
Mer Awi
3
Sidetu
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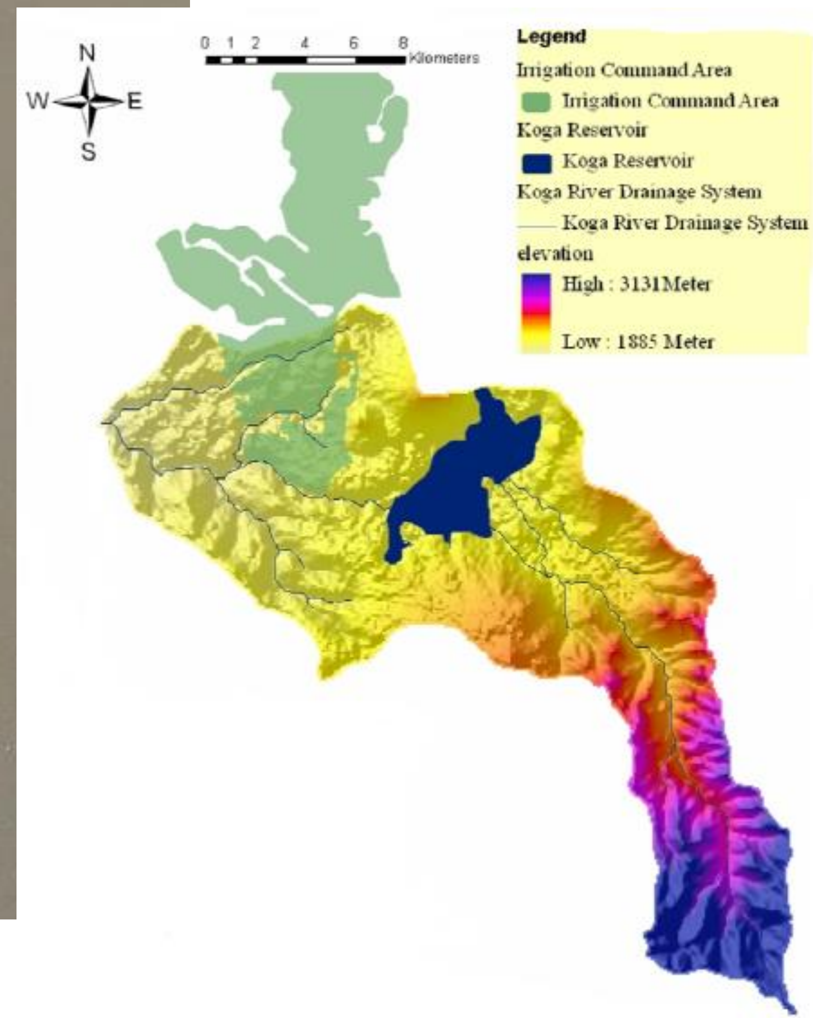
Dam
position


N
W
E
S
0 1 2 4 6 8
Kilometers
Legend
Irrigation Command Area
Irrigation Command Area
Koga Reservoir
Koga Reservoir
Koga River Drainage System
Koga River Drainage System
elevation
High : 3131Meter
Low : 1885 Meter

Koga Dam

- Basin : Blue Nile
- Purpose: Irrigation Ca. 7000ha
- Project includes integrated WSM on 22,000ha
- Dam height 21m
- Embankment Dam
- Reservoir storage ~83.1Mm^3
- Reservoir area ~ 1400 ha
- Financed by AfDB

DESIGN AND ANALYSIS OF EMBANKMENT DAMS

CHAPTER 1- INTRODUCTION

I. Definition : What is a dam?

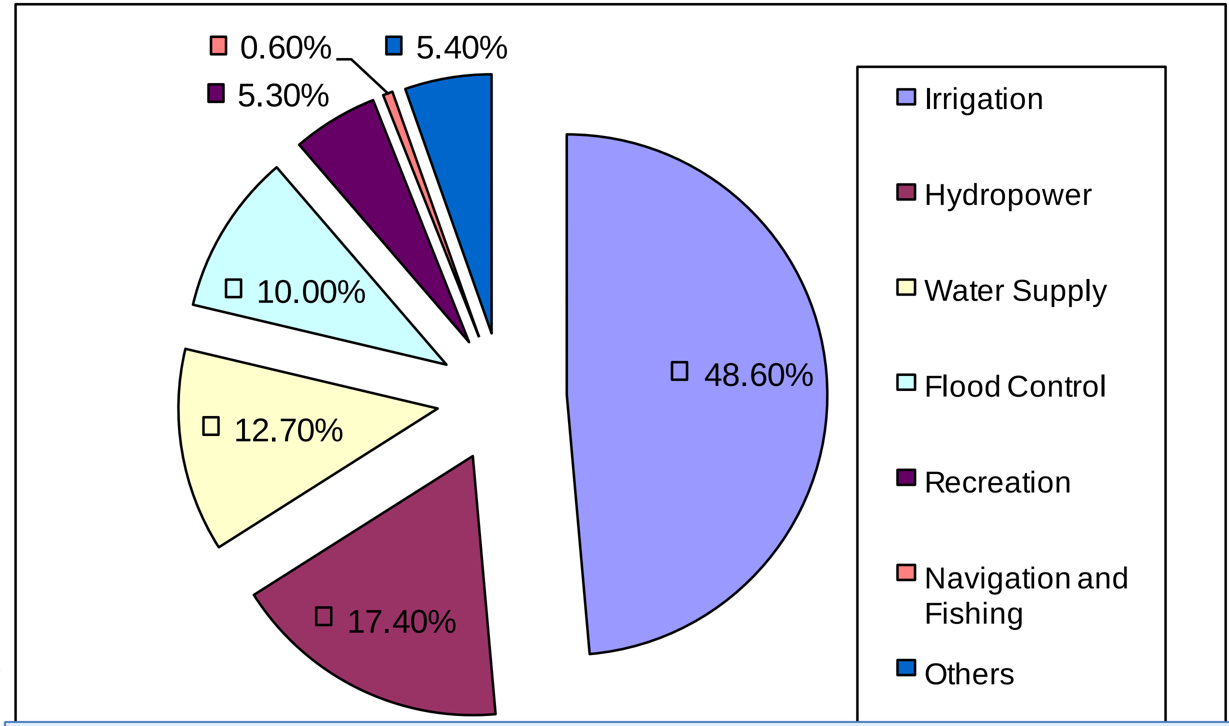
- **"A dam is defined as a barrier or structure across a stream, river or waterway to confine and then control the flow of water." ICOLD**

GIBE III- 243m high Roller Compacted Concrete Dam (RCC) with crest length of 610m.

