KATHMANDU UNIVERSITY
End Semester Examination
February/March, 2018

Marks Scored:

Level : B.E.
Year : IV
Exam Roll No. :

Time: 30 mins.

Course : CIEG 406
Semester : I
F. M. : 10

Registration No.:

Date : MAR 0 7 2018

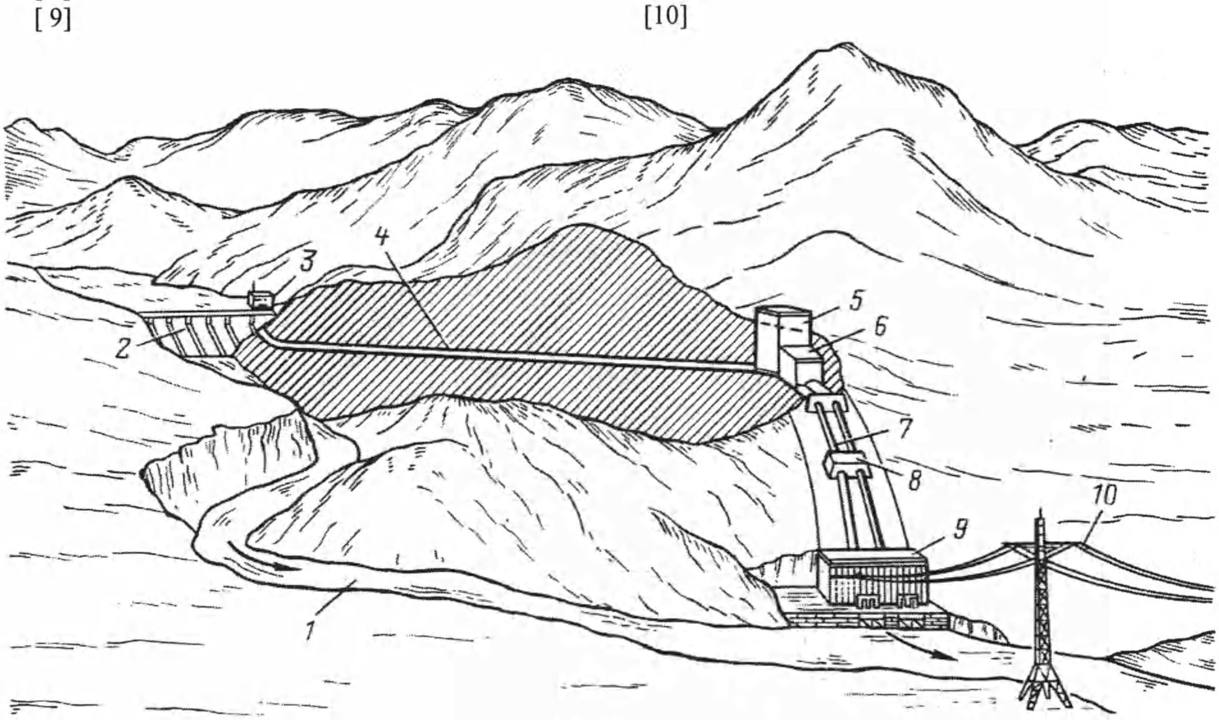
SECTION "A"
[20 Q. × 0.5=10 marks]

Multiple choice question; Tick only the best answer.

1. Recommended type of generator and phase of a 10 kW micro-hydropower plant are:
   [ ] Induction generator, Three phase only
   [ ] Synchronous generator, Three phase only
   [ ] Synchronous generator, Single phase
   [ ] Synchronous or induction, Single or three phase

2. Which technological intervention was applied for solving the hydro-fracture problem during the construction of waterways at Upper Tamakoshi HEP?
   [ ] Reduced slope of headrace Tunnel and using the vertical power shaft to connect the original vertical power shaft.
   [ ] Kept high slope of headrace Tunnel and using the vertical power shaft to connect the original vertical power shaft.
   [ ] Reduced slope of headrace Tunnel and using the vertical power shaft then after.
   [ ] Kept high slope of headrace Tunnel and using the vertical power shaft then after.

3. What type of power plant is this (Sketch)? Name all the components of it in the blanks as numbered
   [ ]
   [ 1] [ 2 ]
   [ 3] [ 4 ]
   [ 5] [ 6 ]
   [ 7] [ 8 ]
   [ 9] [10]



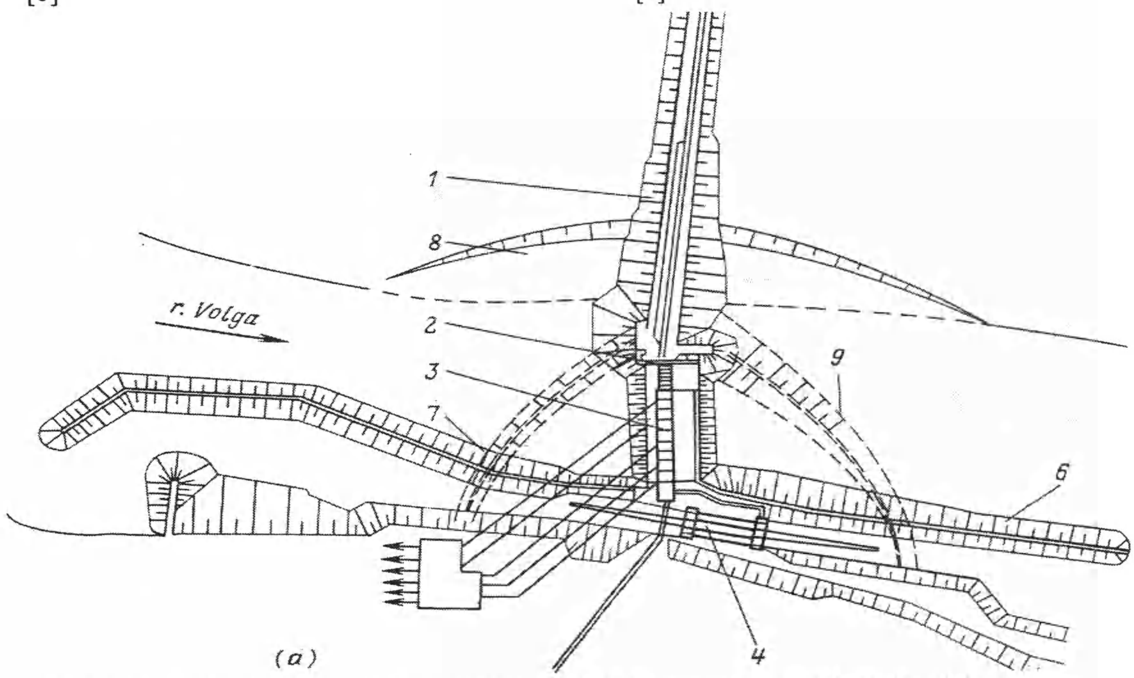

4. The physical sense of hydropower engineering is
   [ ] To gain the otherwise lost kinetic energy
   [ ] To obtain the energy obtained in the water through the construction of civil structures
   [ ] To best utilize the available head and discharge for the production of electricity through the electrical and mechanical means
   [ ] To gain the otherwise lost potential energy in overcoming the frictional resistance imposed by the river beds and the banks

5. The salt dilution method of stream measurement is ideally suitable in
   [ ] A large alluvial river
   [ ] Flood flow in a mountain stream
   [ ] Steady flow in a small turbulent stream
   [ ] A stretch of river having heavy chemical loads.

6. The maximum surge height Zmax =+-vo*SQRT(L/g * A/Ast) is determined by equating
[ ] internal energy in the tunnel and potential energy in the surge tank
[ ] kinetic energy in the surge tank and potential energy in the tunnel
[ ] kinetic energy in the tunnel and internal energy in the surge tank
[ ] kinetic energy in the tunnel and potential energy in the surge tank

7. What type of power plant is this (Sketch)? Name all the components of it in the blanks as numbered

[ ] [1]
[2] [3]
[4] [5]
[6] [7]
[8] [9]



(a)

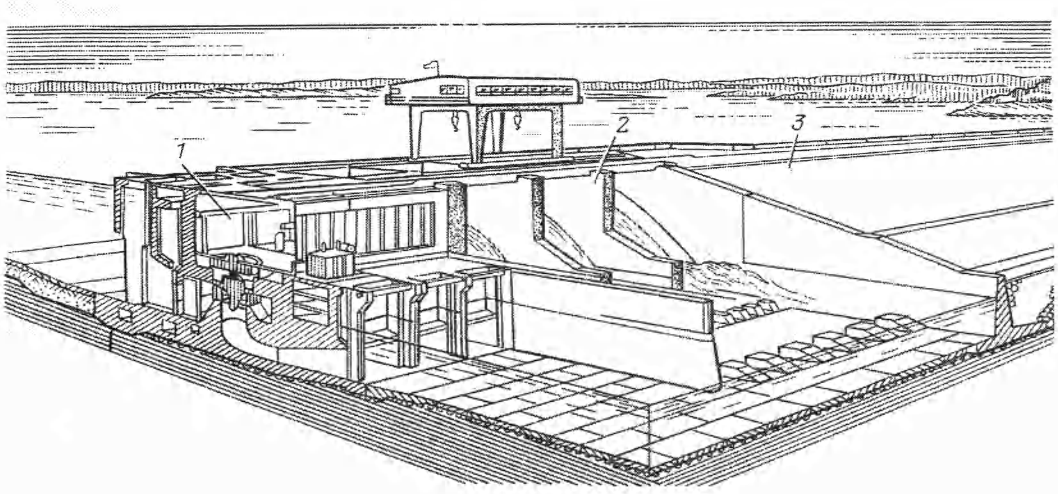
8. If the peak load on a plant with a capacity 141MW in a week was 99MW and the energy produced by the plant was 7.89GWh,then the capacity factor and load factor for the week are respectively
[ ] 33.31% & 47.44% [ ] 31% & 46% [ ] 34.21% & 48.44% [ ] 30% & 45%

