which provides a better unit energy cost is selected as the optimum project scale of the Downstream Project.

**(4) Optimum Development Plan of the Xe Namnoy Project**

According to the above comparative studies on the Xe Namnoy Midstream and Downstream Projects, the optimum development scale of the Xe Namnoy Project (Midstream and Downstream) is determined as the plan below.

| | Midstream | Downstream | |
|---|---|---|---|
| Reservoir HWL | 765.0 | 270.0 | m |
| Reservoir LWL | 747.7 | 266.7 | m |
| Effective Storage Capacity | 250 | 2.0 | MCM |
| Firm Discharge | 20.8 | 24.0 | $m^3/s$ |
| Minimum Outflow (from dam) | 1.0 | - | $m^3/s$ |
| Peak Power Duration | 8 | 6 | hours |
| Maximum Discharge | 60 | 96 | $m^3/s$ |
| Rated Intake Water Level (IWL) | 758.6 | 268.4 | m |
| Rated Tail Water Level (TWL) | 270.0 | 180.0 | m |
| Rated Effective Head (He) | 463.0 | 81.0 | m |
| Installed Capacity | 238 | 67 | MW |
| Dependable Peak Capacity | 230 (8hr) | 66 (6hr) | MW |
| Annual Energy | 1,052 | 332 | GWh |

## 13.4.4 Remarks on the Development Plan

The above development plan is proposed as the optimum plan of the Xe Namnoy Project based on the technical studies with the data and information presently available. Several remarks to be clarified in further stages, however, are indicated as follows;

**a) Technical Matters**

Although it is confirmed that the watertight integrity of the Midstream Project's reservoir could be secured by foundation treatment at the dam site, the distribution range of the permeable basalt present there should be confirmed by further investigations and the foundation treatment method should be studied in further stages.

The geological conditions along the waterway route should also be confirmed by further investigations.

b) **Environmental Issues**

It is estimated that approximately 800 people will require resettlement. Appropriate mitigation measures should be studied in further stages.

Regarding the Xe Pian diversion scheme, a study on the discharge supply for the downstream area is required in further stages. In this study, the Xe Pian diversion scheme is planned with no discharge supply to the downstream area from the viewpoint of the effective use of hydropower potential in the basin. A development plan with no diversion scheme and only using the potential of the Xe Namnoy mainstream could be proposed, but depending on the condition of the downstream area of the Xe Pian River.

Regarding the Downstream Project, study is required on the discharge for maintaining the original river functions of the downstream area. For this, an operation plan using the regulation pond of the Downstream Project as a re-regulating reservoir for Midstream Project. This plan provides inferior independent economic performance for the Downstream Project. In case, however, the required flow condition of the downstream area places constraints on power plant operation for the project, the above plan would provide an advantage for the operation of the Midstream Project.

Table 13.4-1 Study on Reservoir HWL (Xe Namnoy Midstream) (1/2)

(without Xe Pian Diversion)

| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 | Case-5 |
|---|---|---|---|---|---|---|
| Reservoir HWL | m | 750.0 | 755.0 | 760.0 | 765.0 | 770.0 |
| Dam Crest Length | m | 420 | 540 | 740 | 890 | 930 |
| Dam Height | m | 45 | 50 | 55 | 60 | 65 |
| Reservoir Area | km² | 9.6 | 13.2 | 17.3 | 21.8 | 27.2 |
| Gross Storage Capa. | MCM | 104 | 161 | 237 | 335 | 457 |
| Sediment Capa. | MCM | 23 | 23 | 23 | 23 | 23 |
| Net Storage Capa. | MCM | 38 | 95 | 171 | 266 | 304 |
| Regulation Ratio | % | 5 | 13 | 23 | 35 | 40 |
| Reservoir LWL | m | 745.4 | 745.4 | 745.4 | 745.7 | 754.3 |
| Firm Discharge | m³/s | 5.5 | 9.2 | 13.6 | 17.9 | 18.7 |
| River Maint.Release | m³/s | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Base Power Discharge | m³/s | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Max. Power Discharge | m³/s | 13.5 | 24.6 | 37.8 | 50.7 | 53.1 |
| Rated IWL | m | 748.5 | 751.8 | 755.1 | 758.6 | 764.8 |
| Rated TWL | m | 280.0 | 280.0 | 280.0 | 280.0 | 280.0 |
| Gross Head | m | 468.5 | 471.8 | 475.1 | 478.6 | 484.8 |
| Effective Head | m | 443.5 | 446.8 | 450.1 | 453.6 | 459.8 |
| Installed Capacity | MW | 51 | 95 | 146 | 198 | 210 |
| Annual Inflow | MCM | 761 | 761 | 761 | 761 | 761 |
| Annual Evaporation | MCM | 8 | 9 | 11 | 14 | 19 |
| Annual Dam Outflow | MCM | 469 | 267 | 91 | 40 | 40 |
| Annual Turbine Out. | MCM | 284 | 485 | 659 | 707 | 702 |
| Firm Peak Capacity | MW | 51 | 93 | 142 | 192 | 206 |
| Annual Energy | GWh | 299 | 516 | 704 | 764 | 770 |
| Plant Factor | % | 66 | 62 | 55 | 44 | 42 |
| Construction Cost | M.US$ | 105.3 | 140.0 | 180.2 | 231.2 | 248.5 |
| Annual Cost | M.US$ | 11.6 | 15.4 | 19.8 | 25.4 | 27.3 |
| Annual Benefit | M.US$ | 12.6 | 22.4 | 32.7 | 40.5 | 42.6 |
| Unit Energy Cost | $/MWh | 38.8 | 29.8 | 28.2 | 33.3 | 35.5 |
| B-C | M.US$ | 1.0 | 7.0 | 12.8 | 15.1 | 15.3 |
| B/C | - | 1.09 | 1.46 | 1.65 | 1.59 | 1.56 |
| Const.Cost/kW | M.US$ | 2,046 | 1,481 | 1,232 | 1,169 | 1,184 |
| Selected Case (Tentative) | - | - | - | (*) | - | - |

## Table 13.4-1 Study on Reservoir HWL (Xe Namnoy Midstream) (2/2)

(with Xe Pian Diversion : Qdv-max = 15 $m^3/s$)

| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 | Case-5 |
|---|---|---|---|---|---|---|
| Reservoir HWL | m | 750.0<br>Omitted | 755.0 | 760.0 | 765.0 | 770.0<br>Omitted |
| Dam Crest Length | m | - | 540 | 740 | 890 | - |
| Dam Height | m | - | 50 | 55 | 60 | - |
| Reservoir Area | $km^2$ | - | 13.2 | 17.3 | 21.8 | - |
| Gross Storage Capa. | MCM | - | 161 | 237 | 335 | - |
| Sediment Capa. | MCM | - | 23 | 23 | 23 | - |
| Net Storage Capa. | MCM | - | 95 | 165 | 250 | - |
| Regulation Ratio | % | - | 9 | 16 | 25 | - |
| Reservoir LWL | m | - | 745.4 | 746.1 | 747.7 | - |
| Firm Discharge | $m^3/s$ | - | 11.4 | 15.7 | 20.8 | - |
| River Maint.Release | $m^3/s$ | - | 1.0 | 1.0 | 1.0 | - |
| Base Power Discharge | $m^3/s$ | - | 0.0 | 0.0 | 0.0 | - |
| Max. Power Discharge | $m^3/s$ | - | 31.2 | 44.1 | 59.4 | - |
| Rated IWL | m | - | 751.8 | 755.4 | 758.6 | - |
| Rated TWL | m | - | 280.0 | 280.0 | 280.0 | - |
| Gross Head | m | - | 471.8 | 475.4 | 478.6 | - |
| Effective Head | m | - | 446.8 | 450.4 | 453.6 | - |
| Installed Capacity | MW | - | 120 | 171 | 232 | - |
| Annual Inflow | MCM | - | 1,001 | 1,001 | 1,001 | - |
| Annual Evaporation | MCM | - | 9 | 11 | 14 | - |
| Annual Dam Outflow | MCM | - | 413 | 149 | 48 | - |
| Annual Turbine Out. | MCM | - | 579 | 840 | 940 | - |
| Firm Peak Capacity | MW | - | 159 | 160 | 225 | - |
| Annual Energy | GWh | - | 616 | 900 | 1,015 | - |
| Plant Factor | % | - | 59 | 60 | 50 | - |
| Construction Cost | M.US$ | - | 202.6 | 223.4 | 270.7 | - |
| Annual Cost | M.US$ | - | 22.3 | 24.6 | 29.8 | - |
| Annual Benefit | M.US$ | - | 33.3 | 38.9 | 49.8 | - |
| Unit Energy Cost | $/MWh | - | 36.2 | 27.3 | 29.3 | - |
| B-C | M.US$ | - | 11.0 | 14.4 | 20.0 | - |
| B/C | - | - | 1.49 | 1.58 | 1.67 | - |
| Const.Cost/kW | M.US$ | - | 1,690 | 1,308 | 1,168 | - |
| Selected Case (Tentative) | - | - | - | - | (*) | - |

Note) Case 1 does not provide acceptable reservoir storage capacity.
Case 5 is not acceptable for Xe Pian Diversion scheme.

Table 13.4-2 Study on Maximum Diversion Discharge (Xe Pian Diversion)

| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 |
|---|---|---|---|---|---|
| Maximum Diversion | $m^3/s$ | 10.0 | 15.0 | 20.0 | 25.0 |
| Reservoir HWL | m | 765.0 | 765.0 | 765.0 | 765.0 |
| Dam Crest Length | m | 890 | 890 | 890 | 890 |
| Dam Height | m | 60 | 60 | 60 | 60 |
| Reservoir Area | $km^2$ | 21.8 | 21.8 | 21.8 | 21.8 |
| Gross Storage Capa. | MCM | 335 | 335 | 335 | 335 |
| Sediment Capa. | MCM | 23 | 23 | 23 | 23 |
| Net Storage Capa. | MCM | 250 | 250 | 250 | 250 |
| Regulation Ratio | % | 27 | 25 | 24 | 23 |
| Reservoir LWL | m | 747.7 | 747.7 | 747.7 | 747.7 |
| Firm Discharge | $m^3/s$ | 20.8 | 20.8 | 20.8 | 20.8 |
| River Maint.Release | $m^3/s$ | 1.0 | 1.0 | 1.0 | 1.0 |
| Base Power Discharge | $m^3/s$ | 0.0 | 0.0 | 0.0 | 0.0 |
| Max. Power Discharge | $m^3/s$ | 60.0 | 60.0 | 60.0 | 60.0 |
| Rated IWL | m | 758.6 | 758.6 | 758.6 | 758.6 |
| Rated TWL | m | 280.0 | 280.0 | 280.0 | 280.0 |
| Gross Head | m | 478.6 | 478.6 | 478.6 | 478.6 |
| Effective Head | m | 453.6 | 453.6 | 453.6 | 453.6 |
| Installed Capacity | MW | 232 | 232 | 232 | 232 |
| Annual Inflow | MCM | 942 | 1,001 | 1,042 | 1,073 |
| Annual Evaporation | MCM | 14 | 14 | 14 | 12 |
| Annual Dam Outflow | MCM | 44 | 48 | 75 | 77 |
| Annual Turbine Out. | MCM | 883 | 940 | 953 | 984 |
| Firm Peak Capacity | MW | 225 | 225 | 226 | 224 |
| Annual Energy | GWh | 955 | 1,015 | 1,031 | 1,062 |
| Plant Factor | % | 47 | 50 | 51 | 52 |
| Construction Cost | M.US$ | 268.6 | 270.7 | 272.9 | 275.2 |
| Annual Cost | M.US$ | 29.5 | 29.8 | 30.0 | 30.3 |
| Annual Benefit | M.US$ | 48.7 | 49.8 | 50.3 | 50.6 |
| Unit Energy Cost | $/MWh | 30.9 | 29.3 | 29.1 | 28.5 |
| B-C | M.US$ | 19.2 | 20.0 | 20.3 | 20.4 |
| B/C | - | 1.65 | 1.67 | 1.68 | 1.67 |
| Const.Cost/kW | M.US$ | 1,159 | 1,168 | 1,178 | 1,188 |
| Selected Case | - | | | * | |

