Lecture # 9

# Engineering Geology and Seismology

## Role of Geology in site selection for Engineering Structures

## (Dams, Tunneling, Reservoirs and Highways)

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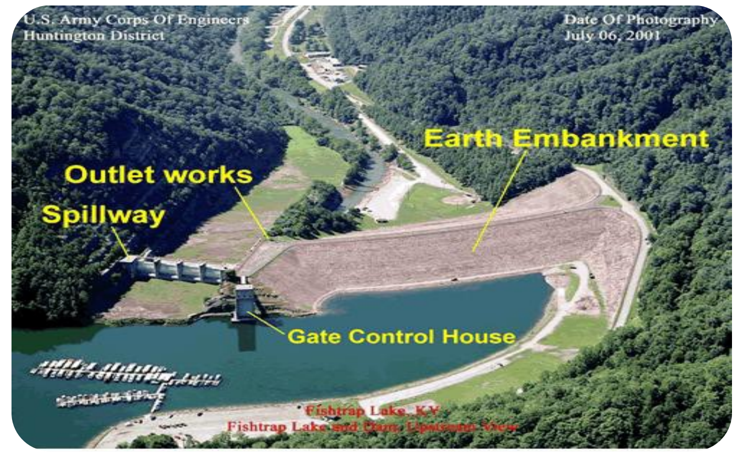
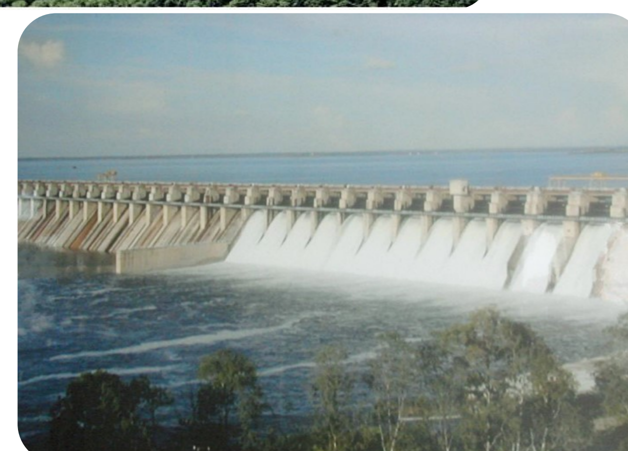
# Geology for Site selection of Dam

- Dam: A solid barrier constructed at a suitable location across the valley with a view of impounding water flowing through that river, for
  - Hydropower energy
  - Irrigation
  - Domestic water supply
  - Control flood
  - For navigation



# Needs for Dam Construction

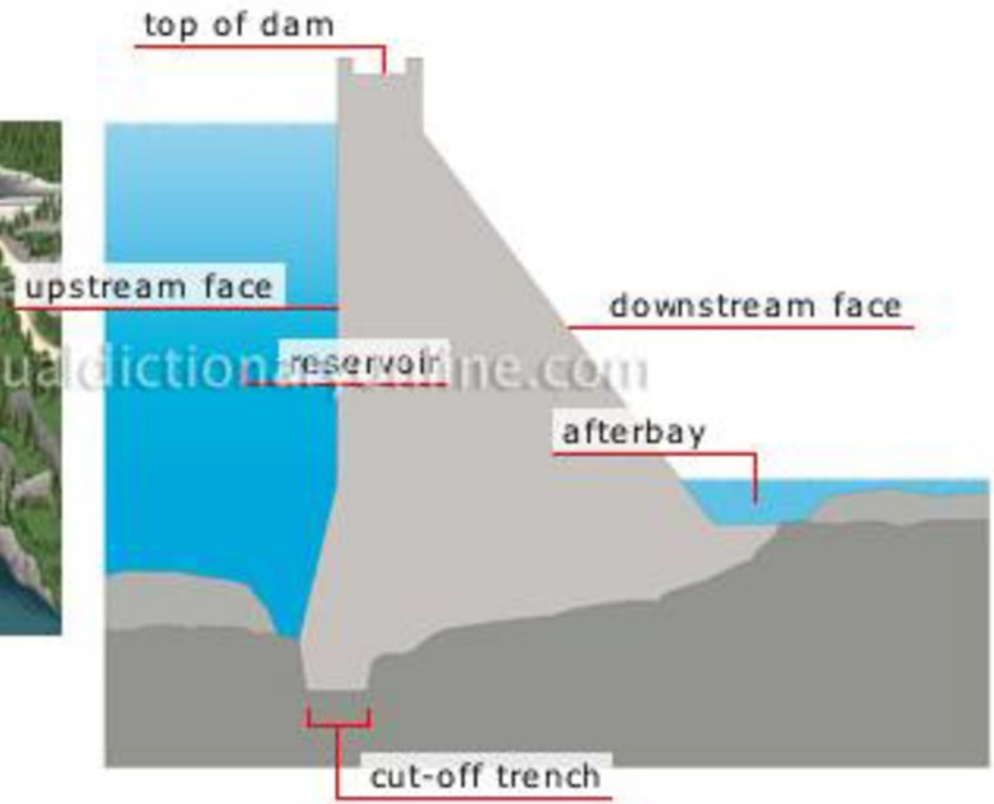
- Drinking and domestic water supply.
- Flood control.
- Irrigation.
- Industrial water supply.
- Hydroelectric Energy production.
- Retention and control of sediments and Inland navigation,
- Improvement of water quality,
- Fish Farming,
- Recreation facilities.

# Type of Dams

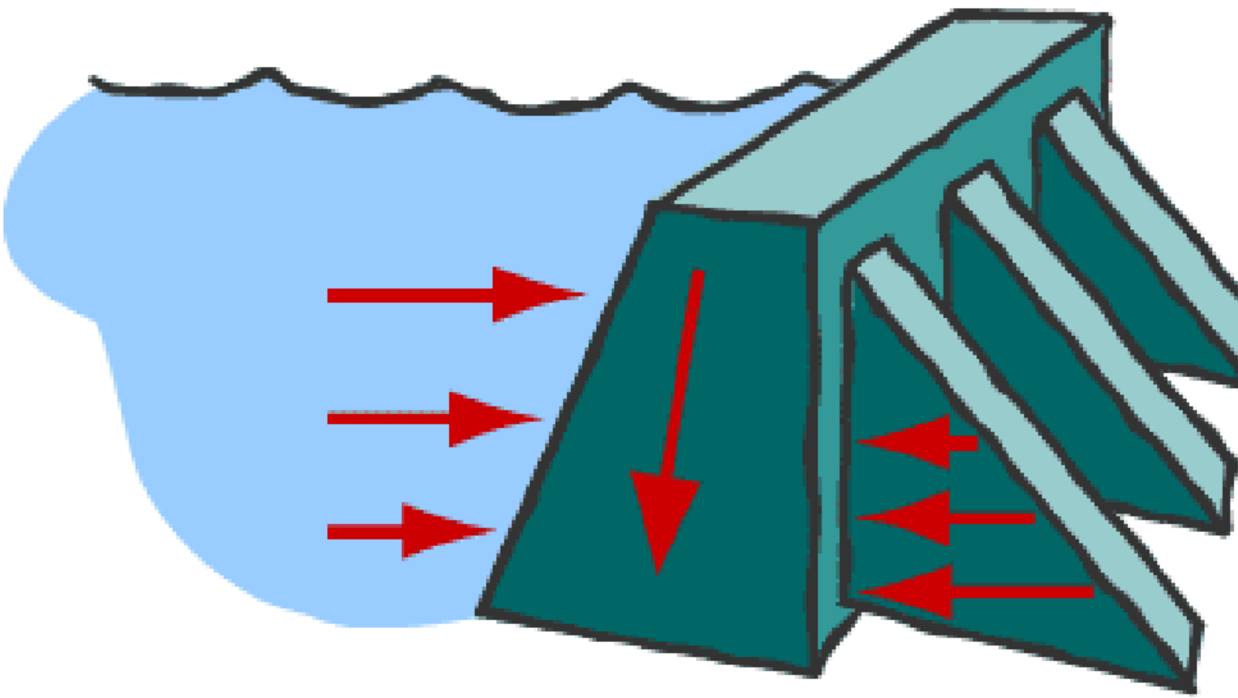
- Based on design
  - Gravity dam
  - Arch dam
  - Buttress dam
- Based on material
  - Concrete dam
  - Rock fill dam
- Size
  - Small dam
  - Large dam

# Gravity Dam

- A gravity dam is a solid masonry or concrete structure, generally of a triangular profile, which is so designed that it can withhold percolated volume of water by virtue of its weight.

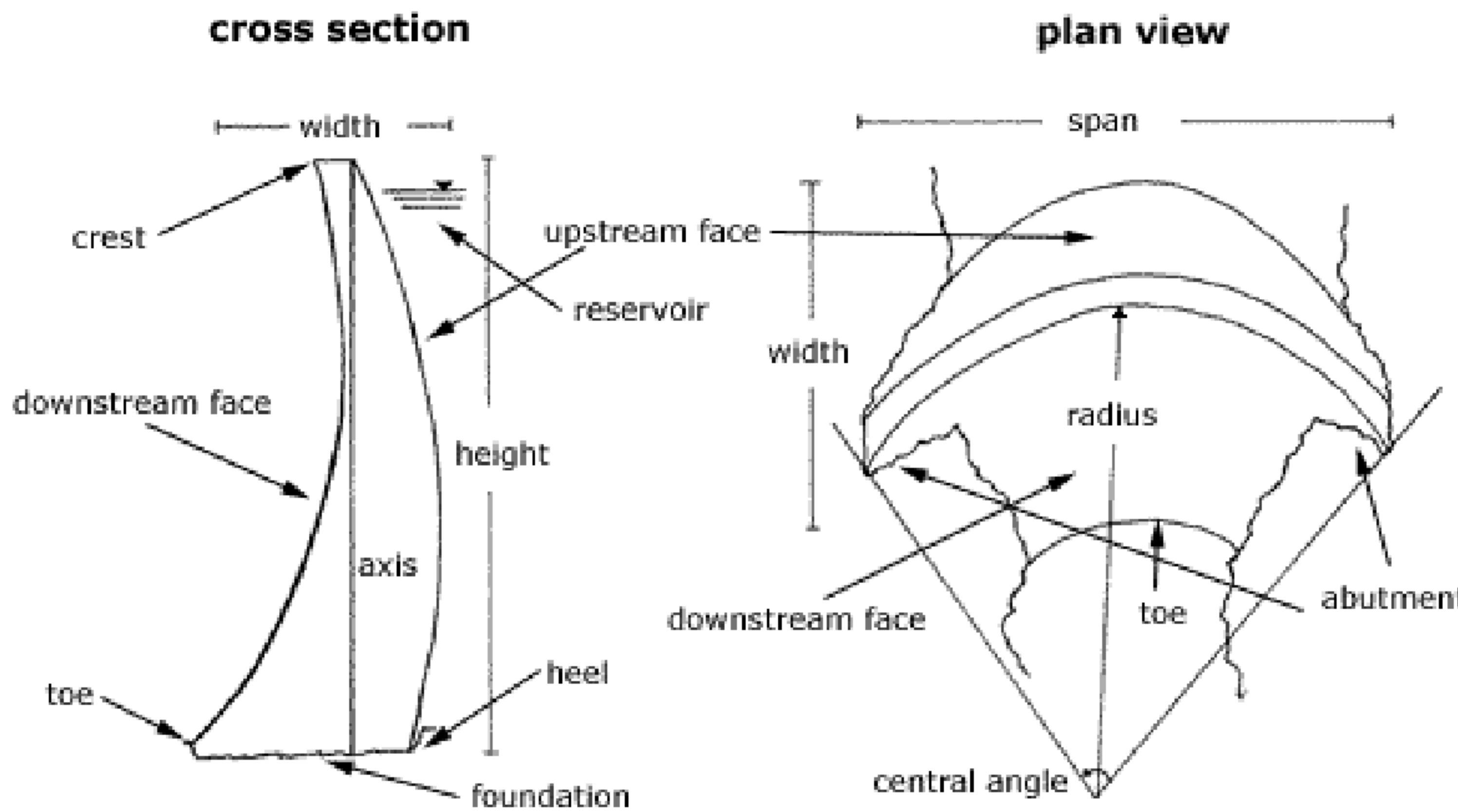


- All forces arising in such a dam is transmitting to the foundation rock. So strength of the foundation rock is most critical
- If properly designed, they are considered to be most safest.
- Buttresses dam is such a type a thin concrete slab is supported from the downstream side
- The upstream surface of the dam may be vertical or inclined, similarly the axis may be straight or curved



# Arch Dam

- An arch shaped dam, mostly of concrete.
- Designed in such a way that most the thrust force acting on the dam surface will be transferred to the abutment, that is the rock either side of the dam.