9. Nepal's first mega size Hydro Power Project from private sector has ---------------- of power generating capacity
[ ] 542 kW [ ] 240 kW [ ] 500 kW [ ] 60 MW

10. What is the power needed by a pump to draw water at 200 lps at the height 100m above if the pump efficiency is 80%
[ ]156.96 kW [ ] 245.25 W [ ] 245.25 kW [ ]156.96 W

11. What type of power plant is this (Sketch)? Name all the components of it in the blanks as numbered.

[ ] [1]
[2] [3]



12. Which one of the following is PROR type Hydropower plants?

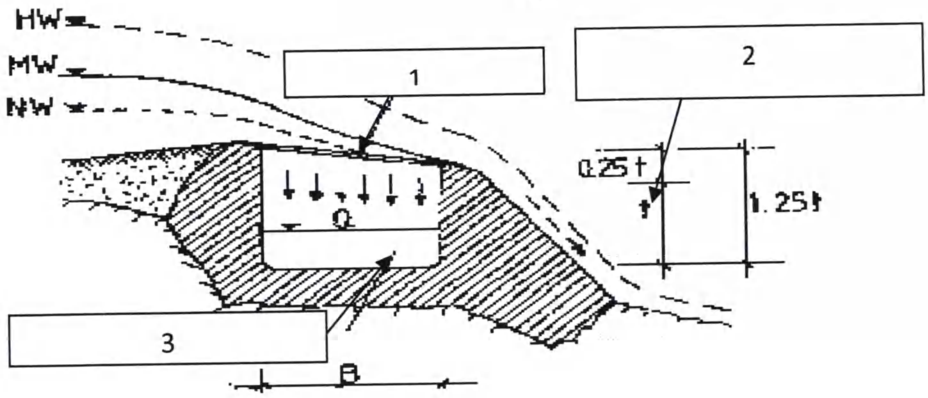
[ ] Bhotekoshi  [ ] Indrawati III

[ ] Khimti  [ ] Sunkoshi

13. What type of intake is this (Sketch)? Name all the components of it in the blanks

[ ]  [1]

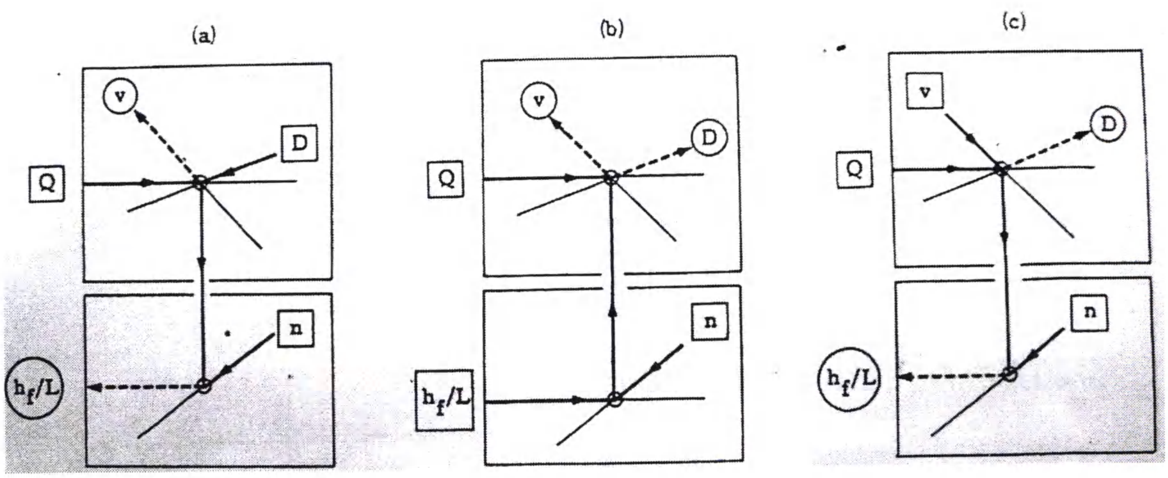
[2]  [3]




14. What is the purpose of these charts? What elements to be given and what elements to be found out in (a), (b) and (c) and what these symbols mean?

[ ]  [a]

[b]  [c]




15. What type of weir is this (Sketch)? Name all the components with symbols on relevant numbers and give the formula in the blank no. 9

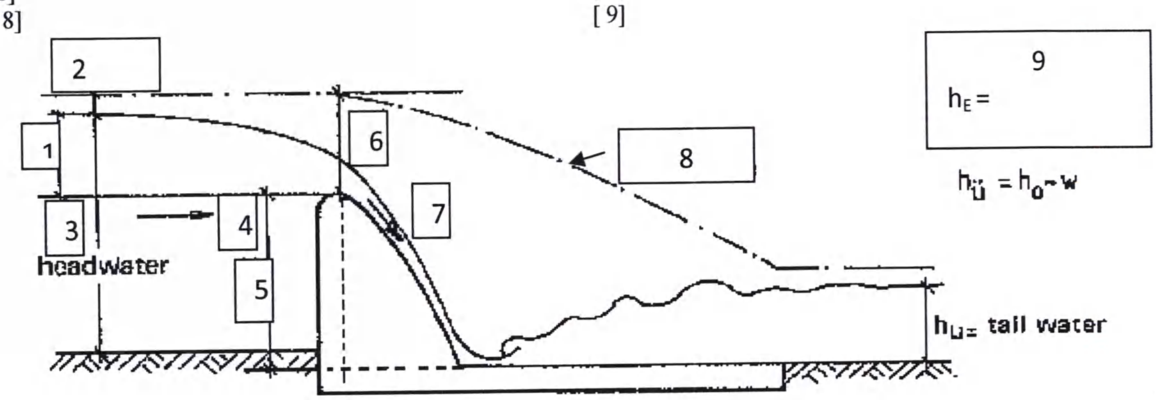
[ ]  [1]

[2]  [3]

[4]  [5]

[6]  [7]

[8]  [9]




16. What are the elements necessary to be implemented during Reactivation, Upgrading and Modernization of a hydropower plant? [2]

[ ]  [ ]

[ ]  [ ]

[ ]  [ ]

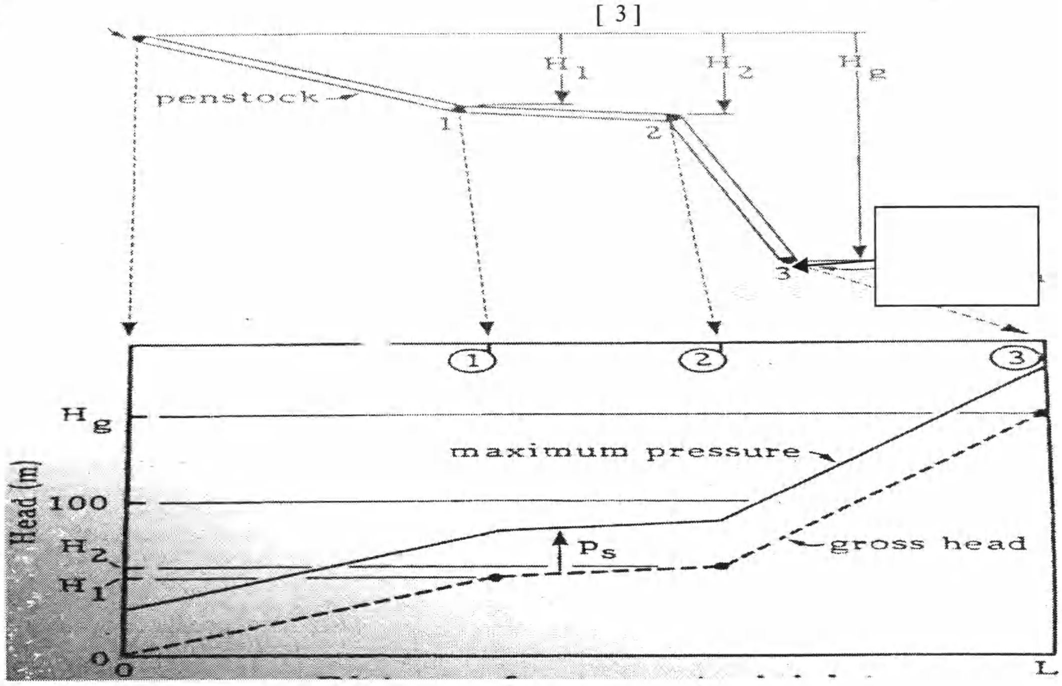
[ ]  [ ]

17. The Terms' of Reference of Hydropower Plant for a consultant basically is a:

[ ] Document of a part of Project Development Agreement (PDA)
[ ] A Document of Agreement between the owner and the consultant
[ ] Document that describes all the components of a hydropower plant
[ ] Document that describes the major concern of an owner for a particular hydropower project

18. What is the purpose of this sketch? Name all the components of it in the blanks

[ ] [$H_g$]
[$p_s$] [ 3 ]



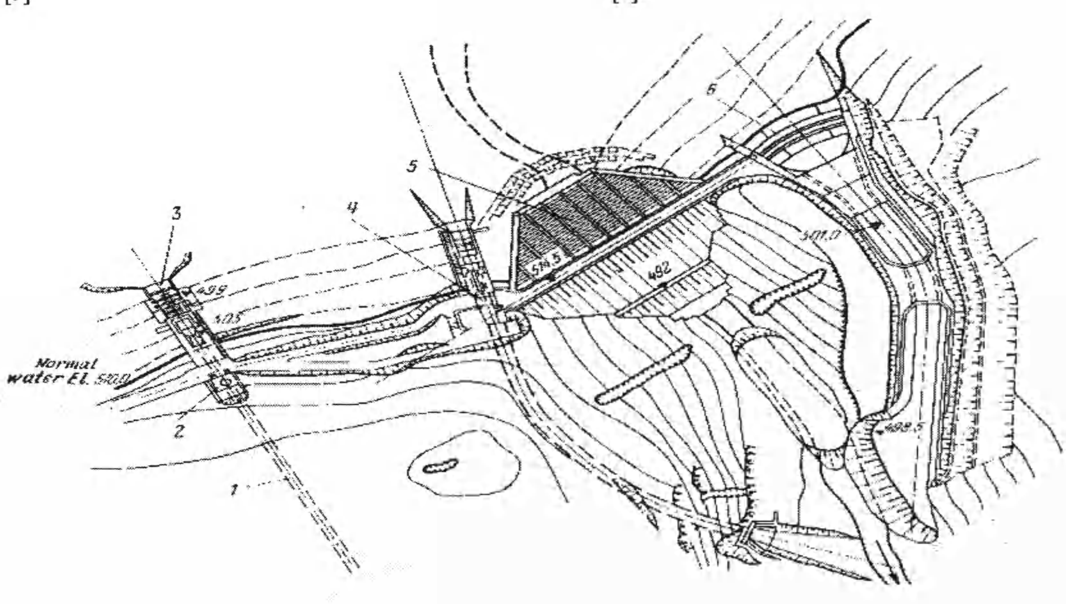

19. Find out the correct sequence according to water resources policy:

a. Drinking water and domestic users;
b. Cottage Industry, industrial enterprises;
c. Navigation;
d. Recreational uses;
e. Irrigation,
f. Agricultural uses such as animal husbandry and fisheries;
g. Hydroelectricity;
h. Other uses.

