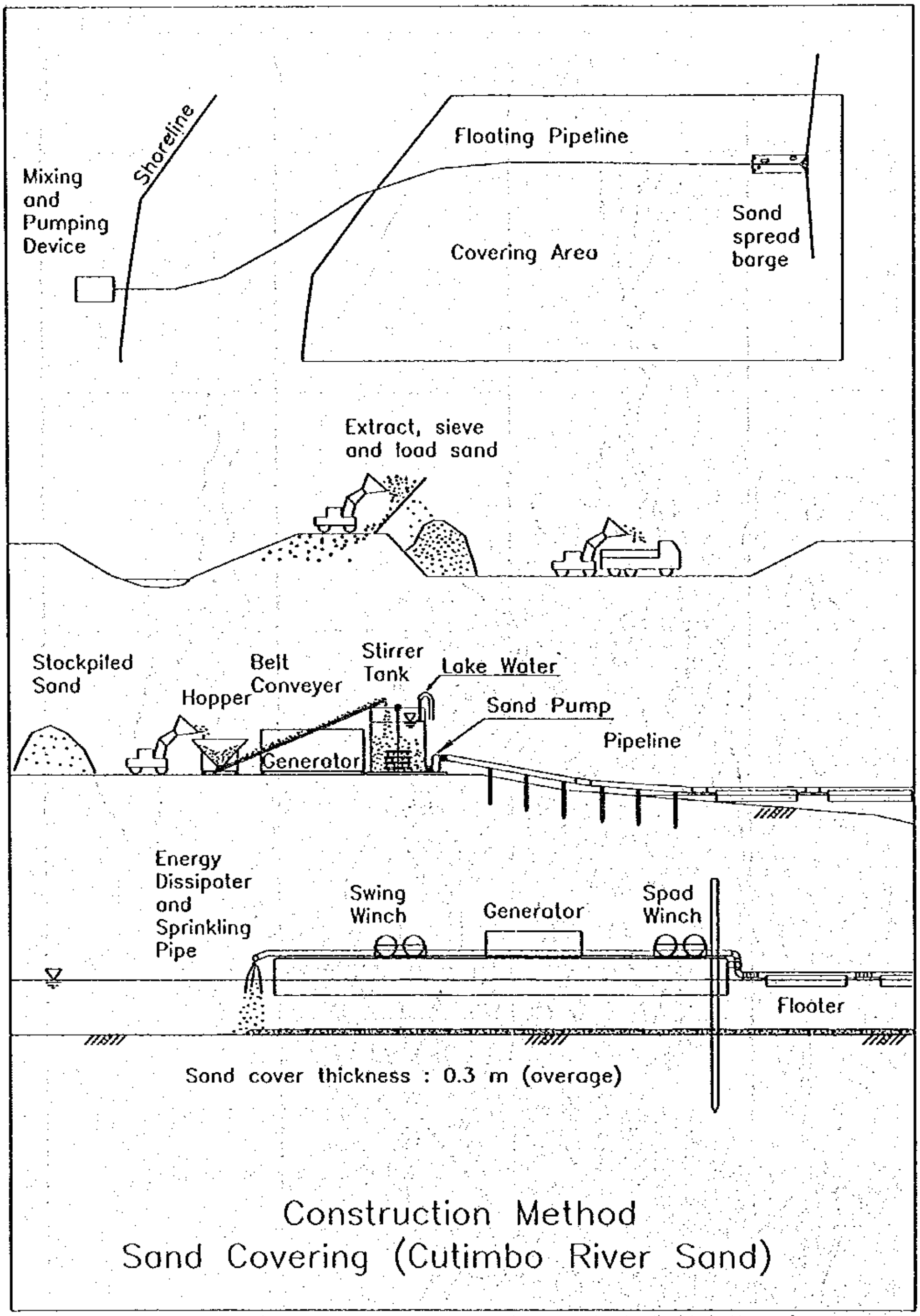



**Figure VII.2.5 Conceptual Figure of Covering Work (Cutimbo River Sand)**

*Case 2 (Charcas Beach Sand)*

The covering work consists of three processes; excavation and loading of the beach sand, offshore transportation and sprinkling the sand.

The areas for the sediment cover is shown in *Figure VII.2.6*. The conceptual figures of the covering work is shown in *Figure VII.2.7*.