Table 13.4-3 Study on Reservoir HWL (Xe Namnoy Downstream)

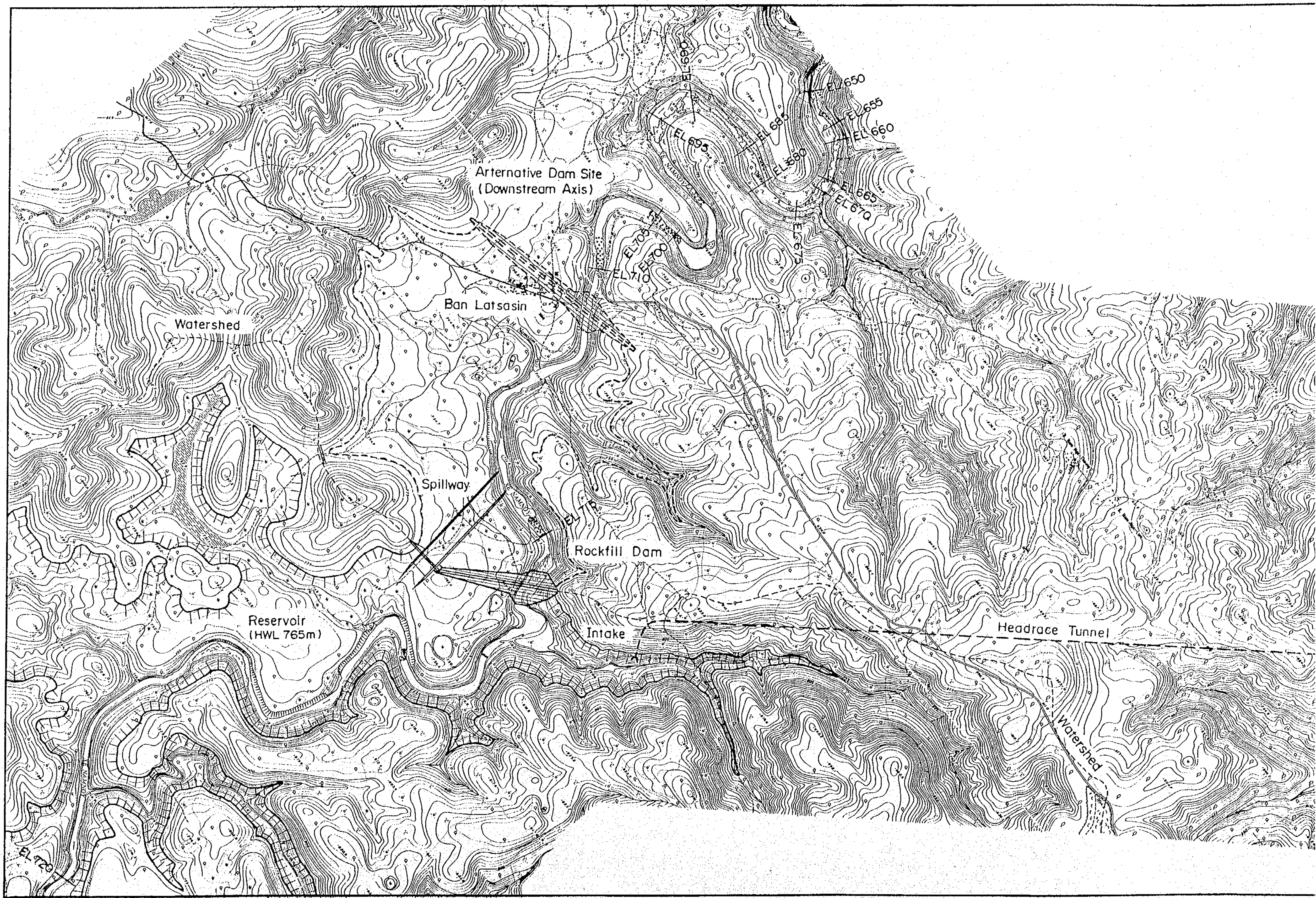
| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 |
|---|---|---|---|---|---|
| Reservoir HWL | m | 265.0 | 270.0 | 275.0 | 280.0 |
| | | | | | |
| Dam Crest Length | m | 290 | 320 | 370 | 435 |
| Dam Height | m | 30 | 35 | 40 | 45 |
| Reservoir Area | km² | 0.5 | 0.7 | 0.9 | 1.1 |
| Gross Storage Capa. | MCM | 3.5 | 6.5 | 10.5 | 15.4 |
| Net Storage Capa. | MCM | 2.0 | 2.0 | 2.0 | 2.0 |
| Reservoir LWL | m | 259.5 | 266.7 | 272.0 | 278.0 |
| | | | | | |
| Firm Discharge | m³/s | 24.0 | 24.0 | 24.0 | 24.0 |
| River Maint.Release | m³/s | 0.0 | 0.0 | 0.0 | 0.0 |
| Base Power Discharge | m³/s | 0.0 | 0.0 | 0.0 | 0.0 |
| Peak Power Duration | Hours | 6 | 6 | 6 | 6 |
| Max. Power Discharge | m³/s | 96.0 | 96.0 | 96.0 | 96.0 |
| Rated IWL | m | 262.3 | 268.4 | 273.5 | 279.0 |
| Rated TWL | m | 180.0 | 180.0 | 180.0 | 180.0 |
| Gross Head | m | 82.3 | 88.4 | 93.5 | 99.0 |
| Effective Head | m | 74.9 | 81.0 | 86.1 | 91.6 |
| Installed Capacity | MW | 62 | 67 | 71 | 76 |
| | | | | | |
| Annual Inflow | MCM | 2,109 | 2,109 | 2,109 | 2,109 |
| Annual Evaporation | MCM | - | - | - | - |
| Annual Dam Outflow | MCM | 411 | 411 | 411 | 411 |
| Annual Turbine Out. | MCM | 1,698 | 1,698 | 1,698 | 1,698 |
| | | | | | |
| Firm Peak Capacity | MW | 61 | 66 | 70 | 75 |
| Annual Energy | GWh | 307 | 332 | 353 | 376 |
| Plant Factor | % | 57 | 57 | 57 | 57 |
| | | | | | |
| Construction Cost | M.US$ | 128.4 | 135.7 | 145.5 | 159.6 |
| Annual Cost | M.US$ | 14.1 | 14.9 | 16.0 | 17.6 |
| Annual Benefit | M.US$ | 14.2 | 15.3 | 16.3 | 17.3 |
| | | | | | |
| Unit Energy Cost | $/MWh | 46.0 | 45.0 | 45.3 | 46.8 |
| B-C | M.US$ | 0.0 | 0.4 | 0.3 | -0.2 |
| B/C | - | 1.00 | 1.03 | 1.02 | 0.99 |
| Const.Cost/kW | M.US$ | 2,078 | 2,031 | 2,047 | 2,111 |
| | | | | | |
| Selected Case | - | | * | | |

Table 13.4-4 Study on Reservoir HWL (Xe Namnoy Downstreeam)
- Integrated Study with Xe Namnoy Midstream -

| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 |
| --- | --- | --- | --- | --- | --- |
| **Xe Namnoy Downstream** | (TWL 180, Qmax 96.0 m³/s) | | | | |
| Reservoir HWL | m | 265 | 270 | 275 | 280 |
| Effective Head | m | 75 | 81 | 86 | 92 |
| Installed Capacity | MW | 62 | 67 | 71 | 76 |
| Firm Capacity (8 hr) | MW | 46 | 50 | 53 | 56 |
| Annual Energy | GWh | 307 | 332 | 353 | 376 |
| Construction Cost | M.US$ | 128.4 | 135.7 | 145.5 | 159.6 |
| **Xe Namnoy Midstream** | (HWL 765 m, Qmax 60 m³/s) | | | | |
| Rated TWL | | 270 | 270 | 275 | 280 |
| Effective Head | m | 463.1 | 463.1 | 458.6 | 453.6 |
| Installed Capacity | MW | 238 | 238 | 236 | 232 |
| Firm Capacity (8 hr) | MW | 230 | 230 | 228 | 225 |
| Annual Energy | GWh | 1,052 | 1,052 | 1,042 | 1,031 |
| Construction Cost | M.US$ | 299.5 | 299.5 | 296.6 | 295.8 |
| **Midstream + Downstream** | | | | | |
| Installed Capacity | MW | 300 | 305 | 307 | 309 |
| Firm Capacity (8 hr) | MW | 276 | 280 | 281 | 281 |
| Annual Energy | GWh | 1,359 | 1,384 | 1,395 | 1,406 |
| Construction Cost | M.US$ | 428.0 | 435.2 | 442.1 | 455.4 |
| Annual Cost | M.US$ | 47.1 | 47.9 | 48.6 | 50.1 |
| Annual Benefit | M.US$ | 63.3 | 64.3 | 64.7 | 65.0 |
| Unit Energy Cost | $/MWh | 34.6 | 34.6 | 34.9 | 35.6 |
| B-C | M.US$ | 16.3 | 16.5 | 16.0 | 14.9 |
| B/C | - | 1.35 | 1.34 | 1.33 | 1.30 |
| Const.Cost/kW | M.US$ | 1.6 | 1.6 | 1.6 | 1.6 |
| Selected Case | - | | * | | |

