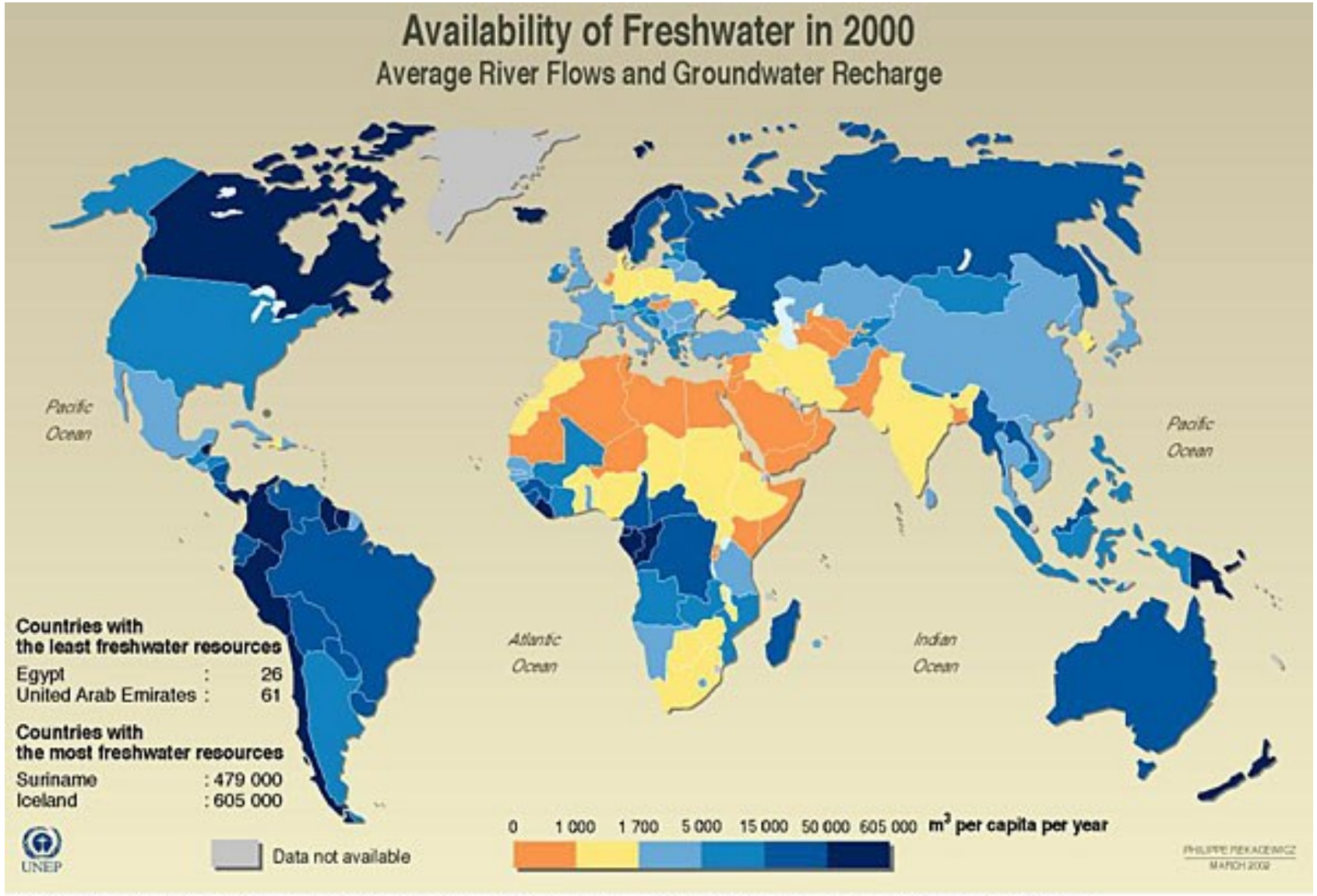
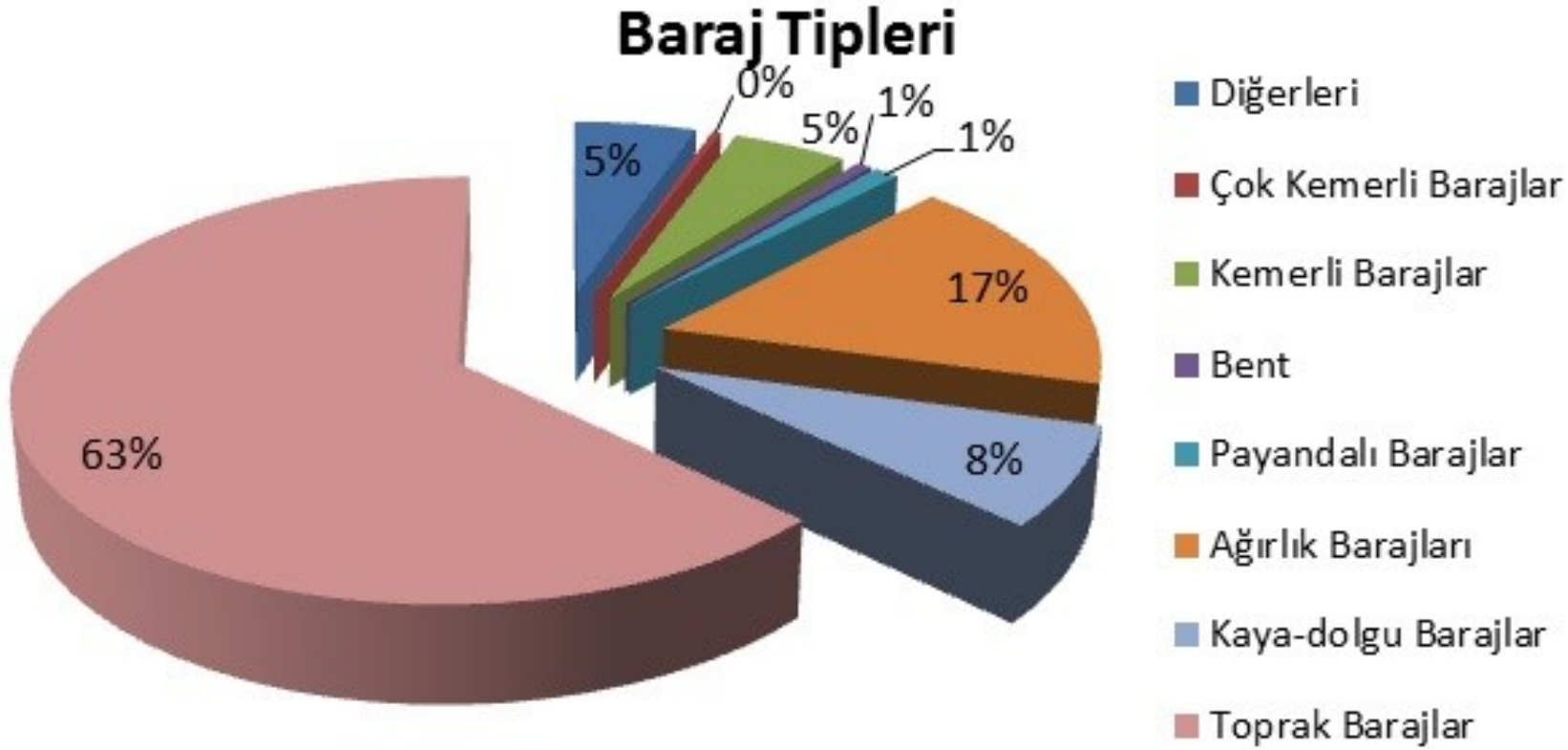
DAM GEOLOGY

DISTRIBUTION of WATER RESOURCES



Source: *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.


Baraj Tipleri
5%
0%
5%
1%
1%
17%
8%
63%
Diğerleri
Çok Kemerli Barajlar
Kemerli Barajlar
Bent
Payandalı Barajlar
Ağırlık Barajları
Kaya-dolgu Barajlar
Toprak Barajlar

Definition

A dam is a structure which prevents the flow of water and accumulates it in a reservoir