Sediment Covering Area : 2,400,000 $m^2$ (see *Figure VII.2.6*)

Covering thickness : 0.30 m

Covering volume : 720,000 $m^3$

Main Equipment :

[excavation and loading] barge (Unifloat UF-1A) x 7, barge (Unifloat UF-1AS) x 2, spad (350mm, L=10m) x 2, winch (15KW 1.8t) x 3, generator (150KVA) x 1, sand pump (75KW) x 1

[offshore transportation] barge (Unifloat UF-1A) x 36, tug boat (200PS) x 1

[sprinking the sand] barge (Unifloat UF-1A) x 7, barge (Unifloat UF-1AS) x 2, spad (350mm, L=10m) x 2, winch (15KW 1.8t) x 3, generator (150KVA) x 1, sand pump (22KW) x 1, water pump (22KW) x 1, anchor boat (1t 50PS) x 1, sprinkling pipe

* after completion of the work, the fleet has no remaining value and scrap

Appurtenant Work: temporary jetty

Contractor : Peruvian contractor

Construction Period : 2009 ~ 2021

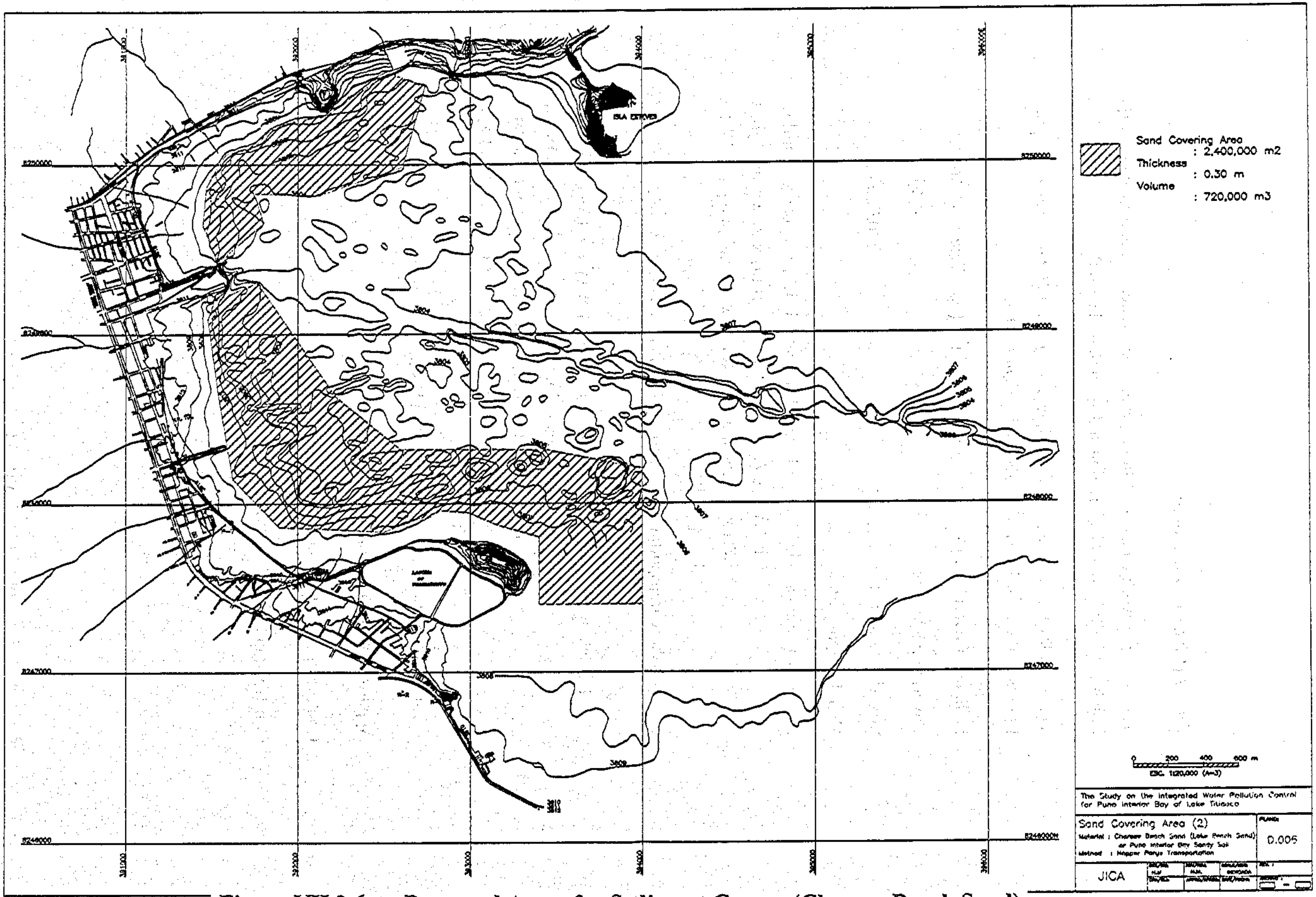



Figure VII.2.6 Proposed Areas for Sediment Cover (Charcas Beach Sand)