- Types of arch dam
  - Variable radius dam: curvature are different at upstream and downstream side
  - Cupola dam: curvature is same in both vertical and horizontal
- Arch dams are better suited for narrow valley with strong and uniformly dipping walls or abutment
- Arch dams are thin in wall, so lighter in weight.

**Karakaya Dam – Fırat River;**
**Height= 173 m**
**Reservoir Capacity= 9,5 billion m$^3$**

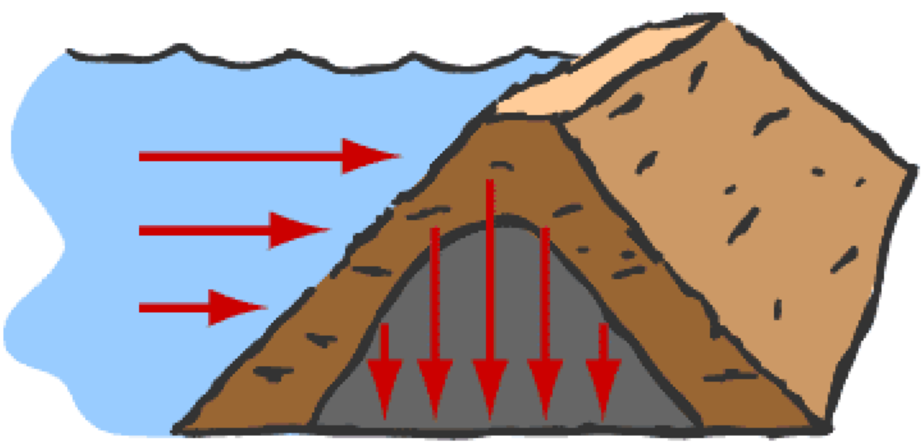
# BUTRESS DAMS

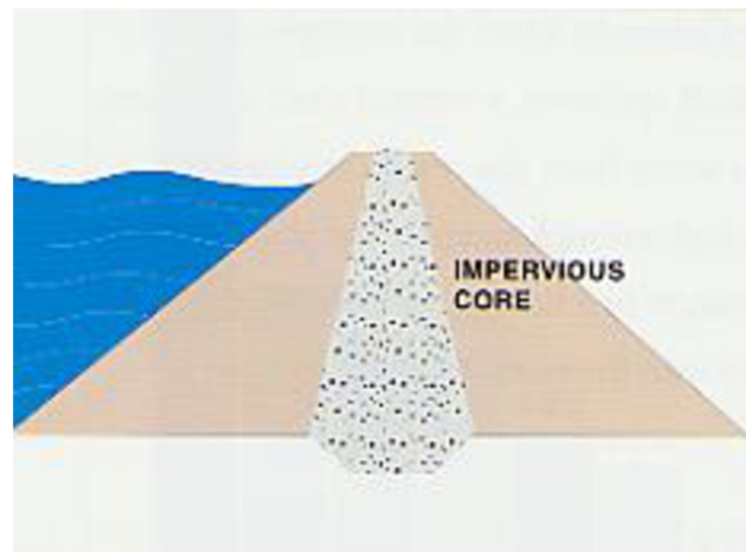
- <u>Buttress Dams</u> use multiple reinforced columns to support a dam that has a relatively thin structure.  Because of this, these dams often use half as much concrete as gravity dams.

**Elmalı II – Göksu River;**
**Height= 42.5 m**
**Reservoir Capacity= 10 million $m^3$**

# Embankment Dam

- Non rigid structures built over wide valleys with varying foundation characteristics.
- Generally trapezoidal shape





# EMBANKMENT DAMS
# (Rock Fill or Earth Fill Dams)

- They are mostly composed of natural materials such as, clay, sand, gravel etc...
- Impervious core is placed in the middle of the embankment body.
- Generally riprap is used to control erosion.

**Atatürk Dam – Fırat River;**
**Height= 169 m;**
**Reservoir Capacity= 48,7 billion m$^3$**

# Tarbela Dam-Earth Rock filled Dam

# COMPOSITE DAMS

- Composite dams are combinations of one or more dam types.
- Most often a large section of a dam will be either an embankment or gravity dam, with the section responsible for power generation being a buttress or arch.

# Forces acting on Dam

- Weight of the Dam
- Water pressure
- Uplift pressure
- Earthquake force
- Other forces
  - Silting
  - Waves
  - Freezing etc…

# Dam site Selection

- The Objective
  - Topographical
    - Narrow valley
    - Enough catchment area
  - Technical
    - Strong, Impermeable and stable site
  - Constructional
    - Easy availability of material required
  - Economical
    - Cost benefits
  - Environmental
    - Animal, vegetation and Man

# Geological characters for Investigation

- General geology of the area
  - General topography of the area
  - Nature of drainage pattern
  - General characteristics of the rock
  - Structure of the area
  - Rate of weathering in that area
- Geology of the site
  - Lithology: type of rock that make the area
  - Structure:
    - Dip and Strike
    - Fault
    - Fold
    - Joint
  - Engineering properties
    - Strength Parameters
    - Porosity and permeability

# GEOLOGICAL CHARACTERS FOR DAM SITE INVESTIGATION

## 1. GEOLOGY OF THE AREA -

The area should reveal the following:-

- main topographic features
- natural drainage patterns
- general characters and structures of rock formations such as their
- stratification , folding and faulting

## 2. GEOLOGY OF THE SITE -

- LITHOLOGY -

  - Surface and subsurface studies using the conventional and latest techniques of geological and geophysical investigations are carried out.

  - **IT REVEALS WHAT TYPE OF ROCKS MAKE UP THAT AREA: IGNEOUS,SEDIMENTARY OR METAMORPHIC.**

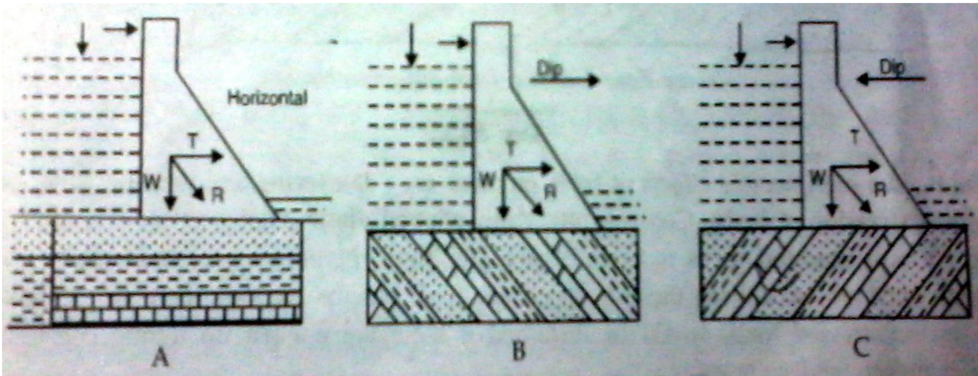
## ➢STRUCUTRES -

❑THIS INVOLVES DETAILED MAPPING OF PLANES OF WEAKNESS LIKE BEDDING PLANES,CLEAVAGE,JOINTS,FOLDING,FAULT ZONES

## ➢DIP AND STRIKE -

❑GENTLY UPSTREAM DIPPING LAYERS OFFER BEST RESISTANCE FORCES IN A DAM.

❑ THE MOST UNFAVOURABLE STRIKE DIRECTION IS THE ONE IN WHICH THE BEDS STRIKE PARALLEL TO THE AXIS OF THE DAM AND THE DIP IS DOWNSTREAM.



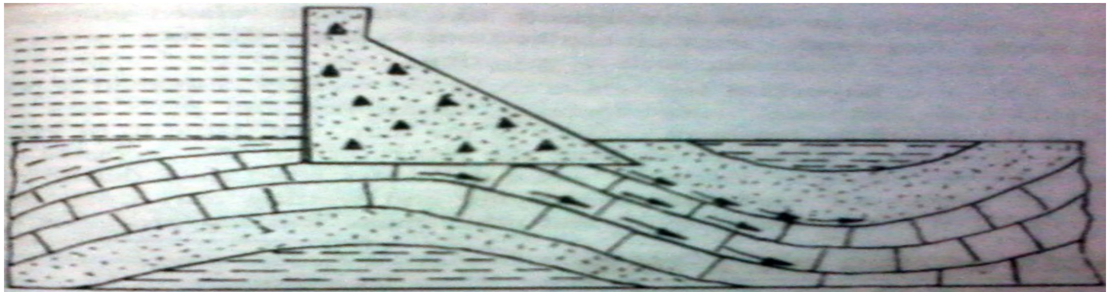
*Different Possible Positions of a Gravity Dam*
*A. On horizontal bedded rocks – stable condition, B. On downstream dipping rocks–unsafe. C. On upstream dipping rocks – safe against R*

## ➢ FAULTS (CAN BE A SOURCE OF DANGER) -

- ❑ FAULTED ROCKS ARE GENERALLY SHATTERED ALONG THE RUPTURE OF THE SURFACES
- ❑ DAMS FOUNDED ON THE BEDS TRAVERSED BY FAULT ZONES AND ON MAJOR FAULT ZONES ARE MORE LIABLE TO SHOCKS DURING AN EARTHQUAKE.
- ❑ ALWAYS DESIRABLE TO AVOID RISK BY REJECTING SITES TRAVERSED BY FAULTS,FAULT ZONES AND SHEAR ZONES FOR DAM FOUNDATION.

## ➢ FOLDS

- ❑ THE MOST NOTABLE EFFECTS OF FOLDS ON ROCKS ARE: SHATTERING AND JOINTING ALONG THE AXIAL PLANES AND STRESSING OF THE LIMBS.



Effect of Folding on Dam Site. Upstream Face of Syncline – Unsafe.

- DAMS ALIGNED ALONG AXIAL REGIONS OF FOLDS WOULD BE RESTING ON MOST UNSOUND ROCKS IN TERMS OF STRENGTH.

## ➢ JOINTS -

- NO SITES ARE FREE FROM JOINTING.

- OCCURRENCE OF MICROJOINTS SHOULD BE DEALT WITH GREAT CARE. BECAUSE IF IT IS LEFT UNTREATED ,COULD BECOME A SOURCE OF MANY RISKS.