Karakaya Dam/Diyarbakır

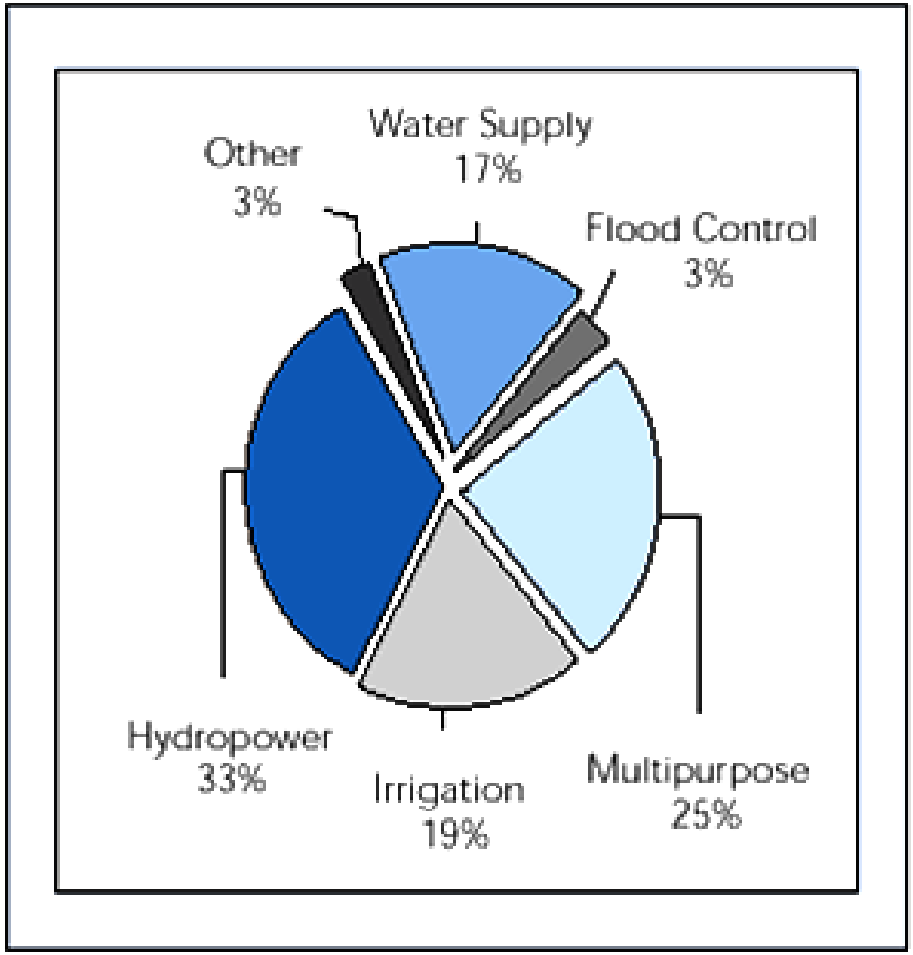
Atatürk Dam/Şanlıurfa

Needs for Dam Construction

1. Drinking and domestic water supply
2. Flood control
3. Irrigation
4. Industrial water supply
5. Hydroelectric energy production
6. Retention and control of sediments

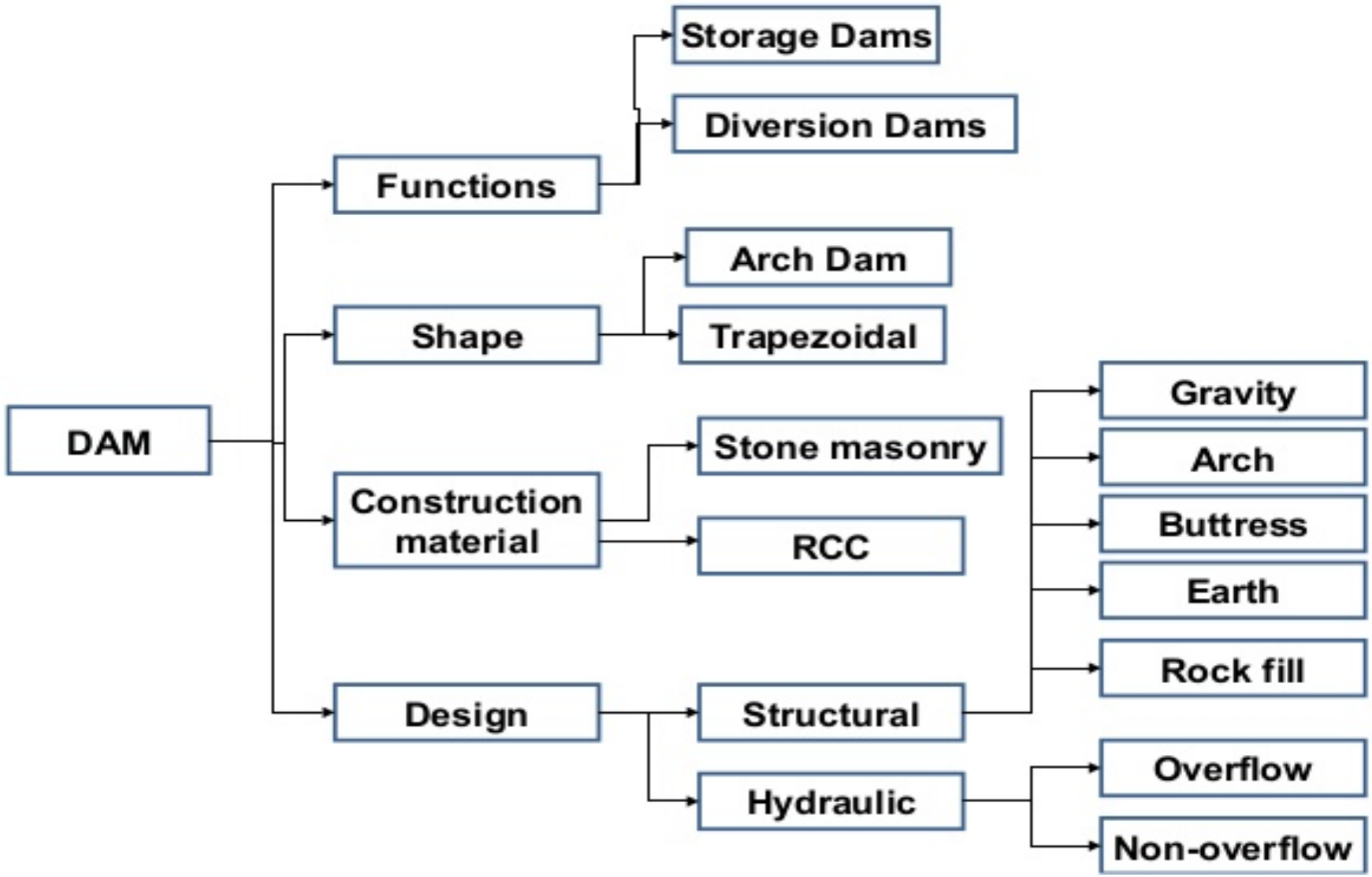
and Inland navigation, Improvement of water quality, Fish Farming, Recreation facilities

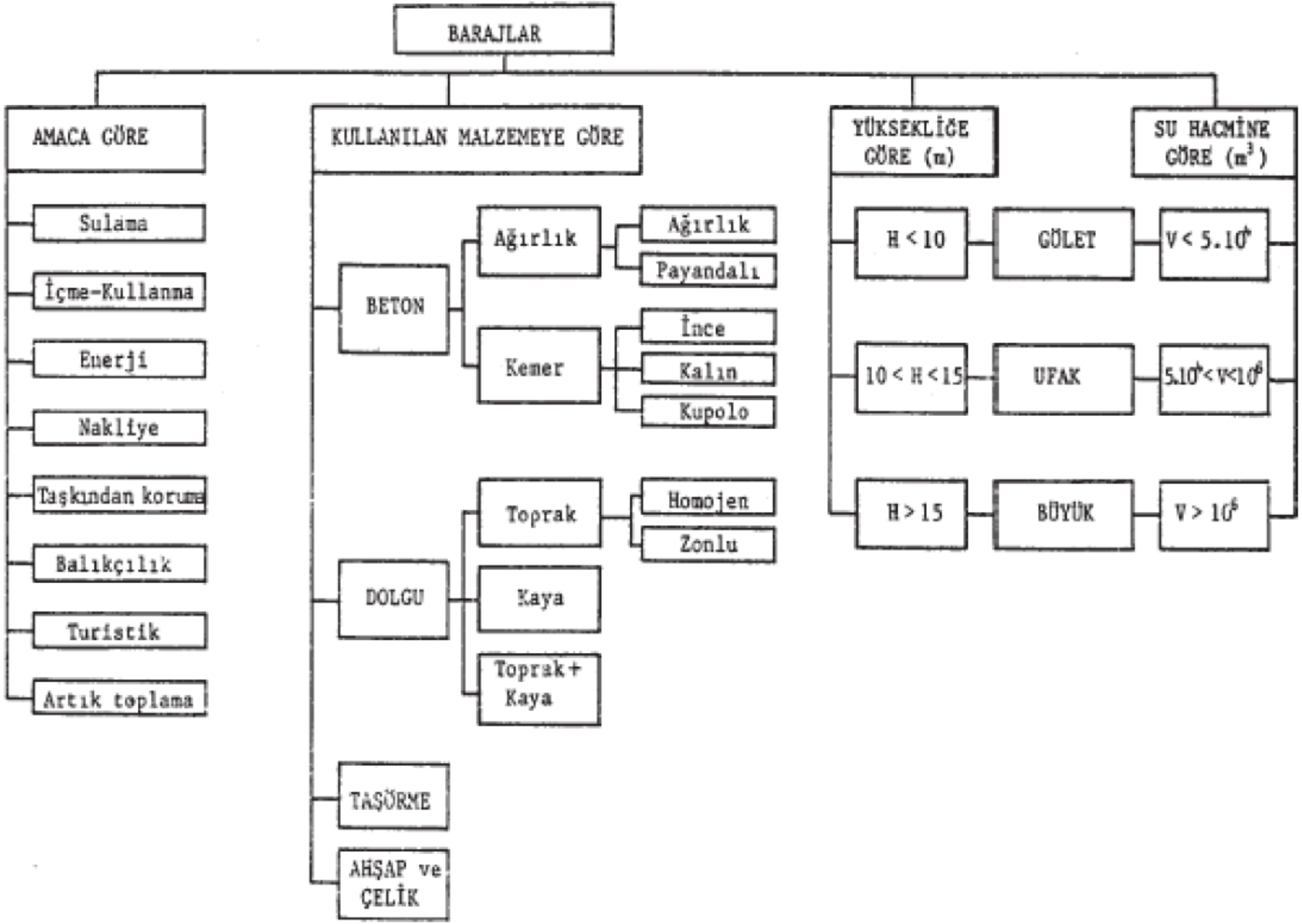
BREAKDOWN by PURPOSE of DAMS in EUROPE



Source: ICOLD, 1998.
Note: Rates of dam commissioning in the 1990s are underreported.