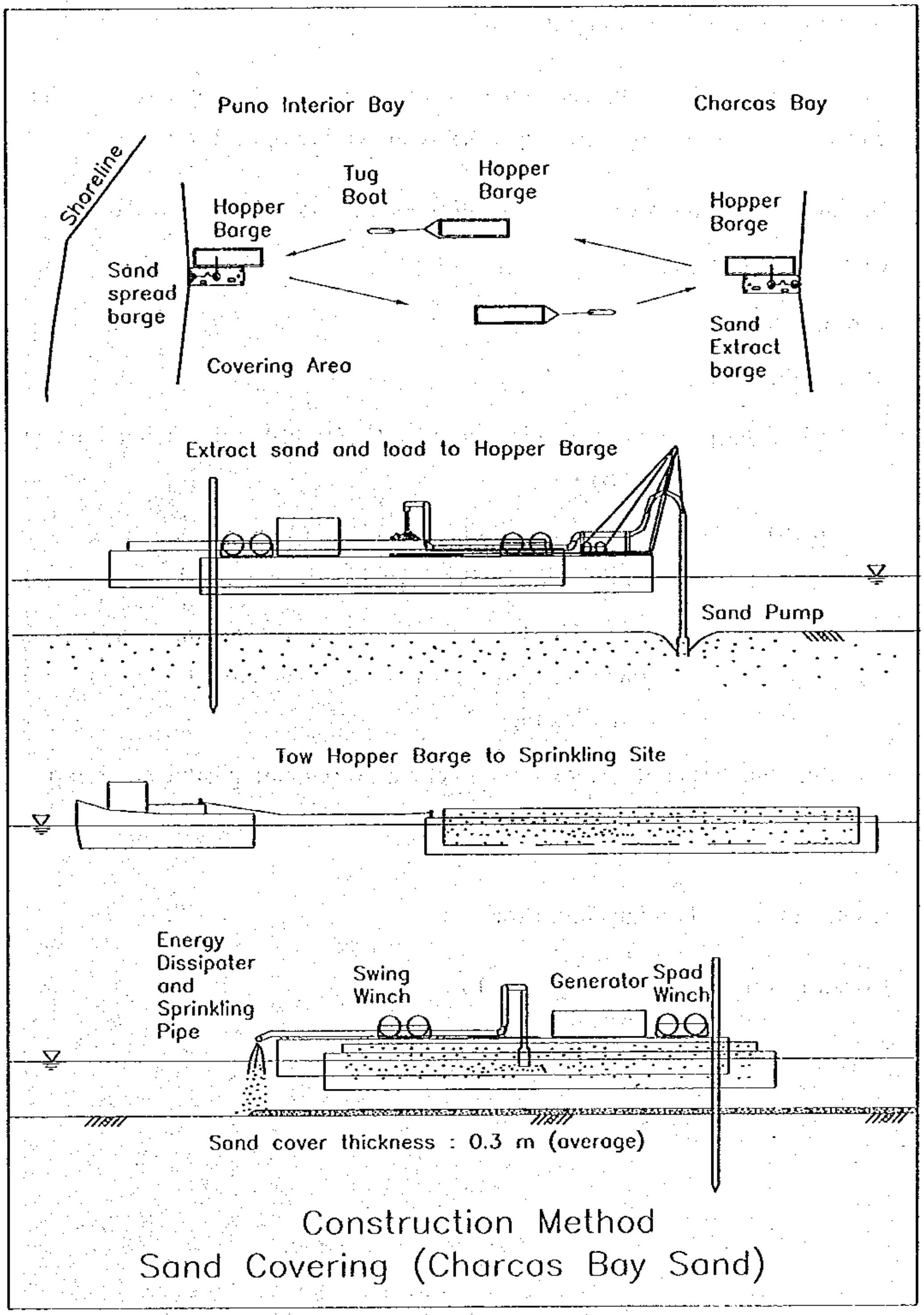



**Figure VII.2.7 Conceptual Figure of Covering Work (Charcas Beach Sand)**

*Case 3 (Puno Interior Bay Sand)*

The covering work consists of three processes; dredging and offshore transportation and sprinkling the sand.

The areas for the sediment cover is the same as that of case 2. The conceptual figures of the covering work is shown in *Figure VII.2.8*.

Sediment Covering Area : 2,400,000 $m^2$ (see *Figure VII.2.6*)

Covering thickness : 0.30 m

Covering volume : 720,000 $m^3$

Main Equipment :

[dredging] portable pump dredger (D-600PS) x 1, anchor boat (1t 50PS) x 1

[offshore transportation] discharge pipe (300mm, steel) x 200, flexible pipe (300mm, rubber sleeve) x 200

[sprinking] barge (Unifloat UF-1A) x 4, spad (350mm, L=10m) x 2, winch (15KW 1.8t) x 2, generator (50KVA) x 1, sprinkling pipe