- **Dams vary in size from small earth embankments often for farm use to large concrete structures**

II. Purposes

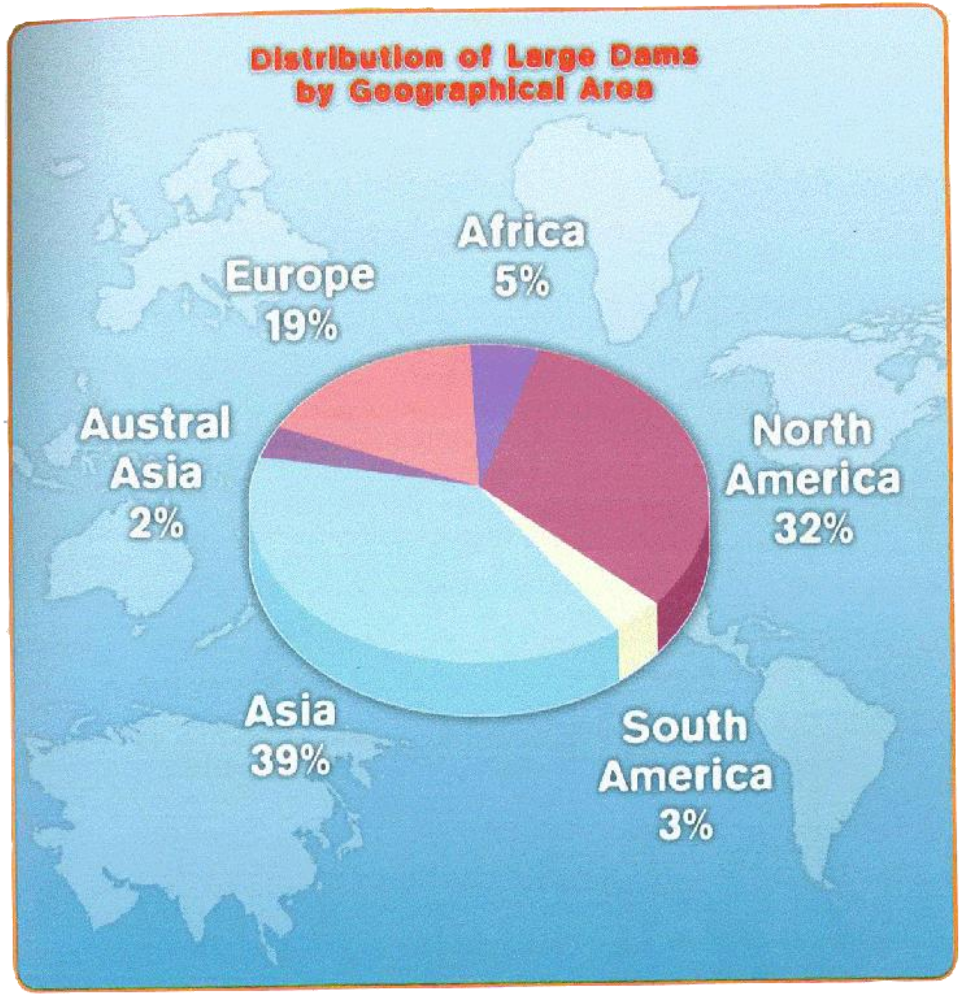
- Irrigation
- Water Supply
- Hydropower
- Pumped Storage
- Flood Control
- Mills
- Ornamental Lakes
- Canals
- Tailings (Mining Waste)



Source: International Commission on Large Dams (ICOLD)

Graph showing the distribution of Large Dams by Geographical Area

- The primary type of dam is the earthfill embankment dam which represents 43.7% of the total.
- This is followed by gravity dams (10.6% of the total) and rockfill embankment dams (5.3% of the total).



For a dam to be considered large and be included in the register it must have a height of 15 meters or **10 to 15 meters and store more than 3 million cubic meters of water** in the reservoir (ICOLD).

The first 6 top countries with the highest number of dams in the world

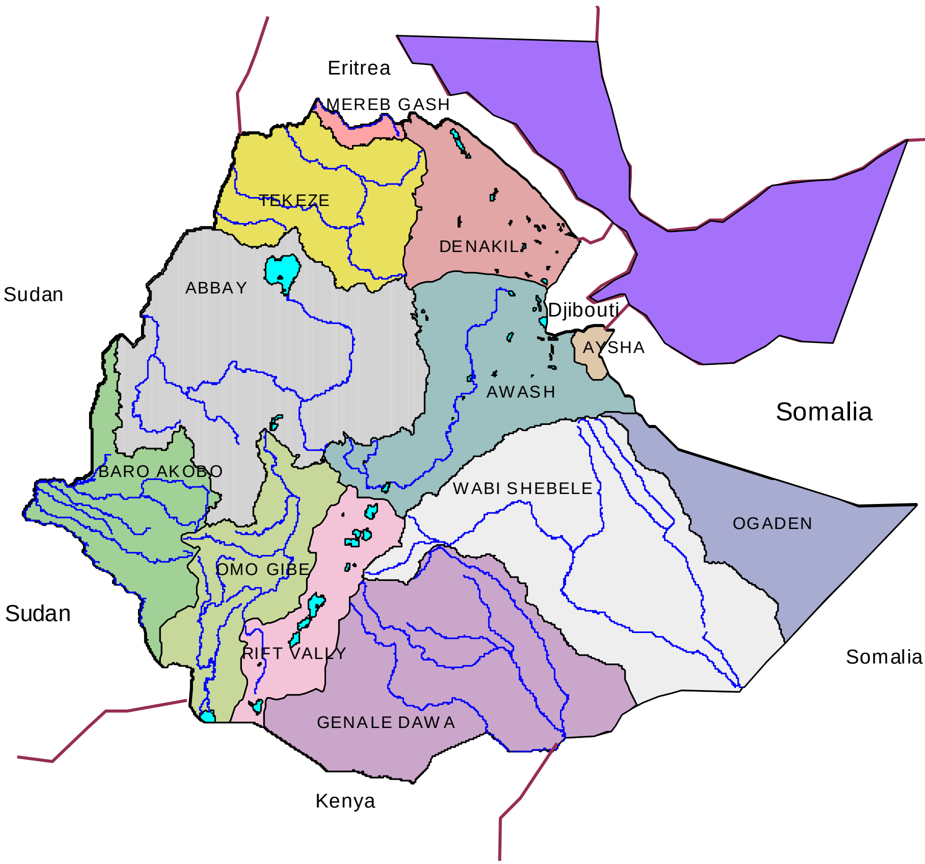
	Country	ICOLD World Register of Dams 2003	Percentage of total dams (%)
1	United States	9,265	28.0
2	China	4,688+	14.2
3	India	4,636	14.0
4	Spain	1,267	3.8
5	South Korea	1,205	3.6
6	Japan	1,121	3.4

Source: ICOLD 2003
Notes: + Other sources estimate the total number of dams in China, to exceed 22,000

Potential & Experience of Dams in Ethiopia

Water Resources

- 12 River Basins
- Total Surface water Potential of 122 BCM
- Renewable ground water Potential of 2.6 BCM
- About 97% of the surface water drains to neighbouring countries
- Water Tower of east Africa
- Contribution to Nile Water ca. 86 %