[ ] a,b,c, d,e,f,g,h
[ ] a,e,f,g,b,c,d,h
[ ] a,c,d,b,e,f,g,h
[ ] a,b,d,e,c,f,g,h

20. By examining the sketch, name all the components of Headworks in the blanks as indicated by respective number

[1] [2]
[3] [4]
[5] [6]



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## SECTION "B"

[Short answer questions]

Critical thinking. Attempt *ONLY TWO.* [16]

1. Build a general framework for planning an integrated river basin's water resources by enlisting the essentials, which would address the issues of Water rights, integration, coordination, dispute resolution, stakeholder participation etc that should be taken into consideration for the planning process. Briefly account the international law on Water Resources giving an example of one known country. What is the way forward for cooperation with India on the development of hydropower and multipurpose projects? [8]

2. Is hydropower a blessing or a curse in Nepal? Give your candid opinion on why people make use it as a blame game. Enumerate the important provisions for sharing electricity royalty as benefits to project affected people under the Local Self Governance Regulations (2056) and the Hydropower Development Policy (2058). [8]

3. Write in short the essentiality of tunneling in hydropower project by describing the types of tunnel supports that are popular in Nepal. How best do you think the construction management should be done to complete a hydropower construction within the stipulated budget and time? Name and sketch all the groups of underground diversion type projects. [8]

4. Attempt *ANY TWO*: [8]

   - What is Flow Duration Curve? How it can be used in Hydropower Project Planning? Show analytically and graphically how the FDC can be developed from a set of hydrological time-series data.
   - What is Load Curve? How are the Load Factor, Capacity Factor, and Utilization Factor interrelated?
   - Draw, with neat sketch, the forces acting on a typical gravity dam and state the Conditions of Stability (COS)? How to improve such COS?
   - What is the importance of a de-sanding basin in a hydropower project? How it the guidelines for its design? Site a de-sander in a typical headwork arrangement.
   - What are the surges in water conveyance structures, and how they are mitigated? How do you find the need of a surge chamber in the conveyance system of a hydropower project?
   - What are the types of turbines used in hydropower projects and what are their selection criteria? Showing an empirical chart, describe how a particular turbine is selected for a design at feasibility stage.

## SECTION "C"

[Long answer questions]

Analytical. Attempt *ONLY TWO.* Assume necessary data appropriately if missing [24]

5. A license to conduct the feasibility study of a seasonal storage type multipurpose project for hydropower, irrigation, drinking water and flood protection on a river in Nepal has been obtained from Department of Electricity Development with an approximate area delineated (outer rectangle) as shown in topomap Fig 1 by a hydropower developer. The Nepal Electricity Authority will be ready to do PPA at NRs 7/- for Summer (spill) energy and NRs 12 /- for Winter (regulated) energy for storage project. The hydropower developer hires you as a consultant to conduct the study. Assume that a 66kV/220kV Transmission system with substation is available at a distance of 10 km downstream of the powerhouse site from where the power will be evacuated to the National Grid. A river hydrograph data is given in the Table 1 (attached at the end) you may choose a storage type plant with a design discharge of $Q_{20\%}$ for which: [12]

a. Delineate appropriately in Fig. 1 the reservoir inundation contour area at a flood water level at 1900 amsl, intake above dead storage, tunnel, Powerhouse and tailrace sites on the topomap to gain a head of ~ 675m on plan and profile. You may propose extension of licensed area if needed to gain the maximum head (hints: waterways shown). [4.5]

b. Show the spillway location nearby the Dam. [1]

c. Plot the hydrograph and corresponding flow-duration curve to find out the seasonal storage for hydropower, irrigation, drinking water, flood protection together and spillway design at the rate of 100 $m^3/s$, 10 $m^3/s$, 5 $m^3/s$, 500 $m^3/s$ and 1000 $m^3/s$ throughout the year as given in Table 1.[2]

d. The design discharge at $Q_{20\%}$ is planned to be carried through a tunnel with diameter 5 m. The roughness coefficient of the pipe $k_s$ is 0.03mm. Assume $\upsilon=1.13 \times 10^{-6}$ $m^2/s$ [1]

- Determined velocity $v_o$ using HRS (see attached chart) chart (if the chart is not applicable determine it analytically). [0.5]
- Find the head loss in the pipe, using explicit formulas of Moody or Barr [0.25]
- Check the necessity for installing a surge tank ($T_s$>3 to 6 s) [0.25]

e. Calculate Installed capacity, firm capacity and total energy stored in the reservoir, total cost, total benefit, Benefit-cost ratio and Simple payback period of the proposed hydropower plant with 55% of plant factor using the format suggested in Table 4. Overall efficiency of the plant is 85%. The specific cost of power plant for option one is NRs. 400,000/kW. [0.25×10=2.5]

6. A Pump-storage Hydropower Project (PSHP) is an important component of INPS for its long-term sustainability and KU is interested to advise the concerned authority for the use of PSHP. It is also essential to be independent from import of electricity from neighboring countries and to end the load shedding for industry and to replace the diesel generator for 4 peak-hrs daily. Fortunately, Nepal is boon to have sites available for PSHP and the use of renewable energy. Water is delivered from the upper impounding reservoir, which is a natural lake, through a low-pressure tunnel and four high-pressure penstocks to the four reversible (pump-turbine) units. The tunnel and penstock is supposed to be separated by a simple surge chamber of 6 m diameter to cope with the transient in waterways. Due to ecological reason, only 65% of maximum reservoir storage of $25*10^6$ $m^3$ can be utilized continuously for a period of 4 hours in Turbine Mode (TM). The volume of lower reservoir, which is also a natural lake, is only $5*10^6$ $m^3$ to store incoming discharge from its rivers. The following data are available from Table 2: [12]

Table 2:

| Given | Symbol | Value | Unit | Mark |
|---|---|---|---|---|
| Elevation of the Impounding Reservoir water level | HWL | 1500 | mamsl | |
| Elevation of the downstream reservoir water level | | 1440 | mamsl | |
| Total volume of Impounding Reservoir (IR) | $V_{IR}$ | $25*10^6$ | $m^3$ | |
| Period of turbine mode (TM) | $T_{TM}$ | 4 | hrs | |
| Period of pumping (PM) | $T_{PM}$ | 4 | hrs | |
| Length of low-pressure tunnel | $L_T$ | 0.5 | km | |
| Diameter of low-pressure tunnel | $D_T$ | 5 | m | |
| Friction factor of low-pressure tunnel | $f_T$ | 0.028 | - | |
| Number of High pressure Penstock | n | 4 | Nos. | |
| Length of each Penstock | $L_P$ | 60 | m | |
| Diameter of Penstock | $D_P$ | 3 | m | |
| Friction factor of Penstock material | $f_P$ | 0.016 | - | |
| Turbine efficiency in Turbine Mode | $\eta_{TM}$ | 90 | % | |
| Turbine efficiency in Pump Mode | $\eta_{PM}$ | 80 | % | |
| Efficiency of Generator in Turbine Mode (Generator with 16 poles, 50 Hz) | $\eta_{GTM}$ | 90 | % | |
| Efficiency Generator in Pumping Mode | $\eta_{GPM}$ | 90 | % | |
| Barometric pressure | BP | 10.3 | m of water column | |
| Thoma's Cavitation coefficient | $\sigma_{TH}$ | $0.043*(n_s/100)^2$ | - | |