Dams - Classification





Barajların değişik açılardan sınıflandırılması (Tarhan, 2002).

COMPONENTS of DAMS

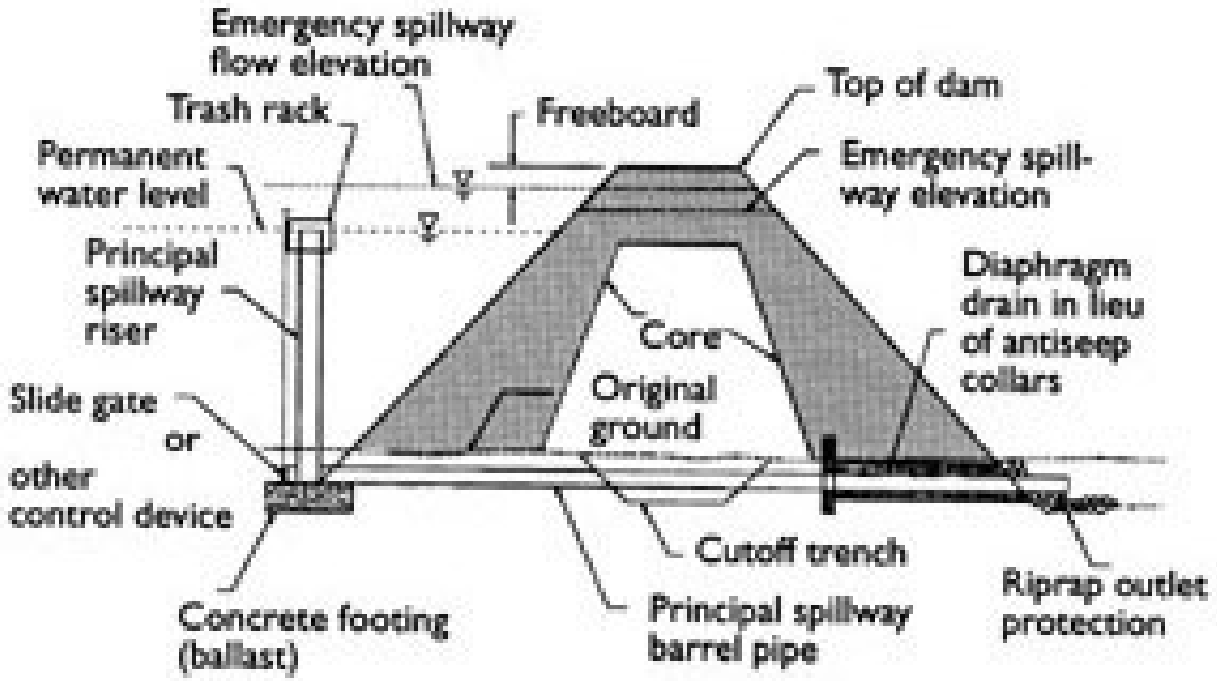
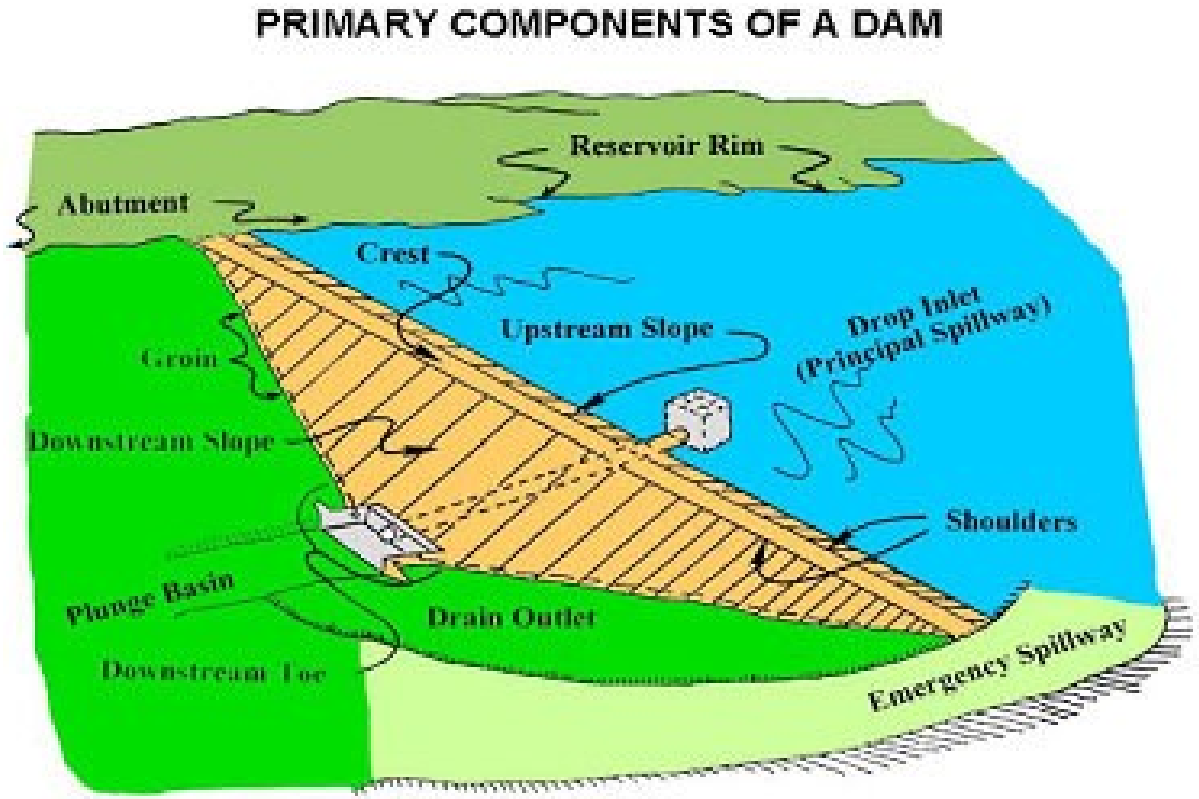
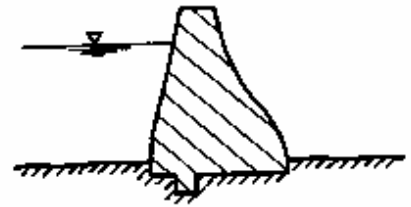
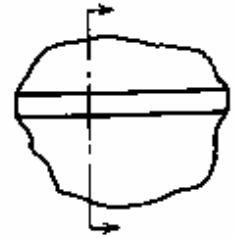
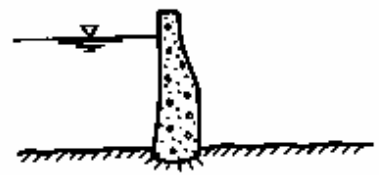
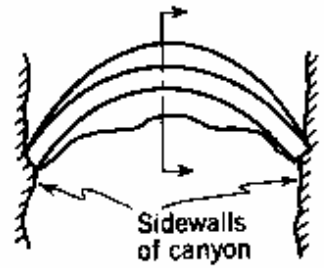
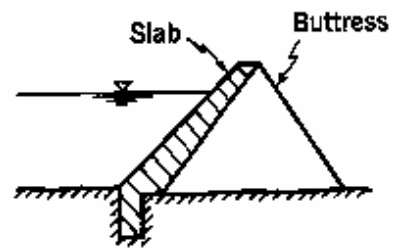
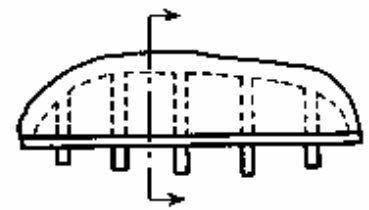
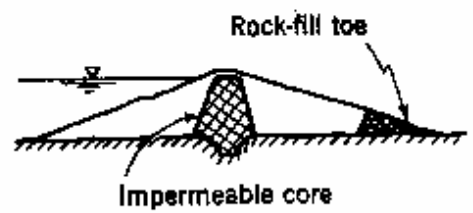
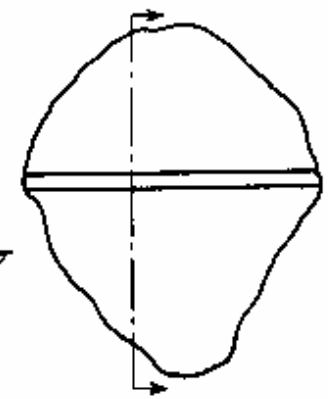


Figure 8. Typical cross section of dam along centerline of principal spillway (not to scale)



Dam types

Type	Material	Sectional View	Plan (Top View)
Gravity	Concrete, rubble masonry		
Arch	Concrete		
Buttress	Concrete also timber and steel)		
Embankment	Earth or rock		

ACCORDING to the SIZE of the DAM

1. ***Large (Big) dam***
2. ***Small dam***

- International Commision on Large Dams, (ICOLD) assumes a dam as big when its height is bigger than 15m.