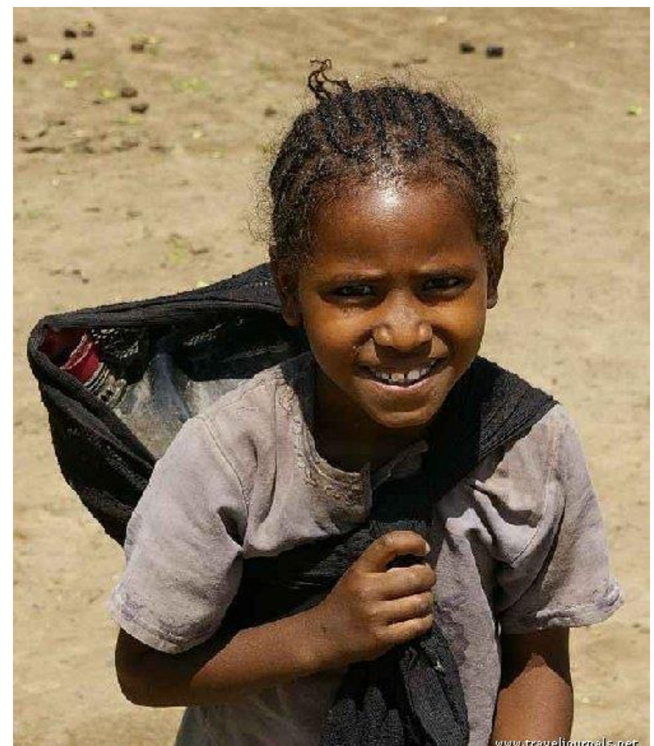


Potential & Status of WR Development

- Hydropower
  - Pot. Economical - 160 GWh or 30,000 MW
  - Developed: ca. 3700 MW (year 2015)
  - <15 %
- Irrigation
  - Pot. Economical – 2.7 Million ha
  - Developed: ca. 290,000 ha
  - ~ 10.8 %
- Water Supply coverage

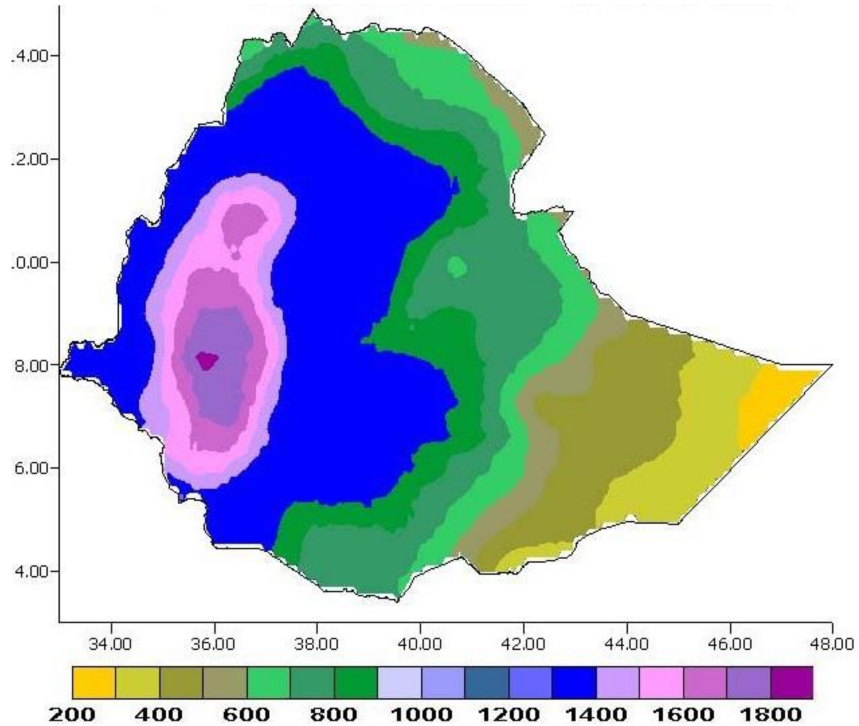
(National WASH Inventory Data in Ethiopia, 2011)

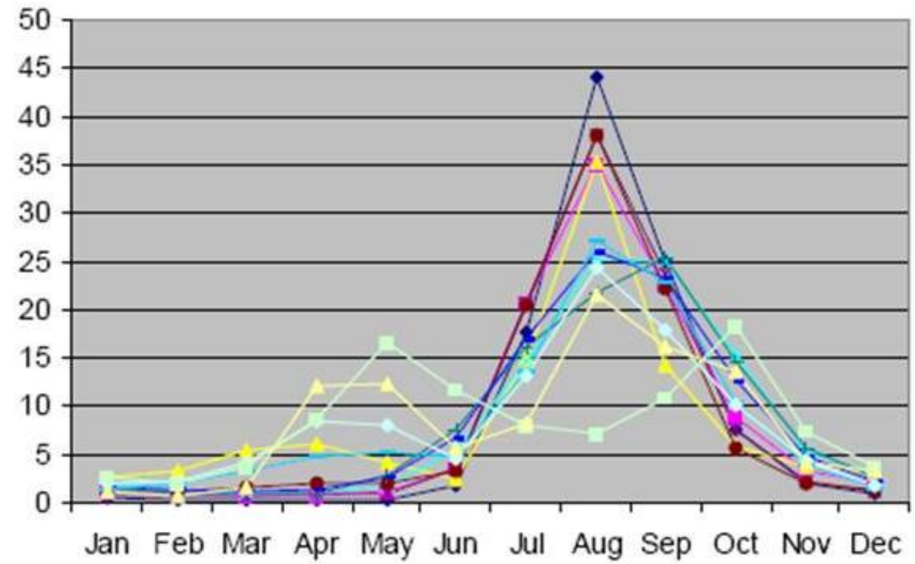
  - Overall – 52 %
  - Urban – 75 %
  - Rural - 49 %



Variability of Water Resources

- Extreme interannual & Intra-annual variability
  - Droughts
  - 19 periods of widespread & severe food shortages in the past 100 yrs alone
- Spatial variability of rain flow
  - Rainfall mainly in the highlands
  - Lowlands are arid to semi-arid
- International nature of its most significant water resources