* after completion of the work, the fleet has no remaining value and scrap

Appurtenant Work: temporary jetty

Contractor : Foreign contractor

Construction Period : 2009 ~ 2014

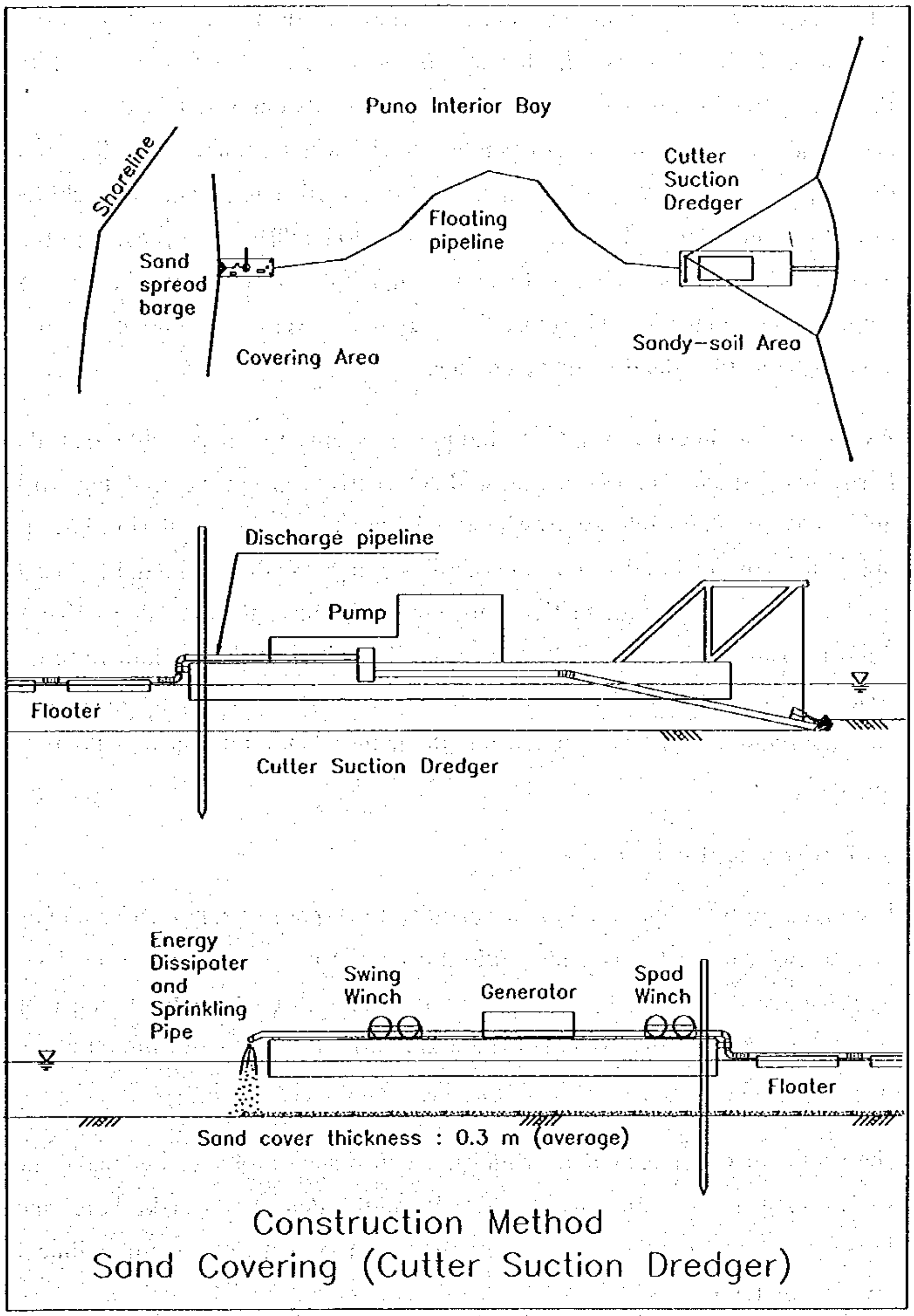



**Figure VII.2.8 Conceptual Figure of Covering Work (Puno Interior Bay Sand)**

### 3) Evaluation of Alternative Plans

#### a. Technical aspect

Thin-layer dredging requires higher technique than the sand covering technique does. Because the former should be carried out more carefully than the latter, in order to keep the pollution loads deposited in the bottom sediment from returning or resuspending to the water column. Such special dredging technique require a specially designed equipment and skilled operators and labors. Unfortunately, it seems to be difficult at present to find a contractor who has a capacity and equipment for this work in Peru or neighboring countries. Therefore the sediment covering technique is rather advantageous than the dredging technique.

As for the sediment covering technique, it seems to be possible that the Peruvian contractors carry out almost all alternatives except the dredging work in the case of Puno Interior Bay sand. If so, it must be a criterion how to obtain the sand material. Two alternatives which use the river sand or beach sand, have to transport the materials for longer distances than the alternative of Puno Interior Bay sand do. It may cause difficulties of the work or raise the cost. The alternative of Puno Interior Bay sand is advantageous because it does not require the process of carrying the materials for a distance by boats or trucks.

#### b. Environmental aspect

The dredging technique requires the facility to dispose of removed sediment. The facility can settle suspendid solid but cannot remove dissolved nutrients significantly unless a coagulant addition process is contained. It must be difficult to contain the coagulant addition process due to the limitation of project cost.

The sediment cover technique would not cause such problem, but make the water depth in the area shallower. It might deform the lakeshore and deteriorate the scenic view to excavate the beach sand at Charcas for sediment covering material.