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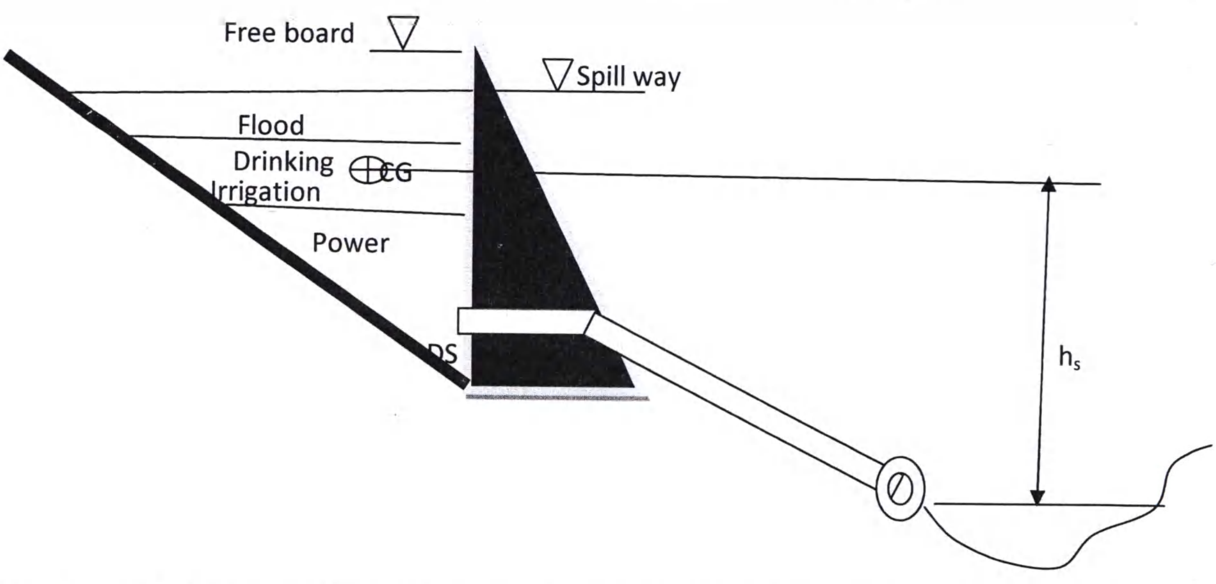
7. Design Penstock for above mentioned PSHP. The required data is given in Table 3 below: [12]

| Given | Symbol | Value | Unit | Remarks |
|---|---|---|---|---|
| Diameter of Penstock | DPS | 3 | m | |
| Total Turbine Discharge | $Q_t$ | 1085 | $m^3/s$ | With 4 bifurcation |
| Gross head | Hg | 60 | m | |
| Total length of Penstock | $L_P$ | 60 | m | |
| Young's modulus of Elasticity | (E) | 2110000 | $kg/cm^2$ | |
| Allowable hoop stress | (σ) | 1400 | $kg/cm^2$ | |
| Joint Efficiency | $\eta_j$ | 0.9 | - | |
| Density of Steel | (ρ) | 7850 | $Kg/m^3$ | |
| Bulk modulus of water | (B) | $1.96 \times 10^9$ | $N/m^2$ | |
| Ultimate tensile strength = | UTS | 410 ×106 | $N/m^2$ | |
| Density of water= | (γ) | 1000 | $kg/m^3$ | |
| **Assumptions** | | | | |
| Life span of Penstock | (n) | 35 | years | |
| Cost of Energy | COE | 12 (dry month)<br>7 (wet month) | NRs/kWh | See Fig.6 total energy in a typical dry month |
| Cost of Energy | COE | 13 (dry peak hr)<br>8 (dry off peak) | NRs/kWh | See Fig.6 for total peak and off-peak energy every day |
| Peak hour time and duration | $P_{peak}$, T | 16:30-20:30, 4 hrs, | kW, hrs | |
| Dynamic head (35% Hg) | $h_d$ | | m | |
| Friction factor | f | 0.0465 | - | |
| Gate closer time | $T_c$ | 40 | s | |
| Coefficient of pipe entrance | $K_{entrance}$ | 0.2 | - | |
| Coefficient of pipe bend | $K_{bend}$ | 0.3 | - | |
| Coefficient of pipe contraction | $K_{contraction}$ | 0.5 | - | |
| Coefficient of pipe expansion | $K_{expansion}$ | 0.3 | - | |
| Dynamic viscosity of water at 20°C | μ | 1.002 | N s/m²) x $10^{-3}$ | |

8. Attempt both questions [12]

a) For the given figure, calculate the total energy stored in the reservoir having volume of 5x106 m3 and the mean power that can be generated from the hydropower plant, whose turbine is, located 150 m below the dam base from its Center of Gravity (CG). The overall efficiency of the turbine is taken as 80%. Take the shape of reservoir as triangular as shown in Fig 2. [4]




b) A micro-hydropower plant has to be implemented at an altitude of 3000 m in a National Park to get the permission from the park authority. The ambient temperature inside the powerhouse during midsummer afternoons can be up to 18° C. You will proceed with (a) the preliminary selection of an appropriate turbine by looking at the specific speed $n_q$ in Fig 3 (b) the determine the generator rating in kVA with 50 Hz frequency and has 2 pair poles and (c) find the type of the hydropower project which operates under a discharge of 400 l/s and a gross-head of 60 m. Take the overall plant efficiency of 60 % and head loss 5%. To control the power output, an ELC with ballast load is suggested and the villagers also plan to use tube lights. Use the appropriate data from Table 4 below. Give your conclusive remarks on your result. [2+2+2+2=8]

**Charts, if used, to be attached to your answer sheets**

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Table

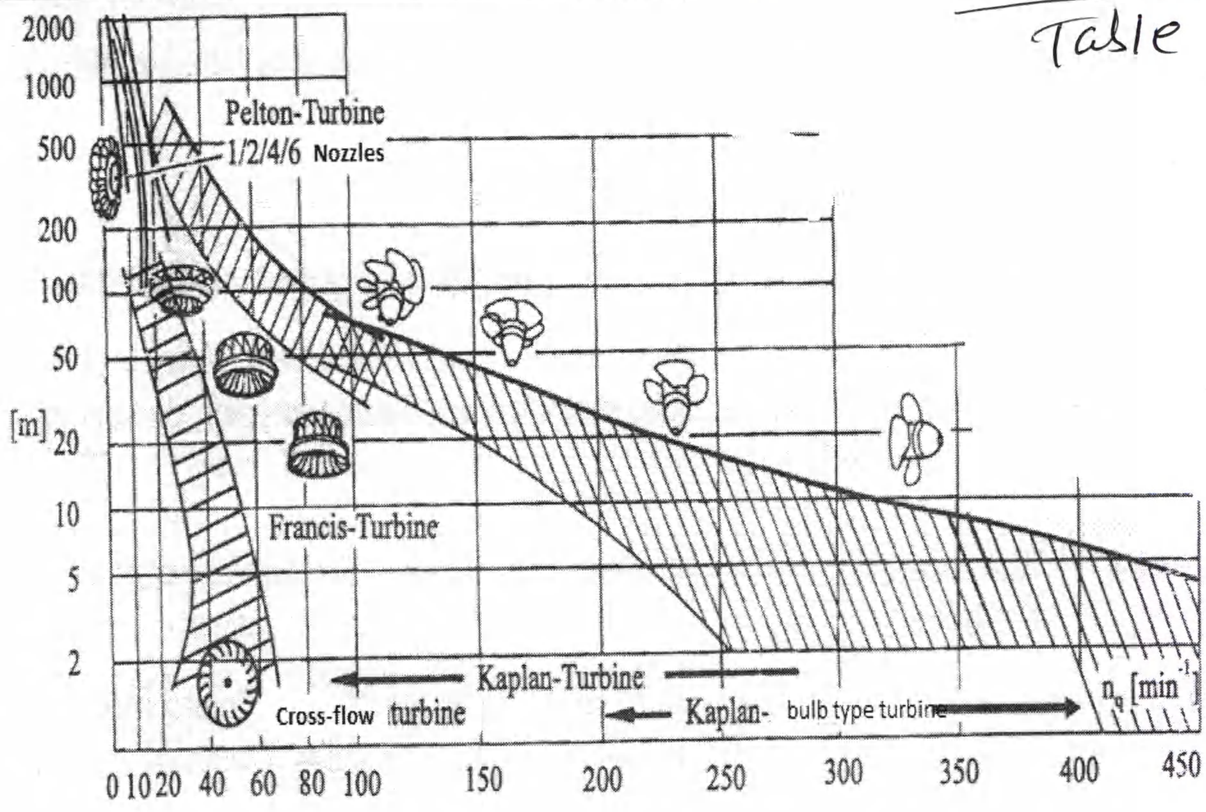


Fig. 3: Head vs specific speed curve for the preliminary determination of turbine type