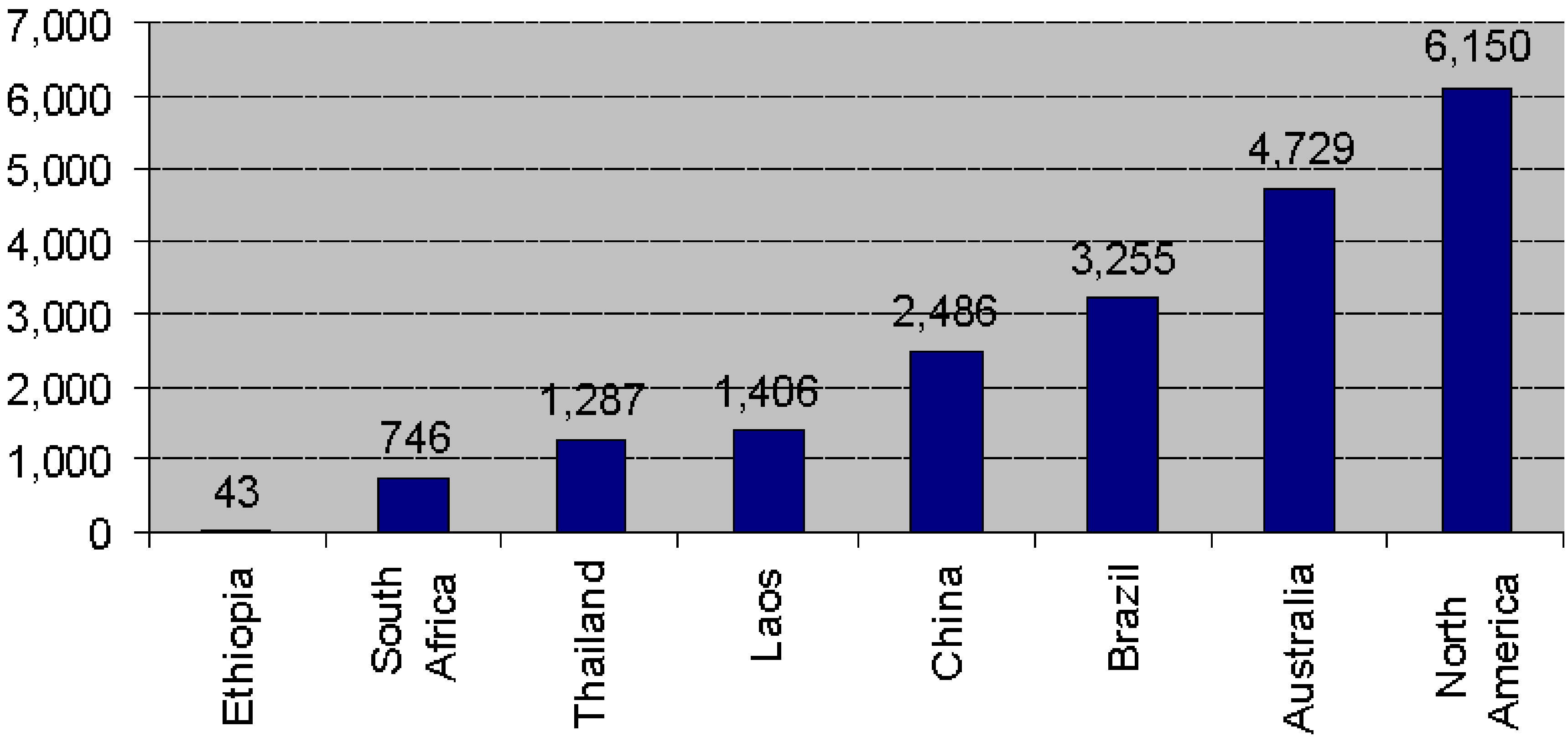




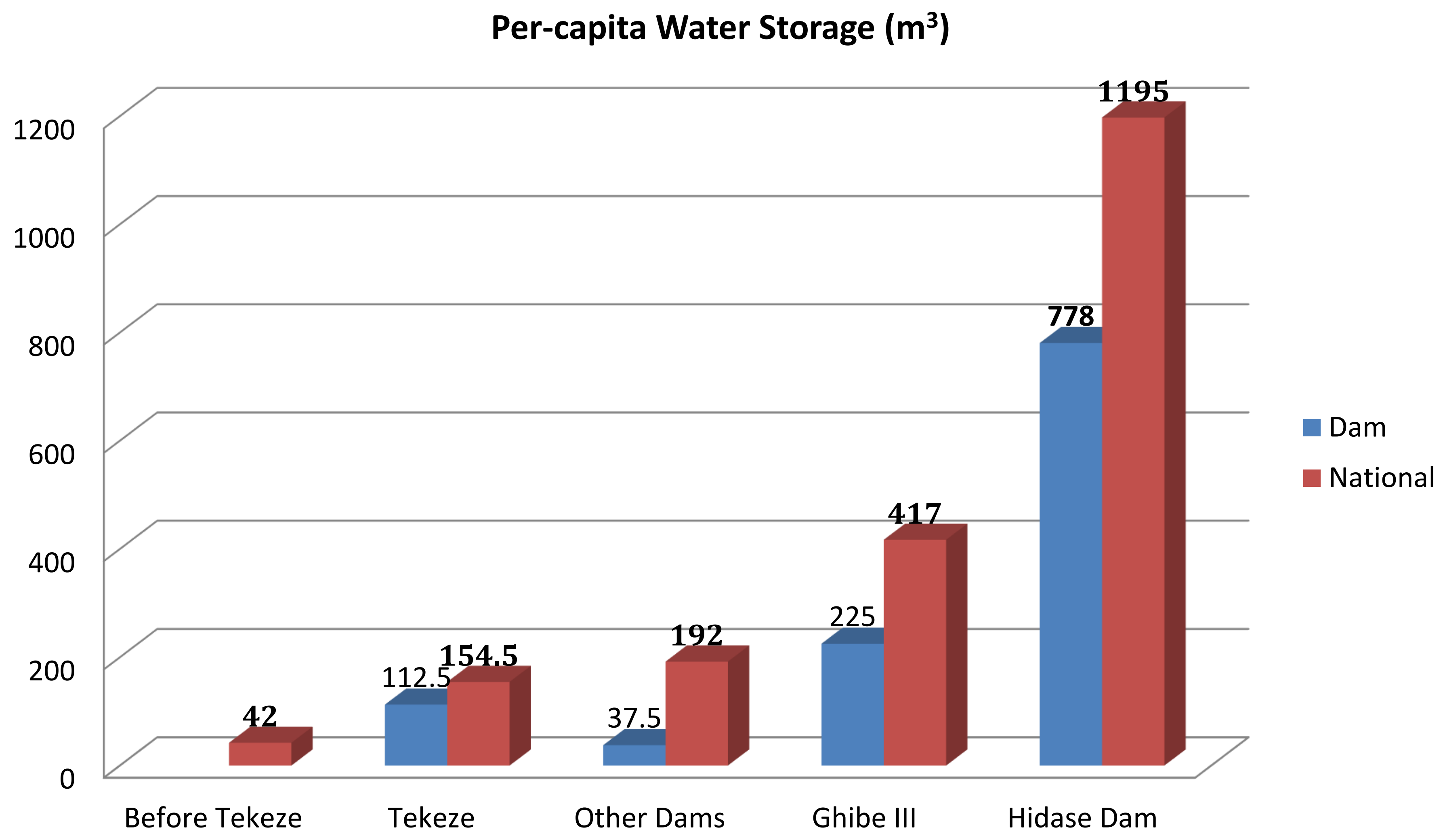
Justification for Dams

- Low level of development
  - Food security of its peoples
  - Access to Safe drinking water supply
  - Access to affordable electricity supplies
- Resources of the country (Land, Water, Labour)
- Water resources are highly variable (spatially and temporally)
- Dams are required to safeguard its people against the ill-effects of recurrent drought and bring about development
- Regional development – specially by tapping the country's huge Hydropower Resources for the regional market