- If the height of the dam is between 10m and 15m and matches the following criteria, then ICOLD accepts the dam as big:

    - If the crest length is bigger than 500m
    - If the reservoir capacity is larger than 1 million m^3
    - If the flood discharge is more than 2000 m^3/s
    - If there are some difficulties in the construction of foundation

ACCORDING to HEIGHT of DAM

- *High Dam or Large Dam*
    - If the height of the dam is bigger than 100m
- *Medium Dam*
    - If the height of the dam is between 50m and 100m
- *Low Dam or Small Dam*
    - If the height of the dam is lower than 50m

ACCORDING to the STATICAL DESIGN of DAM BODY

- Gravity Dams (Sarıyar, Çubuk I, Kemer, Sır II Karacaören II)
- Arch Dams (Gökçekaya, Karakaya, Oymapınar, Gezende)
- Butress Dams (Elmalı II)
- Embankment Dams (Atatürk, Seyhan, Aslantaş)
- Composite Dams (Keban)

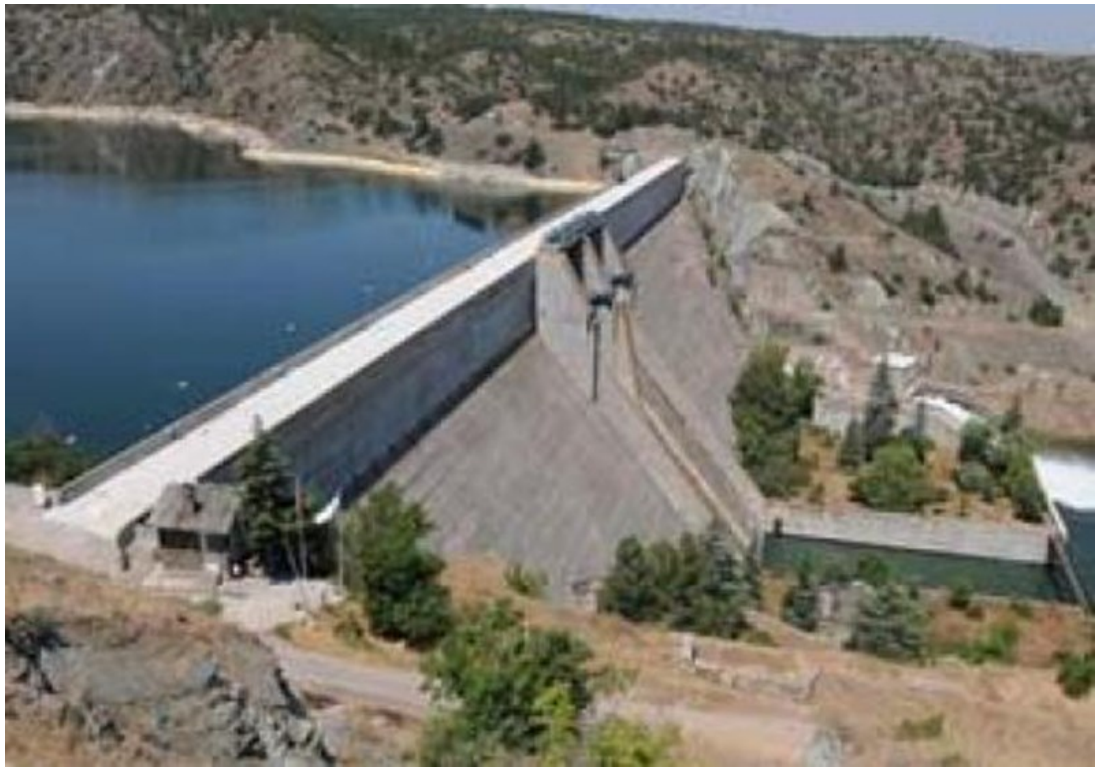
DAM TYPES

Concrete dams

- Gravity Dams
- ButtressDams
- Arch Dams

Gravity Dams

- Use their triangular shape and the sheer weight of their rock and concrete structure to hold back the water in the reservoir.
- The axes may be slightly curved in the correct shape or upstream.
- The cross section of the dam is triangular-like.
- Gravity dams are required to have a solid foundation.
- The slopes of the valley can have little inclination, wide V shape.



DAM TYPES

Buttress Dams 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

- The upstream side of such dams is a flat or slightly inclined reinforced concrete curtain which stands against water pressure.
- On the downstream side there are separators that convey water pressure.
- Consealed weight dams are less concrete than gravity dams, and the foundation ditch is less. Power stations and some other constructions may be located between the piers.
- There are too much burden on the buttress, however; not too much burden among the pylons. Zones of weakness (faults, cracks, etc.) are encountered between the buttresses.
- Buttresscan be built in wide V-shaped valleys with little slope.

DAM TYPES

Arch Dams utilize the strength of an arch to displace the load of water behind it onto the rock walls that it is built into.

Arch Dam is a water retention facility consisting of a single curved concrete wall.
To give the water pressure to the slopes by the effect of the arch, the concrete wall is curved towards the fount. If the pressure is equally distributed and the slopes are equally distributed, the dam can be made as a gravity or gravity-arch.
If a part of the burden can be transferred to the slopes by the influence of the arch, this dam is called a thin arch dam. For this, the slopes should be very strong and the arch should be well clamped into the slope.
Giving the form of rock to the rocks prevents the accumulation of stresses and the formation of cracks in the concrete.
In order to clamp the arch to the slopes well, it must be at least 45 degrees at the junction of the arch and the vane. Also, a large center angle should be given to the arch as it comes from the hand.

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

DAM TYPES

Earth Fill Dams

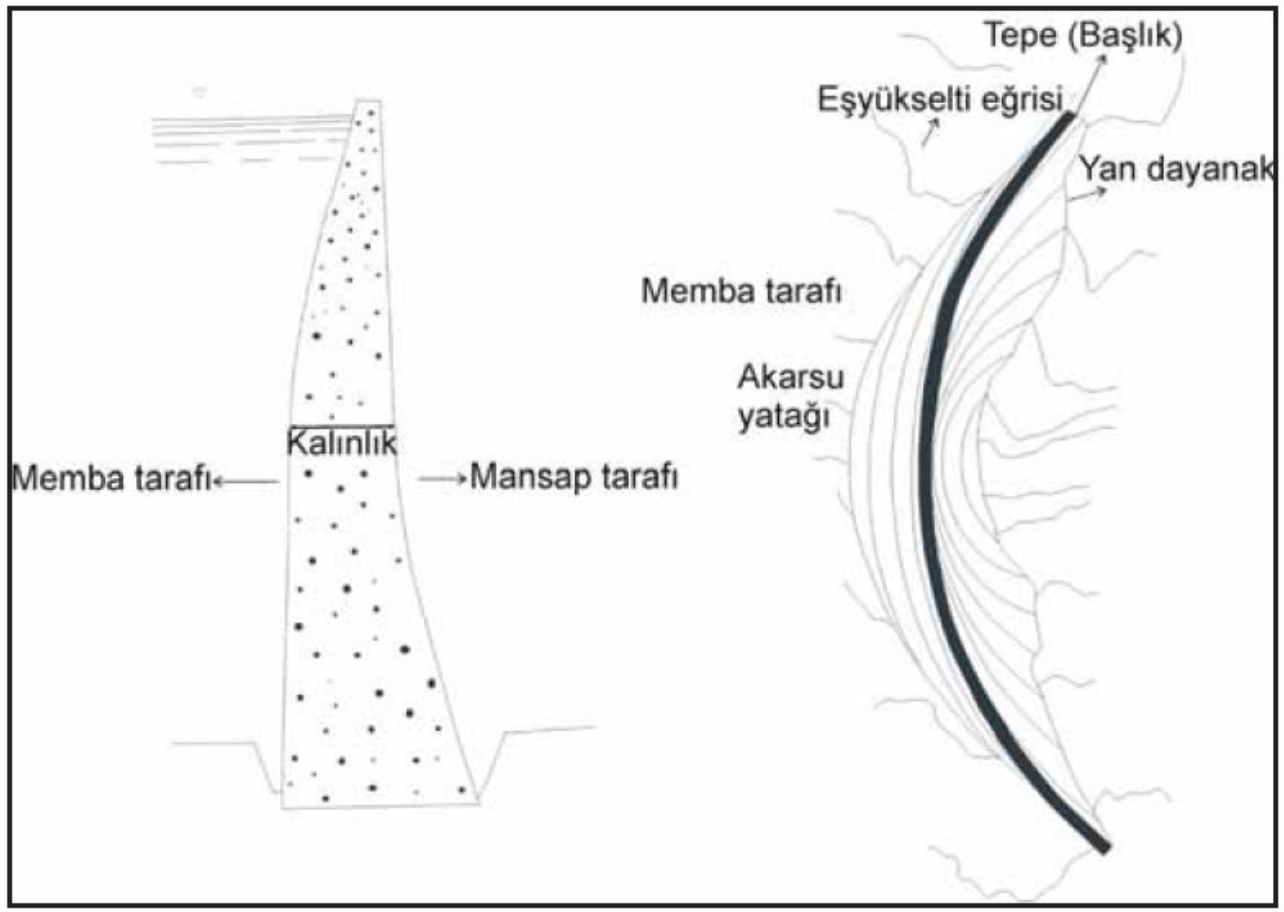
Soil dams are water-holding plants made by mixing soil and rock at a specific location. Such dams are preferred if the floor is not sufficiently strong and homogeneous.

Wide and flat earthen dam in the valley is made.