Table 13.4-5 Study on Maximum Discharge (Xe Namnoy Downstream)

| Description | Unit | Case-1 | Case-2 | Case-3 | Case-4 | Case-5 |
|---|---|---|---|---|---|---|
| Qmax/Qfirm | - | 2.4 | 3.0 | 4.0 | 5.0 | 6.0 |
| Reservoir HWL | m | 270.0 | 270.0 | 270.0 | 270.0 | 270.0 |
| Dam Crest Length | m | 320 | 320 | 320 | 320 | 320 |
| Dam Height | m | 35 | 35 | 35 | 35 | 35 |
| Reservoir Area | $km^2$ | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Gross Storage Capa. | MCM | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| Net Storage Capa. | MCM | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Reservoir LWL | m | 266.7 | 266.7 | 266.7 | 266.7 | 266.7 |
| Firm Discharge | $m^3/s$ | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| River Maint.Release | $m^3/s$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Base Power Discharge | $m^3/s$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Peak Power Duration | Hours | 10 | 8 | 6 | 4.8 | 4 |
| Max. Power Discharge | $m^3/s$ | 57.6 | 72.0 | 96.0 | 120.0 | 144.0 |
| Rated IWL | m | 268.4 | 268.4 | 268.4 | 268.4 | 268.4 |
| Rated TWL | m | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 |
| Gross Head | m | 88.4 | 88.4 | 88.4 | 88.4 | 88.4 |
| Effective Head | m | 78.7 | 79.8 | 81.0 | 81.7 | 82.3 |
| Installed Capacity | MW | 39 | 49 | 67 | 84 | 102 |
| Annual Inflow | MCM | 2,109 | 2,109 | 2,109 | 2,109 | 2,109 |
| Annual Evaporation | MCM | - | - | - | - | - |
| Annual Dam Outflow | MCM | 806 | 637 | 411 | 238 | 122 |
| Annual Turbine Out. | MCM | 1,303 | 1,472 | 1,698 | 1,871 | 1,987 |
| Firm Peak Capacity | MW | 39 | 49 | 66 | 83 | 99 |
| Annual Energy | GWh | 248 | 284 | 332 | 366 | 387 |
| Plant Factor | % | 73 | 66 | 57 | 50 | 43 |
| Construction Cost | M.US$ | 101.2 | 114.0 | 135.7 | 158.3 | 182.5 |
| Annual Cost | M.US$ | 11.1 | 12.5 | 14.9 | 17.4 | 20.1 |
| Annual Benefit | M.US$ | 10.0 | 12.1 | 15.3 | 18.2 | 20.9 |
| Unit Energy Cost | $/MWh | 44.8 | 44.2 | 45.0 | 47.5 | 51.9 |
| B-C | M.US$ | -1.2 | -0.5 | 0.4 | 0.8 | 0.8 |
| B/C | - | 0.90 | 0.96 | 1.03 | 1.05 | 1.04 |
| Const.Cost/kW | M.US$ | 2595 | 2308 | 2030 | 1876 | 1790 |
| Selected Case | - | | | * | | |



Arternative Dam Site
(Downstream Axis)
Ban Latsasin
Watershed
Spillway
Rockfill Dam
Reservoir
(HWL 765m)
Intake
Headrace Tunnel
Watershed
EL 690
EL 650
EL 655
EL 660
EL 685
EL 695
EL 680
EL 665
EL 670
EL 675
EL 705
EL 700
EL 710
EL 720

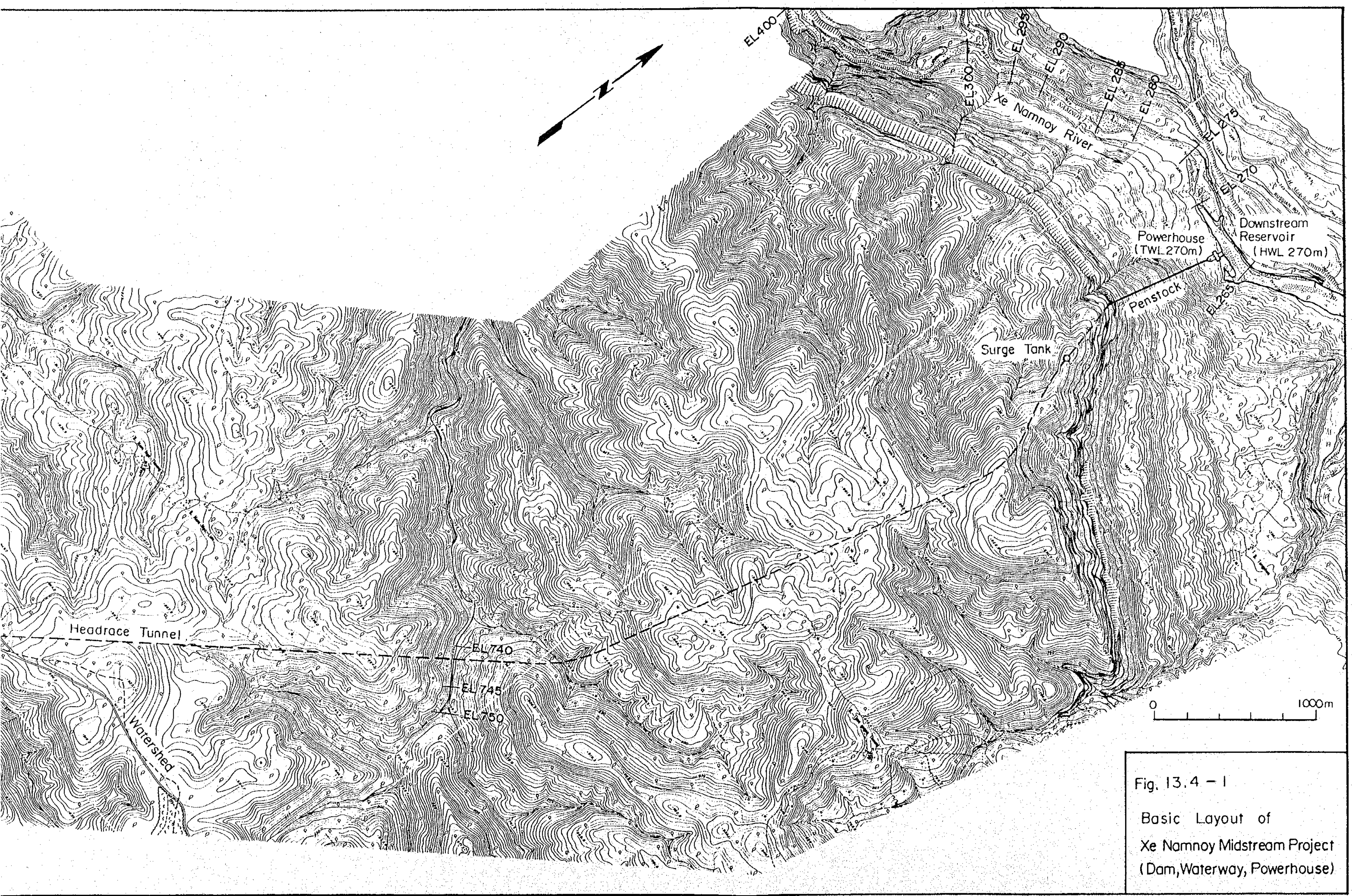
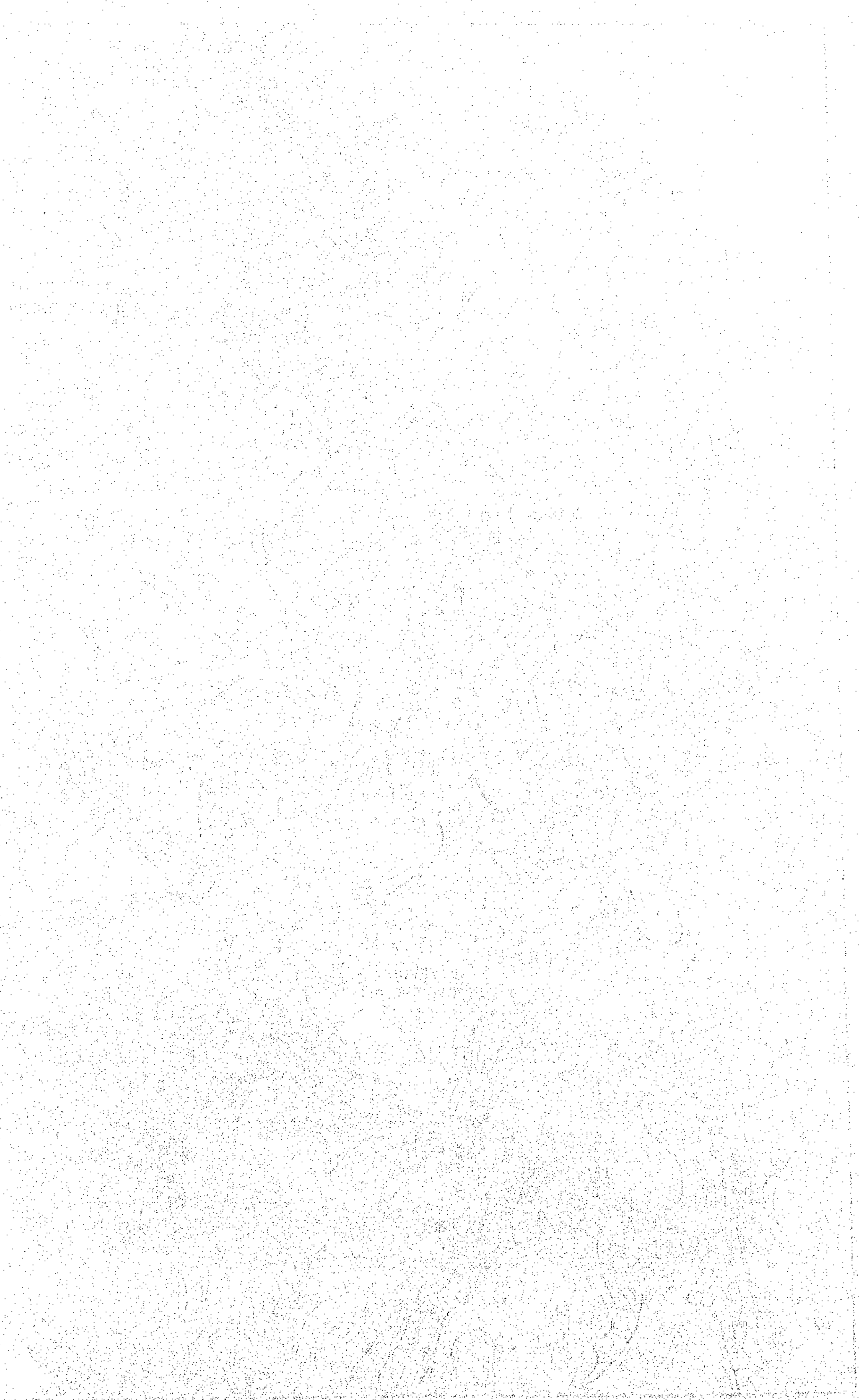
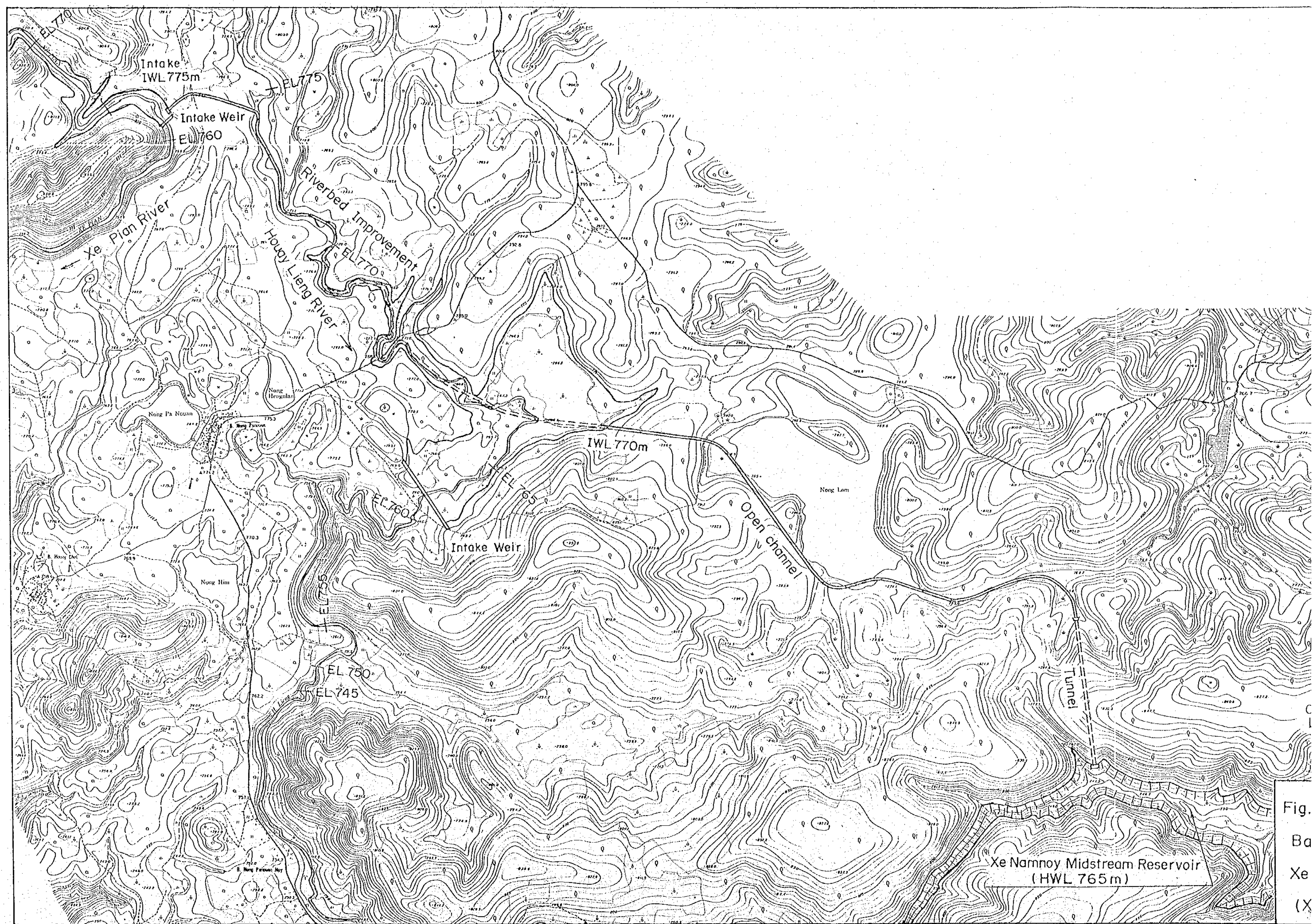