#### c. Financial aspect

Direct costs (direct construction cost + equipment cost ; not including IGV) for alternatives are estimated as follows:

- Dredging : S/.120,436 thousand Soles
- Sediment Cover (Cutimbo River Sand) : S/.23,800 thousand Soles
- Sediment Cover (Charcas Beach Sand) : S/.29,338 thousand Soles
- Sediment Cover (Puno Interior Bay Sand) : S/.19,670 thousand Soles

As a result, the sediment cover by Puno Interior Bay sand is the most advantageous from the financial viewpoint.

#### d. Overall evaluation

Based on the above evaluations, the cost of the dredging method is rather high and not recommendable. The sediment covering method is applicable to the work in Puno Interior Bay from the technical viewpoint. Among three alternatives, the method which material is taken from the bottom sediment in f Puno Interior Bay should be proposed from the environmental and financial viewpoints.

### 4) Cost

Project cost for the proposed plan, namely the sediment cover by Puno Interior Bay sand, are estimated as follows:

| | |
|---|---|
| a. Direct construction cost : | S/.13,952 thousand Soles |
| b. Engineering cost [ = a. x 10% ] : | S/.1,395 thousand Soles |
| c. Contingency cost [ = (a.+b.+d.) x 10% ] : | S/.2,106 thousand Soles |
| d. Equipment cost : | S/.5,717 thousand Soles |
| e. Administration cost [ = a. x 1% ] : | S/.140 thousand Soles |
| Total | S/.23,311 thousand Soles (not including IGV) |

### 5) Implementation

In-lake treatment should be implemented when the measures against the external loading do not produce the expected effect. Therefore, the sediment covering work should be implemented from the year 2009 after completing the first phase of sewerage project. In the first year 2009, some preparation work such as survey, detailed design, or procedure for licence will be necessary. Main work should be implemented from 2010 to 2014. The implementation schedule is shown in *Figure VII.2.9.*

The sediment covering work shall be started from the north side of the target area. Because the lake water quality is expected to be improved from the north side following the spread of sewer network systems.