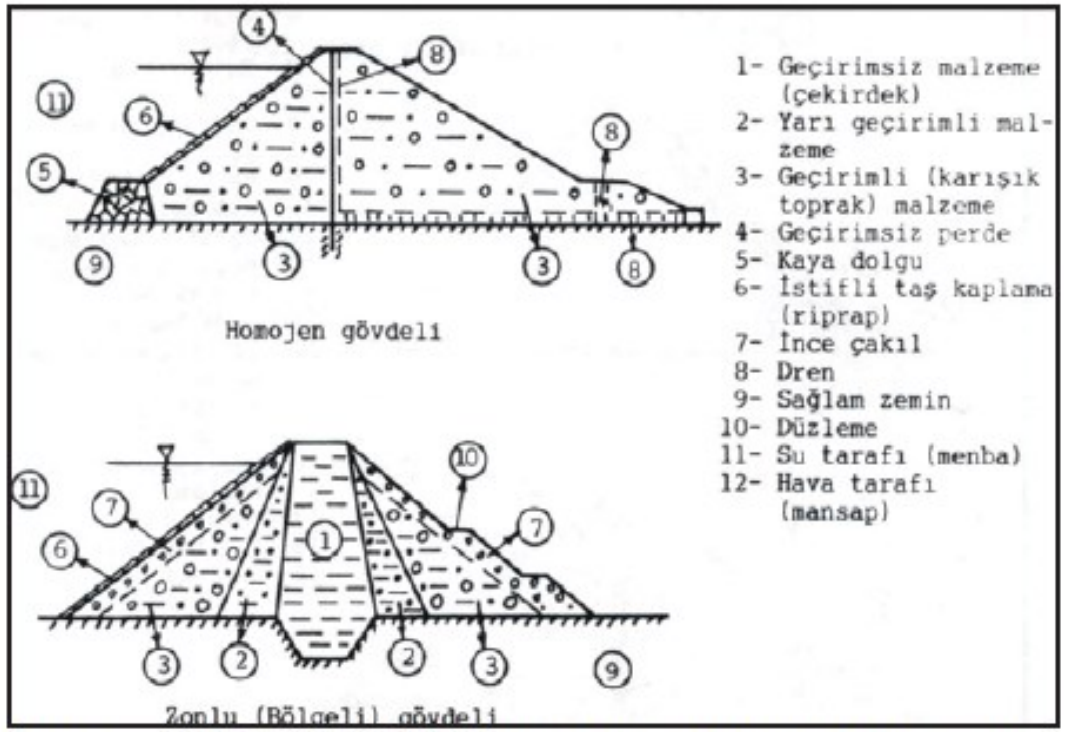
Classification of soil dams according to material used in dam body:

- Homogeneous body
- Regional
- Rock fill body
- Soil fill body
- Rock-soil body

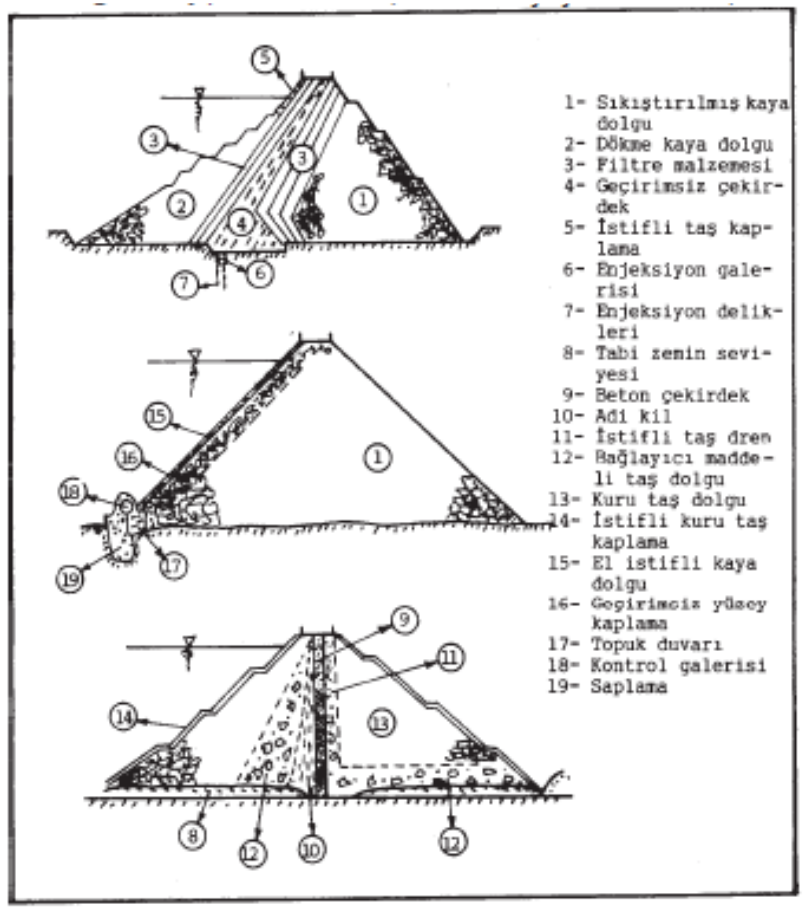
Homogeneous body is the same material on each side. The zoneed bodys have an impermeable part in the middle, a permeable part growing gradually outward on the two sides and a filter on the upstream and downstream heels. The rock fill bodies are made of broken stone. Sometimes the impermeable core is found and sometimes the upstream face is covered with an impermeable cover (clay, asphalt, steel, reinforced concrete, etc.).



Şekil 11.4. Bir kemer baraj ve kesiti (Ertunç, 2003).



Şekil 11.7. Toprak dolgu baraj *(earth fill dams)* türleri ve çeşitli kısımları (Tarhan, 2002).



kil 11.8. Kaya dolgu baraj *(rockfill -embankment- dams)* türleri ve çeşitli kısımları (Tarhan, 02).

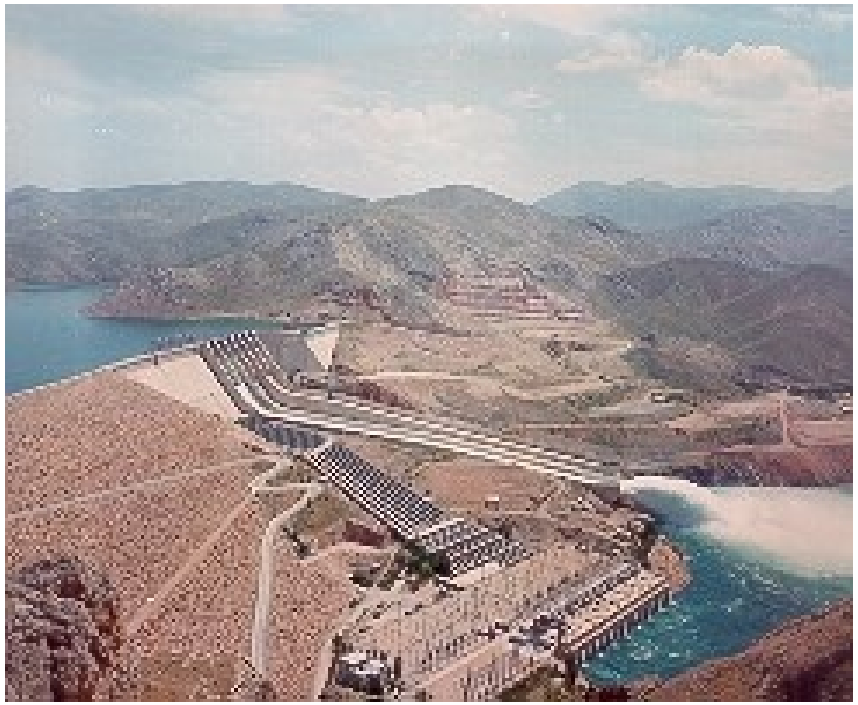
EMBANKMENT DAMS
(Rock Fill or Earth Fill Dams)

- 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

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.



Gravity & Rock Fill

Keban Dam – Fırat River;
Height= 163 m;
Reservoir Capacity= 31 billion m^3

ENGINEERING GEOLOGICAL STUDIES IN THE DAM AND THE FACTORS AFFECTING THE SELECTION OF THE PLACE

1. **Dam site features:** The topography of the dam site, the geological structure of the basin and the slopes, the power of carrying, possible faults, cracks, alluvium thickness, full weir location and capacity, derivation conditions, transportation situation, dam distance of the material to be used in dam construction,
2. **Lake area features:** The topography and geological structure of the lake area, types of rocks, the thickness and impermeability of the rocks, the features of the lake area such as water retention, the stability of the lake slopes and the landslide condition are examined.
3. **Hydraulic and hydrological characteristics of precipitation basin:** The hydraulic, hydrological, meteorological and morphological characteristics of the precipitation basin should be investigated. Depending on the precipitation flow relationships in this framework, the amount of material flow, sediment accumulation, infiltration, evaporation, stream drainage system and vegetation cover of the river are examined.
4. **Settlement, expropriation and costs associated with the renovation:** Dam reservoir and settlement areas, industrial facilities, agricultural land, transportation roads, etc. that will be inundated in the region will be investigated.
5. **Environmental impact:** The effects of the dam on the climate and life conditions of the region, the protection of the groundwater balance for agriculture (salting), the submergence of historical sites and the deterioration of the natural structure of the region are examined.