Fig. 13.4 – 1

Basic Layout of
Xe Namnoy Midstream Project
(Dam, Waterway, Powerhouse)




Intake
IWL 775m
EL770
EL775
Intake Weir
EL 760
Xe Pian River
Riverbed Improvement
Houay Lieng River
EL770
Nong Pa Nouan
IWL 770m
EL 765
EL760
Intake Weir
Open channel
Nong Lom
EL755
EL 750
EL 745
Tunnel
Xe Namnoy Midstream Reservoir
(HWL 765m)
Fig.
Ba
Xe
(X

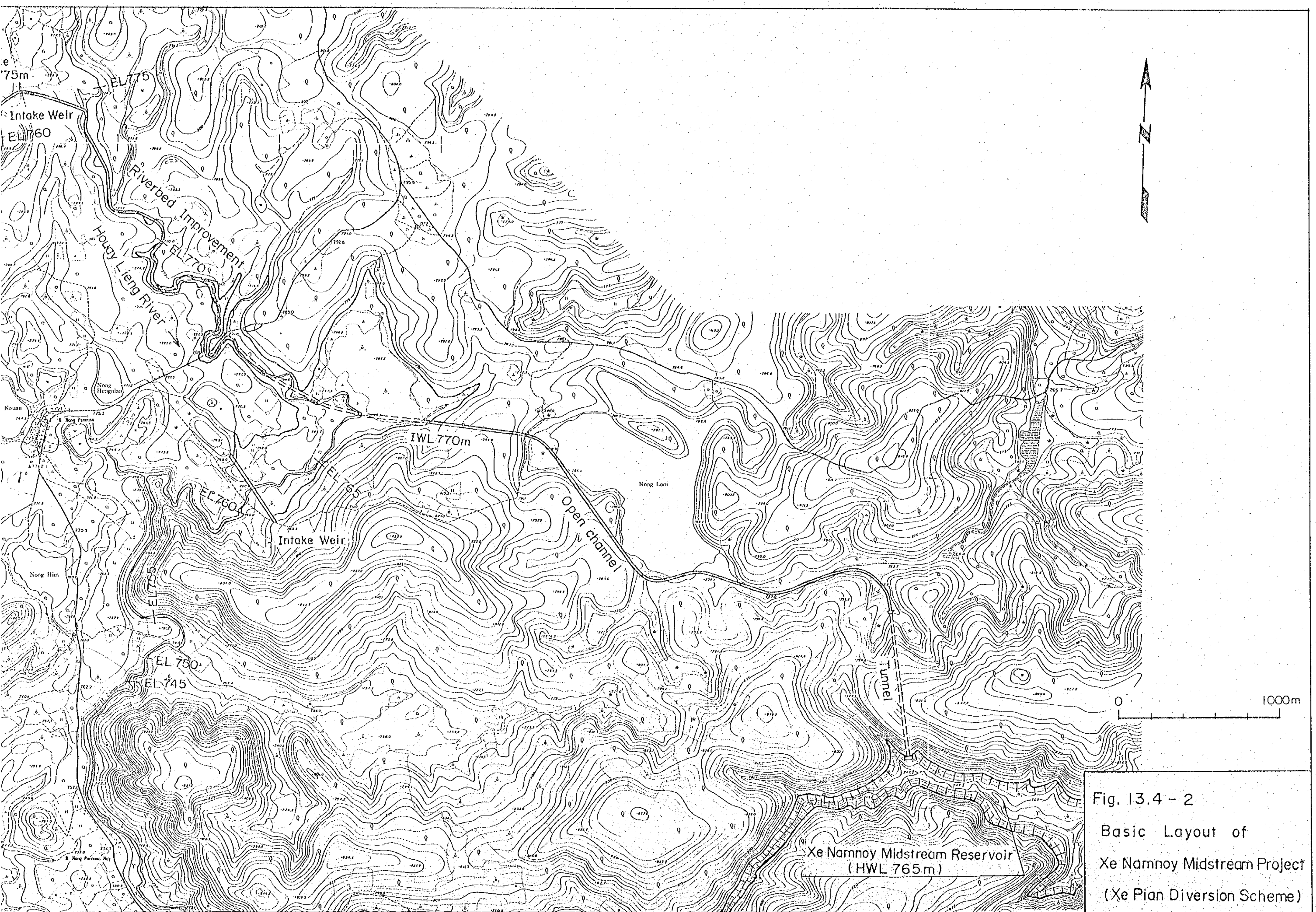



Fig. 13.4 - 2
Basic Layout of
Xe Namnoy Midstream Project
(Xe Pian Diversion Scheme)