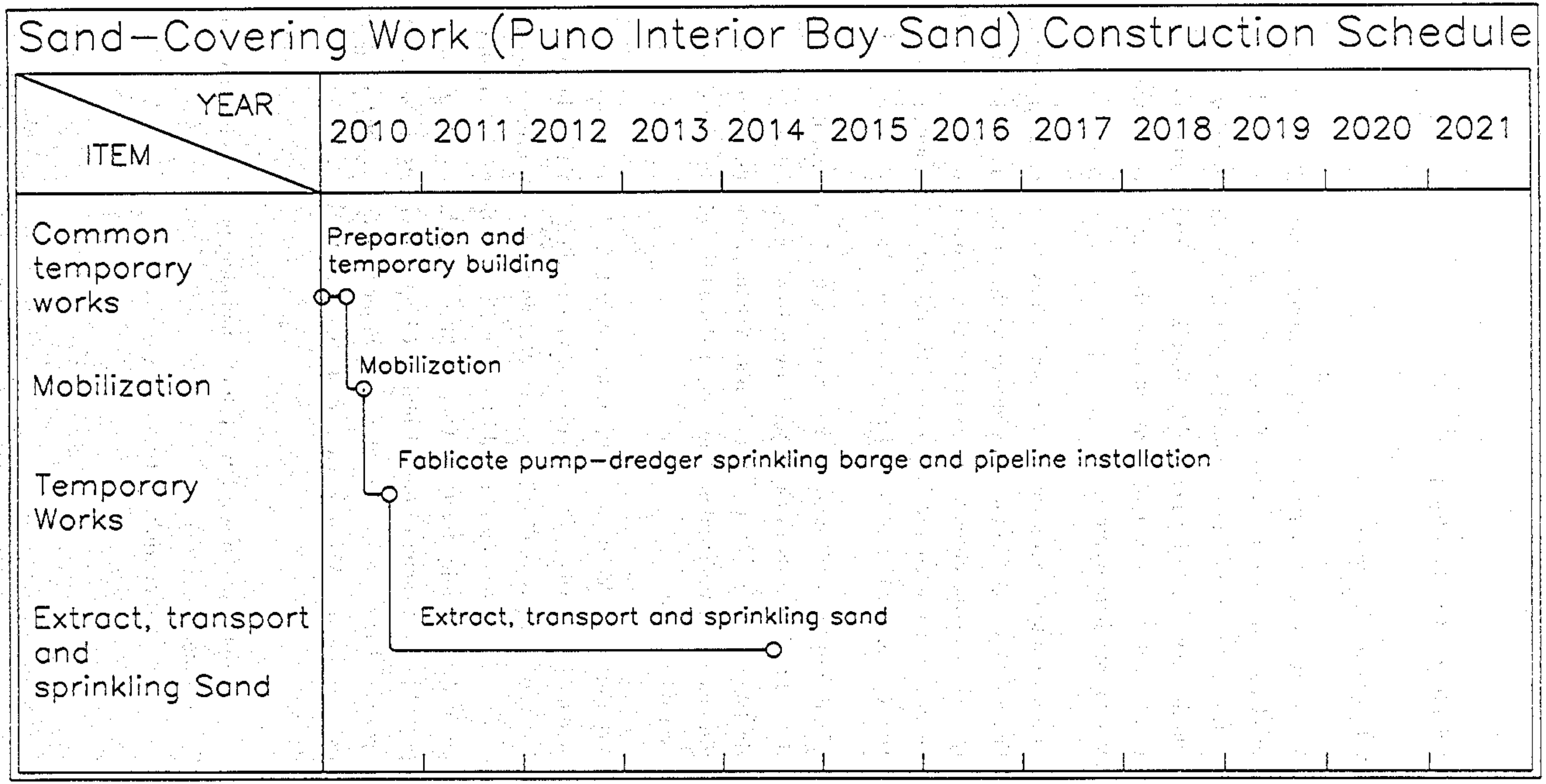



**Figure VII.2.9 Implementation Schedule of Sediment Covering Work**

### (3) Replanting of Reed (Totora)

#### 1) Target and Strategy

"Totora" is a species or reed, a group of emergent macrophyte, which not only characterizes the scenic view of Lake Titicaca but also provides ecological benefits to the biological communities that live in the shore or littoral area. From the view point of water quality control, it is also important to consider the role of "Totora" as a biological filter/absorber and its contribution to the environmental improvement.

Tourists seem to expect a view of "Totora" belt as the suitable scenes of the Lake Titicaca. However, "Totora" is scarce along the western shore of Puno Interior Bay. The extreme climatic events that cyclically occurred, such as floods and droughts, are considered to have caused the decline of "Totora". The situation have been worsened by the intensive use of "Totora" as forage for livestock.

Replanting of "Totora" along the western shore has been planned and studied by PELT. PELT intends to carry out it by citizen's participation. The citizen's participation will enhance the citizen's awareness and understanding of the environmental administration, however, it should be voluntary or should not be expected too much.

In principle, in order to protect the wild Totora belt, the replanting of "Totora" should not be carried out by the manner that the seedling is obtained by separating the roots of wild "Totora". The manner does not necessarily bring a high rooting rate or sometimes damages the wild Totora bush unless the root is carefully cut or a cut end is carefully treated. On the other hand, high rooting rate can be expected by the manner of transplanting seedling. Therefore the latter maner is proposed. The manner needs the process to multiply the seedling at the growth beds is required. Major processes of the rehabilitation of "Totora" are as follows:

- Multiplication of seedling "Totora" (including processes for gathering and germinating seeds)
- Planting of multiplied "Totora"

According to the field reconnaissance, it was observed that duckweeds (*Lemna*) were trapped by the existing "Totora" belt when the eastward wind was dominantly blowing. A V-shaped "Totora" belt may be useful to prevent the *Lemna* from spreading over the lake (see *Figure VII.2.10*).

### 2) Proposed plan

Rehabilitation of Totora belt consists of two phases; the multiplication of seedling "Totora" and the planting.

#### a. Planning area

The planning area for the planting of seedling "Totora" is along the western shore of Puno Interior Bay as shown in *Figure VII.2.10.* The area is placed counterclockwise from the shore in front of UNA to Espinar Island taking the future waterfront development plan into account.

#### b. Multiplication of seedling "Totora"

- Period of multiplication : 7 years
- Required area for growth beds : 720 $m^2$ ( 3 lines x 240$m^2$/year )
- Required site area: 1,890 $m^2$ (refer to *Figure VII.2.11*)

#### c. Planting of the seedling "Totora"

- Period of planting : 7 years
- Unit belt : length = 200 m<br>width = 40 m
- Number of unit : 18 units
- Total of planting area : 14.4 ha (refer to *Figure VII.2.10*)

#### d. Required number of staff

Required number of the staff is shown in *Table VII.2.4.*

- Permanent staff : 24 man-months/year
- Temporary staff : 30~90 man-days/year

#### e. Required equipment

Special equipment is not required.

### 3) Cost

The costs necessary for operation and maintenance are estimated as in *Table VII.2.5.* No investment for construction or equipment is required.

| | |
|---|---|
| Personnel expenses : | S/.142,200 Soles |
| Rental fee (boat, vehicle, etc.) : | S/.14,700 Soles |
| Administration cost (1%) : | S/.1,400 Soles |
| Total : | S/.158,300 Soles (not including IGV) |

### 4) Implementation

Implementation Period : the year 2000 ~ 2008

For the first year, some preparation work will be necessary. Seedling will be multiplied at the growth beds, and after that, the seedling will be planted.