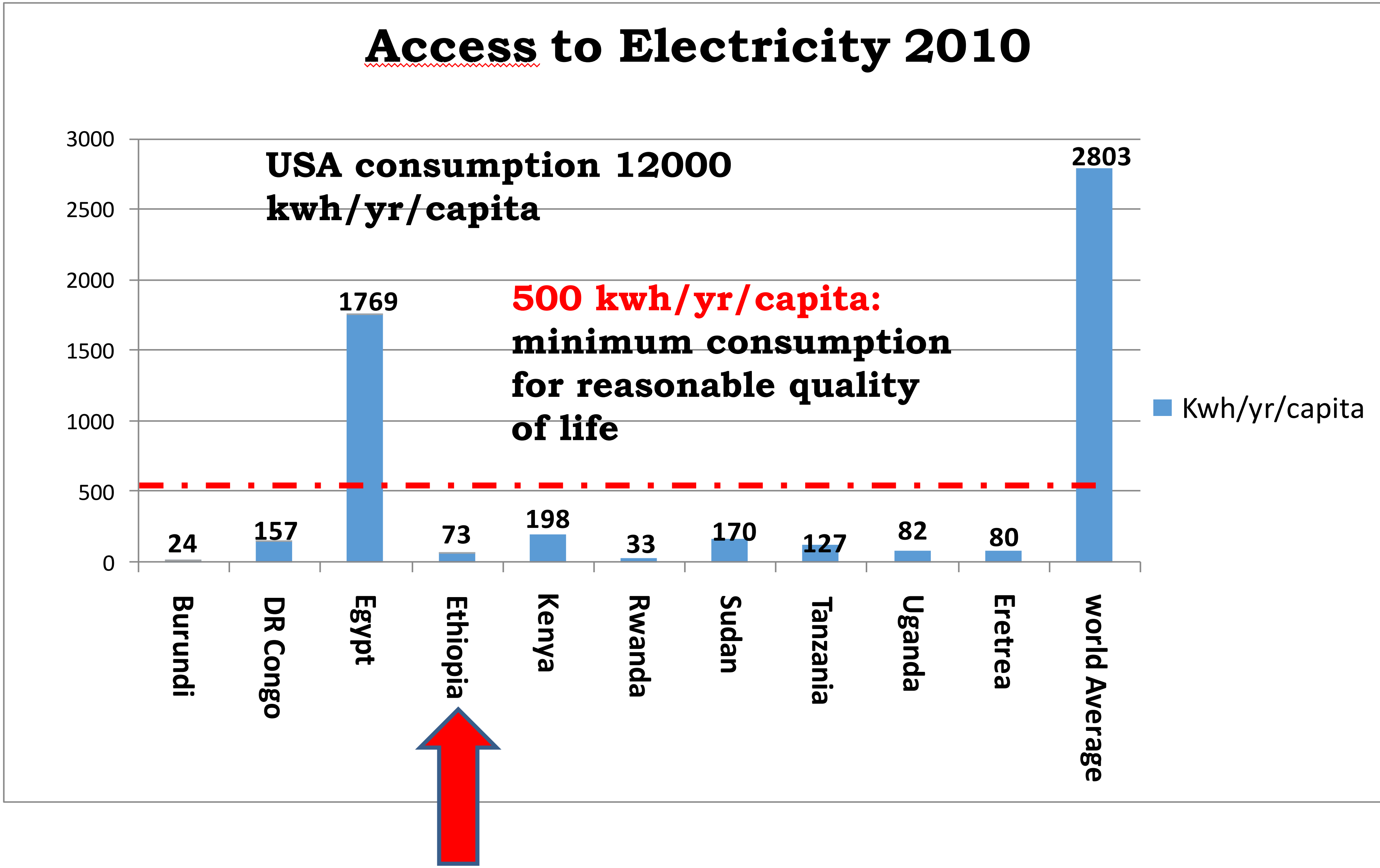
Water storage per capita (m^3) in the world



Threshold 1: Water storage in Ethiopia



Threshold 2: Access to Electricity



Important Large Dams in Ethiopia

N°	Name of dam	Major basin	Yr. Completed	Height (m)	Initial Capacity (x10^3 CM)	Purpose
1	Abasamuel*	Awash	1939	22.00	65 000	HP
2	Alwero**	Baro Akobo	1995	16.00	74 600	IRR
3	Angereb	Blue Nile	1991	34.00	5 300	WS
4	Dire	Awash	1999	46.00	19 000	WS
5	Finchaa	Blue Nile	1973	25.00	650 000	HP,IRR
6	Gafarsa	Awash	1955	17.00	7 000	WS
7	Gilgel Gibe	Omo-Gibe	2004	41.00	839 000	HP
8	Koka	Awash	1960	42.00	1 860 000	HP,IRR,FP
9	Legadadi (Main)	Awash	1979	40.00	38 000	WS
10	Legadadi (Subsidiary)	Awash	1979	22.00	4 000	WS
11	Melka Wakena	Wabeshebele	1988	40.00	750 000	HP
12	Midimar	Tekeze	1996	33.00	10 000	WS
13	Chara Chara	Blue Nile	1996	9	9,100,000	Regulation

* Inoperative since 1970

** Only the dam construction has been completed

CM: Cubic Meters

HP-Hydropower, IRR-Irrigation

WS-Water Supply, FP-Flood Protection

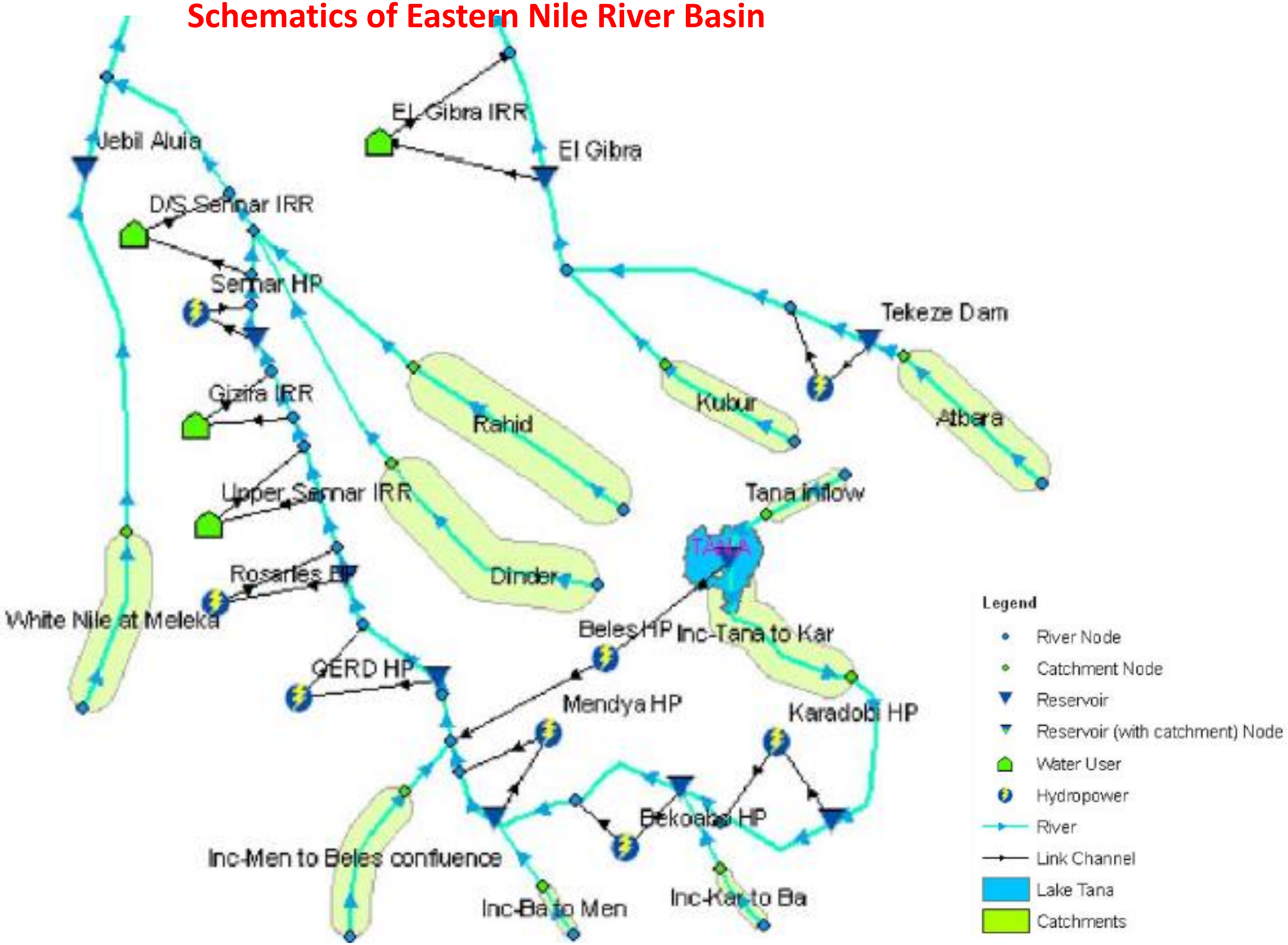
Abay Planned power plants

The cascade comprises five plants :