# ENGINEERING PROPERTIES OF ROCK

## ➢STRENGTH PARAMETER -

- IT CONSIST OF THREE INVESTIGATIONS – LABORATORY, IN-SITU STATIC AND DYNAMIC.
- THE COMPRESSIVE AND SHEARING STRENGTH OF THE ROCKS ARE ESTIMATED BY LABORATORY TEST.
- THE SHOCK WAVE VELOCITY RELATES TO THE DENSITY, RIGIDITY, POROSITY AND PERMEABILITY OF THE ROCKS AT THE SITE.
- STATIC STUDY: BY THIS TEST SETTLEMENTS AND STRAINS ARE RECORDED WITH DIFFERENT LOADINGS WHICH IS USED TO ESTIMATE THE BEARING STRENGTH, MODULUS OF ELASTICITY AND POISSON'S RATIO.

- POROSITY AND PERMEABILITY:-

  - POROSITY AND PERMEABILITY OF THE ROCKS ARE TESTED BOTH IN LABORATORY AND IN-SITU. ARTIFICIAL TREATMENT IS GIVEN TO THE CRITICAL ZONES SUCH AS GROUTING TO MAKE THE ROCKS WATER TIGHT.

# Reservoir

- Types
  - Storage or Conservation reservoir
  - Flood control reservoir
  - Distribution reservoir
- Important terms
  - Pool level: Designed level up to which the reservoir shall be full of water.
    - Maximum Pool level
    - Minimum Pool level
    - Normal Pool level
  - Storage capacity
    - Useful Storage
    - Dead Storage
    - Surcharge Storage
  - Reservoir yield
    - Volume of water can be drawn from a given reservoir in a certain interval of time

# Reservoir

- Geological Characteristics
  - Topographical Stability
  - Ground water condition
  - Permeability
  - Structural constitution
  - Trend and rate of weathering

# Tunnels and Road cutes

- Tunnels: is and underground rout or passage driven through the ground without disturbing the overlying soil or rock cover
- Types
  - Traffic tunnel
  - Hydro-power tunnel
    - Pressure tunnel: Tunnels which feeds water to turbine under great pressure
    - Discharge tunnel: Tunnel which use to convey water from one part to another
  - Public utility tunnel

# Geological Investigation

- Objective
  - Selection of tunnel site (alignment)
  - Selection of excavation method
  - Selection of design for tunnel
  - Assessment of cost and stability
  - Assessment of environmental hazard

# Methods

- Preliminary survey
  - General topography
  - Lithology
  - Hydrological condition
  - Structural condition
- Detail survey
  - Borehole drilling
  - Exploratory shaft and audit
    - Mineral composition
    - Strength
    - Module of elasticity
    - Porosity permeability
    - General chemical character

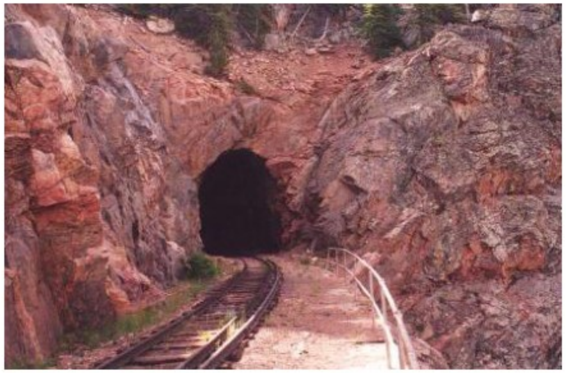
**Geological profile**

- Location
- Type of rock
- Structure
- Hydrological condition
- Ground temperature

# Geological Consideration in Tunnel

- **Rock:**
  - Consolidated
    - Lithology
    - Geological Structure
    - Ground water condition
  - Unconsolidated
    - Geological profile
    - Lithological character
    - Ground water regime

Tunnel Boring Machine (TBM)
Rock blasting method (RBM)



# Geological structure

- Contols
  - Design
  - Stability
  - Cost

# Considerations of geological structures

- Dip and strike
  - Horizontal strata
    - Thick bed
    - Thin bed
  - Moderately inclined strata
    - Parallel to dip
      - » Merit: Good for strength point of view due to bridge action
      - » Demerit: Number of strata need to be excavated
    - Perpendicular to dip
      - » Merit: Uniform character of strata
      - » Demerit: Chance of sliding through bedding plain
      - » Bridge action is week
    - Oblique to dip
      - » Draw back of both situation would act
  - Steeply inclined strata
    - Parallel to strike
    - Perpendicular to strike
    - Case of folding
    - Faulting
    - Joint
  - Ground water condition
    - Through erosion and corrosion
    - Pressure

# Soft ground tunneling

- Geological profile
- Lithological characterization
- Ground water regime

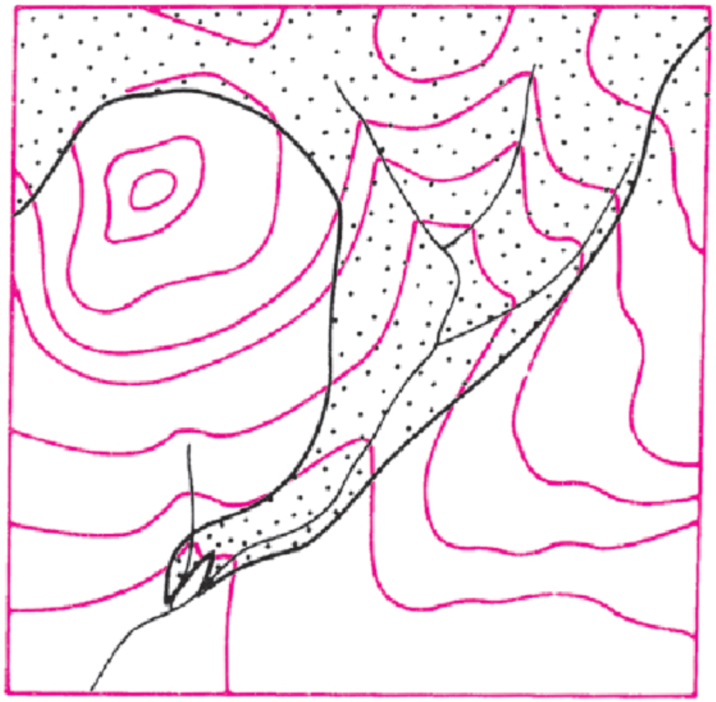
# Geology for Site selection of Highways

- **Topography**
- **Lithology**
  - Consolidated ground
  - Unconsolidated ground
- **Geological Structure**
  - Dip and strike
    - Parallel to dip-Safe
    - Perpendicular to dip-Unsafe
    - Angular to dip-Unsafe
      - Precautions: Enlarging the section of cutting to stable limit
      - Strong retaining wall
      - Good drainage system
  - Joint
  - Fault
- **Ground water condition**
- **Weathering**

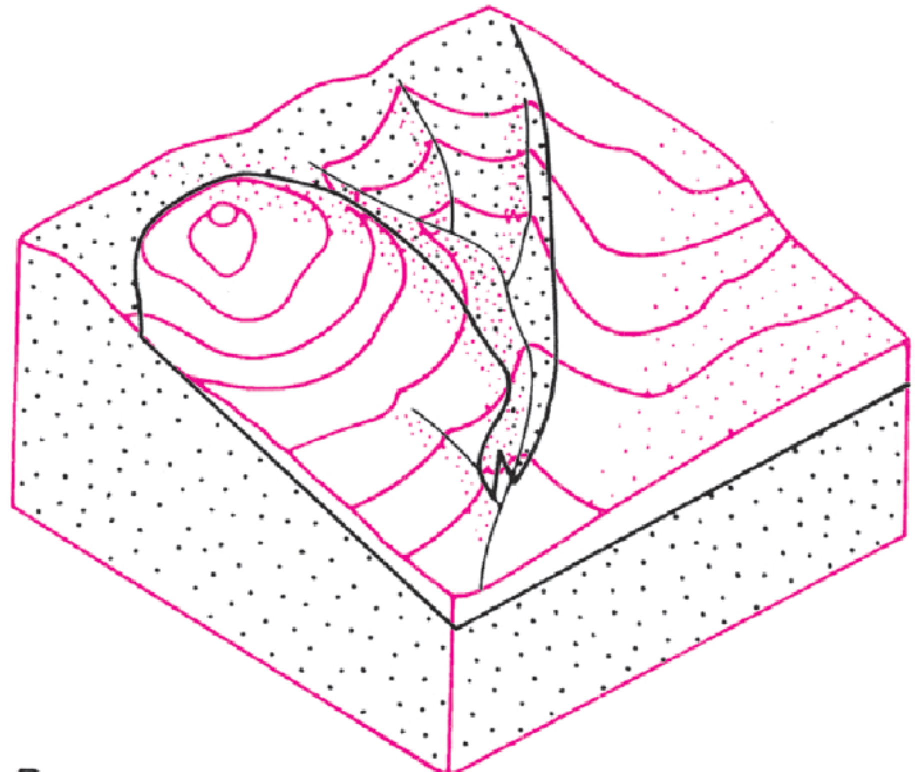
# Geological problems after road construction

- Frost action
  - Treatment
    - Removing porous soil
    - Lowe down water table by adequate drainage
- Erosion problem