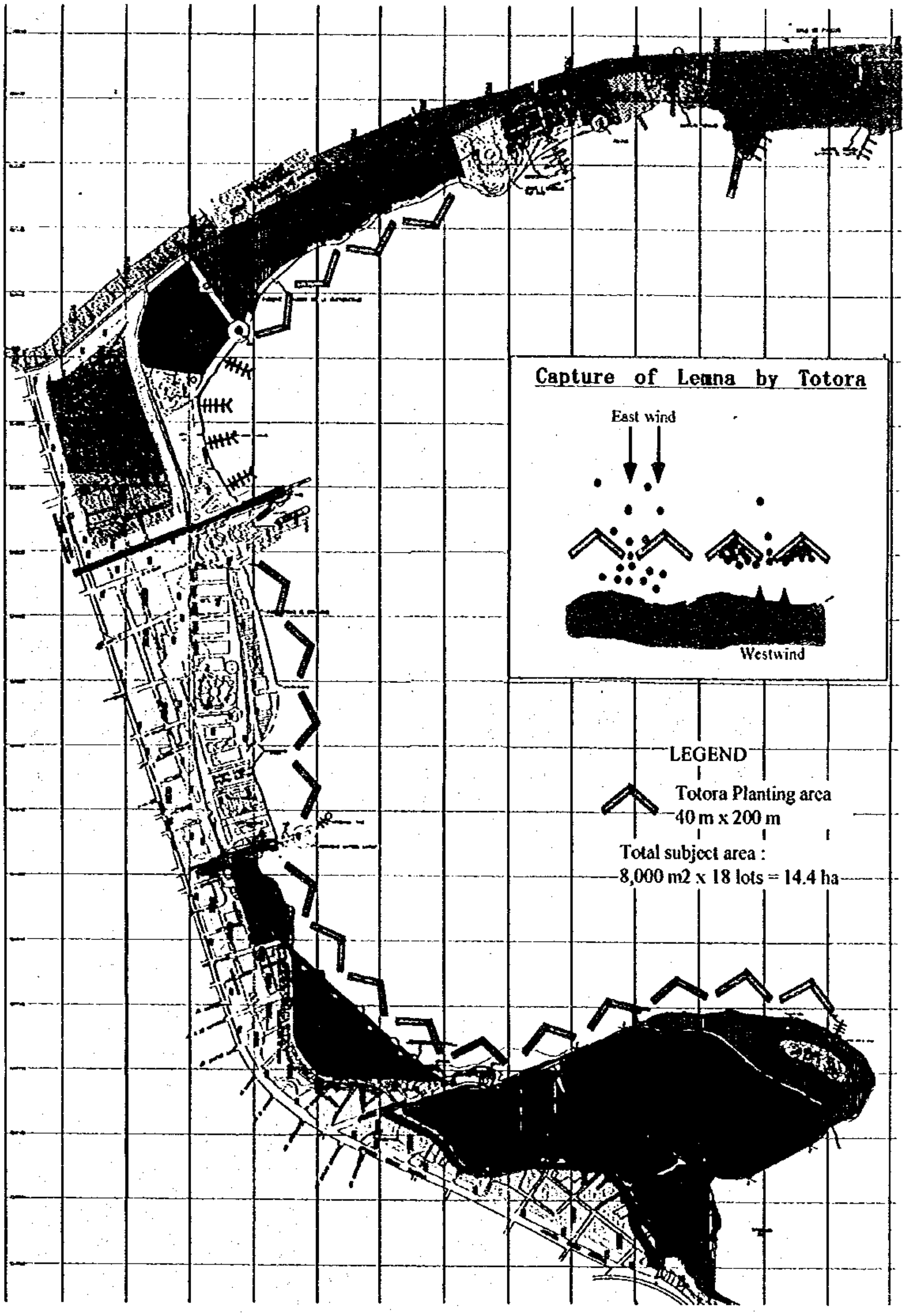



Figure VII.2.10 Planning Area for Replanting of "Totora"