1. **GERDP (6000MW)[Border Dam]**
2. **KARADOBY (1 650 MW)**
3. **MENDAIA (1 580 MW)**
4. **MABIL (Bekoabo) (1 650 MW)**
5. **BESHILO (700 MW)**

- 11580MW **~Energy 45,295 GWh/yr**

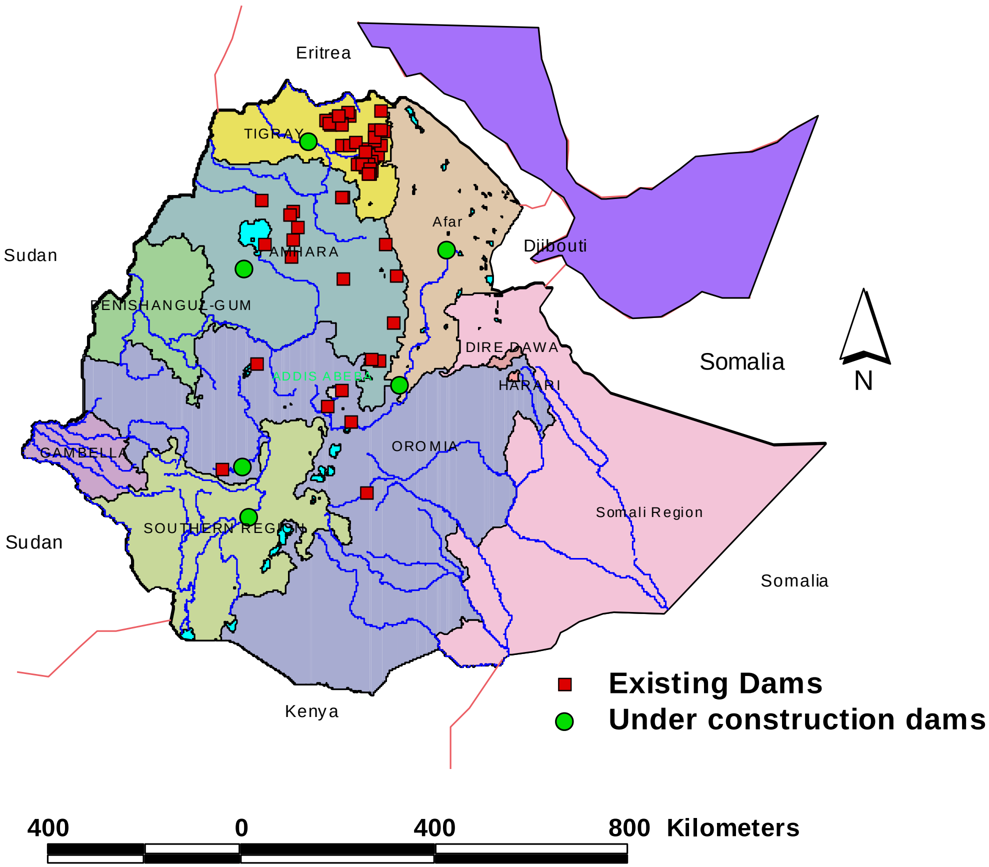
Schematics of Eastern Nile River Basin



Existing Micro-dams

- \> 50 Large dams (According to ICOLD Classification (2003))

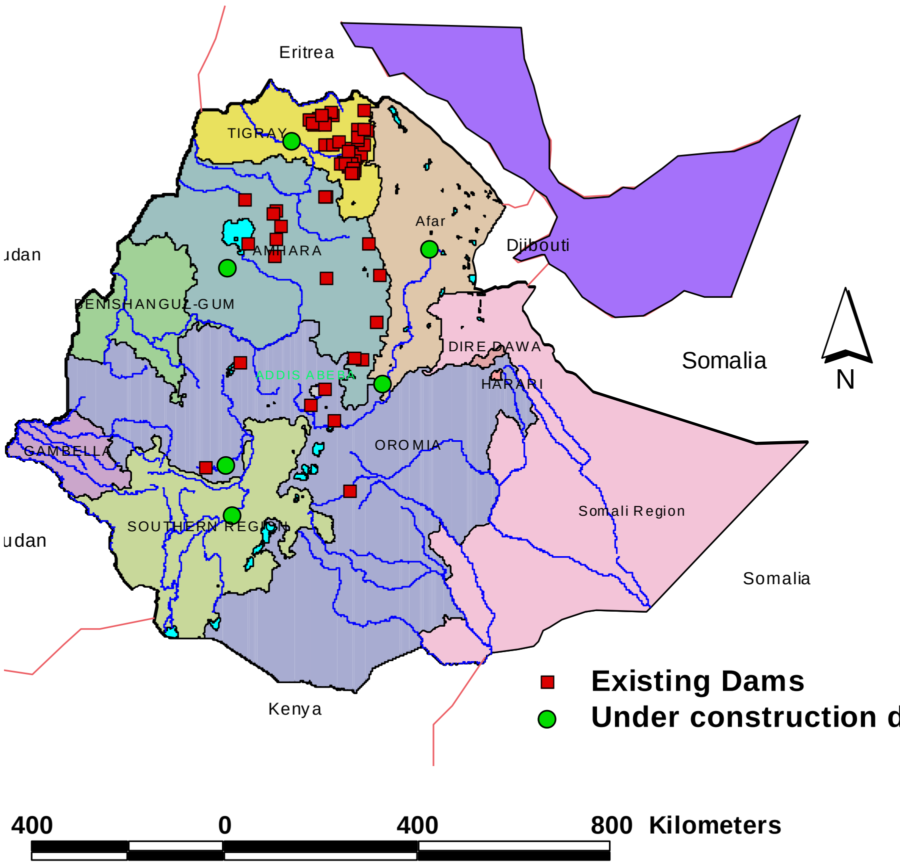
(greater than 15 m in height from base to crest, or storage capacity exceeding 3 million cubic meters for heights between 5 and 15 m)



- FAO - Aquastat Database 2006
- 10 Large dams

Micro-dams

- Small dams (micro-dams) constructed for irrigation supply are concentrated in the Northern Amhara and Tigray regional states.
- Construction took place b/n 1995 – 2000
- 64 Dams in Tigrai Region
  - 28 are large dams according to ICOLD classification
- 14 dams in Amhara Region
  - 12 are large dams according to ICOLD



Performance of the Microdams

- According to a study in 2003 (VLIR), out of the 64 microdams in Tigrai
  - Only 18 dams had no problems
  - 24 dams have seepage problem
  - Nine dams have sedimentation problems
  - 13 dams have both sedimentation & seepage problems

- According to a study in 2006 (Tefera B.), out of the 14 microdams in Amhara
  - Only one of the 14 dams is functioning according to the plan of implementation
  - hydraulic problems (16.7%),
  - hydrological problems (41.7%),
  - sedimentation problems (33.3%),
  - seepage failures (58.3%), and
  - structural failures (8.3%).