# Geological Mapping

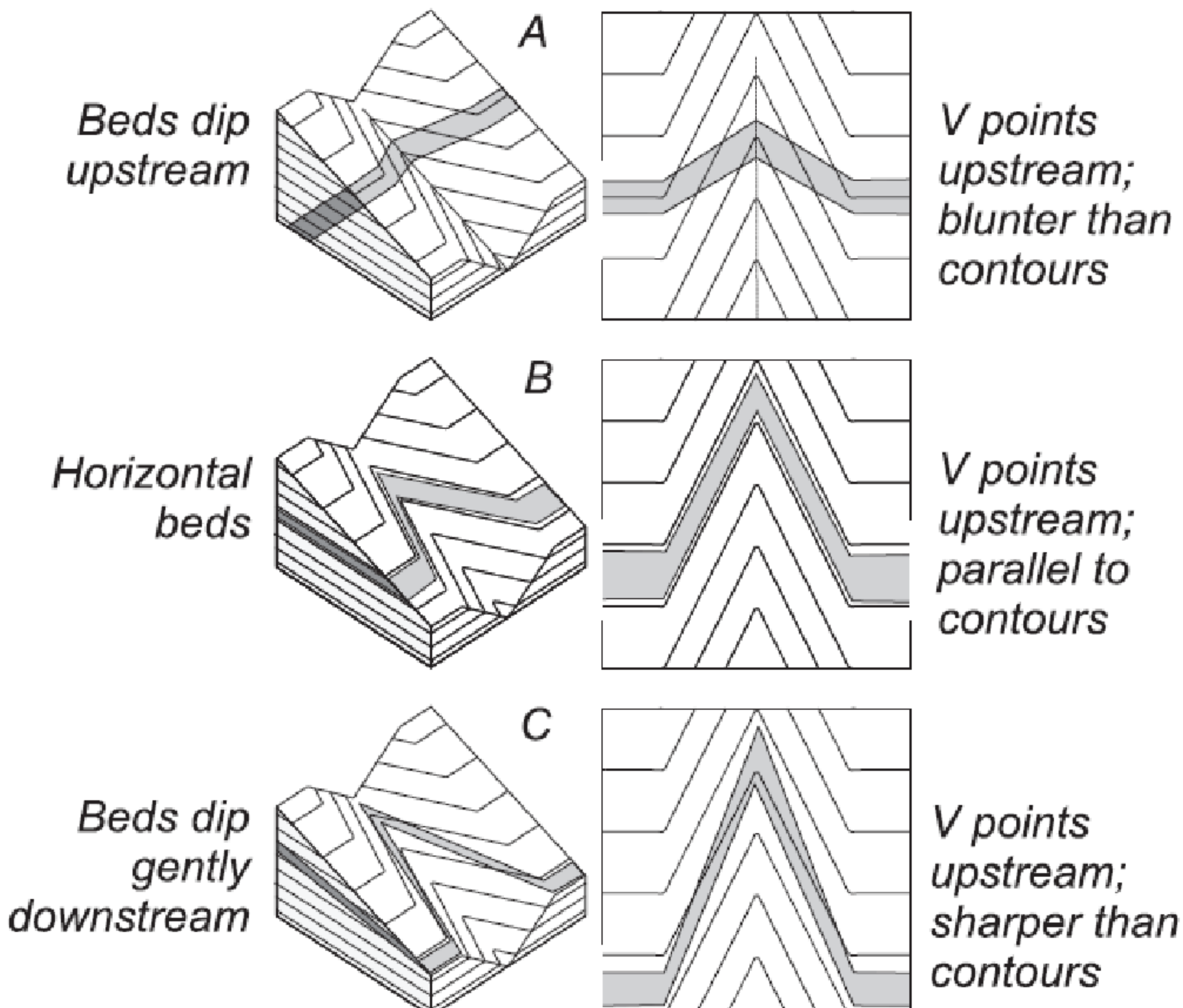


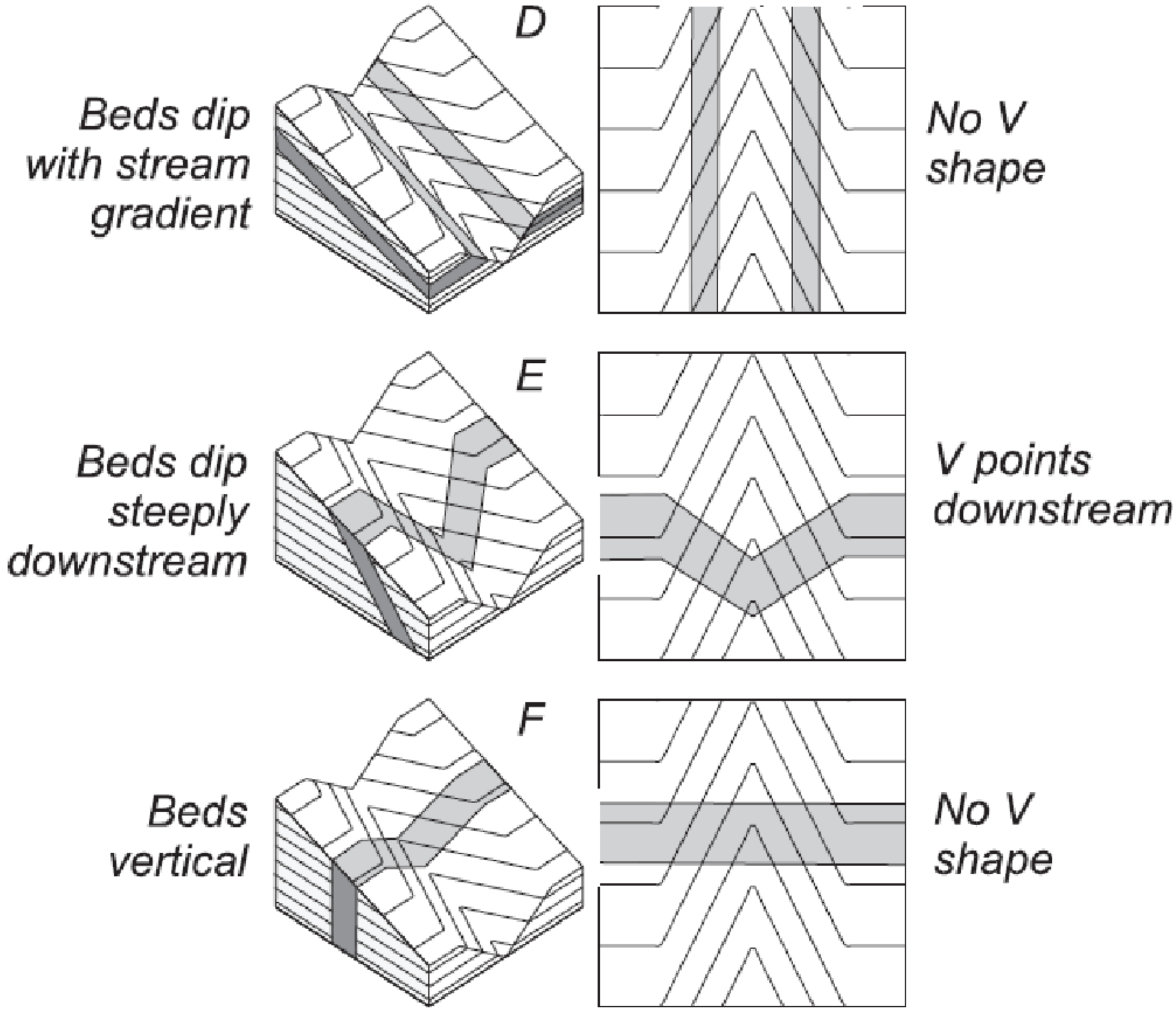
A

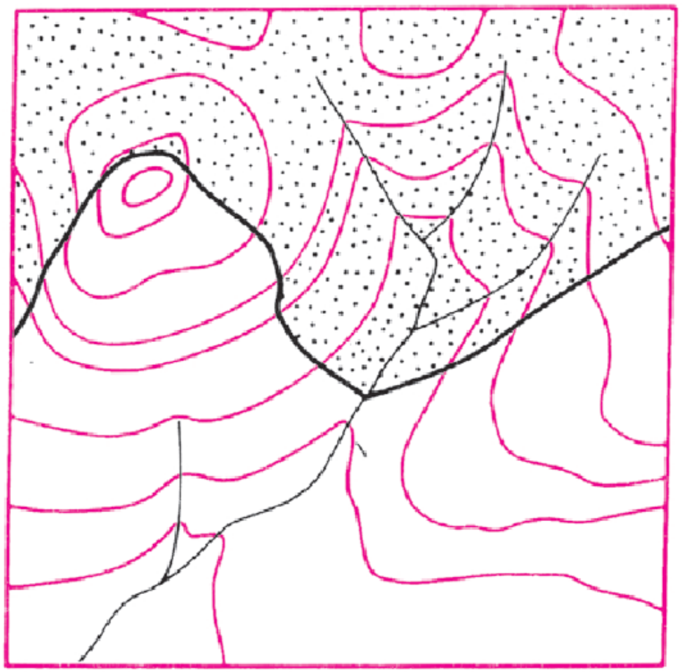


B

# Beds in Map


A
Beds dip upstream
V points upstream; blunter than contours
B
Horizontal beds
V points upstream; parallel to contours
C
Beds dip gently downstream
V points upstream; sharper than contours


D
Beds dip with stream gradient
No V shape
E
Beds dip steeply downstream
V points downstream
F
Beds vertical
No V shape



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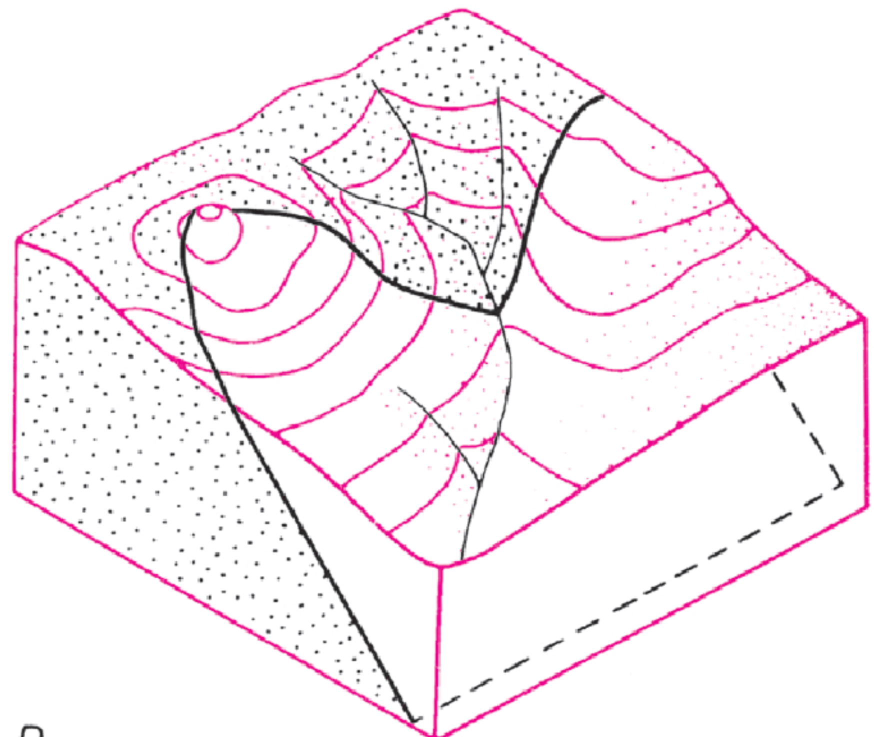


D

# HYDEL POWER DEVELOPMENT
# BEST REMEDIAL MEASURES
# FOR
# ELECTRICAL & WATER CRISES

Energy the lifeline of, industrial economic, development and quality of life.

Pakistan is the poorest of the poor as far as energy consumption per capita is concerned.