FACTORS AFFECTING SELECTION OF DAM TYPE

1. **Topographical situation of the dam site:** The topography of the dam site is the first criterion to be taken into consideration in the selection of the dam type.

2. Foundation and geological structure: The foundation condition of the dam site is not suitable for each dam type.

3. Location and type of suitable material to be used in dam construction: There are three types of natural materials required for dam construction. These are aggregate for rock, concrete for soil, filler and riprap for filling.

4. Transportation facilities : If the dam site is close to existing roads, which reduces the cost of new road construction. Access to the material quarries is also important when selecting the dam site.

5. Translate (derivation) conditions : In order to be able to construct the dam under dry conditions, the upstream and downstream sides of the construction site should be suitable to be closed with low dams called altitude.

6. Full spillway capacity and location

7. Earthquake

8. Climatic conditions and duration of construction

9. Landslide: Large waves can be created from ground slopes of the dam to the landslide and the lake.

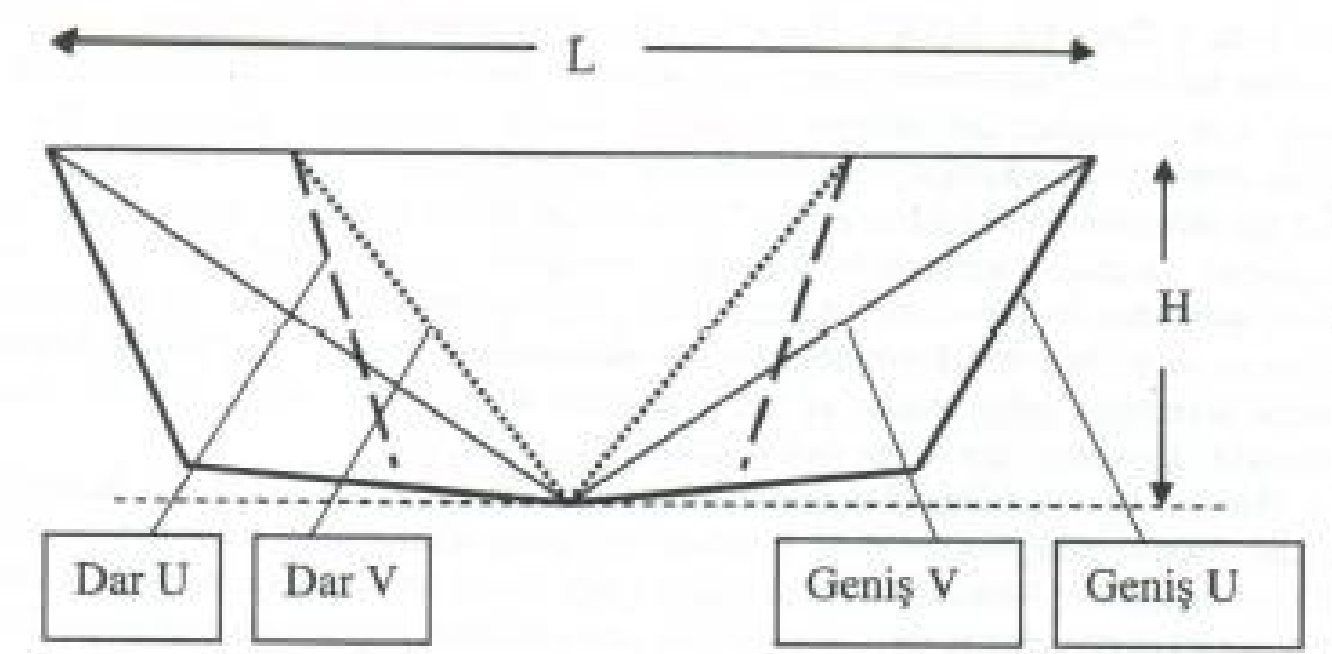
10. Economic situation of the country

11. Machine park area availability, types and capacities of machines

TOPOGRAPHIC SITUATION of DAM / Valley Factor:

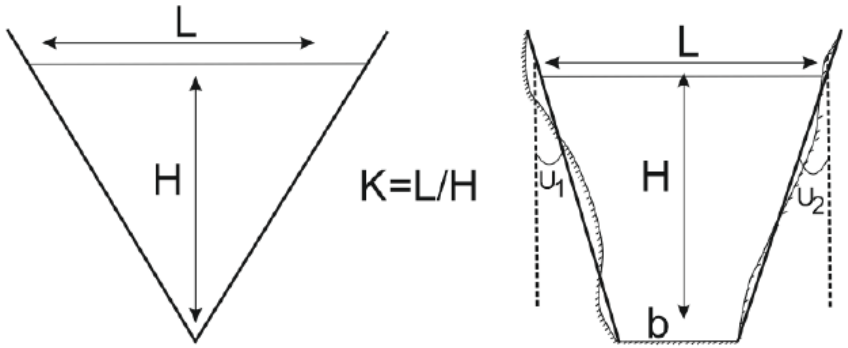
One of the important factors in the selection of the dam site is the valley shape. The valley types constitute an important criterion for determining the types of dams to be built on them. The shape of a valley, the valley in opening the geological units of properties, valley opens factor (glacial, river) valley height, the stream flow system, varies depending on the grooves in the stage of the valley formed phase. According to the shape and width of the valley, some dam types are not considered at all. For example, concrete arch dam is not made on a wide valley. It is considered to construct gravity or arch type dam if the valley consists unfolded, non broken rocks.

Valley Types
1. Narrow V type
2. Wide V type
3. Narrow type
4. Wide U type



TOPOGRAPHIC STATUS of DAM site/ Valley Shape Factor:

Where a dam is intended to be constructed, the ratio of the peak height to the maximum dam height is called the "valley factor" and is indicated by "K".



Valley shapes and parts
L = peak length of the dam;
B = floor width of the valley;
H = Dam height;
U1 and U2 = Vertices made by the slope averages

$$K=\frac{\text{Tepe Uzunluğu}}{\text{Max. Baraj Yüksekliği}}=\frac{L}{H} \quad \text{veya} \quad K=\tan U_1+\tan U_2$$

Formülü ile vadi tabanında bir genişlik olması durumunda

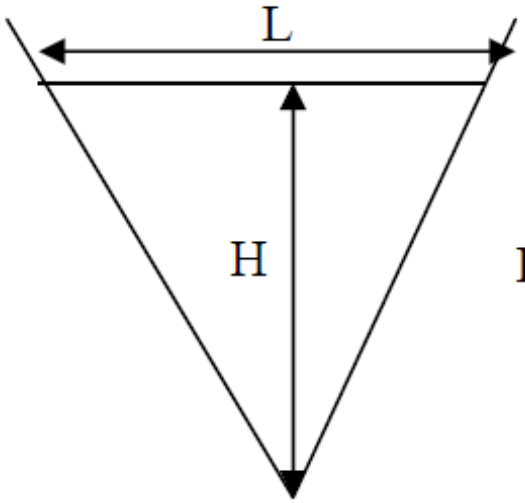
$$K=\frac{b+H(\tan U_1+\tan U_2)}{H}=\frac{b}{H}+(\tan U_1+\tan U_2)$$

TOPOGRAPHIC STATUS of DAM site/ Valley Shape Factor:

Valleys is classified according to L / H ratio

1. Throat shaped valleys (L / H < 3),
2.Narrow valleys (3 < L / H < 6)
3. Wide valleys (L/H > 6).

Throat shaped valleys allow the construction of thin or thick concrete arch dam
If other factors are available in narrow U and V shaped valleys, the type of belt or weight is considered first.
Rock filled or soil filled dams are considered to contruct on wide valleys.
If height is available, contruction gravity dams is feasible
alley factor (K), economic limit for concrete dam 5 in America; 7 in Italy; It is accepted as 11 in France. If it is greater than it, it requires that no concrete dam.