Common Problems encountered in Microdams

Common problems identified include:

- Overtopping due to inadequate spillway capacity – flood estimation problem
- Seepage through foundation, abutments and reservoir area – site selection problem
- Cracking or structural failure – geotechnical problem
- Less inflow in the reservoir – hydrological analysis problem
- Sedimentation- design problem and lack of watershed Mgt.
- Lack of proper maintenance and rehabilitation work
- The rush in implementation without adequate investigation in all aspects

Problems identified should give a good lesson for future building of similar dams.

Classification of Dams

Dams are classified on several aspects, some of the important aspects are:

i. According to dams height /also capacity (USA dam safety)

- If height b/n crest elevation and foundation level is greater than 15 m then it can be considered as a **Large Dam.**
- If dam height is less than 15 m then **Small Dam.**
- If dam height is greater than 50 m then **High Dam**

Based on USACE Dam Safety (Engineering Regulation)

Category	Storage (Ac-Ft)	Height (Ft)
Small	< 1000 and ≥ 50	< 40 and ≥ 25
Intermediate	≥ 1000 and $< 50{,}000$	≥ 40 and < 100
Large	$\geq 50{,}000$	≥ 100

ii. Based on Hydraulic Design:

- Over flow dams (e.g. concrete dams)
- Non over flow dams (e.g. embankment dams)

iii. Based on Structural Design:

- Gravity dams
- Arch dams
- Buttress dams

iv. Based on Usage of Dam:

- Storage dams
- Diversion dams
- Detention dams

v. Based on Construction Material:

- Concrete / Masonry dams
- Earthfill dams
- Rockfill dams
- Earthfill rockfill dams
- Concrete faced rockfill dams (CFRD)

Dam Project planning and Development

- Planning **and Study**
  - Reconnaissance Study
  - Feasibility Study
  - Environmental Document
- Design
  - Preliminary (Conceptual) Design
  - Detailed Design
  - Construction Documents (plans & specifications)
- Construction
- Startup and testing
- Operation

FEASIBILITY STUDY

A) Determination of water demand

- Estimate various types of demands through the life time

B) Determination of water potential

- From available sources and available past data

C) Optimal plans

- Check out the relation D versus S.

D) Determination of dam site

◘ Factors to be taken into consideration:

- Topography
- Geology and dam foundation
  - faults and weak geologic formations should be avoided
  - Type of soil affects the overall stability of dam body

D) Determination of dam site (continued)

- Availability of construction materials
- Flood hazard
- Seismic hazard
- Spillway location and possibilities
- Construction time
- Climate (earth fill dam is not appropriate for rainy climates)
- Diversion facilities
- Sediment problem
- Water quality
- Transportation facilities
- Right of way cost

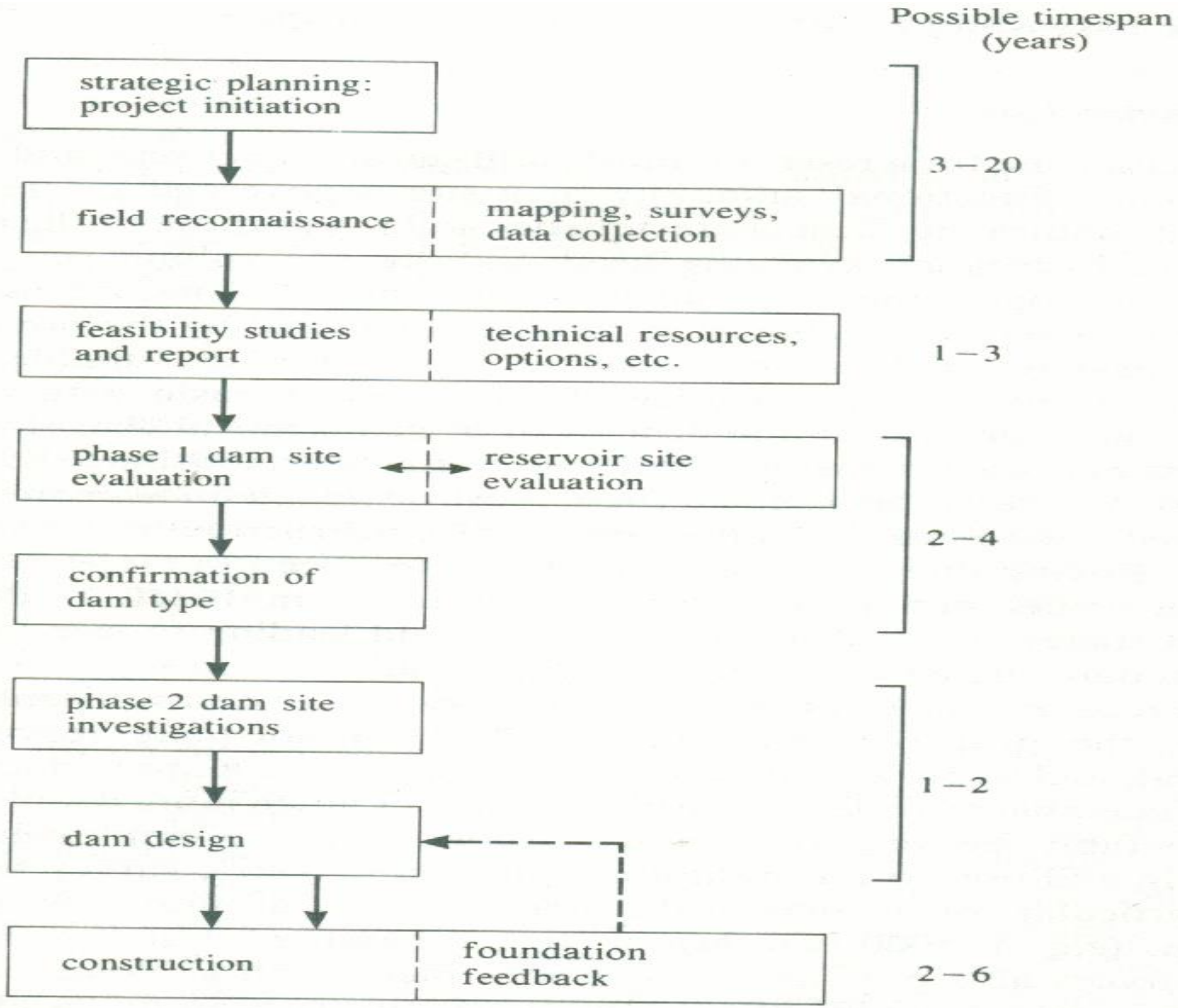
PROJECT DESIGN

- involves the computation of dimensions of the dam.
- Hydrologic design (max. lake elevation + spillway cap. + crest elevation)
- Hydraulic design (static & dynamic loads + spillway profile + outlet dimensions)
- Structural design (stress distribution + required reinforcement)

Necessary Data

- Location and site map
- Hydrologic data
- Climatic data
- Geological data
- Water demand data
- Dam site data (foundation, material, tailwater)

Stages for Dam Site Appraisal



Stages in dam site appraisal and project development.