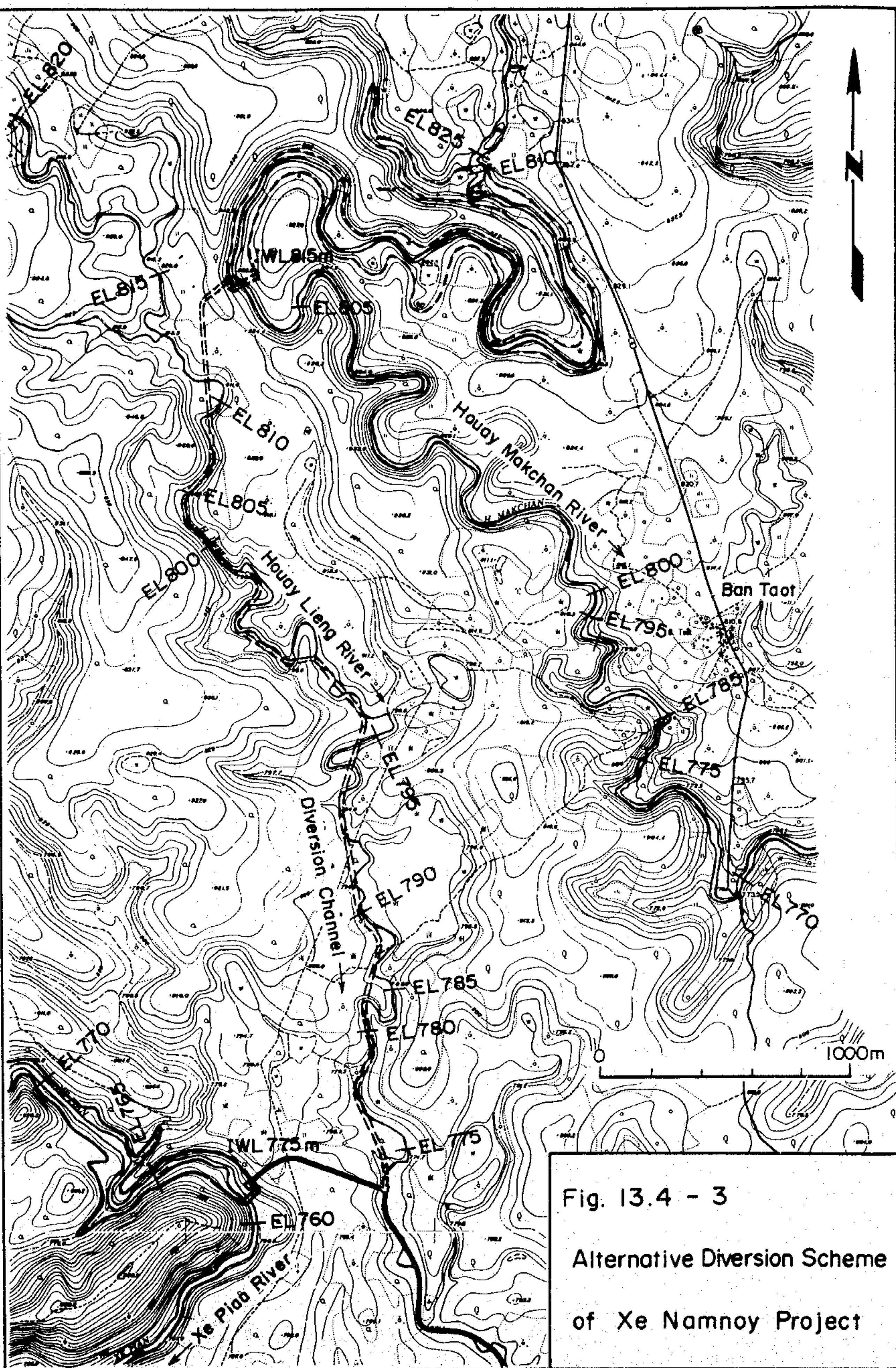



Fig. 13.4 - 3

Alternative Diversion Scheme of Xe Namnoy Project

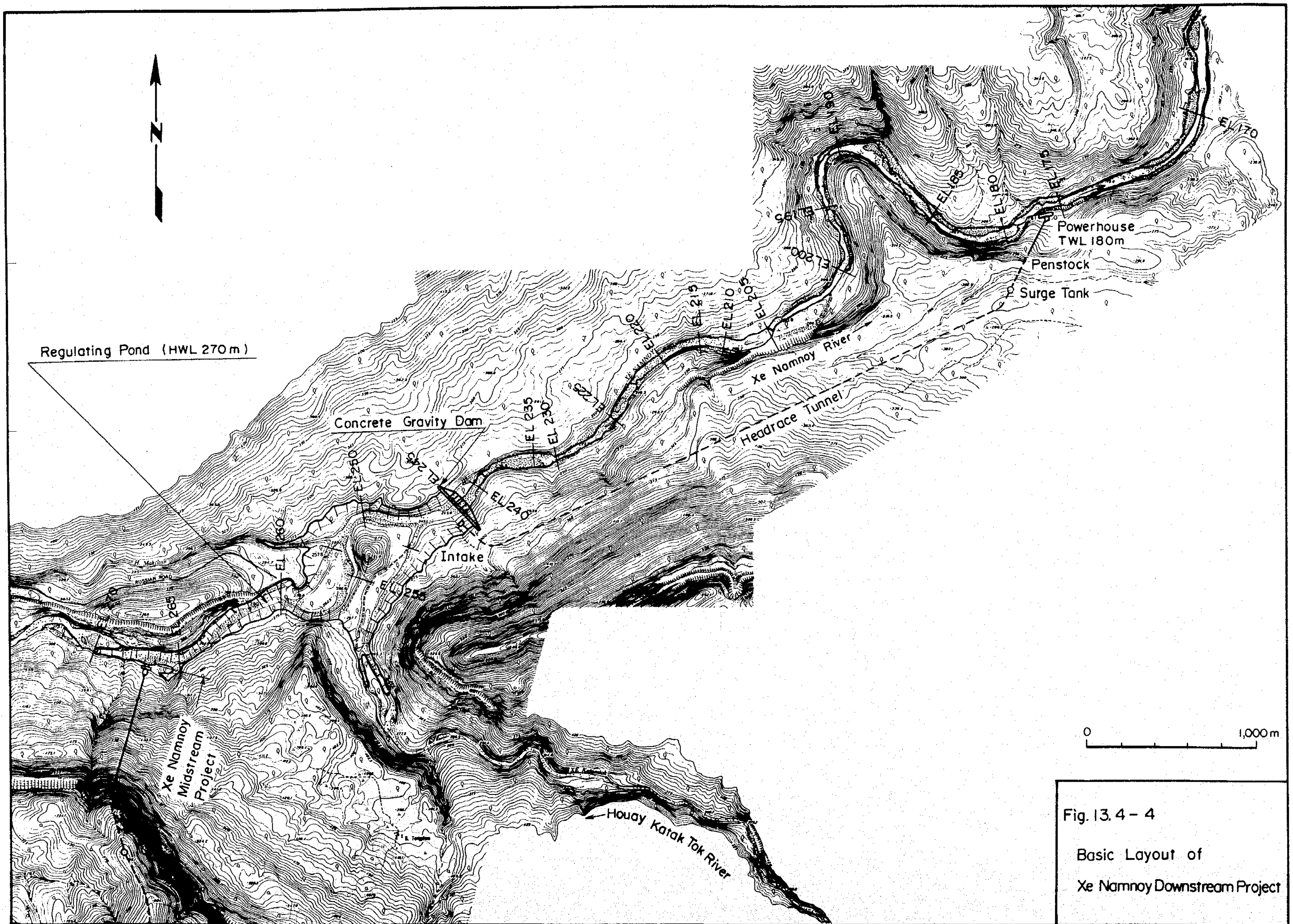
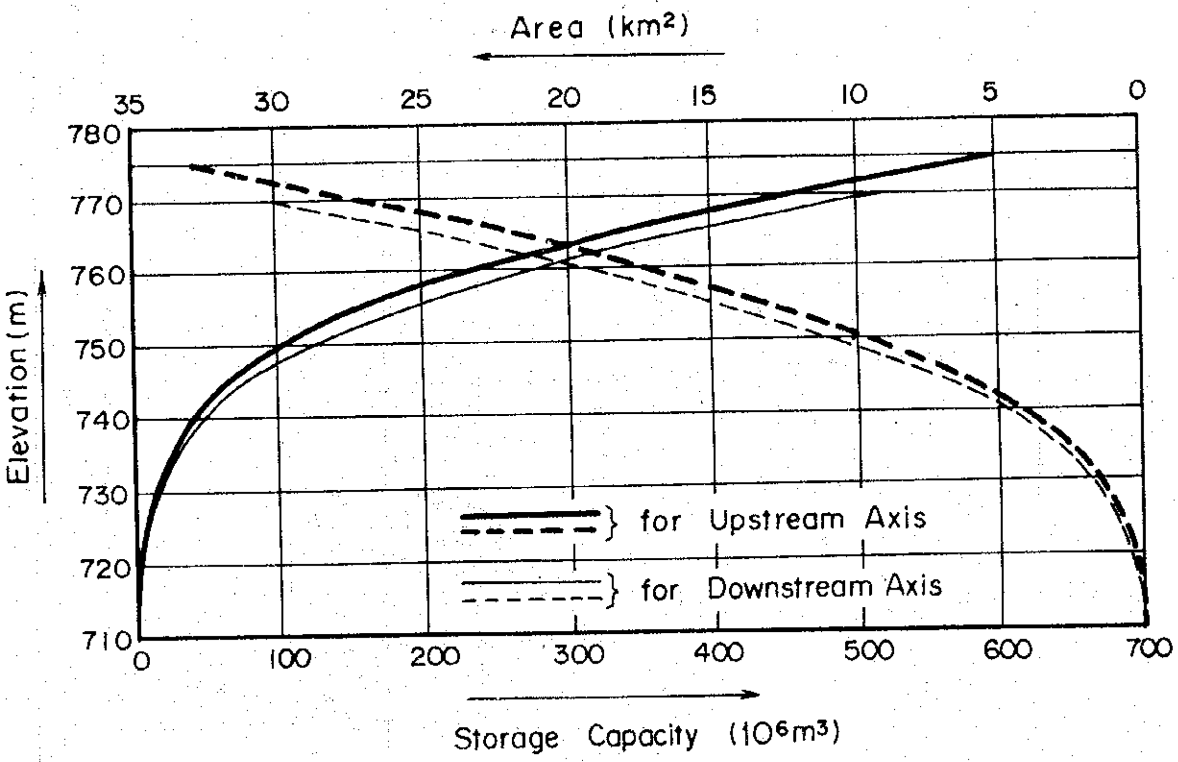



Fig. 13.4 – 4

Basic Layout of

Xe Namnoy Downstream Project

**Fig. 13.4-5 Area and Storage Capacity Curve of Xe Namnoy Midstream Reservoir**

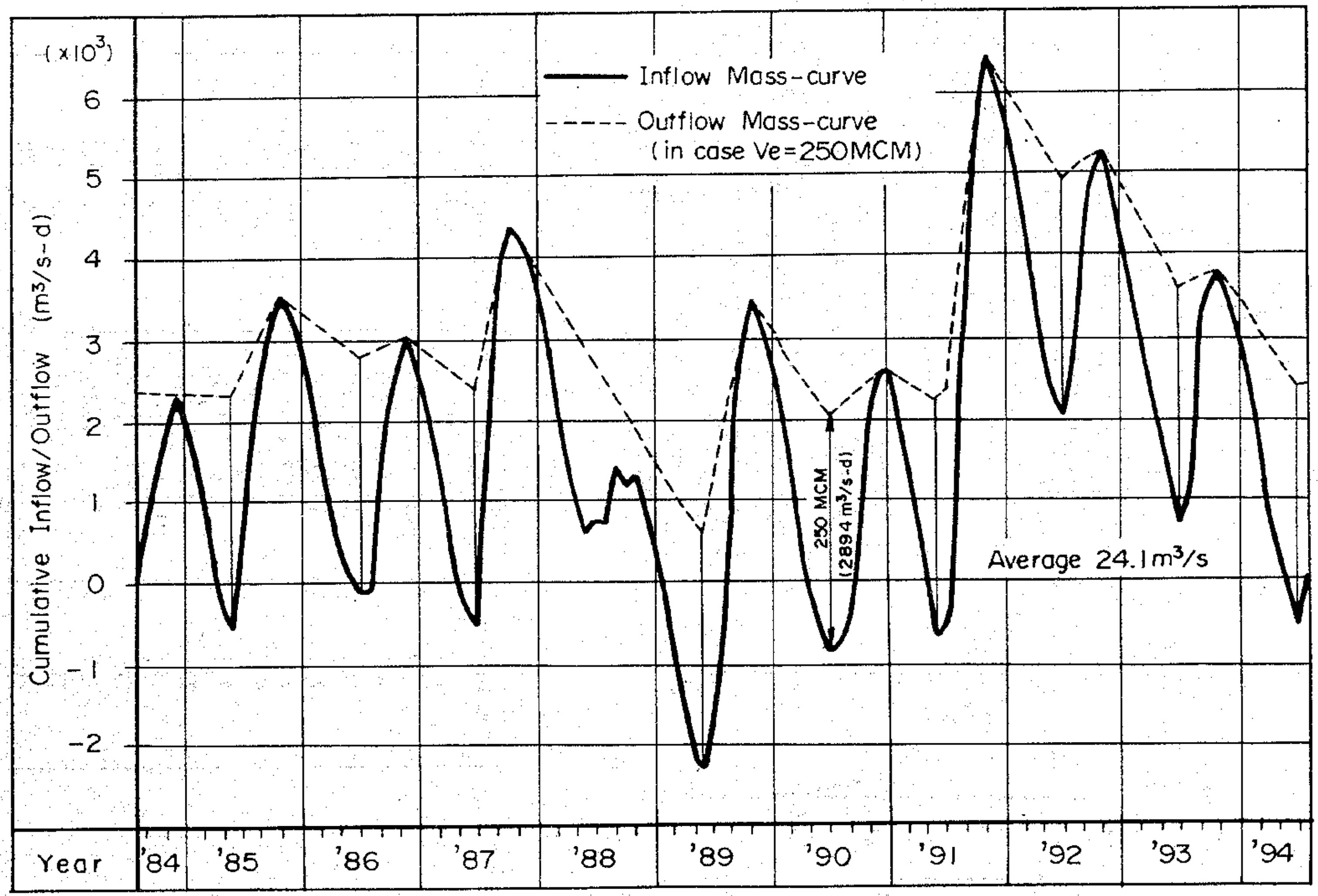



| Elevation (m) | * Area ($km^2$) | Storage Capacity ($10^6$ $m^3$) |
|---|---|---|
| 775 | 32.94 ** | 607 ** |
| 770 | 27.16 (30.05) | 457 (520) |
| 765 | 21.84 (24.47) | 335 (383) |
| 760 | 17.29 (19.64) | 237 (273) |
| 755 | 13.21 (15.16) | 161 (186) |
| 750 | 9.55 (10.93) | 104 (121) |
| 745 | 6.71 (7.56) | 63 (75) |
| 740 | 4.17 (4.78) | 36 (44) |
| 735 | 2.61 (3.06) | 19 (24) |
| 730 | 1.41 (1.73) | 9 (12) |
| 725 | 0.79 (1.03) | 3 (6) |
| 720 | 0.29 (0.48) | 1 (2) |
| 715 | 0 (0.12) | 0 (0) |
| 710 | - (0) | - (0) |