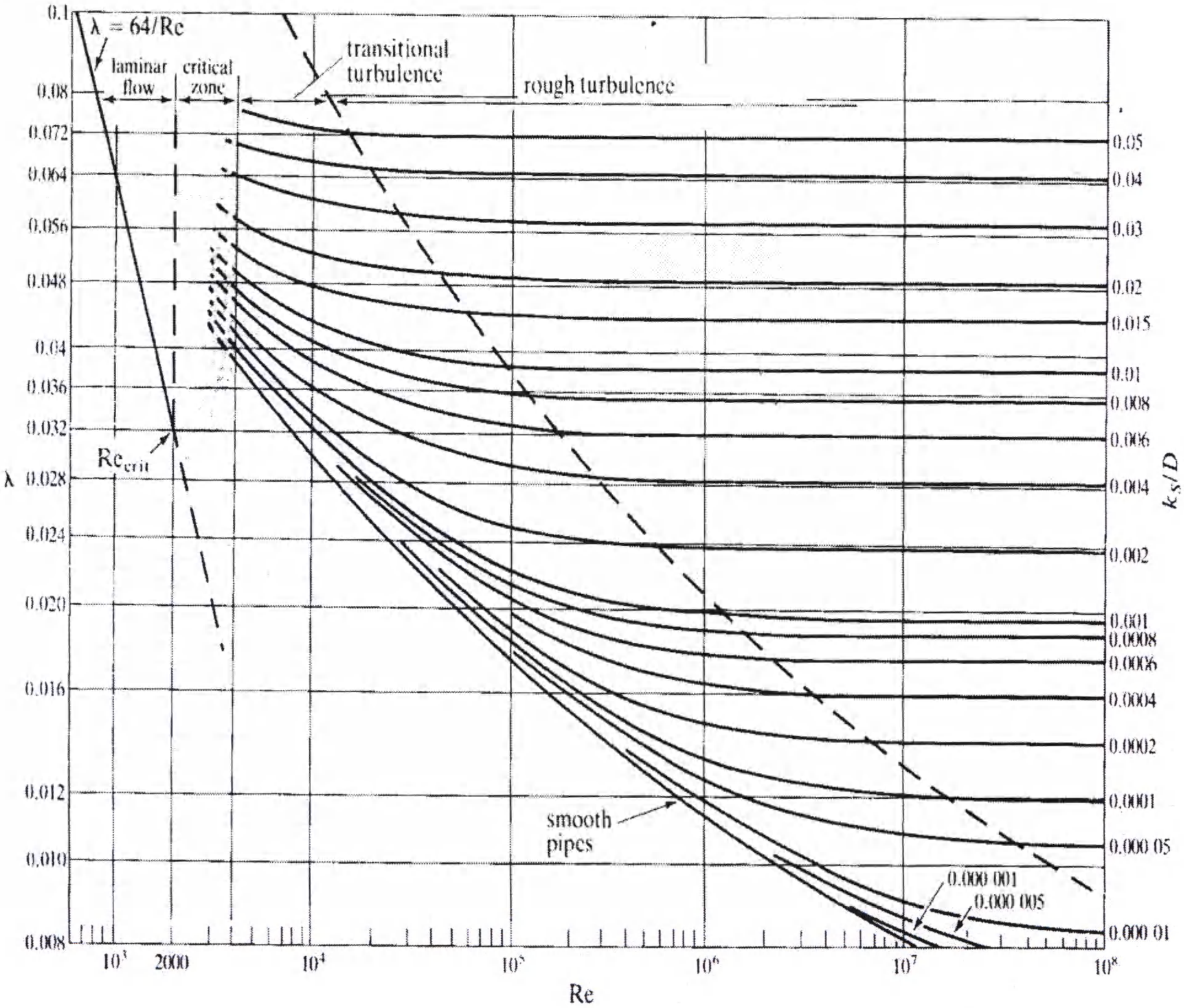


Fig. 4: The Moody diagram

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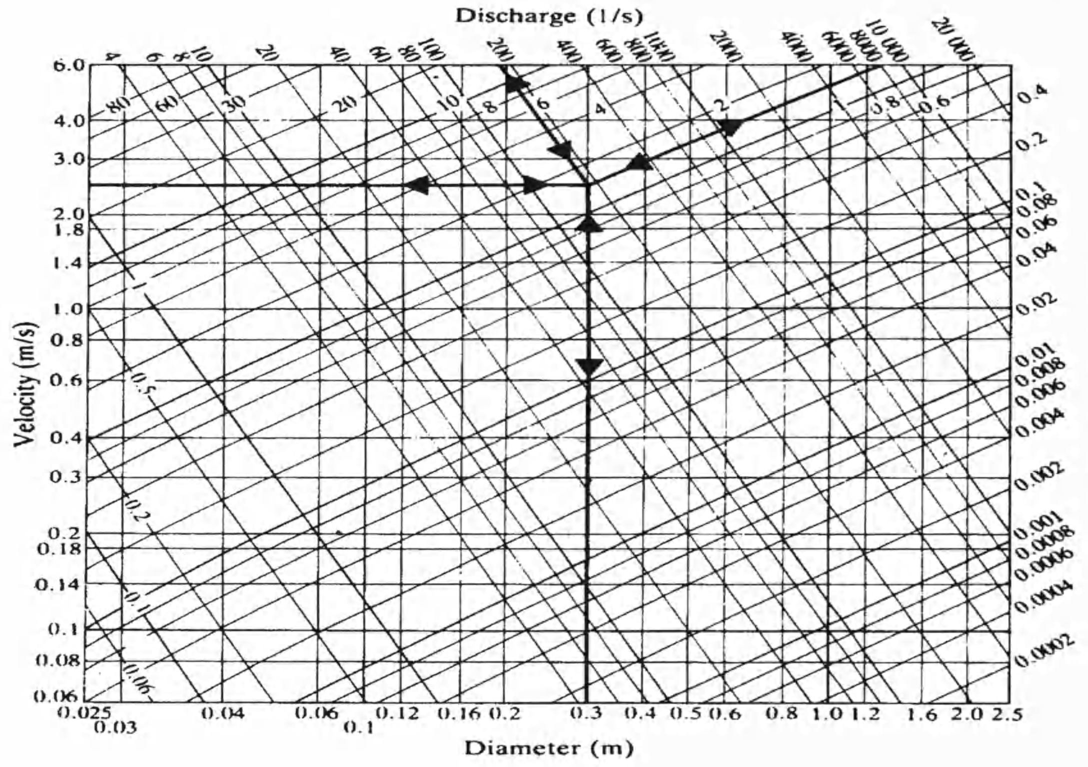


Fig. 5: Hydraulics Research Station Chart for $k_s$ = 0.03 mm

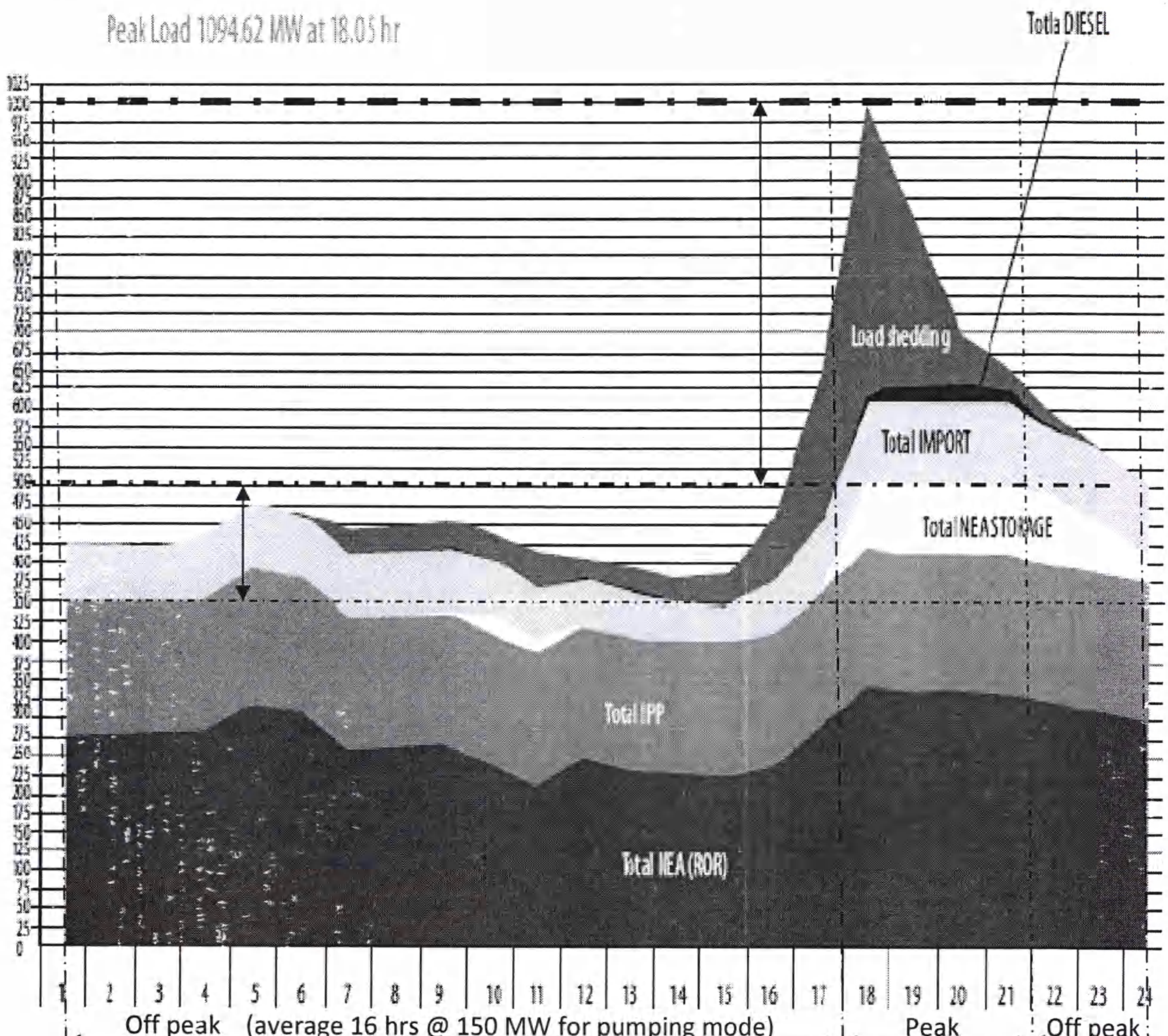


Fig. 6: Typical time-of-day daily load curve during dry periods of INPS (Peak 500 MW)

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**Fig. 1: Topo Map (color) for question no. 5 (to be attached to your answer sheets)**