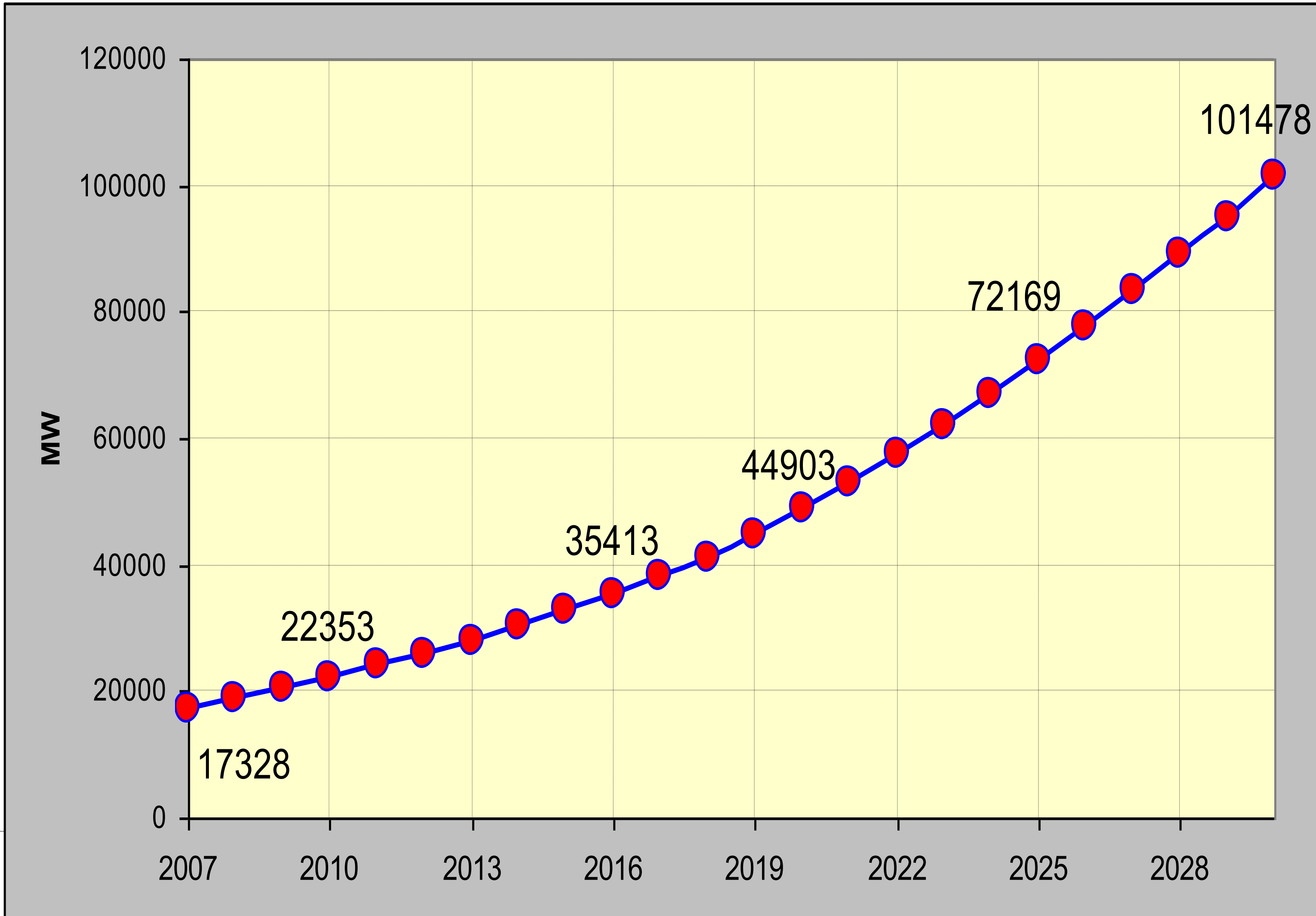
Pakistan ranks 25$^{th}$ in World Energy consumption and 31s t in Electricity production.

Per Capita electrical consumption per year of Pakistan is 470kWh, of Malaysia 2,708 & of Singapore 6,775 kWh

Pakistan has developed 12% of total hydel potentials, India has 30% & rich countries 75% of hydel potential

Hydel power supplies 715,000 MW or 19% of World Electricity.

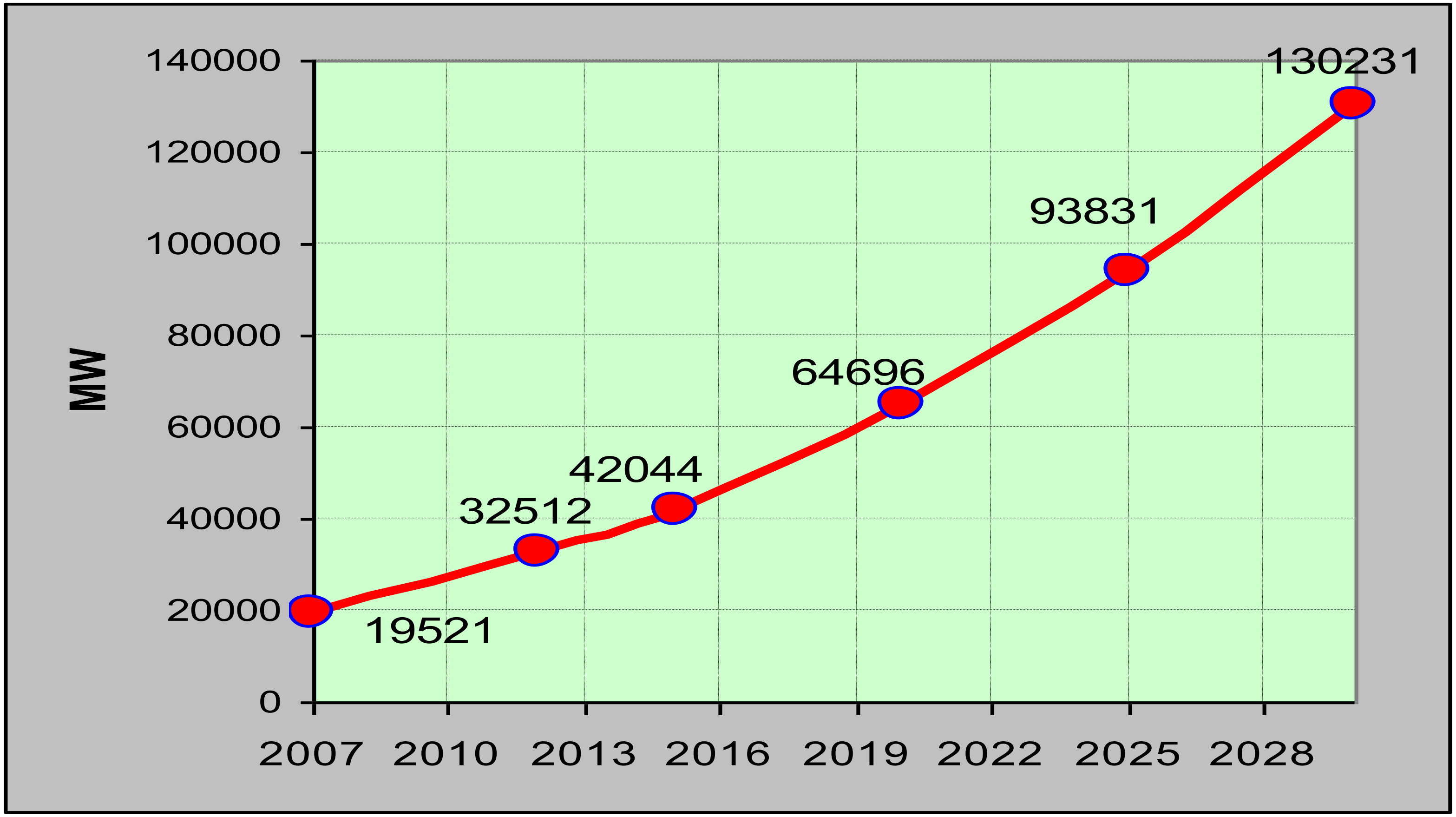
# Electric Power Demand (2007-2025)



# Generation Expansion Plan 2007-2030

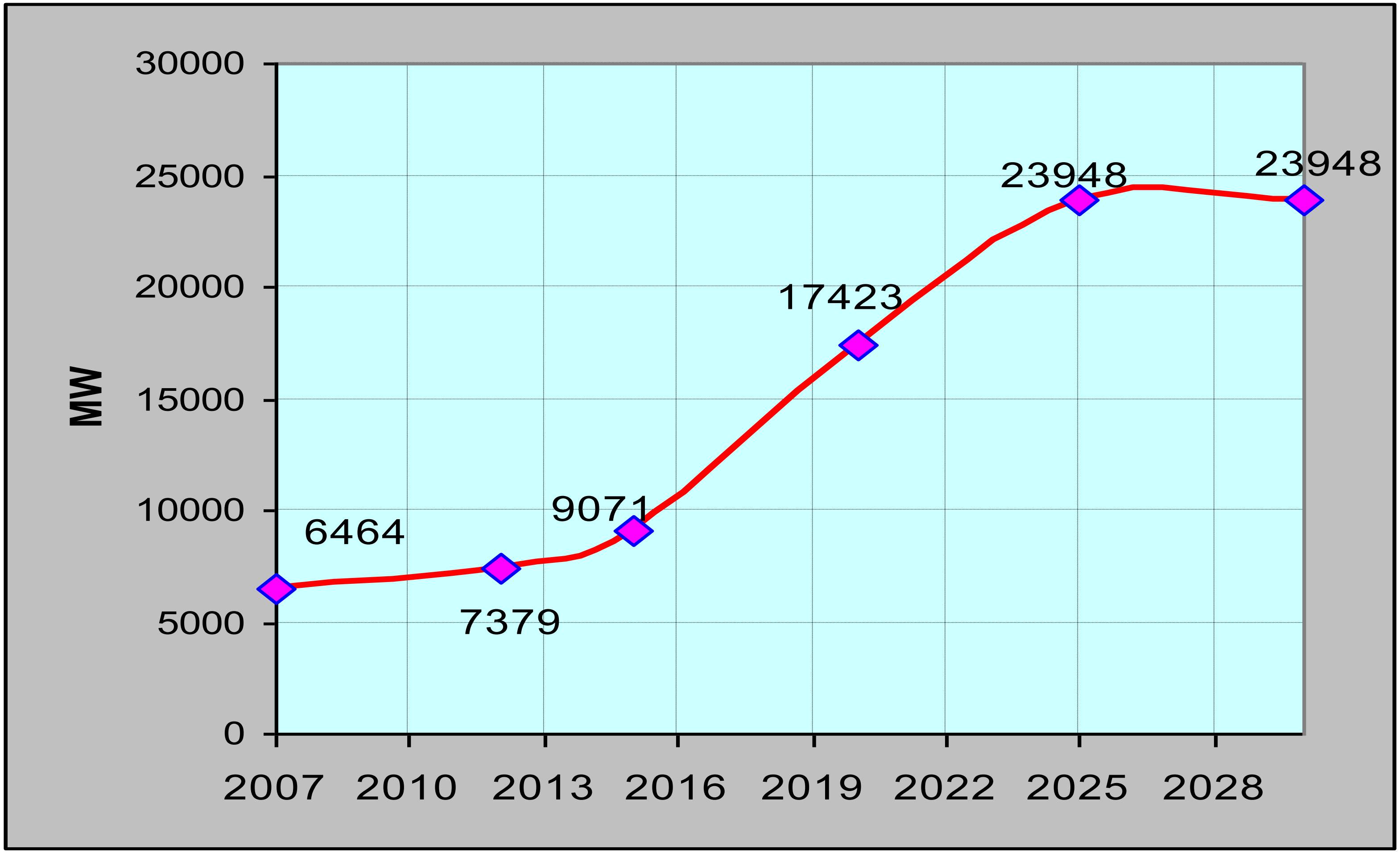
| | 2007 | 2012 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Hydel | 6474 | 7379 | 9071 | 17423 | 23948 | 23948 |
| IPPs | 6466 | 14205 | 22045 | 36345 | 58955 | 95355 |
| Genco+KESC | 6431 | 10082 | 10082 | 10082 | 10082 | 10082 |
| Rental | 150 | 846 | 846 | 846 | 846 | 846 |
| Total | 19521 | 32512 | 42044 | 64696 | 93831 | 130231 |