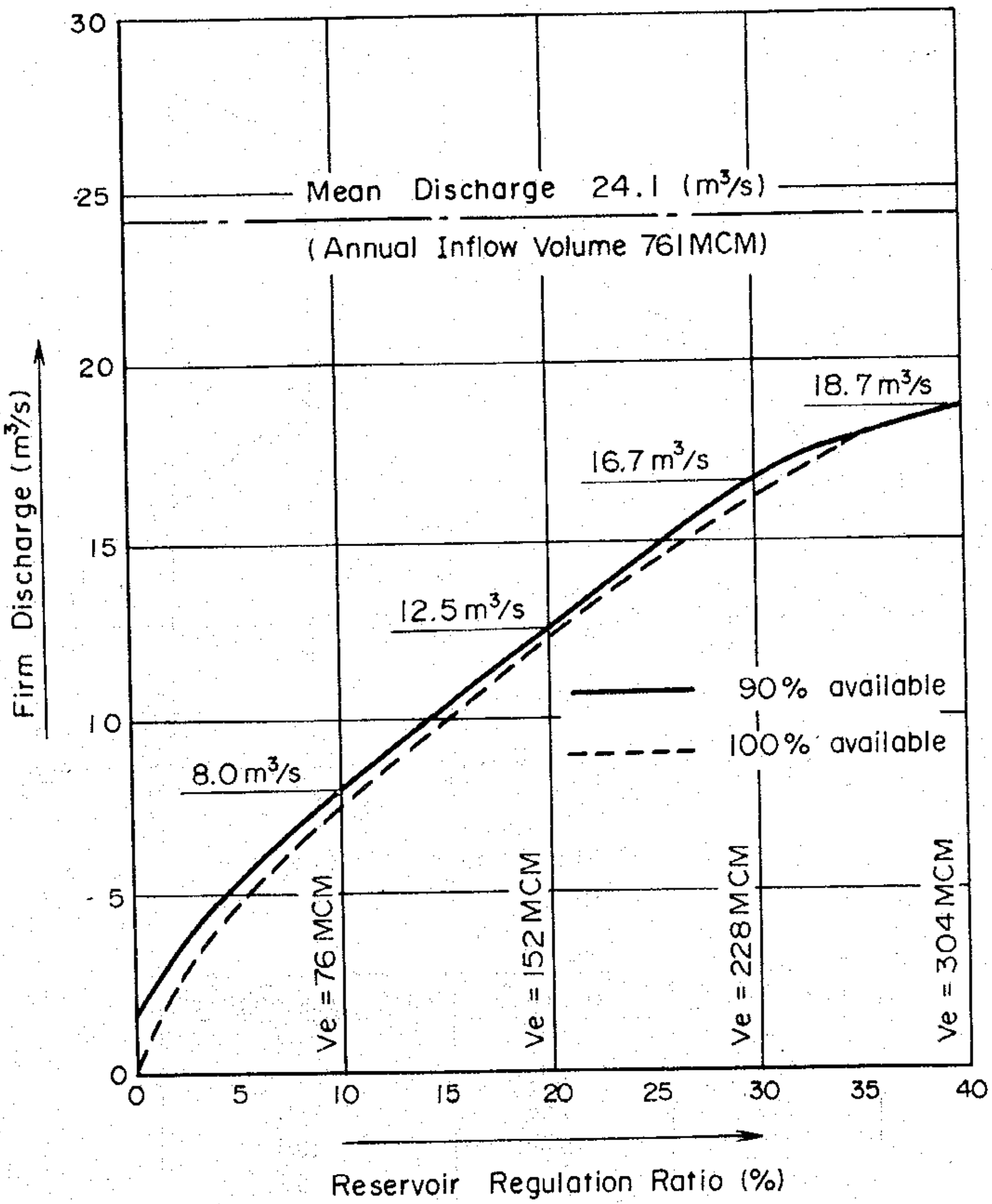
* measured using 1/10,000 scale topographic maps

** figures in parenthese are of alternative dam axis (downstream axis)

Fig. 13.4-6 Mass-curves at Xe Namnoy Midstream Dam Site



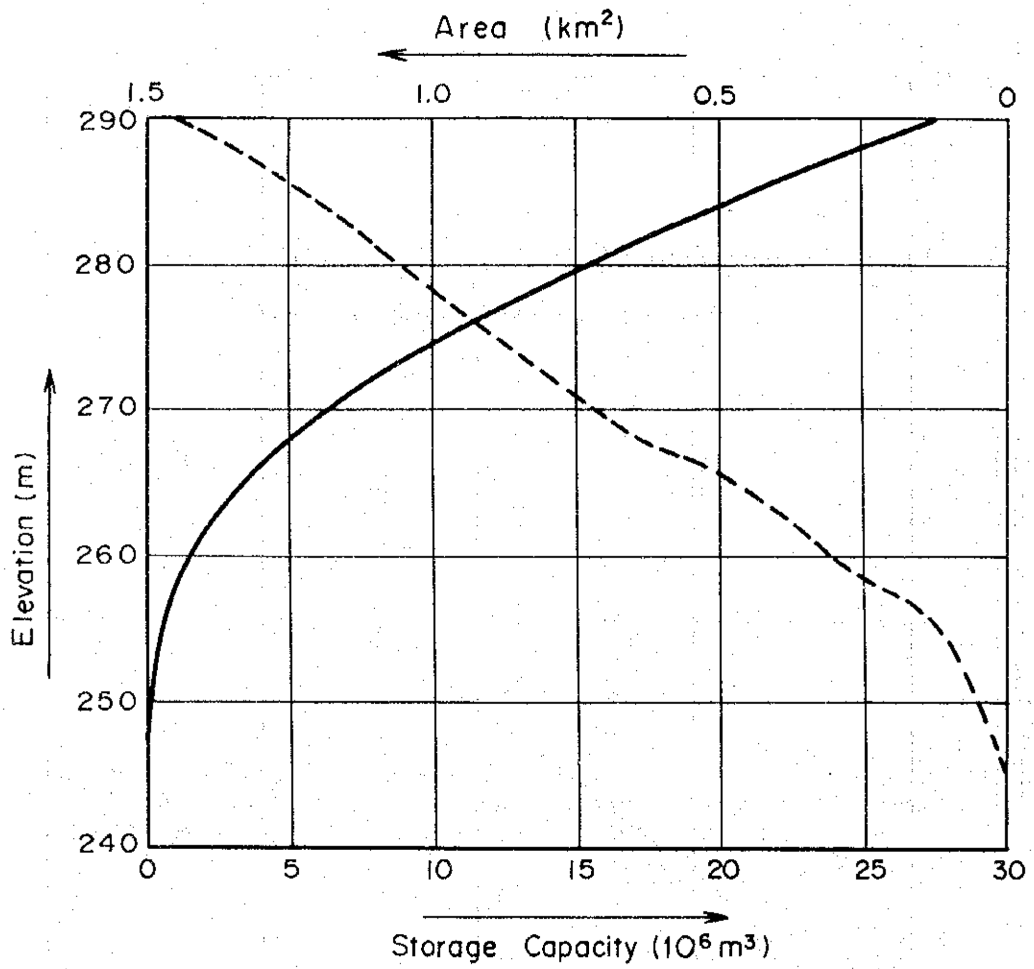
## Fig. 13.4-7 Firm Discharges provided by Xe Namnoy Midstream Reservoir




Note 1) This figure is prepared based on the mass-curve calculation for 10 years period with carry-over reservoir operation rule.

2) This figure is for the condition without diversion scheme from the Xe Pian River.

**Fig. 13.4-8 Area and Storage Capacity Curve of Xe Namnoy Downstream Reservoir**




| Elevation (m) | * Area ($km^2$) | Storage Capacity ($10^6$ $m^3$) |
|---|---|---|
| 290 | 1.44 | 27.7 |
| 285 | 1.22 | 21.0 |
| 280 | 1.06 | 15.4 |
| 275 | 0.89 | 10.5 |
| 270 | 0.72 | 6.5 |
| 265 | 0.47 | 3.5 |
| 260 | 0.30 | 1.6 |
| 255 | 0.12 | 0.6 |
| 250 | 0.05 | 0.1 |
| 245 | 0 | 0 |

* measured using 1/10,000 scale topographic maps

## 13.5 Remarks Regarding the Development Plan Inventory

Certain basic parameters of each project such as the reservoir HWL and tail water level (TWL) proposed in the studies on the optimum development plan at the Pre-feasibility Study stage present differences from the parameters proposed in the development plan inventory. Accordingly, in this section, as a reference, remarks are provided on the differences between the project parameters proposed in the two stages respectively. These remarks include the effects to the upstream and downstream projects.

However, the basic data such as the discharge data and topographic maps used in the Pre-feasibility study in this chapter are more reliable and accurate than that used in the study on the development plan inventory in Chapter 7. Also, the criteria applied in both studies also differ in their policies and purposes. It is, therefore, inappropriate to revise the development plan inventory by directly referring the study results in this chapter. In this connection, the inventory proposed in Chapter 7 is not revised in this study.

### 13.5.1 Se Kong No.4 Project

In the case of the Se Kong No.4 Project, the reservoir HWL and tail water level (TWL) were proposed with figures different from those of the development plan inventory. Accordingly, remarks are provided concerning the effect of the study results on the development plan inventory including the Se Kong No.3 and No.5 Projects.

**(1) Tail Water Level (TWL) and the Se Kong No.3 Project**

In the inventory plan, the tail water level (TWL) of the Se Kong No.4 Project was set to be EL.160m, and the reservoir HWL of the Se Kong No.3 Project located downstream was set to be EL.160m based on the riverbed elevation indicated on the 1/50,000 scale topographic maps. However, the 1/10,000 scale map provides a TWL of EL.145m for the Se Kong No.4 Project, thereby providing a 15m difference between the TWLs on each map.

This difference is, however, within an allowance, because the contour interval of the 1/50,000 maps is 20m in elevation and the elevations indicated on them include a 20m maximum error in general. Also, to retain a rational relationship between the basic parameters of the projects at both downstream and upstream, it is inappropriate to refer to the results of the study using 1/10,000 scale maps.

It is important, however, in further studies on the Se Kong No.3 Project to confirm the elevations in the reservoir area. Particularly, Sekong Town, the center of Sekong Province, is located in the reservoir area of the Se Kong No.3 Project and inundation of this town may provide a problem. Accordingly, clarification of the land elevation in this area is important.