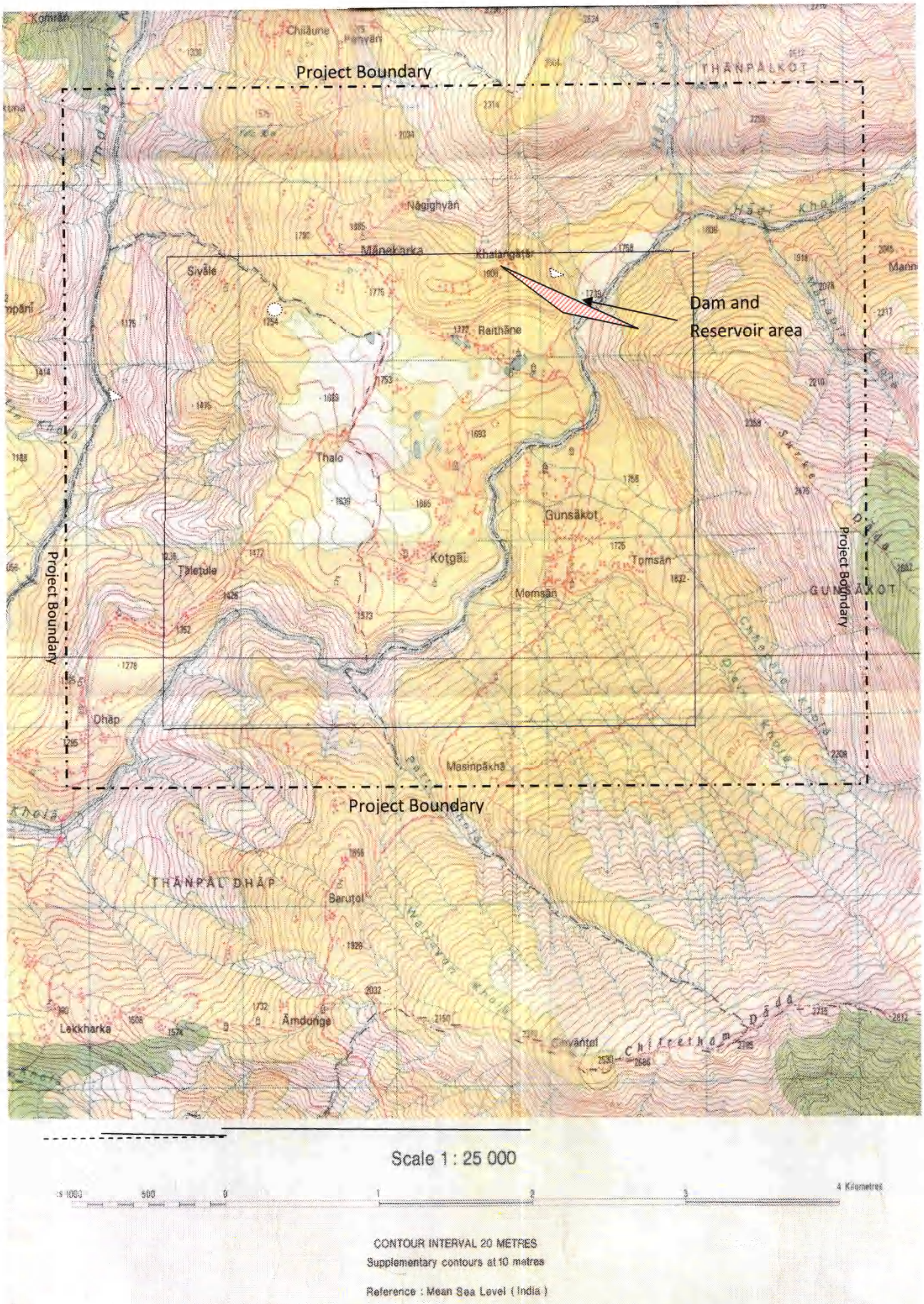


Fig. 1: Topographical Map of hydropower site (Scale 1:25000)

Table-CIEG-406

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Table 1: For Question No. 5 (***to be used for calculation and be attached to the answer sheet after completing it***).

| Power, Energy and Reservoir Volume Calculation Sheet | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Given and fill in the blanks appropriately as given in the question no. 5** | | | | | | | | | | |
| **Gross Head** | m | ? | | **Design Flow at $Q_{20\%}$** | $m^3/s$ | ? | | | **Design Flow** | $m^3/s$ |
| Generator efficiency | [-] | **0.98** | | **Min. release to river** (10% of mini. River flow | $m^3/s$ | ? | | | **Discharge for Flood** $Q_{fld}$ from Jun-Oct | $m^3/s$ |
| Turbine efficiency | [-] | **0.92** | | Dry season energy rate | NRs/kWh | **?** | | | Discharge for irrigation $Q_{irr}$ from Jan-Apr and from Oct-Dec. | $m^3/s$ |
| Conveyance efficiency | [-] | **0.95** | | Wet season energy rate | NRs/kWh | **?** | | | Discharge for Drinking $Q_{dr}$ throughout the year | $m^3/s$ |
| Dead Volume | **15% of total storage volume** | | | | | | | | | |
| Dry season: | **Dec 16 - April 15** | | | | | | | | | |
| Wet season: | **April 16 - Dec. 15** | | | | | | | | | |

**Calculation**

| **Month** | **No of days** | **Discharge $m^3/s$** | | | | | | **Power (kW)** | **Energy (kWh)** | **Storage Volume ($m^3$)** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Q_R$ | $Q_A$ | $Q_T=Q_{50\%}$ | $Q_{ir}$ | $Q_{dw}$ | $Q_{fl}$ | $P_i$ | E | $V_A$ | $V_{fl}$ | $V_{dw}$ | $V_{ir}$ | $V_{dead}$ | $V_T$ | $V_{res}$ |
| 1 | 2 | 3 | 4 | 5 | 6 | | | 7 | | 8 | 9 | 10 | 11 | | | 12 |
| **Jan** | **31** | 20 | | | | | | | | | | | | | | |
| **Feb** | **28** | 10 | | | | | | | | | | | | | | |
| **Mar** | **31** | 5 | | | | | | | | | | | | | | |
| **Apr** | **30** | 5 | | | | | | | | | | | | | | |
| **May** | **31** | 50 | | | | | | | | | | | | | | |
| **Jun** | **30** | 250 | | | | | | | | | | | | | | |
| **Jul** | **31** | 400 | | | | | | | | | | | | | | |
| **Aug** | **31** | 1050 | | | | | | | | | | | | | | |
| **Sep** | **30** | 700 | | | | | | | | | | | | | | |
| **Oct** | **31** | 290 | | | | | | | | | | | | | | |
| **Nov** | **30** | 50 | | | | | | | | | | | | | | |
| **Dec** | **31** | 40 | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **$Q_R$** | River Discharge | $P_i$ | Design Power ( for Installed capacity) | | |
| **$Q_A$** | Available Discharge (after deduction for ecological flow | $V_a$ | Annual storage | $V_{Res}$ | Reservoir Capacity |
| **Q $Q_{fl}$** | Flood Storage Discharge | $V_{fl}$ | Storage for Flood mitigation | **$V_{dead}$** | Dead Volume for sediment storage |
| **$Q_{dw}$** | Drinking water discharge | $V_{dw}$ | Storage for drinking water | **$E_{st}$** | Storage Energy |
| **$Q_{ir}$** | Irrigation water discharge | $V_{ir}$ | Storage for irrigation | | |
| **$Q_T$** | Turbine Discharge | $V_T$ | Storage for powergeneration | | |

| | | | |
|---|---|---|---|
| 1 | | Installed Capacity $P_{inst}$, kW | |
| 2 | | Firm Capacity, $P_{firm}$, kW | |
| 4 | | Total Reservoir capacity [$m^3$] | |
| 6 | | Total Stored Energy[kWh] | |
| 7 | | Total cost of Hydropower Installation | |
| 8 | | Total annual benefit from hydropower | |
| 9 | | Simple payback period | |
| 10 | | Your candid conclusion | |

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Table 2: For Question No. 6 (***to be used for calculation and be attached to the answer sheet after completing it).***

| Requirement: | | | | |
|---|---|---|---|---|
| Draw a neat profile of the project components and show all necessary descriptions with dimensions | | | | 2 |
| (a) Determine the Installed Capacity of PSHP in turbine mode for 4 hrs. | $P_{TM}$ | | MW | 0.5 |
| | $E_{TM}$ | | MWh | |
| (b) Estimate the specific speed and specify the type of turbine. Give the fundamental difference between these two quantities. | $n_s$ | | rpm | 0.5 |
| | $n_q$ | | | |
| (c) Determine the safe turbine setting level relative to the downstream reservoir water level. | $H_s$ | | mamsl | 2 |
| (d) Determine the position of centerline of runner for vertical turbine setting. | $H_T$ | | mamsl | 2 |
| (e) Estimate: | | | | |
| • The maximum upsurge and down surge in the surge chamber for a sudden rejection of one unit; and | $Z_{max, US}$ | | mamsl | 2 |
| | $Z_{max, DS}$ | | | |
| • The maximum down surge for sudden acceptance of demand on one unit. And the time of oscillation. Is there any need to install a surge tank? | $Z_{max, DS}$ | | mamsl | 0.5+0.5 |
| | T | | s | |
| (f) Determine the power and energy needed for pumping the same volume of water if the pumping power can be available for 16 hrs daily. | $P_{PM}$ | | MW | 1 |
| | $E_{PM}$ | | MWh | |
| (g) Determine extra volume the lower reservoir's capacity that is needed to store the water during turbine mode. Give your final remarks on what needs to be done if the reservoir volume is not enough as well as compare Fig 6 for capacity of PSHP in turbine and pumping modes. | $V_{ELR}$ | | $m^3$ | 0.5+0.5 |

Table 3: For Question No. 7 (***to be used for calculation and be attached to the answer sheet after completing it).***

| Find: | Symbol | Formula | Answer | Unit | Marks |
|---|---|---|---|---|---|
| 1. Thickness of pipe | t | | | | 1.0 |
| 2. Head loss | $h_f$ | | | | 1.0 |
| 3. Power loss | PL | | | | 0.5 |
| 4. Annual Energy loss | EL | | | | 0.5 |
| 5. Cost of Annual Energy loss (dry) | $CoEL_d$ | | | | 0.5 |
| 6. Cost of Annual Energy loss (wet) | $CoEL_w$ | | | | 0.5 |
| 7. Total cost of energy loss | TCoE | | | | 0.5 |
| 8. Wave velocity | C | | | | 0.5 |
| 9. Critical time | $T_c$ | | | | 0.5 |
| 10. Total Head | $h_T$ | | | | 0.5 |
| 11. Volume of Penstock | V | | | | 0.5 |
| 12. Cost of penstock pipe | CoP | | | | 0.5 |
| 13. Design pressure | p | | | | 0.5 |
| 14. Economic Diameter (Sarkaria) | $D_e$ | | | | 0.5 |
| 15. Economic Diameter (USBR) | $D_e$ | | | | 0.5 |
| 16. Losses in Penstock | | | | | |
| a. Wall loss | $h_{wall\ loss}$ | | | | 0.5 |
| b. Turbulent losses | $h_{turbulence\ loss}$ | | | | 0.5 |
| 17. Total losses in penstock | | | | | 0.5 |
| 18. Your concluding remarks | | | | | 1.0 |
| 19. Neat sketch depicting all parameters | | | | | 1.0 |

| **Table 4: Factors affecting Generator Rating** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temperature in °C | | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| A | Temp. factor | 1.1 | 1.08 | 1.06 | 1.03 | 1 | 0.96 | 0.92 | 0.88 |
| Altitude in m | | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| B | Altitude factor | 1 | 0.96 | 0.93 | 0.9 | 0.86 | 0.83 | 0.8 | 0.77 |
| C | ELC correction factor | Without Electronic Load Controller | | | | | | | 1 |
| | | With Electronic Load Controller | | | | | | | 0.83 |
| D | Power factor | When only light bulbs are used | | | | | | | 1 |
| | | When tube lights and other appliances are used | | | | | | | 0.8 |