# Generation Expansion Plan (2007-2030)

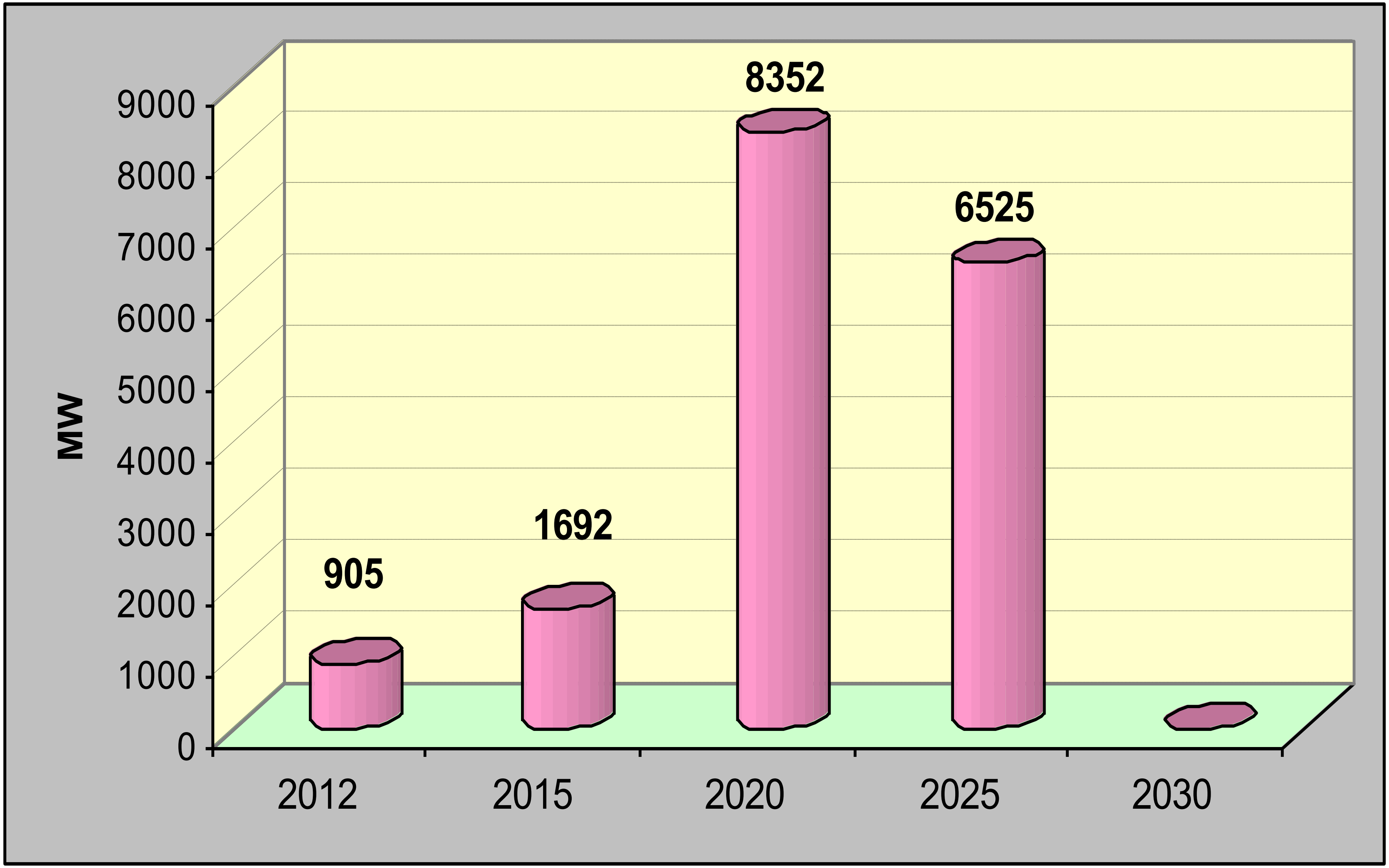



***As per generation expansion plan system needs additions of 32512 MW and 93831 MW by years 2012 and by 2025, respectively.***

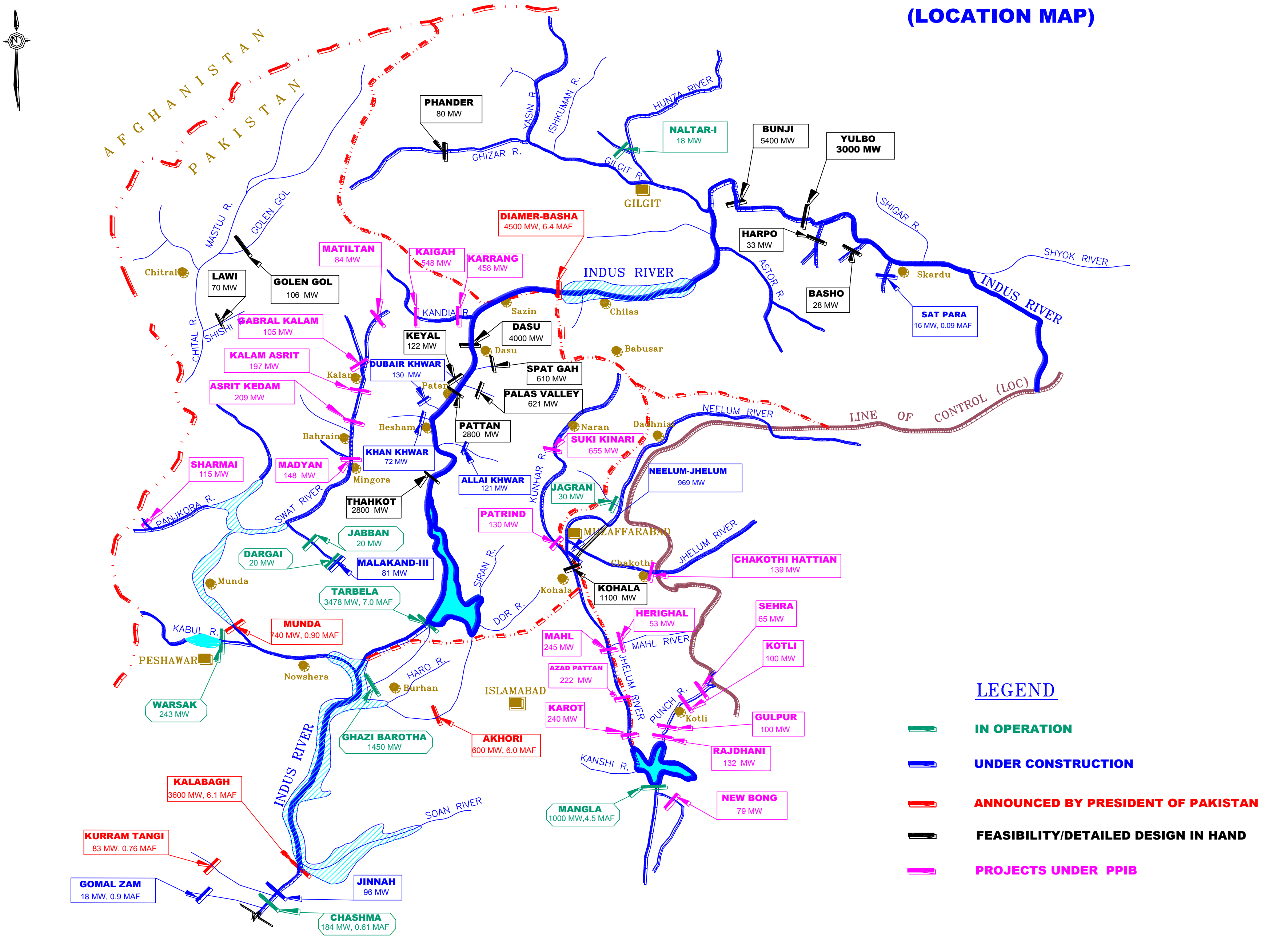
# Hydropower Generation Expansion Plan



# Hydropower Addition as Per Generation Expansion Plan



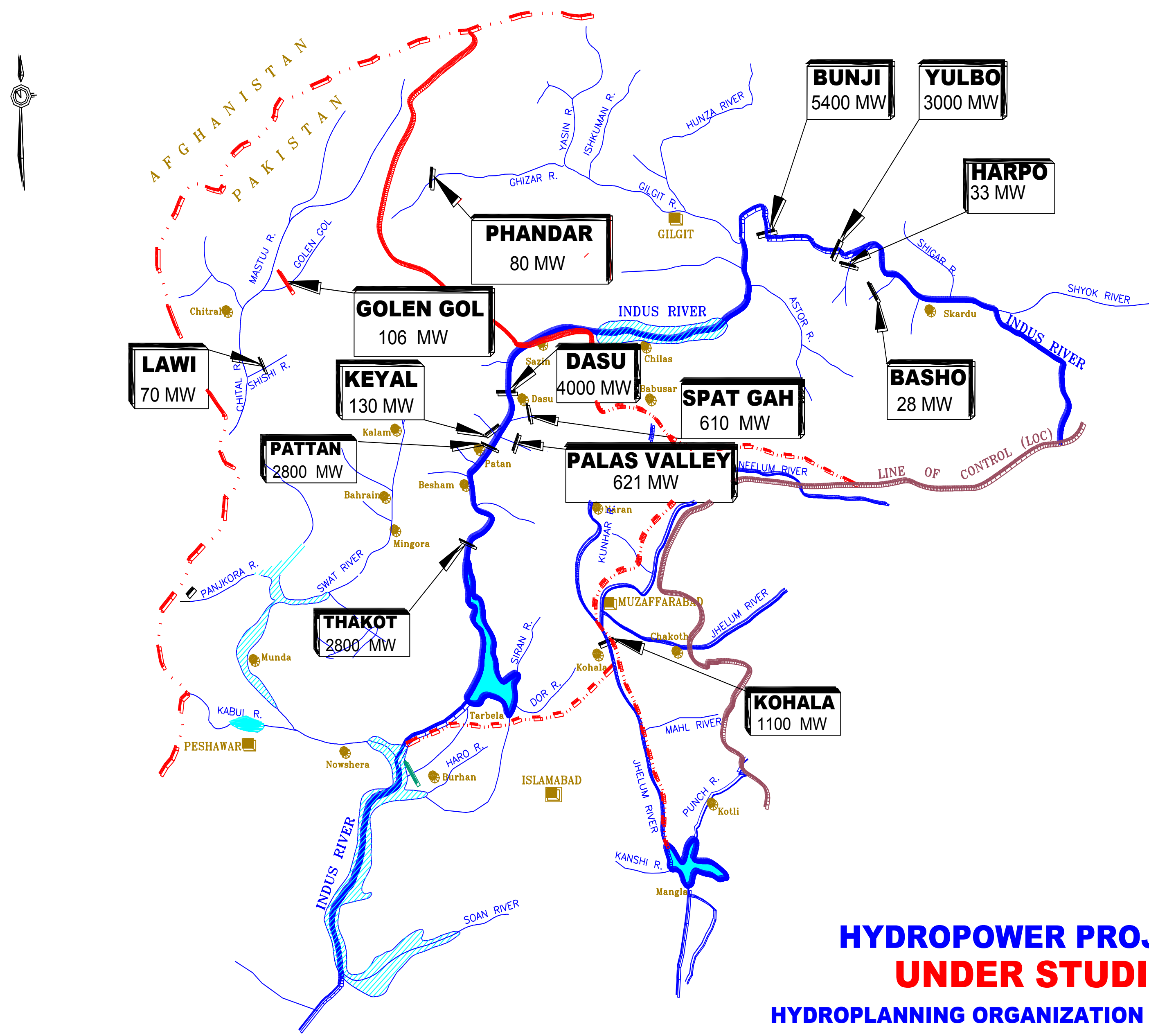
# HYDROPOWER DEVELOPMENT IN PAKISTAN
## (LOCATION MAP)




GENERAL MANAGER (HYDRO) PLANNING, WAPDA

05-03-2008

FIG-2




# HYDROPOWER PROJECTS UNDER STUDIES

**HYDROPLANNING ORGANIZATION (HPO) WAPDA**

# Hydropower projects under studies by WAPDA

| Sr. No. | Project | River | Locati on | Installed Capacity (MW) | Tentative completion month of the study | Present Status | Estimated Construction Cost Millen (US$) |
|---|---|---|---|---|---|---|---|
| 1 | Kohala | Jhelum | Kohala | 1100 | Aug, 2009 | Feasibility Study, Detailed Design and Tender Documents in progress. | 2,115 |
| 2 | Dasu | Indus | Dasu | 4320 | Mar, 2011 | Feasibility Study completed Design being started | 7,800 |
| 3 | Spat Gah | Spat Gah | Patan | 567 | Oct, 2009 | Feasibility Study in progress. | 614 |
| 4 | Palan Vally | Chor Nullah | Patan | 621 | Nov 2009 | Feasibility Study in progress. | 667 |
| | | | | | | | |