**(2) Reservoir HWL and the Se Kong No.5 Project**

In this chapter, the reservoir HWL of the Se Kong No.4 Project was set to be EL.290m, against an HWL of EL.300m in the inventory plan. However, there is a 15m difference in the riverbed elevation at the dam site between the 1/50,000 and 1/10,000 scale maps.

By applying the elevation gap, the HWL of EL.290m on the 1/10,000 map is converted to EL.305m on the 1/50,000 map. In this connection, the gap with the HWL of EL.300m is an allowable error. Therefore, it is notable that the study result in this chapter does not affect the development plans of the Se Kong No.4 and No.5 Projects proposed in the inventory study.

In further studies, however, it is necessary to confirm the riverbed elevations at and around the dam site and the outlet site of the Se Kong No.5 Project.

### 13.5.2 Xe Kaman No.1 Project

Regarding the Xe Kaman No.1 Project, the reservoir HWL and tail water level (TWL) were proposed with figures different from those of the development plan inventory. Accordingly, remarks are provided concerning the effect of the study results on the development plan inventory including the Xe Kaman No.2 Project.

**(1) Tail Water Level (TWL)**

In the inventory plan, the tail water level (TWL) of the Xe Kaman No.1 Project was set to be EL.120m based on the riverbed elevation indicated on the 1/50,000 scale topographic maps. However, the 1/10,000 scale map provides a TWL of EL.125m for the Xe Kaman No.1 Project.

Here, the elevation difference between these is only 5m which is within the allowance and no effect is expected on the inventory plan.

(2) **Reservoir HWL**

In this chapter, the reservoir HWL of the Xe Kaman No.1 Project was set to be EL.260m, against an HWL of EL.280 m in the inventory plan.

As indicated above, however, the difference in the riverbed elevation at the dam site between the 1/50,000 and 1/10,000 scale maps is only 5m in contrast to a 20m difference in the HWL. In this connection, the HWL gap of 20m is at an effective level with regard to the 20m contour interval of the 1/50,000 map and does provide an effect on Xe Kaman No.2 Project in the inventory.

Here, the plan of the Xe Kaman No.1 Project with a reservoir HWL of EL.260m has been studied as an alternative in the inventory study in Chapter 7.

(3) **Xe Kaman No.2 Project**

As stated in (2), the Xe Kaman No.1 Project with an HWL of EL.260m provides an effect to the upstream Xe Kaman No.2 Project.

The dam site of the No.2 Project proposed in the inventory study, is located at the site with a riverbed elevation of EL.280m on the Xe Kaman River. This project provides an inferior B/C (less than 1.0) under the study policy aiming at the evaluation of hydropower potential. In this connection, the plan was proposed at the minimum development scale with an effective storage capacity of 20% of the mean annual inflow volume.

When the HWL of the Xe Kaman No.1 Project is EL.260m, a site approximately 8 km downstream is available for the dam site of the No.2 Project. This case provides room for the reservoir capacity of No.2 Project and it is, therefore, possible to propose a lower HWL. However, the incremental reservoir capacity is not large and the decrease of the HWL is small, since the valley is narrow along the river between the riverbed elevations from EL.280m to EL.260m. Accordingly, the effect of the HWL change in the No.1 Project to the inventory plan, which is aiming to evaluate the hydropower potential, is expected to be minimal.

Further, the Xe Kaman No.3 and No.4 Projects were proposed upstream of the No.2 Project, and these projects provide better economic performance than No.2 Project. No.1 Project also affects these projects. It is, therefore, recommended to review the overall development plan of the Xe Kaman River basin when the basic data such as topographic maps and hydrological data are prepared.

### 13.5.3 Xe Namnoy Project

Regarding the Xe Namnoy Project, the reservoir HWLs and TWLs of both the Midstream and Downstream Projects were proposed with figures different from those of the development plan inventory. Accordingly, remarks are provided concerning the effect of the study results on the development plan inventory.

#### (1) Xe Namnoy Midstream Project

In this chapter, the reservoir HWL of the Xe Namnoy Midstream Project was set to be EL.765m, against an HWL of EL.760m in the inventory plan. Since the elevation difference between them is only 5m which is within the allowance of the 1/50,000 scale maps, no effect is expected on the inventory plan.

#### (2) Xe Namnoy Downstream Project

In this chapter, the reservoir HWL of the Xe Namnoy Downstream Project was set at EL.270m, against an EL.280m HWL in the inventory plan. Comparing the elevations at the dam and powerhouse site of the Downstream Project indicated in both the 1/50,000 and 1/10,000 scale maps, the 1/10,000 map indicates elevations approximately 10m lower than those in the 1/50,000 map. Accordingly, the EL.270m HWL proposed in this chapter is equivalent to the HWL of EL.280m proposed in the inventory plan and provide no affect to the development plan inventory.

### 13.5.4 Summary of Proposed Projects

Features of the three projects proposed both in the hydropower potential study and in the pre-feasibility study are shown in **Table 13.5-1** for reference purpose.

## Table 13.5-1 Summary of Plans proposed in Hydropower Potential Study and Pre-feasibility Study

| Description | Potential Study | | Pre-feasibility Study | |
|---|---|---|---|---|
| **1. Basic conditions** | | | | |
| Scale of topographic maps | 1/50,000 | | 1/10,000 | |
| Discharge data period | 5 years | | 10 years | |
| Reservoir operation | Annual operation | | Carry-over operation | |
| Peak power duration | 12 hours | | 8 hours | |
| **2. Proposed Plans** | | | | |
| **Se Kong No.4** | | | | |
| Reservoir HWL | 300 | m | 290 | m |
| Effective Storage Capacity | 1,287 | MCM | 1,700 | MCM |
| Regulated Firm Discharge | 144 | $m^3/s$ | 143 | $m^3/s$ |
| Maximum Discharge | 288 | $m^3/s$ | 370 | $m^3/s$ |
| Rated Effective Head | 140 | m | 137.0 | m |
| Installed Capacity | 346 | MW | 443 | MW |
| Plant Factor | 63 | % | 47 | % |
| **Xe Kaman No. 1** | | | | |
| Reservoir HWL | 280 | m | 260 | m |
| Effective Storage Capacity | 833 | MCM | 1,270 | MCM |
| Regulated Firm Discharge | 93 | $m^3/s$ | 89 | $m^3/s$ |
| Maximum Discharge | 186 | $m^3/s$ | 228 | $m^3/s$ |
| Rated Effective Head | 159 | m | 129.9 | m |
| Installed Capacity | 255 | MW | 256 | MW |
| Plant Factor | 61 | % | 51 | % |
| **Xe Namnoy Midstream** | | | | |
| Reservoir HWL | 760 | m | 765 | m |
| Effective Storage Capacity | 255 | MCM | 250 | MCM |
| Regulated Firm Discharge | 25 | $m^3/s$ | 20.8 | $m^3/s$ |
| Maximum Discharge | 50 | $m^3/s$ | 60 | $m^3/s$ |
| Rated Effective Head | 446 | m | 463.0 | m |
| Installed Capacity | 192 | MW | 238 | MW |
| Plant Factor | 69 | % | 50 | % |
| **Xe Namnoy Downstream** | | | | |
| Reservoir HWL | 280 | m | 270 | m |
| Firm Discharge | 33.4 | $m^3/s$ | 24.0 | $m^3/s$ |
| Maximum Discharge | 100 | $m^3/s$ | 96.0 | $m^3/s$ |
| Rated Effective Head | 74 | m | 81.0 | m |
| Installed Capacity | 63 | MW | 67 | MW |
| Plant Factor | 61 | % | 57 | % |

Notes: 1) Location of projects in the potential study is shown in Fig.7.3-1.
2) Location of projects in the pre-feasibility study is shown in the beginning of the Report.

# 14. Preliminary Design of Main Structures

# 14. Preliminary Design of Main Structures

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# 14. Preliminary Design of Main Structures

## 14.1 General

In this chapter, the results of preliminary design which were carried out of three projects, the Se Kong No.4, Xe Kaman No.1 and Xe Namnoy, which were selected for the execution of pre-feasibility study as stated in the sub-section 7.4 in the Chapter 7 are described herewith.

As a basic concept of the preliminary design, the basic features and type of the structures based on the water level for intake, method of intake, power generation system and project scale which were chosen in the Chapter 13 "Selection of Optimum Development Plan" will be examined and the layout of the project, using the topographic maps of scale 1/10,000 which were presented in the study, will be finalized.

The outline of design is described herewith for these 3 projects in the pre-feasibility study.

## 14.2 Se Kong No.4 Project

### 14.2.1 Civil Structures

#### (1) General

Se Kong No.4 is only one project site which was selected in the main Se Kong River in the pre-feasibility study stage. In this project, a 164 m high dam will be constructed at the location about 18 km upstream from Se Kong town and the water will take out from a intake facility located in the right bank at the dam site and a power station is constructed at just downstream of dam and connect these structures by the waterway of 800 m length.

The major project figures designed for the Se Kong No.4 project are shown in **Table 14.2-1**.

Preliminary design of main structures are described hereinafter.

(2) **Dam**

On a topographic condition around the dam site, a river width is 160 m, which is rather wide and a gradient of the riverbed is gentle. The slope at the lower location of right bank is more gentle, and slope is 10° and above EL. 200 m, the slope is 40°, and also at the left bank, the slope is 40°, and above EL.200 m the slope is 20°. This means that the slope gradients are comparatively gentle, Also at just the upstream, the river flow suddenly turn the right and the slope become very gentle. Therefore, it was judged that the location of a dam axis is not variable from the location where was selected in the master plan study. A predicted profile of the main dam has about 900 m of crest length. From the topographic condition, a fill type of dam structure is recommended, but in case of a conventional zoning type, a dam volume was estimated to be more than 20,000,000 $m^3$. In this condition, from view points of heavy rainfall in wet season in the project area and comparatively a long construction period, it should be considered to minimize a dam volume and to apply construction method to be performed in a shorter period. A type of dam to meet these requirements is a concrete face rockfill dam (CFRD). Also in the case of this type of dam, a slope is generally set up steeper than the conventional type of the dam such as zone type fill dam. Slope of dam face were selected 1:1.4 for the both slopes, upstream and downstream, taking a low level of earthquake factor into consideration. Because in this area the geological age is old and comparatively stable and there is no remarkable records of damages by earthquakes. And a width of the dam at crest is 8 m.
Further to avoid any overtopping of flood, 5 m freeboard was added for the dam safety. Total layout of the dam structure is shown in **DWG. 14.2-1**.

(3) **Diversion Tunnel**

A flood discharge is a basic figure for design of the diversion tunnel. A flood discharge was decided by a hydrological analysis as follows;

| Return Period (Year) | Flood Discharge ($m^3$/sec) |
|---|---|
| 5 | 3,524 |
| 10 | 4,454 |
| 20 | 5,404 |
| 50 | 6,718 |
| 100 | 7,767 |
| 200 | 8,870 |

As a fill type dam was selected in this project, an overtopping from the top of dam shall be avoided. Therefore, a flood discharge in 20 years of return period was selected for design purpose.