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Table 5: **Formulae List: Hydropower (assume appropriately if any missing data found)**

| **Design of Trashrack and head loss** | **Discharge though orifice, weir and bottom intake** |
|---|---|
| $S = \frac{1}{k_1}\left(\frac{t+a}{a}\right)\frac{Q}{v_0}\frac{1}{\sin\alpha}$<br>$h_r = k_s\left(\frac{t}{a}\right)^{\frac{4}{3}}\frac{v^2}{2g}\sin\alpha$<br>$h_i = k\frac{v^2}{2g}$<br>$K_1$-coefficient related to the partial clogging of the screen<br>• For no automatic raker = 0.20 to 0.30<br>• For automatic raker with hourly operation = 0.4 to 0.6<br>For automatic raker with differential pressure sensor = 0.8 to 0.85 | $Q = AC\sqrt{2g(NWL - TWL)}$<br>$Q = \frac{2}{3}c\mu bL\sqrt{2gh}$<br>$C = 0.6\frac{a}{d}\cos^{\frac{3}{2}}\beta$<br>$h = \frac{2}{3}h_E\chi$<br>Energy calculation for a reservoir<br>$E=1/(3.6x10^6) * g * \rho_w * V*h_s$ [kWh] |
| $P_{max/min} = \frac{\sum V}{B}\left[1 \pm \frac{6e}{B}\right]$<br>$\bar{x} = \frac{\sum M}{\sum V}, e = \bar{x} - \frac{B}{2}$<br>$F_{sliding} = \frac{cB + \sum V.\tan\phi}{\sum H}$<br>Stability Analysis | $Q = Av$<br>$v = \frac{1}{n}R^{2/3}S^{1/2}$<br>$A = By + zy^2$<br>$P = B + 2y\sqrt{1+z^2}$<br>$R = \frac{A}{P}$<br>$f_s=1.76d^{1/2}$<br>$P=4.75Q^{1/2}$, |
| $v_{fall} = \sqrt{0.33(s-1)gd}$<br>$v_{permissible} = a\sqrt{d}$<br>$a = 36; d > 1mm$<br>$a = 44; 0.1 \le d \le 1mm$<br>$a = 51; d < 0.1mm$<br>$L = f\left(H\frac{v}{w - u_*}\right)$<br>$f = safety\ factor = 1.2\ to\ 1.5$<br>$u_* = \sqrt{gRS_e}$<br>$S_e = \left(\frac{Q}{nAR^{2/3}}\right)^{1/2}$<br>$\sigma_c = 0.625\left(\frac{n_s}{380.78}\right)^2$ for Francis Turbine<br>**Setting of turbine** $H_s = (H_a - H_v) - \sigma_s H_n$ | Hydraulic machine design<br>$n_q = n_{syn}\frac{\sqrt{Q}}{h_f^{0.75}}\ [min^{-1}]$<br>$n_{syn} = \frac{60 * f}{P}\ [min^{-1}]$<br>$n_s = \frac{2400}{\sqrt{H}}rpm$ for Francis Turbine<br>$n_{syn} = \frac{n_s H^{5/4}}{\sqrt{P\,[HP]}}$ **rpm**<br>$D = \frac{84.6\phi H}{n_{syn}}$ **m**<br>$\phi = 0.0197\ n_s^{2/3} + 0.025$<br>$n_s = \frac{n_{syn}\sqrt{P\,[kW]}}{H_n^{5/4}}$ |
| $submergence\ head\ S = 1.5\frac{v^2}{2g}$<br>*vortex free criteria*<br>$\frac{S}{v\sqrt{d}} > 0.5$<br>Submergence | Friction loss<br>$\lambda = 0.005[1 + ((2000ks)/D + 10^6/Re)^{1/3}]$<br>$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{k_s}{3.7D} + \frac{5.1286}{R_e^{0.89}}\right)$ |
| $h_{dyn}=(a*v)T_R/(g*T_s)$<br>$T_s = \frac{\frac{QL}{A}}{gH}$<br>Surge calculation | $A_{surge\ shaft} = \frac{v_0^2 A_t L_t}{2gP_0H_0}$<br>$h_f = \frac{flv^2}{2gD}$<br>Surge and head loss calculation |

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$$t = \frac{pR}{\sigma_{st}\eta_j - 0.6p} + 0.15(cm)$$

$$v_{opt} = 0.125\sqrt{2gH}$$

$$D = 0.52H^{-0.17}(P/H)^{0.43}$$

$\sigma_{st} = 1200 \quad kg/cm^2$ **Penstock design**

$$Generator\ rating = 1.3 * \frac{Turbine\ rating(kW)}{A * B * C * D} \quad [kVA]$$

$$C_P = \sqrt{\frac{\frac{K}{\rho}}{1+\frac{D*K}{t*E}}} \text{ m/s}$$

$$t = \frac{P_a D}{2\sigma} \text{mm}$$

$$h_f = \frac{fLv^2}{2gD} \text{ m}$$

$T_c = 2\times(L/Vc)$

$$D_e = 0.62 \times \frac{P^{0.35}}{H^{0.65}}[m]$$

$$V_{eco} = 0.125\sqrt{2gH}[m/s]$$

$Z_{max}=v_o Sqrt(L_T A_T/(gA_{ST}))[m]$
$P_o=h_f/Z_{max}$ [-]
$hp=C_p*v_P/g$[-]
$Z_{max, US}= Z_{max}(1-2/3P_o+1/9*P_o^2)[m]$
$Z_{max, DS}= Z_{max}(-1+2P_o[m]$
$T=2pi* Sqrt(L_T A_{ST}/(gA_T))[s]$
Surge calculation

$$h_f = k\left(\frac{t}{a}\right)^{\frac{4}{3}}\frac{v^2}{2g}\sin\alpha$$

Where; hf- loss of head through racks, m
t- thicknes of rack bars, mm
a-clear distance (spacing) between bars, mm
v- velocity of flow through the trashrack, m/s
α-angle of bar inclination to the horizontal
k-factor depending on bar shape

k=2.42 k=1.83

$$h_{fi} = \xi\frac{v_n^2}{2g}$$

$v_n$-normal velocity through orifice

$\xi = \xi_s + \xi_\alpha$

| Shape | $\xi_s$ | Cone angle | $\xi_\alpha$ |
|---|---|---|---|
| Bell mouth | 0.03 to 0.05 | 30° | 0.002 |
| Slightly rounded | 0.12 to 0.25 | 45° | 0.04 |
| Sharp cornered | 0.5 | 60° | 0.07 |

$$Q_A = \frac{2}{3}c\mu bL\sqrt{2gh}$$

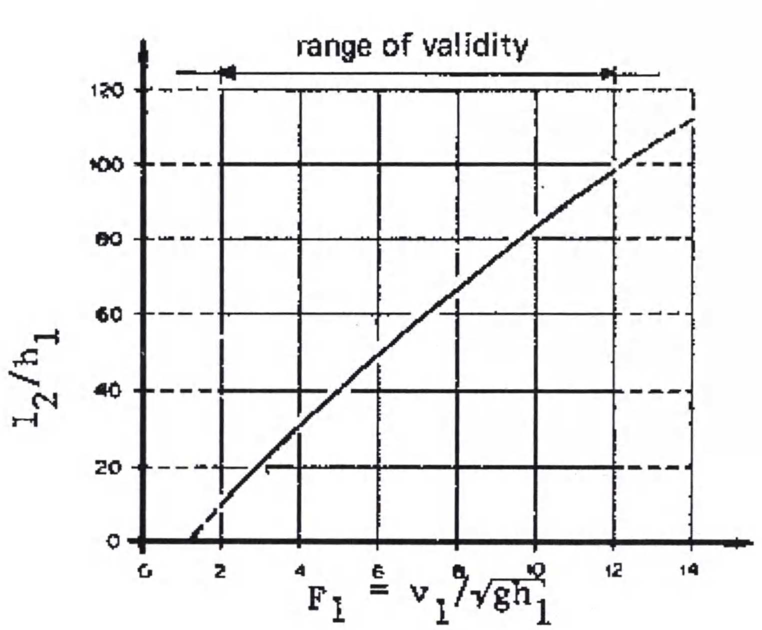
c-correction factor for submerged over-fall

$$c = 0.6\frac{a}{d}\cos^{1.5}\beta$$

Where a-internal width between bars
d-centre to centre distance between bars

$$h = \frac{2}{3}\chi h_E$$

| β | χ | β | χ |
|---|---|---|---|
| 0° | 1.00 | 14° | 0.899 |
| 2° | 0.980 | 16° | 0.865 |
| 4° | 0.961 | 18° | 0.851 |
| 6° | 0.944 | 20° | 0.837 |
| 8° | 0.927 | 22° | 0.825 |
| 10° | 0.910 | 24° | 0.812 |
| 12° | 0.894 | 26° | 0.800 |



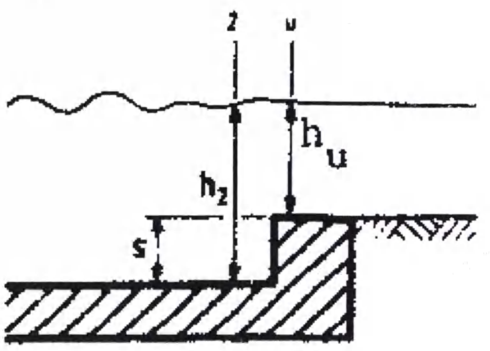




Fig. 7: Diagram for determining the hydraulic jump length L for horizontal rectangular channels