# Hydropower projects under studies by WAPDA

| Sr. No. | Project | River | Location | Installed Capacity (MW) | Tentative completion month of the study | Present Status | Estimated Construction Cost Millen (US$) |
|---|---|---|---|---|---|---|---|
| 5 | Basho | Basho | Skardu | 28 | Oct 2009 | Design and Tender Documents in process. | 35 |
| 6 | Lawi | Shishi | Darosh - Chitral | 70 | Jun 2011 | Feasibility Study completed. PC-I for Design and Tender Documents initiated. | 120 |
| 7 | Thakot | Indus | Thakot | 2800 | Jun 2013 | Feasibility Study completed Detailed Design and Tender Documents to starts. | 6,000 |
| 8 | Patan | Indus | Patan | 2800 | Jun 2015 | PC-II for Feasibility Study, Design and Tender Documents submitted. | 6,000 |

# Hydropower projects under studies by WAPDA

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Phandar | Ghizar | Gilgit | 80 | Sep 2009 | Feasibility completed Design and Tender Documents in process. | 70 |
| 10 | Keyal Khwar | Keyal Khwar | Patan | 122 | August, 2009 | Feasibility Study completed. Detailed Design and Tender Documents in program completed | 180 |
| 11 | Golen Gol | Golen Gol-Mastuj | Chitral-Mastuj | 106 | Nov 2008 | Detailed Design and Tender Documents completed . | 130 |
| 12 | Harpo | Harpo-Lungma | Skardu | 33 | | PC-II for Design and Tender Documents prepared. | 40 |
| 13 | Shyok | Shyoh | Skardu | 600 | | Desk studies | 1,000 |
| 14 | Yulbo | Indus | Skardu | 3000 | | Desk study & field reconnaissance initiated | 6,600 |
| **TOTAL** | | | | 16,247 | | | **31.37 Billion** |

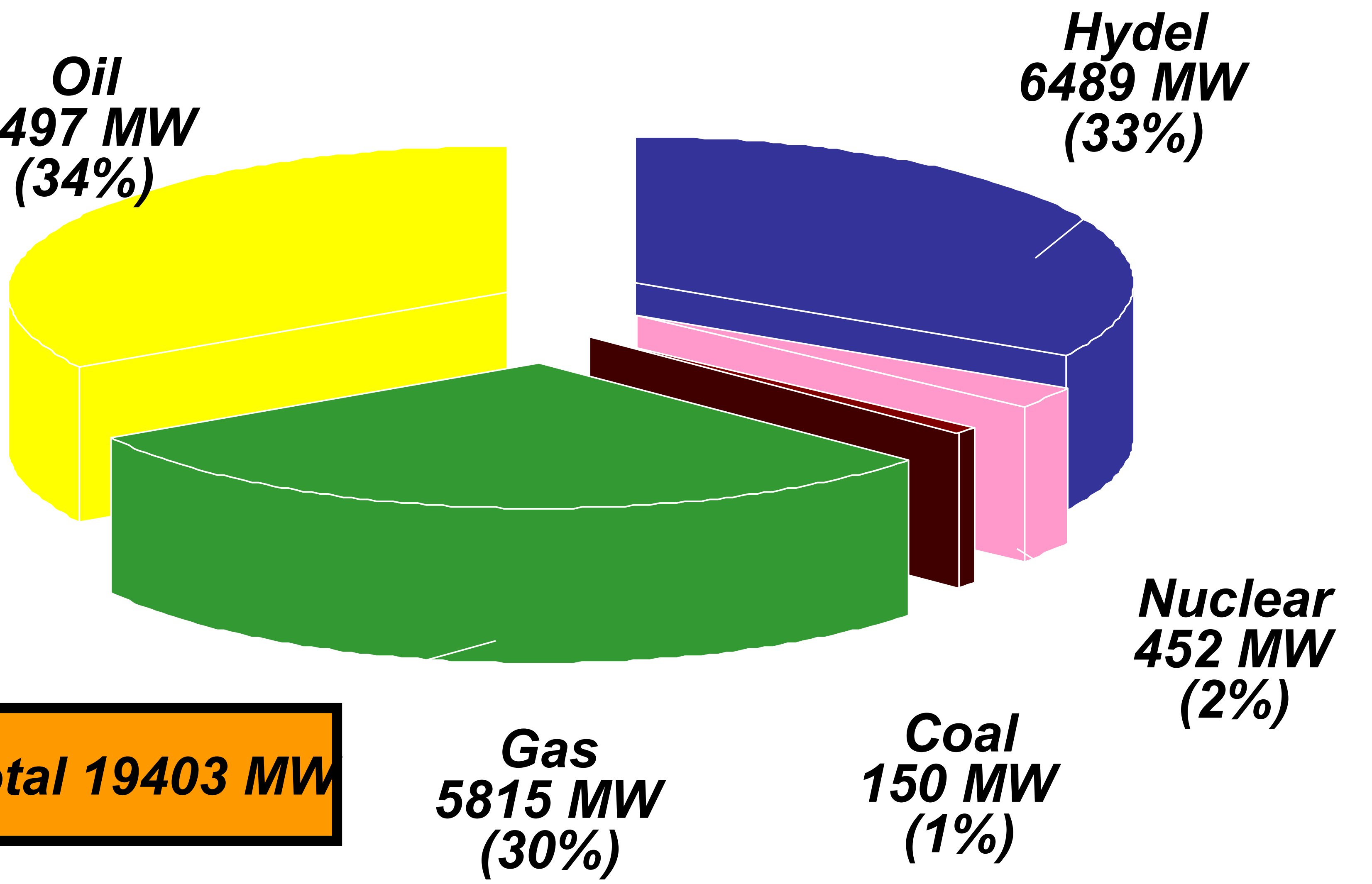
# Installed Hydropower Stations in Pakistan

| Sr. No. | Name of Station | Installed capacity (MWs) |
|---|---|---|
| 1 | Tarbela | 3478 |
| 2 | Ghazi Barotha | 1450. |
| 3 | Mangla | 1000. |
| 4 | Warsak | 240.0 |
| 5 | Chashma | 184.0 |
| 6 | Rasul | 22.0 |
| 7 | Malakand | 19.6 |
| 8 | Dargai | 20.0 |
| 9 | Nandipur | 13.8 |
| 10 | Shadiwal | 13.5 |
| 11 | Chichoki Malian | 13.2 |
| 12 | K.Garhi & Renala | 5.1 |
| 13 | Chitral | 1. |
| 14 | Satpara | 4.86 |
| | **Total** | **6464** |

# Hydropower Projects in Private Sector

| Name of Project | Capacity (MW) | Tentative Commissioning |
|---|---|---|
| New Bong Escape at | 84 | 2010 |
| Rajdhani at Punch (AJK) | 132 | 2011 |
| Matiltan at Swat | 84 | 2012 |
| Malakand III( ) | 81 | 2008 |
| Kotli | 100 | 2011 |
| Gulpur (AJK) | 120 | 2012 |
| Gabral – Kalam | 101 | 2012 |

# OVERVIEW OF PAKISTAN POWER SECTOR
## GENERATION PATTERN




Total 19403 MW

# Barriers in the Development of Hydel Power

1. **To achieve consensus among people & provinces.**
2. Technology and Information Barriers.
3. Policy Barriers.
4. Regulatory Barriers.
5. Institutional Barriers.
6. Financial Barriers.
7. Interconnection Barriers.
8. Tariff.
9. Procedural impediments.

   9. Risks
      a. Hydrological Risks
      b. Geological Risks.
      c. Environment Risks.
      d. Miscellaneous.

# Technology and information Barriers.

- We lack knowledge & information about the Technology of hydel.
- Need for education of hydel power technology not only for the Engineers but also for general public & decision makers.

## Strategy to achieve five E's

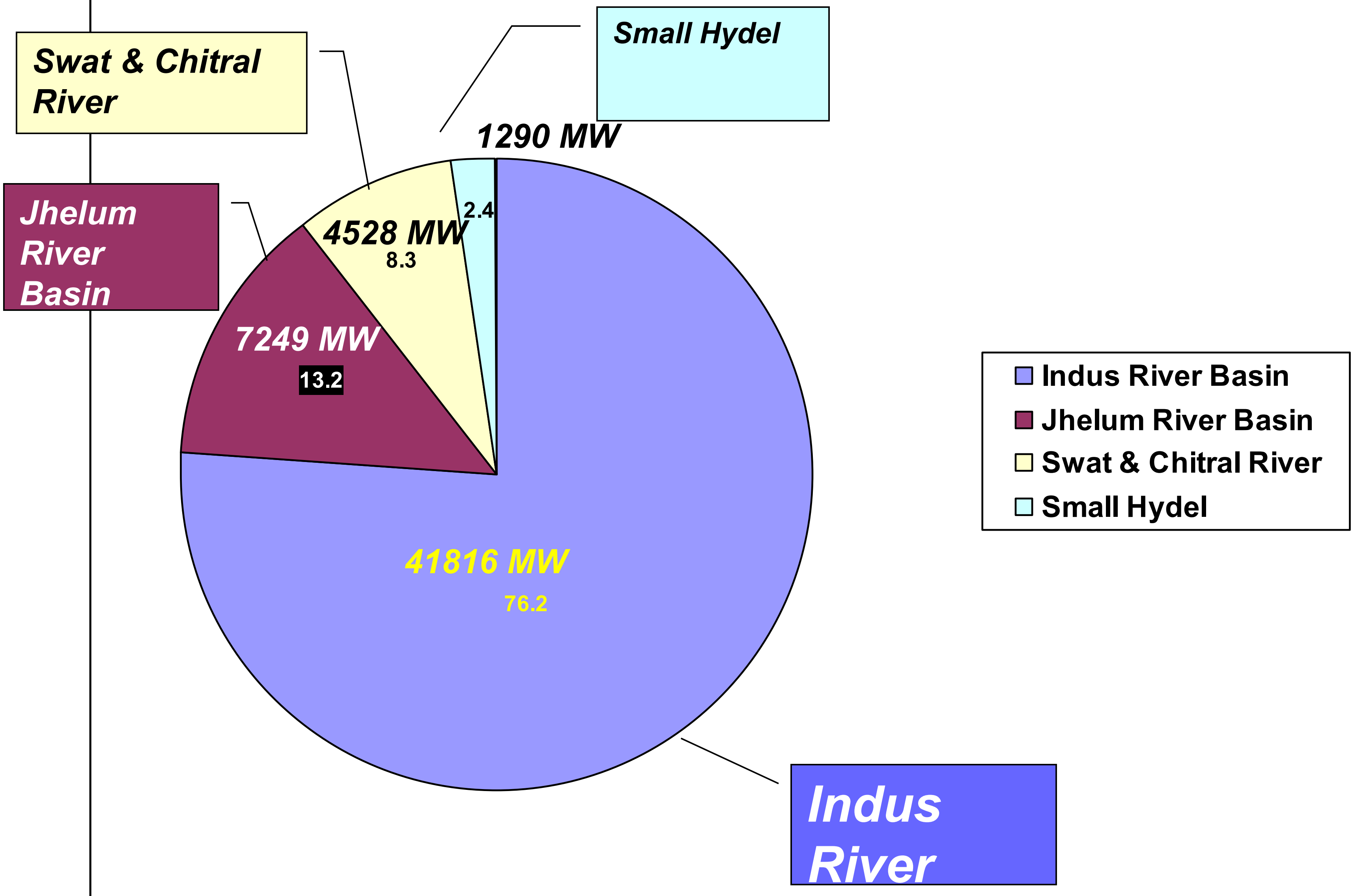
**E------ Education**
**E------ Energy**
**E------ Employment**
**E------ Equity**
**E------ Enterprise**

UET Taxila has taken a lead in starting the classes for post graduate students about Hydel Power to implement the most important "Es" of Education in Energy & for Employment on Equity basics for Enterprises.