K= L / H

TOPOGRAPHIC SITUATION OF THE DAM / foundation geology and geological structure

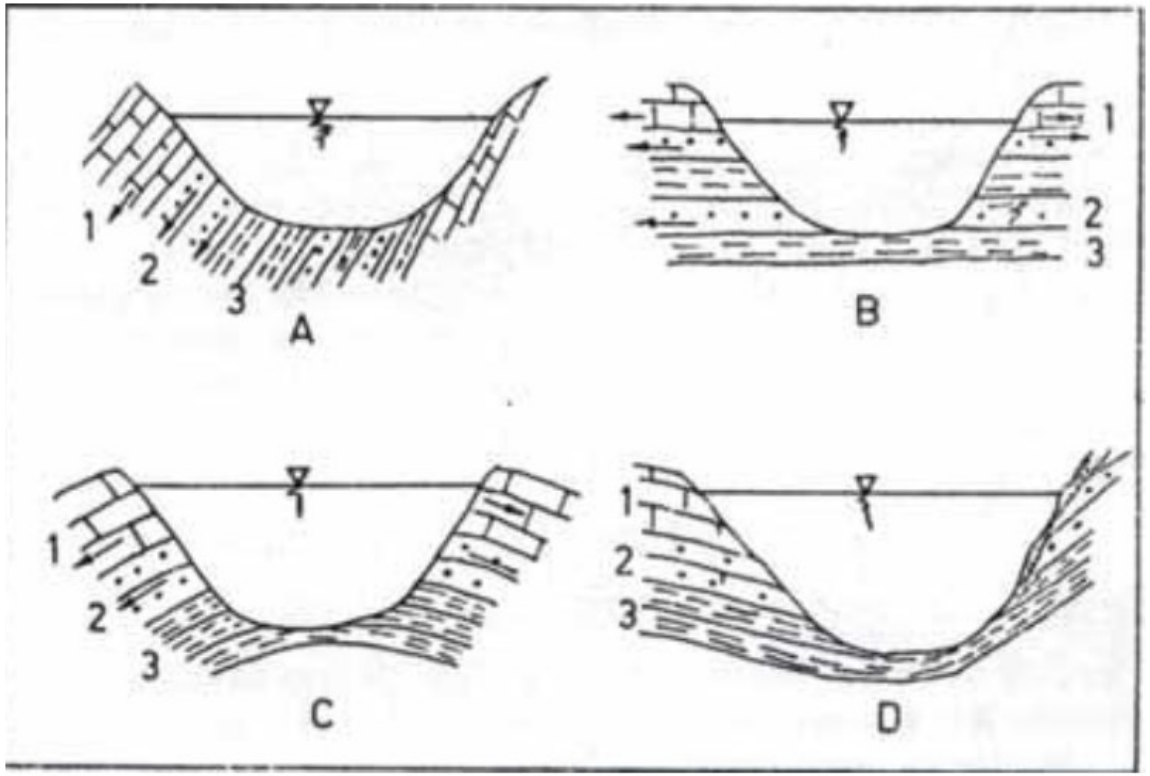
Solid rock foundations : They have a high carrying capacity, homogeneous and generally impermeable. They are suitable for all types of dams. On such bases, the dissociated surface rock must be stripped and the cracks must be blocked by injection.

Gravel foundations : On these foundations, the carrying power is quite good, the seating quantities are negligible, but the permeability is high. These are generally not suitable for arches and splintered dams. If it is well-stuck cases, they are suitable for rock filled, soil filled and gravity dams. Since there may be a large amount of water infiltration, some leakage reducing measures must be taken.

Silt or fine sand foundations: Erosion may occur on these bases, which have low strength, large settlements and high permeability. It is therefore suitable foundations for low concrete and soil filled dams. Basic settlement, Excessive infiltration loss and the carving of the downstream façade are important problems.

Clay foundations: Their carrying capacity is very small, due to consolidation, the seating is very high and their permeability is low. Therefore, they are recommended only for low-earth fill dams. Such projects require special projects and experienced engineers

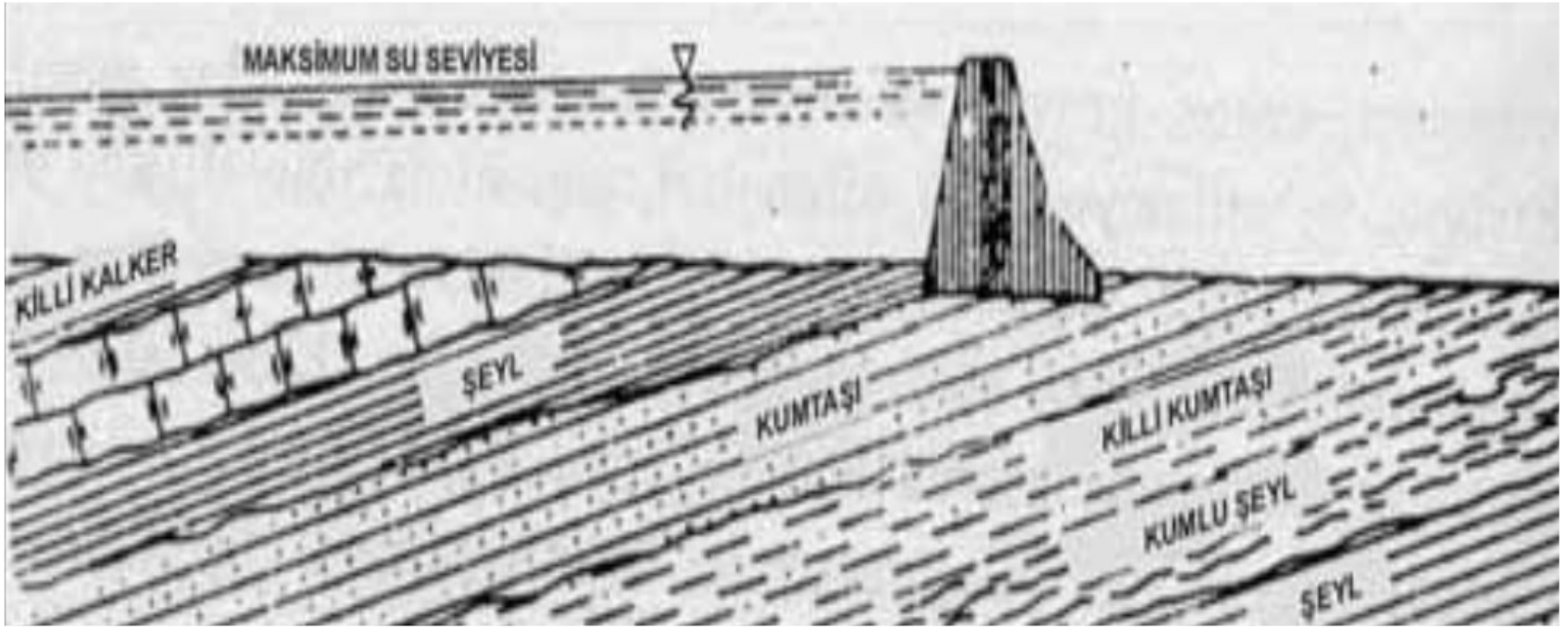
TOPOGRAPHIC SITUATION OF THE DAM / Basic geological and geological structure



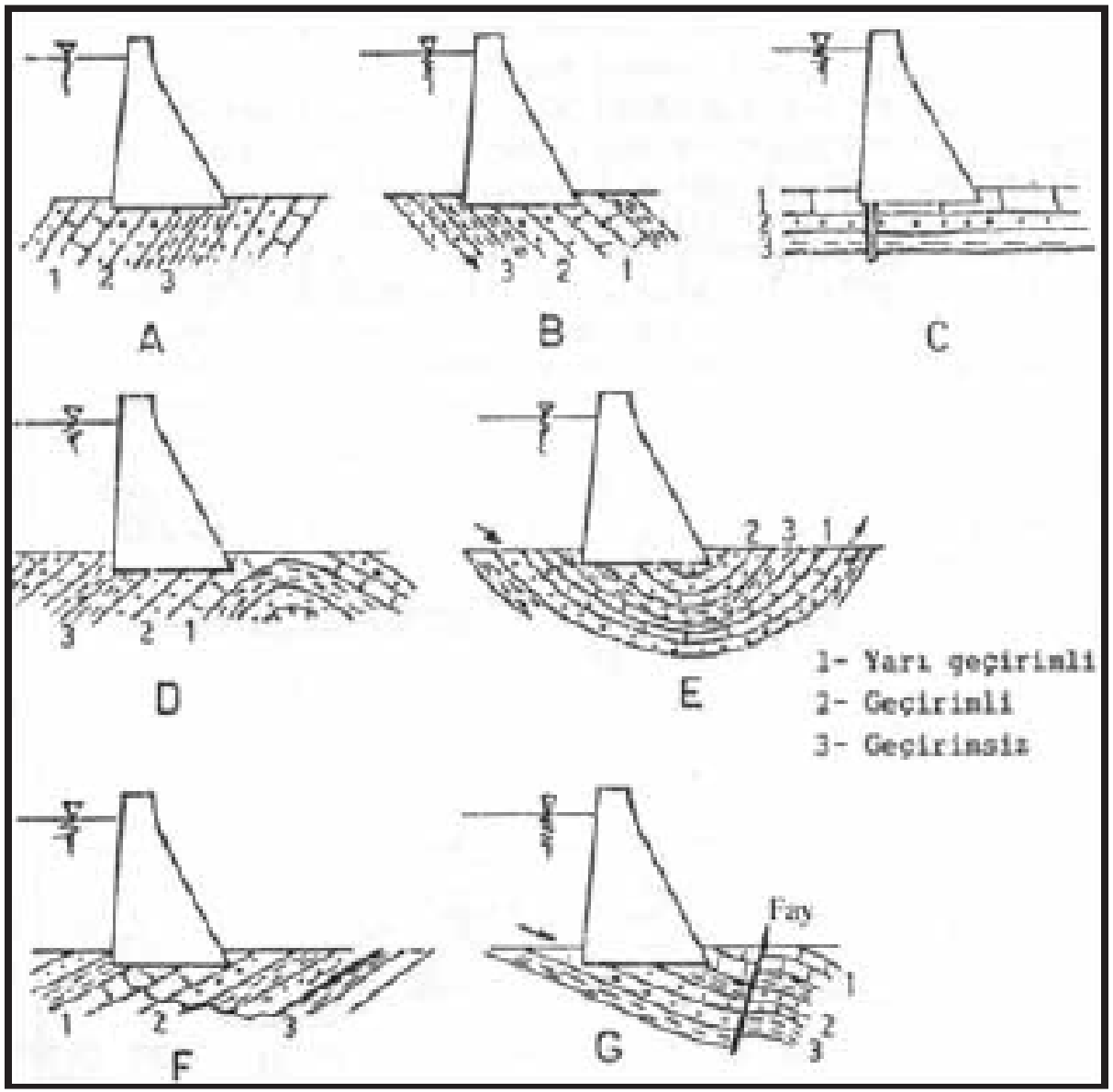
Where the direction of discontinuities (stratum, cracks, etc.) is perpendicular to the axis of the dam, the water in the dam will escape out of the dam through the permeable rocks. Water leaks will occur in the strata of the "A", "B" and "C" specimens, which form oblique, horizontal and anticline structures respectively. If the permeability of these units is high, it will not be possible to collect water in the dam reservoir. The dam will run out to the sides and the dam will be empty. The underlying syncline structure, which is bounded below by the impermeable unit in section "D", will prevent groundwater from escaping to the sides. However, there will be fugitives from strata extending towards the dam downstream (perpendicular to the axis of the dam).