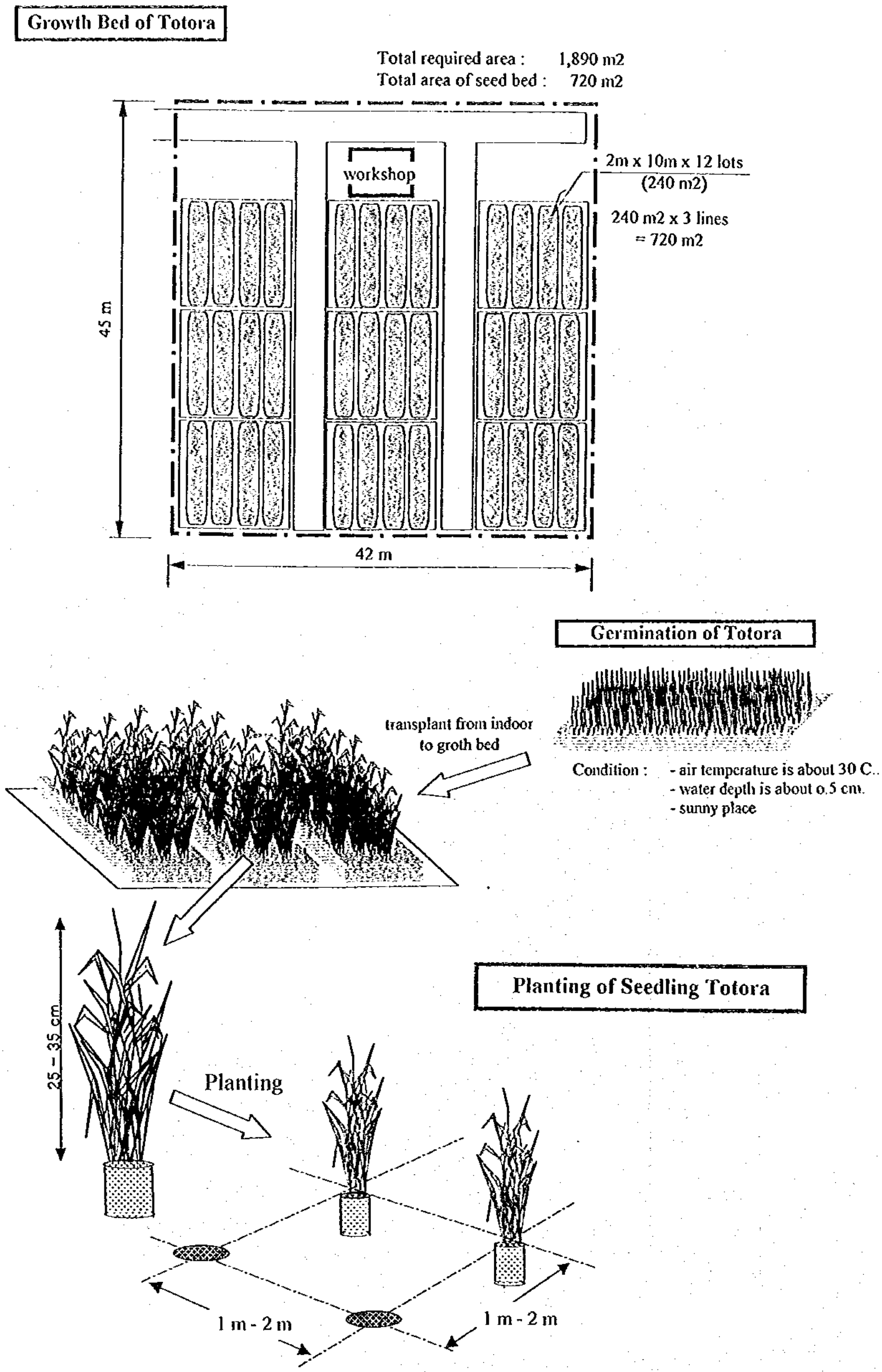



**Figure VII.2.11 Required Growth Bed of Seedling "Totora"**

## Table VII.2.4 Required Number of Staff for Replanting Totota

**< Rehabilitation of Totora >**

unit : man-month

| Permanent Staff | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | ~ | 2015 | ~ | 2025 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project term | Administration (2000–2001) → Multiplication of seedling (2001–2008) → Planting of Totora (2003–2008) | | | | | | | | | | | | | | |
| Chief | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Technician | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | - | - | - | - | - | 108 |
| Labor | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | - | - | - | - | - | 108 |
| Total | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 0 | 0 | 0 | 0 | 0 | 216 |

unit : man-day

| Temporary Staff | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | ~ | 2015 | ~ | 2025 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labor (multiplication) | 0 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 210 |
| Labor (preparation) | 0 | 0 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 0 | 0 | 0 | 0 | 0 | 154 |
| Labor (planting) | 0 | 0 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 0 | 0 | 0 | 0 | 0 | 266 |
| Total | 0 | 30 | 90 | 90 | 90 | 90 | 90 | 90 | 60 | 0 | 0 | 0 | 0 | 0 | 630 |

## Table VII.2.5 Cost Estimation of Rehabilitation of Totora

Operation and Maintenance

unit : Soles

| Items | | Quantity | Foreign currency | Local currency | Foreign C. | Local C. | Total |
|---|---|---|---|---|---|---|---|
| Personnel expenses | Chief | 0 man-month | - | 1,200 soles/man-month. | 0 | 0 | 0 |
| | Technician | 108 man-month | - | 800 soles/man-month. | 0 | 86,400 | 86,400 |
| | Labor ( Permanent) | 108 man-month | - | 400 soles/man-month. | 0 | 43,200 | 43,200 |
| | Labor (Temporary) | 630 man-day | | 20 soles/man-day. | 0 | 12,600 | 12,600 |
| Sub-total | | | | | 0 | 142,200 | 142,200 |
| Rental cost | Car | 28 car-day | - soles | 300 soles/car-day | 0 | 8,400 | 8,400 |
| | Boat with engine | 28 car-day | - soles | 100 soles / boat-day | 0 | 2,800 | 2,800 |
| | Boat without engine | 140 car-day | - soles | 25 soles / boat-day | 0 | 3,500 | 3,500 |
| | Others 1% | 1 set | - soles | | 0 | 1,422 | 1,422 |
| Sub-total | | | | | 0 | 16,122 | 16,122 |
| Total | | | | | 0 | 158,322 | 158,322 |

Others : It is equal to 1 % of the personnel expenses