# PAKISTAN'S HYDROPOWER POTENTIAL (SUMMARY)

| Sr. No. | River/ Tributary | Power (MW) |
|---|---|---|
| 1. | Indus River | 35760 |
| 2. | Tributaries of Indus (Northern Areas) of NWFP | 5558 |
| | Sub Total (1+2) | 41318 |
| 3. | Jhelum River | 3143 |
| 4, | Kunhar River | 1250 |
| 5. | Neelum River & its Tributaries | 2459 |
| 6. | Poonch River | 397 |
| | Sub Total (3+4+5+6) | 7249 |
| 7. | Swat River & its Tributaries | 2388 |
| 8. | Chitral River & its Tributaries | 2282 |
| | Sub Total (7+8) | 4670 |
| 9. | Schemes below 50 MW on Tributaries | 1290 |
| TOTAL | | 54, 527 |

# PAKISTAN'S HYDROPOWER POTENTIAL



# PAKISTAN POWER DAM PROJECT

## (And Not KALABAGH DAM As It Is Multi Purpose But Made Controversial)

- Pakistan Dam dedicated for 3,600 MW Electricity.
- No Provision for canal.
- 35 million acres land irrigated Canal with drawl.
- Storage depleted by 6MAF to be supplemented.
- Situation of water shortage, threat of famine.
- Have reached the stage of “acute water shortage”, where people fight for every drop of water.
- Electricity generated will also pump water from tube wells
- Investigations studies started In 1953 and project planning feasibility in 1982

# Reservoir of Pakistan Dam

| | |
|---|---|
| Live storage | 6.1 MAF |
| Gross storage | 7.9 MAF |
| Maximum Retention level | 915 ft |
| Minimum reservoir level | 825 ft |
| Average Flow | 123,000 cusec |
| **Main Dam** | |
| Crest elevation | 940 ft |
| Maximum height | 260 ft |
| Length | 4,375 ft |
| **Installed Capacity** | 3600 MW+600=4200 |
| Yearly generation | 12 Billion kWh |
| Annual Benefits | Rs. 88 Billion |
| **Estimated Cost** | **US$6.2 Billion** |

# BENEFITS OF PAKISTAN DAM

The benefits to be derived from Pakistan Dam are enormous. On average, every year they will be higher than as given below

| | |
|---|---|
| | (Rs in Billion) |
| Average annual power benefits | 64.64 |
| Average annual irrigation benefits | 12.53 |
| Average annual flood alleviation benefits | 1.44 |
| Additional power from Tarbela | 8.97 |
| Average yearly benefits | 87.58 |

# NATIONAL LOSS IF PAKISTAN DAM IS NOT BUILT

- The Annual energy generated would be equivalent to 20 million barrels of oil otherwise needed to produce thermal power.
- National food needs would be jeopardized.
- 38% loss of storage capacity of the existing reservoirs due to sedimentation, results in shortage of committed irrigation supplies.
- Industrial, Commercial, Economic & quality of life will deteriorate further.
- For implementation of Water Apportionment Accord 1991, new storages are essential. it would give rise in bitter inter-provincial disputes,

# Salient Features of Pakistan

**(AS OF 1993)**

| | | |
|---|---|---|
| Irrigated Area | 34.5 | M.Acres |
| Cultivated Area | 51 | M.Acres |
| Total Area | 197 | M.Acres |
| Total Surface Flow | 151 | M.Acre Ft |
| Canals Withdrawals | 106 | MAF |
| Ground Water Pumps | 43 | MAF |
| Total length of Canals | 58,500 | KM |
| Agricultural Produce | 26% | of GDP |

# WATER STORAGE CAPACITIES OF SOME COUNTRIES

- Pakistan can store only 30 days of water.
- India can store 120-220 days of water
- South Aferica can store 500 days of water
- Eygpt Aswan dam can store upto 700 days of water

# APPREHENSIONS OF SINDH

**(1) No surplus water to fill Pakistan Dam reservoir**

- ® Annual average of 35 MAF escape below Kotri to Sea.
- ® Pakistan Dam reservoir will be filled up by only 6MAF, which will gradually be released to the provinces.
- ® Indus River System Authority (IRSA) has studied and confirmed that sufficient water is available for further storage
- ® Surface flow annual 151 MAF

**(2) Anxiety the project would render Sindh into desert.**

® Dams don’t consume water! These only store water during flood season and make it available on crop demand basis

® After Pakistan Dam, the canal withdrawals for Sindh would further increase by about 2.25 MAF.

**(3) Outlets would be used to divert water from the reservoir**

® The project design must not include any provision for canals.

® **T**elemetric system are working well which are installed at each barrage and flow control points to monitor discharge in various canals commands, on real time basis under the auspices of Indus Water River System Authority (IRSA) and in all provinces.

**(4) Cultivation in "Sailaba" areas would be effected**

® Flood peaks above 300,000 cusecs would still be coming after construction of Pakistan Dam, without detriment to the present agricultural practices, while large floods would be effectively controlled. This would, in fact, be conducive to installation of permanent tube wells to provide perennial irrigation facility in rive rain areas. The farmer can have two crops annually instead of the present one crop.

**(5) Sea Water intrusion estuary would accentuate.**

® Data shows that sea water intrusion, seems to be at its maximum even now, and it is unlikely to be aggravated further by Pakistan Dam.

# APPREHENSION OF NWFP (KPK)

**1. flooding of Peshawar Valley including Nowshera**

- ®Backwater effect of Dam lake would end about 10 miles downstream of Nowshera.

**2. Area of Mardan, Pabbi and Swabi plains would be adversely affected creating water logging and salinity.**

- ® Lowest ground levels at Mardan, Pabbi and Swabi areas are 970, 960 and 1000 feet above MSL respectively, as compared to the maximum conservation level of 915 ft for dam, Operation pattern of reservoir cannot block the land drainage and cause water logging or salinity

**4. Operation of Mardan SCARP would be adversely affected.**

® The invert levels of main drains of Mardan SCARP are higher than reservoir elevation of 915 feet and the back water level in Kabul River. These drains would keep on functioning without any obstruction.

**5. Fertile cultivable land would be submerged.**

® Total cultivable affected land under the reservoir is only 35,000 acres,(24,500 acres in Punjab 3,000 acres in NWFP).irrigated land would be only 3,000 acres (2,900 acres in Punjab and 100 acres in NWFP).

**6. Population Dislocation**

® Total population to be relocated is 120320 of which 78,170 shall be from Punjab and 42,150 from NWFP.

**Resettlement of Affected Population will be properly compensated**

# BENEFITS OF HYDEL POWER DEVELOPMENT

- Hydel Potential of 54,000MW to be harnessed to avoid load shedding
- To reduce dependency on oil import
- Hydel power a stimulator for the socio-economic growth
- Highly reliable, cheap operation and maintenance
- Able to respond to rapidly changing loads without loss of efficiency
- The plants have a long life so highly economical

# BENEFITS OF HYDEL POWER DEVELOPMENT

- No nuisance of smoke, exhaust gases, soot, as environment, friendly
- Multipurpose to give additional advantages of irrigation, flood control
- Optimal Utilization for development of Hydropower Projects in cascade
- Cheap Electricity, food security, drinking water, flood control, drought mitigation, environment control, carbon credit

# Challenges in Hydropower Projects

- To achieve consensus among people & provinces.
- Generally located in remote area, lack of basic infrastructure (access roads, tunnels, electricity, telephone, colony, potable water, manpower)
- Dedicated and expensive delivery infrastructure required
- Extra thermal capacity for backup in low water season
- Hydel Generation varies with availability of water & head
- Limited International experience in Private Hydropower Projects

# Challenges in Hydropower Projects

- ❖Specific Tariff & Security Documents issues
- ❖Project Agreements (IA, PPA) are different and complex
- ❖Clearances from the Provinces, Water Use Agreement etc.
- ❖More Capital intensive compared to thermal
- ❖Longer gestation and construction Period
- ❖More Construction Risks (inflation, cost overruns, delays, geological surprises, floods, extreme weather, socio-political)

Higher Tariff in the initial years

No "off-the-shelf" or standard machines similar to thermal plants

# Challenges in Hydropower Projects

- Very site specific. Usually a number of options for developing each site
- High percentage of civil works (70-75%) - difficult to estimate end costs
- Operational Risks (hydrological risk, multiple uses, future developments/diversions)
- Environmental & resettlement issues
- Institutional set up at provincial level
- **To mitigate the conspiracy that "No large dam to be allowed to be build in Pakistan"**

# COMPARISON OF HYDRO POWE PLANTS

EXISTING, UNDER CONSTRUCTION AND PLANNED

| | *Pakistan* | | *India (Himalayan region)* | |
|---|---|---|---|---|
| | *No. of Projects* | *Capacity ( MW)* | *No. of Projects* | *Capacity ( MW)* |
| *Existing* | *6* | *6,385* | *74* | *15,208* |
| *Under Construction* | *7* | *1,405* | *37* | *17,765* |
| *Planned* | *35* | *33,769* | *318* | *93,615* |
| *Total* | *48* | *41,559* | *429* | *126,588* |

# MAJOR HYDROELECTRIC STATIONS OF THE WORLD

| *S.No* | *Name* | *Country* | *Year of Completion* | *Total capacity (MW)* | *Annual Electricity Production (TWh)* |
|---|---|---|---|---|---|
| 1 | *Three Gorges Dam* | *China* | *2009* | *22,500* | *>100* |
| 2 | *Itaipu* | *Brazil / Paraguay* | *1984/2003* | *14,000* | *90* |
| 3 | *Guri* | *Venezuela* | *1986* | *10,200* | *46* |
| 4 | *Grand C oulee* | *USA* | *1942 / 1980* | *6,800* | *22.6* |
| 5 | *Tarbela* | *Pakistan* | *1976* | *3,478* | *13* |
| 6 | *Mangla* | *Pakistan* | *1967* | *1,000* | *-* |

| | |
|---|---|
| ***Project Location*** | ***Chilas on Indus River 315 km upstream of Tarbela Dam,*** |
| ***Height of Dam*** | ***272 m*** |
| ***Length of Dam*** | ***990 m*** |
| ***Gross Storage*** | ***8.1 Million-acre feet (MAF)*** |
| ***Live Storage*** | ***6.4MAF*** |
| ***Total Installed Capacity*** | ***4,500MW*** |
| ***Total Number of Units*** | ***12, each of 375 MW*** |
| ***Power Houses*** | ***2 (2,250 MW each)*** |
| ***Average Generation*** | ***18,000 Gwh/ annum*** |
| ***Construction Period*** | ***2009-2017*** |

***Present Status***

- ***Feasibility Completed in 2007.***