Table



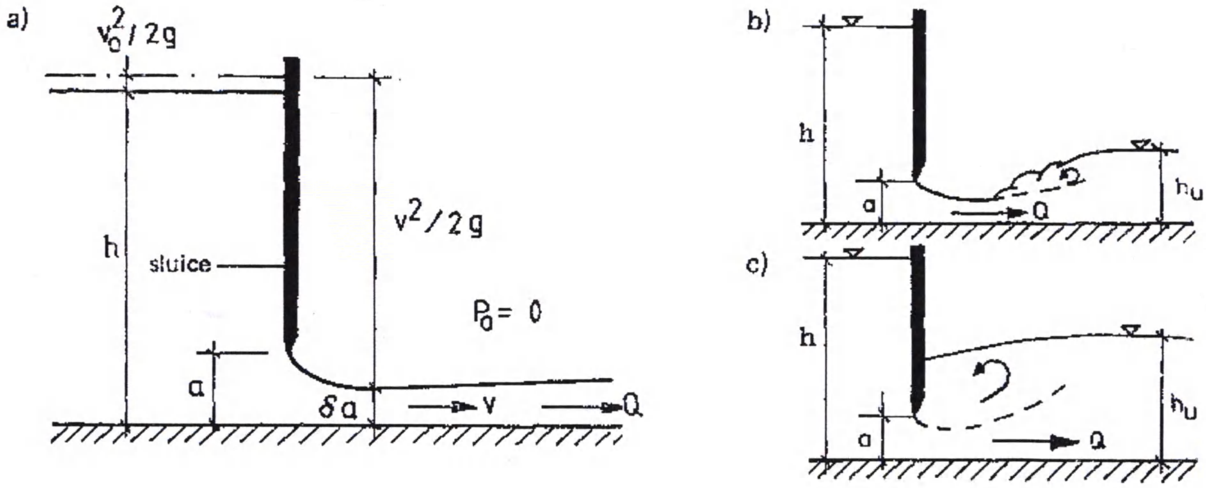
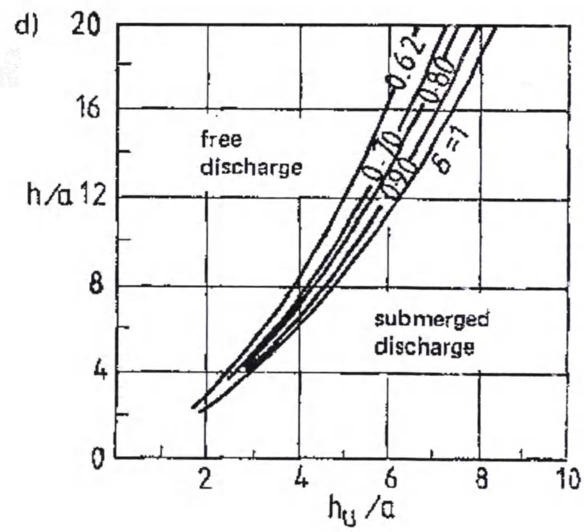
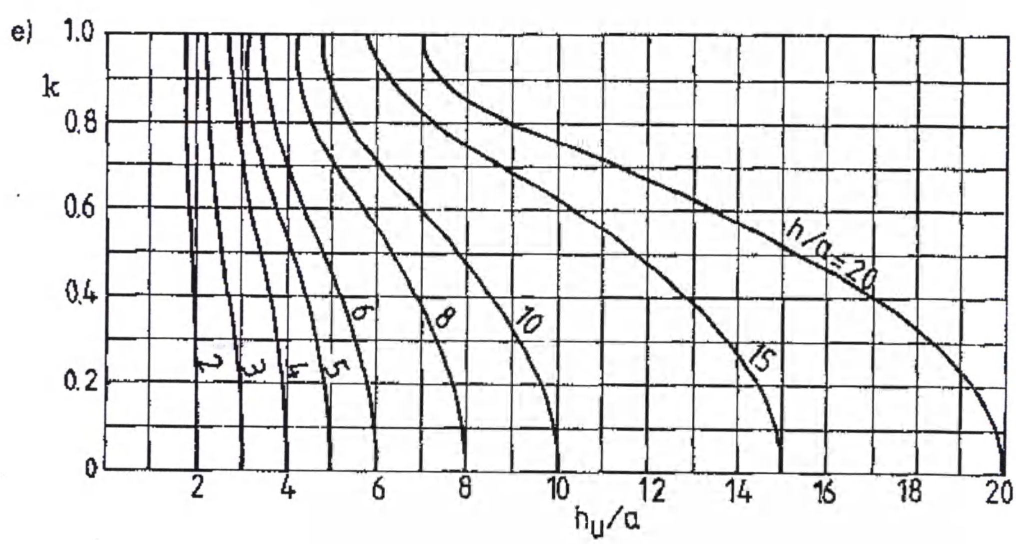
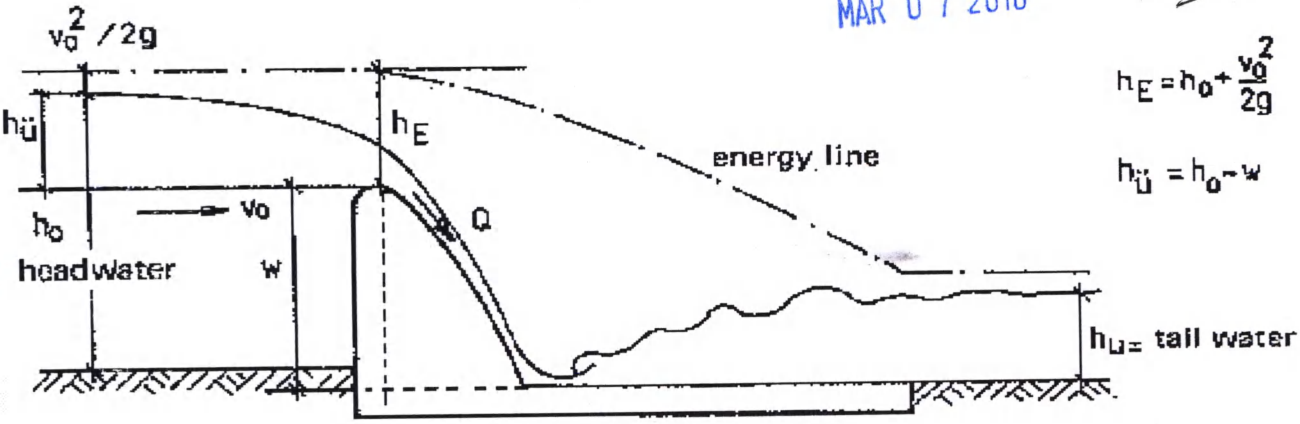



Fig. 38: Dimensioning of the discharge below a sluice. δ contraction coefficient
a) Discharge below a sluice
b) Free discharge
c) Submerged discharge
d) Limit between free and submerged discharge
e) k values for the submerged discharge as a function of h/a and $h_u/a$, for δ = 0.7 as average value, as the influence of δ upon k is relatively small

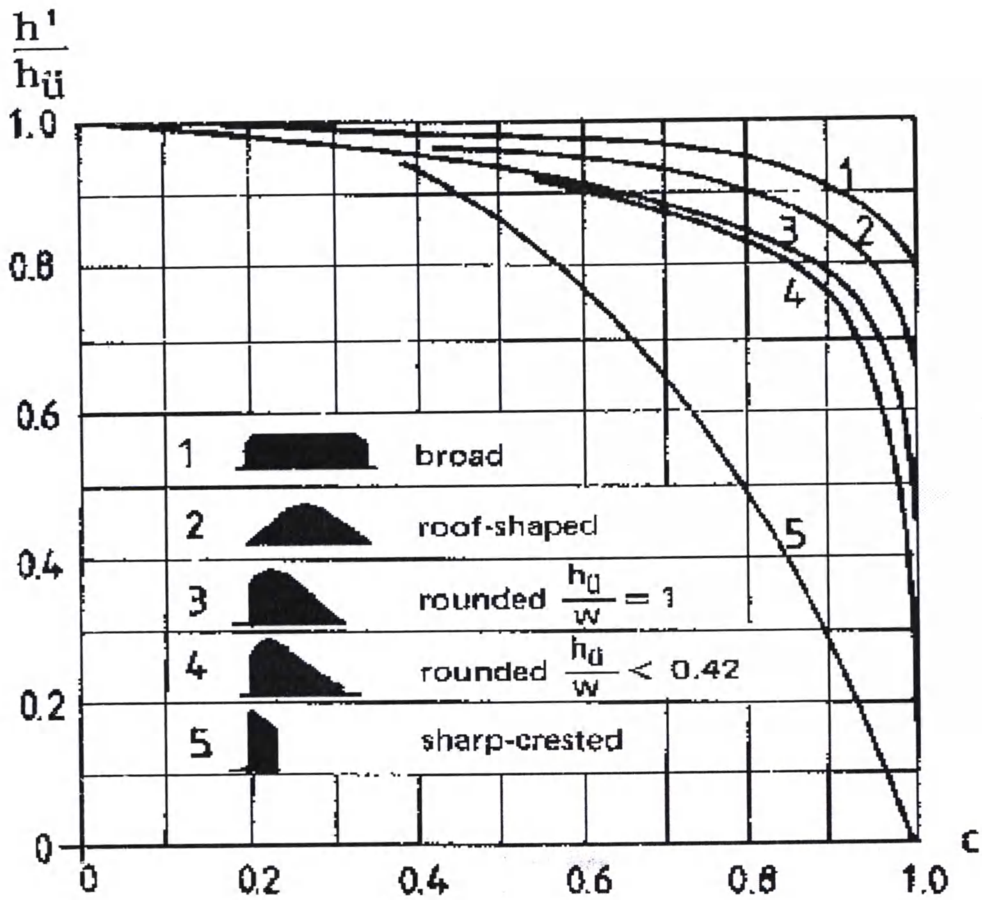


Table




fixed weir: Position of water surface and energy line




Correction factor c for submerged overfall

| crest form | μ |
|---|---|
| broad; sharp edges | 0.49-0.51 |
| broad; round edges | 0.50-0.55 |
| round overfall | 0,70 |
| sharp-edged | 0.64 |
| rounded | 0.75 |
| roof-shaped | 0.79 |

weir coefficient μ for different weir forms (acc. to Press/Schröder [3])