Flood discharge at 20 year return period is 5,400 $m^3$/sec. To treat safely the said flood discharge, a tunnel diameter is required to be 12.5 m and number of tunnel is two lines. In this respect, a height of cofferdam is 35 m and the dam crest elevation is EL.180 m. An alignment of the diversion tunnel is shown in **DWG. 14.2-1**.

**(4) Spillway**

In case of a rockfill type dam, it shall be avoided to facilitate a spillway structure on the top of the dam body because of dam stability. Therefore, in general a spillway structure will be arranged in a separate location from the dam. In this project, a spillway will be located separately from the dam considering dam stability and site condition and topographic condition. Finally a location was selected in the left bank.

**a) Design Flood**

Design flood for examination was estimated from the hydrological analysis and it is 16,400 $m^3$/sec equivalent to PMF. However, hydrological data in the Se Kong Basin at this stage is not enough to examine the design of dam structures. Actually there is no data on records of floods and by this fact, examination of hydrograph to be produced from the flood records was not able to execute, so that a study on scale of spillway could not be done and therefore examination of spillway scale was checked in an assumption that all of the design flood is to be treated through the spillway at the high water level.

**b) Type of Spillway**

The high water level is E.L.290 m, and all of design flood shall be discharged at this water level. To meet this requirement, the bottom level of the spillway is EL. 272 m and the spillway structure is 136 m wide and 18 m high and total 8 units of the radial gate, 14 m width and 18 m height will be installed to discharge the design flood. The layout of the spillway is shown in **DWG. 14.2-1 and 14.2-2**.

### (5) Intake

#### a) Type of Intake

Intake level of the dam is 290 m at high water level and 275.4 m at low water level and this means that a range of water supply is comparatively limited and a sedimentation level is rather low level from the hydrological analysis. Therefore, a location of the intake has not specific restriction for selection, but as an intake for dam type power station, from the total layout the location was selected at a small valley in the right bank. The inlet level of the intake was selected at EL.263.1 m in order to protect an occurrence of air sanction, and also for maintenance and inspection of the headrace tunnel, it is considered to install a gate between the intake structure and headrace tunnel..

#### b) Capacity of Intake

A total discharge from the reservoir for power generation is 369 $m^3$/sec at maximum. This is for four units of generator and from this point layout of a waterway was examined and then the design of intake was selected as a symmetric type. There are two inlets in a symmetric arrangement. The location of the intake is shown in **DWG. 14.2-1**.

### (6) Waterway

As a route of waterway, it was considered that two lines of tunnel from the intake will be arranged and the tunnel goes through mountain at right bank and comes out from the mountain at downstream side and be connected to a penstock route. The penstock route goes down directly to the powerhouse. Following this concept, the preliminary design of waterway structures was executed.
A general layout is shown in **DWG. 14.2-1**.

#### a) Headrace Tunnel

Two lines of the pressure tunnel was selected to connect from the intake inlet at EL.263.1 m. Tunnel diameter was set 6.2 m and the length are 315 m and 365 m, respectively.

b) **Penstock**

A penstock is connected from the outlet of the tunnel and the penstock is extended to rear side of a powerhouse along the downstream slope, of which a slope has about 30 degrees.
As a exact data on weathering of rock is not available, so that a penstock pipes is extended 70 m into the mountain to resist a rock pressure. A type of the penstock is ring girder type and supported by anchor block and a number of saddles. The total length of penstocks are 440 m in both tunnels. A diameter of the penstock pipes are 5.4 m in general, but after bifurcation the diameter will be 4.5 m and 4.0 m, respectively to meet each scale of turbine.

(7) **Powerhouse and Switchyard**

A type of the powerhouse was decided as semi-underground below EL.154.5 m which is a level of generator , judging from the topographic condition.
A scale of the powerhouse is different due to type of turbine and generator and manufacturers even in the same capacity, and therefore, a required space will be changed.
By considering a general scale and type, and generator size, number of unit, and etc., a scale of the powerhouse was decided as width : 20 m, height : 43 m, and length : 100 m.
Also a switchyard will be arranged at the opposite bank. Total layout of the powerhouse is shown in **DWG. 14.2-1** and layout of powerhouse building. is shown in **DWG. 14.2-4**.

(8) **Tailrace**

A tailrace will be located at just downstream of dam, checking the topographic maps, but considering that a switchyard is to be constructed as closed to the powerhouse, the area for the switchyard will be prepared by backfilling of the riverbed at downstream of the dam. Therefore, the tailrace structure is culvert type and the draft tube will be arranged to face to downstream side. The size of the tailrace structure is 12 m width, 18 m height, and 100 m length.

(9) **Access Road**

Road conditions in the southern part of Lao PDR as described at Section 8.5 in Chapter 8, are not enough for use as access road for the project. Especially in discussing the condition for the Se Kong No.4 project, route No.16 connects between B. Thateng in north terminal and Attapu in south terminal, however, the nearest village to the project site is B. Phon and it is 18 km from this village to the project site. There is a village road on the way , but after that there is no road which mobile can pass. By this reason, for the performance of the project, it is necessary to construct a new road between B.Phon at the junction with National road No.16 and the dam site. In this preliminary design of pre-feasibility study, in this section total 15 km, improvement and new construction are considered. Road design is 7 m width and two lanes for traffics and paved with gravel material.

### 14.2.2 Generators and Components

#### (1) Selection of Number and Capacity of Unit

The output of the Se Kong No. 4 Power Plant is planned to be 443MW. There are several conceivable combinations of number and capacityof units to satisfy this output. But the fewer number of units is, the lower the construction cost becomes. 2 or 3 units will be optimum in providing the required economical performance.

However, it is necessary to ensure a 30 $m^3$/sec river retaining flow for 24 hours for the Se Kong No. 4 Power Plant. There are two methods to discharge this river retaining flow to the downstream through the turbine/generator; install a dedicated turbine/generator or determine the number and capacity of units so that those turbine/generator can operate at a minimum 30 $m^3$/sec flow.

Regarding a plan to install the dedicated turbine/ generator for river retaining flow, the retaining flow is relatively large at 30 $m^3$/sec. Its output will be approx. 80MW. This plan was not accepted this time as its designs for a back-up system against accidents, the powerhouse layout, penstock, and headrace would be complicated.

Therefore, despite the merit of its smaller scale, a combination of 4 units; 2 large turbine/generators (125 $m^3$/sec) and 2 small turbine/generators (60 $m^3$/sec) has been determined. The Francis turbine is available for the effective head as it is operational with approx. 30% - 40% flow of the maximum flow. The river retaining flow is equivalent to a 50% flow. It should be operate with no cavitation or vibration problems. Also, its design specifications are the same for either penstock or headrace due to a 2-unit combination each. the powerhouse layout is also simplified.

A combination of 5 units will also overcome the river retaining flow operation. However, it will lost the scale merit significantly. Also, the penstock, number of headrace and the inner diameter of the headrace become combinations of 2 and 3 units. For these reasons, it was not employed.

In the next Feasibility Study stage, it is necessary that the optimum selection of number and capacity of units be re-checked by considering the measures for the river retaining flow, turbine/generator operation conditions, transport conditions, and the cost of not only the electrical components, but also the construction cost of the civil structures.

The output of each turbine/generator was calculated as below;

Large turbine/generator $= 9.8 \times He \times Q_{tmax} \times \eta_{TL} \times \eta_{GL}$
$= 9.8 \times 137\ m \times 125\ m^3/sec \times 0.914 \times 0.979$
$\fallingdotseq 150{,}000\ kW$

Small turbine/generator $= 9.8 \times He \times Q_{tmax} \times \eta_{TS} \times \eta_{GS}$
$= 9.8 \times 137\ m \times 60.0\ m^3/sec \times 0.912 \times 0.976$
$\fallingdotseq 71{,}500\ kW$

### (2) Type and Ratings of Major Equipment

The vertical shaft Francis turbine is appropriate considering the maximum discharge and effective head. The vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine. Since the large turbine/generator is revolving at 180rpm, umbrella type generators were selected. The semi-umbrella type generators were selected for the small turbine/generators.

The rated power factor of this generator is 0.85 to contribute to voltage control in the power system in response to the long distance transmission from the load end. The transmission lines from Se Kong No.4 to Roi Et Substation in load side via Ban Houaykong Substation are long distance and one direction transmission. Since above condition of the system is very difficult caused by the Ferranch Effect in night time and voltage drop in heavy load time. The selection of power factor would be re-studied in the next Feasibility Study taking into these transmission consideration.

Considering the transportation condition (max. 30 tons), 3 outdoor oil filled single phase transformers were selected for each unit as the major transformers in response to the increase from generator voltage to the system transmission voltage of 230kV.

The combination of single bus and transfer bus, as in Nam Ngum, was selected for the switchyard. The switchyard equipment is a conventional type. It is also possible to use a Gas Insulated Switchgear (GIS) when considering reduction of the switchyard area and simple maintenance. It is necessary that this matter be studied in the next Feasibility Study or in the Detailed Design stage. The switchyard is equipped with a terminal equipment with a 22kV transmission line to supply electricity to the local load and an interconnected transformer to step down from 230kV to 22kV.

Since this will be an important power plant, a diesel power generator will be installed as an emergency facility to back-up the power source in the plant. The single-line diagram is shown in **Fig. 14.2-1.**

The ratings of major electro-mechanical equipment are as follows ;

**Large Water Turbine**

| | |
|---|---|
| Type | Vertical shaft, Francis |
| Number of units | 2 |
| Normal effective head | 137.0 m |
| Maximum discharge | 125 $m^3$/sec |
| Turbine output | 150,000 kW |
| Revolving speed | 180 rpm |

**Small Water Turbine**

| | |
|---|---|
| Type | Vertical shaft, Francis |
| Number of units | 2 |
| Normal effective head | 137.0 m |
| Maximum discharge | 60.0 $m^3$/sec |
| Turbine output | 71,500 kW |
| Revolving speed | 250 rpm |

**Large Generator**

| | |
|---|---|
| Type | Three phase, alternating current, synchronous |
| Number of units | 2 |
| Output | 174,000 kVA |
| Power factor | 0.85 lag |
| Voltage | 15.4 kV |
| Frequency | 50 Hz |

| | |
|---|---|
| Revolving speed | 180 rpm |

**Small Generator**

| | |
|---|---|
| Type | Three phase, alternating current, synchronous |
| Number of units | 2 |
| Output | 86,200 kVA |
| Power factor | 0.85 lag |
| Voltage | 15.4 kV |
| Frequency | 50 Hz |
| Revolving speed | 250 rpm |

**Large Main Transformer**

| | |
|---|---|
| Type | Outdoor, oil filled, single phase |
| Number of units | 2 set ( 6 units) |
| Capacity | 174,000 kVA |
| Voltage primary : | 15.4 kV |
| secondary : | 230 kV |

**Small Main Transformer**

| | |
|---|---|
| Type | Outdoor, oil filled, single phase |
| Number of units | 2 set ( 6 units) |
| Capacity | 86,200 kVA |
| Voltage primary : | 15.4 kV |
| secondary : | 230 kV |

**Outdoor Switchyard**

| | |
|---|---|
| Bus system | Single bus + transfer bus |
| Bus | Aluminum line |
| Number of transmission lines connected | 230 kV × 1 cct |
| | 22 kV × 2 cct |