TOPOGRAPHIC SITUATION OF THE DAM / Basic geological and geological structure

The most appropriate stratification at the dam site to be chosen to prevent the water in the dam lake from escaping under the dam is a system consisting of layers inclined towards the dam lake (impermeable layer). In other words, the dam site is ideal if the dam body is impervious to layers and if the direction of the discontinuities is parallel to the axis of the dam and inclined towards the body. Accordingly, it is the ideal choice of dam site in terms of water retention.



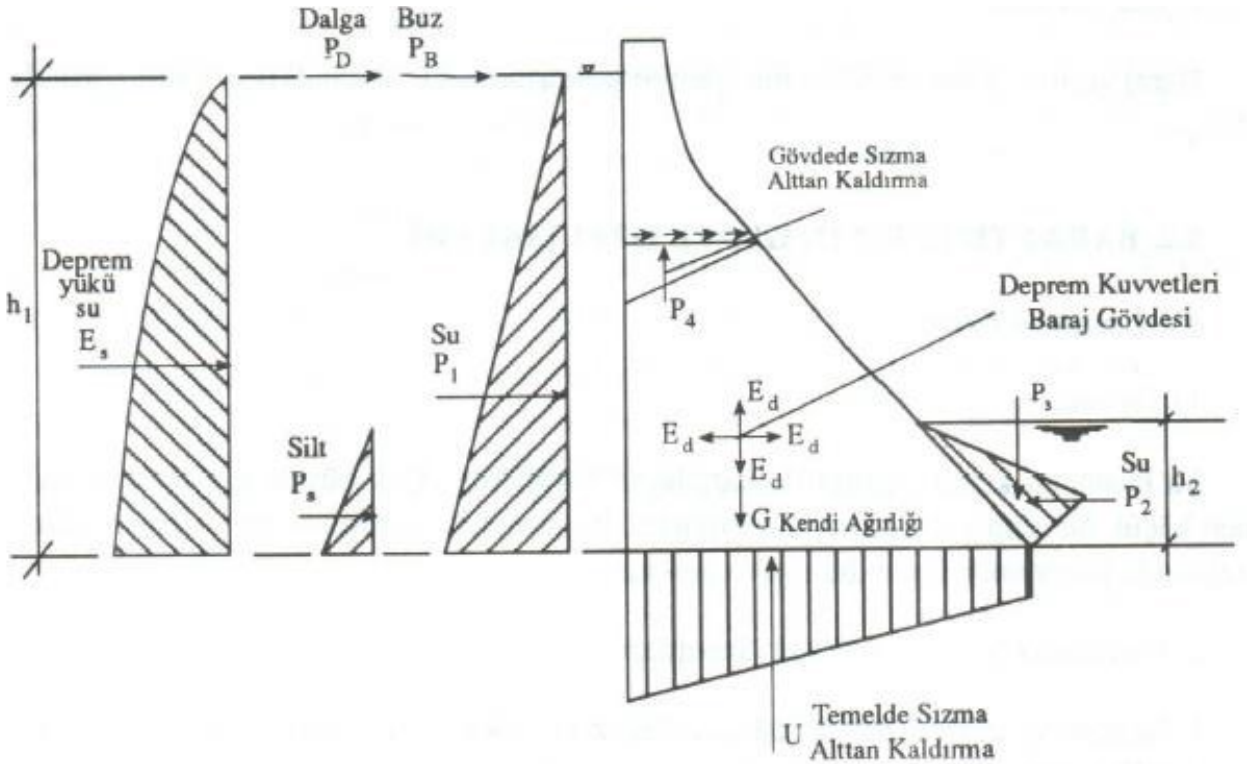
TOPOGRAPHIC SITUATION OF THE DAM / Basic geological and geological structure



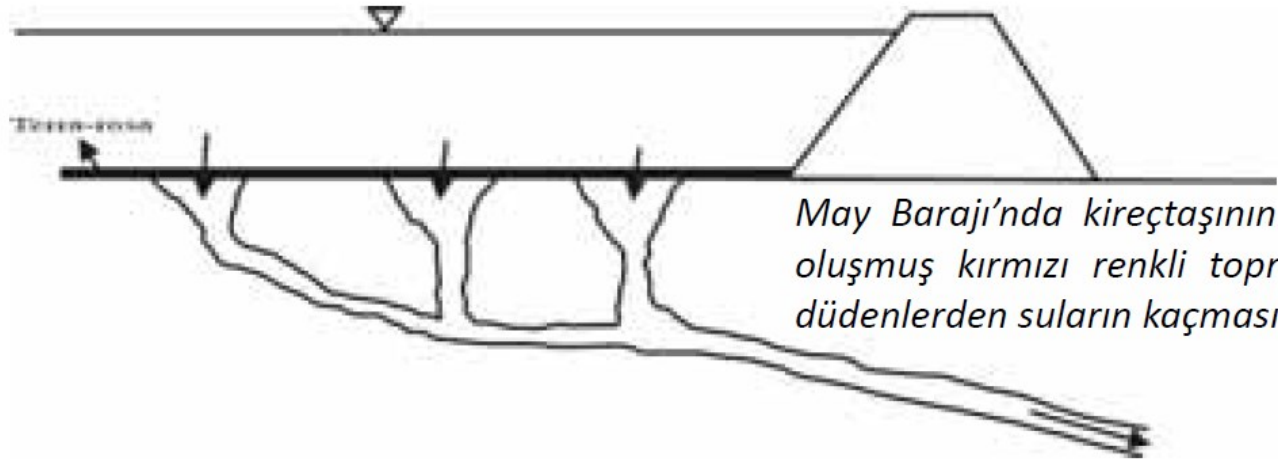
FORCES AFFECTING to DAM

A dam must be able to withstand all static and dynamic forces acting on it. The most influential forces,

1. The dam's own weight
2. Hydrostatic water pressure
3. Base and pore pressure
4. Earthquake strength
5. Ice is the pressure.



G = Kendi ağırlığı, P_1, P_2, P_3 = Hidrostatik su basıncının yatay ve düşey bileşenleri,
P_4 = Sızıntı kuvveti, P_D = Dalga Kuvveti, P_B = Buz basıncı, E_d, E_s = Deprem kuvvetleri,
U = Alttan kaldırma kuvveti,



May Barajı'nda kireçtaşının ayrışmasıyla oluşmuş kırmızı renkli toprak ile örtülü düdenlerden suların kaçması

Keban Barajı rezervuarından, yer altı karstik boşlukları içinden kaçan suların sifon yaparak Keban Deresi sol yamacından çıkması

Vayont Barajı göl havzasında oluşan kütle hareketi ve oklar ile gösterilen kayma yüzeyi.

1. RECONNAISSANCE STUDY

1. Evaluation of the data having at archives of MTA, DSI, EIE, Universities,.....etc
2. Field investigation for limited time (Reconnaissance Study)
3. Some maps in small scale, for example 1/25.000 or 1/50.000
4. Some hydraulic data about
   a. Basin
   b. Precipitation area
   c. Runoff, maximum discharge {$Q=R/t$ (m^3/s)}
   d. Modulus of Runoff ($R/t/m^2$ ~ $R/t/km^2$)
5. Some approach to the reservoir area, dam site and type of dam and height of dam...etc
6. Photogeological studies
7. A preliminary report

2. PRELIMINARY STUDIES at the RESERVOIR AREA and DAM SITE

1. Dam site investigations
    1. Location of dam axis
    2. Location of diversion tunnel
    3. Location of spillway
    4. Location of powerhouse...etc
2. Geological studies
3. Geophysical surveying
4. Underground investigations
    1. Boreholes
    2. Investigation galleries
    3. Pitholes
5. Surveying for materials
    1. Field surveying
    2. Laboratory tests

6. Slope stability investigations
7. Earthquake hazard & risk analysis
8. Environmental studies
9. Leakage possibilities from reservoir area
10. Leakage possibilities from dam site
11. Erosion, sedimentation & siltation

DETAILED INVESTIGATION at DAM SITE

1. Topographic surveyings
2. Geological mappings 1/5000 – 1/1000 or 1/500
3. Underground explorations Boreholes, adits....etc
4. Hydrogeological studies
5. Slope stability analysis

FACTORS AFFECTING to the DAM TYPE SELECTION

- Topography
- Geology
    - Bearing capacity of the underlying soil
    - Foundation settlements
    - Permeability of the foundation soil

- Material availability
- Spillway position
- Earthquakes
- Safety
- Height
- Aesthetic view
- Qualified labour
- Cost

FACTORS AFFECTING to the PLACE of the DAM AXIS

- Topography
- Geology
- Materials
- Spillway location availability
- Derivation
- Sediments in the flowing water
- Water quality
- Expropriation costs
- Earthquake possibility
- Downstream water rights