Disciplines in Dams Engineering

- Dams Engineer
- Hydrology
- Geology
- Geotechnical
- Seismic Specialist
- Tunnel Specialist
- Sedimentation Specialists
- Environmental Specialists
- Mechanical/Electrical
- Contracts
- Economist
- Irrigation Specialists

Parts of a dam

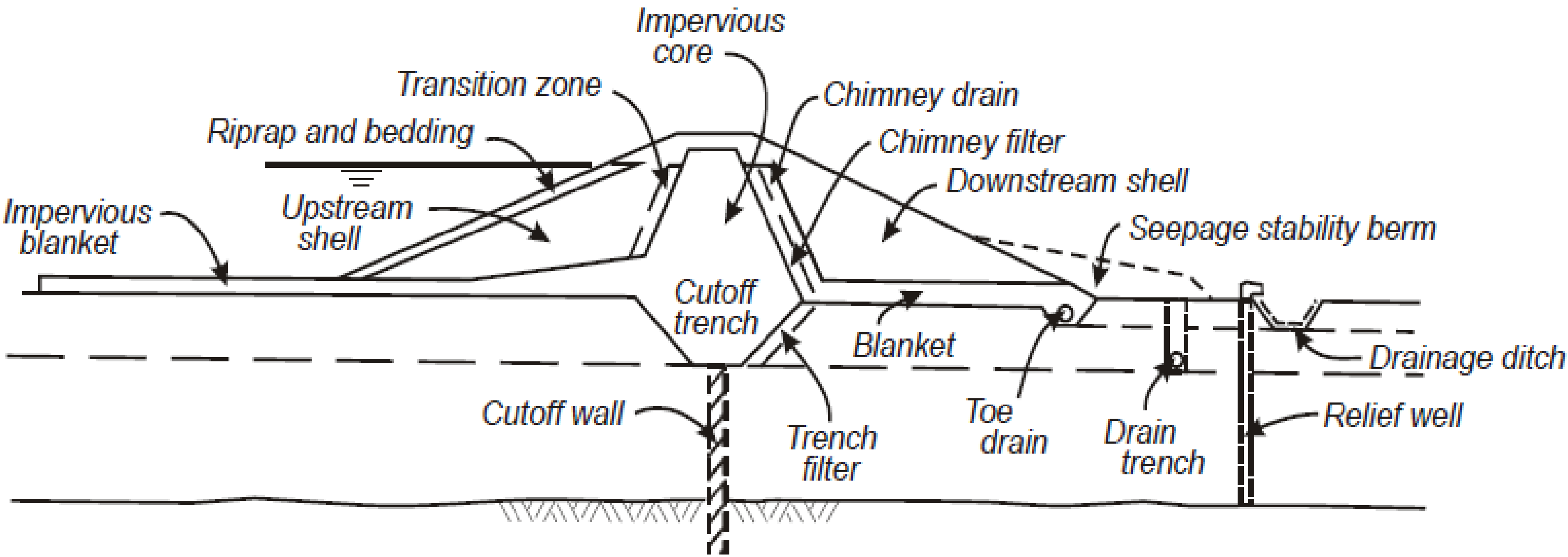
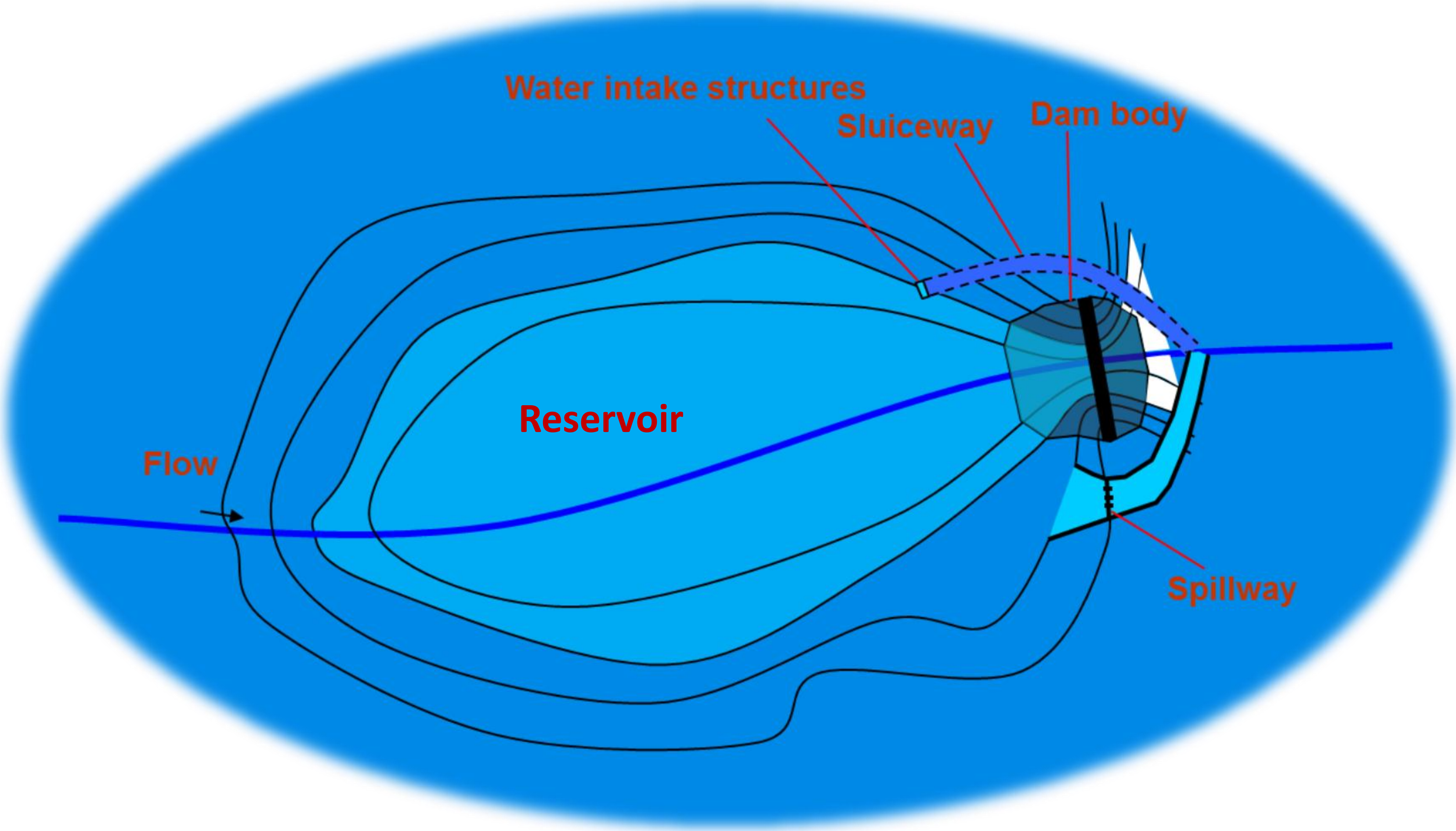


Figure illustrating components of a modern embankment dam

Parts of Dams/General layout



DAM FOCUS POINTS

Dams have following focus points and thus differ from other major civil engineering structures.

1. Every dam, large or small, is quite unique; foundation geology, material characteristics, catchment yield and flood hydrology are each site specific.
2. Dams are required to function at or close to their design loadings for extended periods.
3. Dams do not have a structural life span, components must be designed for long life. Dams may have notional life for accounting/economic purposes, or a functional life span dictated by the reservoir sedimentation.
4. Majority of dams are of earth fill made from a range of natural soils, and are least consistent of construction materials. Dam engineering draws together a range of disciplines to a quite unique degree (Hydrology, hydraulics, geology, geotech, structure etc).
5. All type of dams may be constructed at the site, thus plan alternative design until discarded due to technical, financial or environmental reasons
6. Dam engineering is critically dependent upon the application of informed engineering judgment

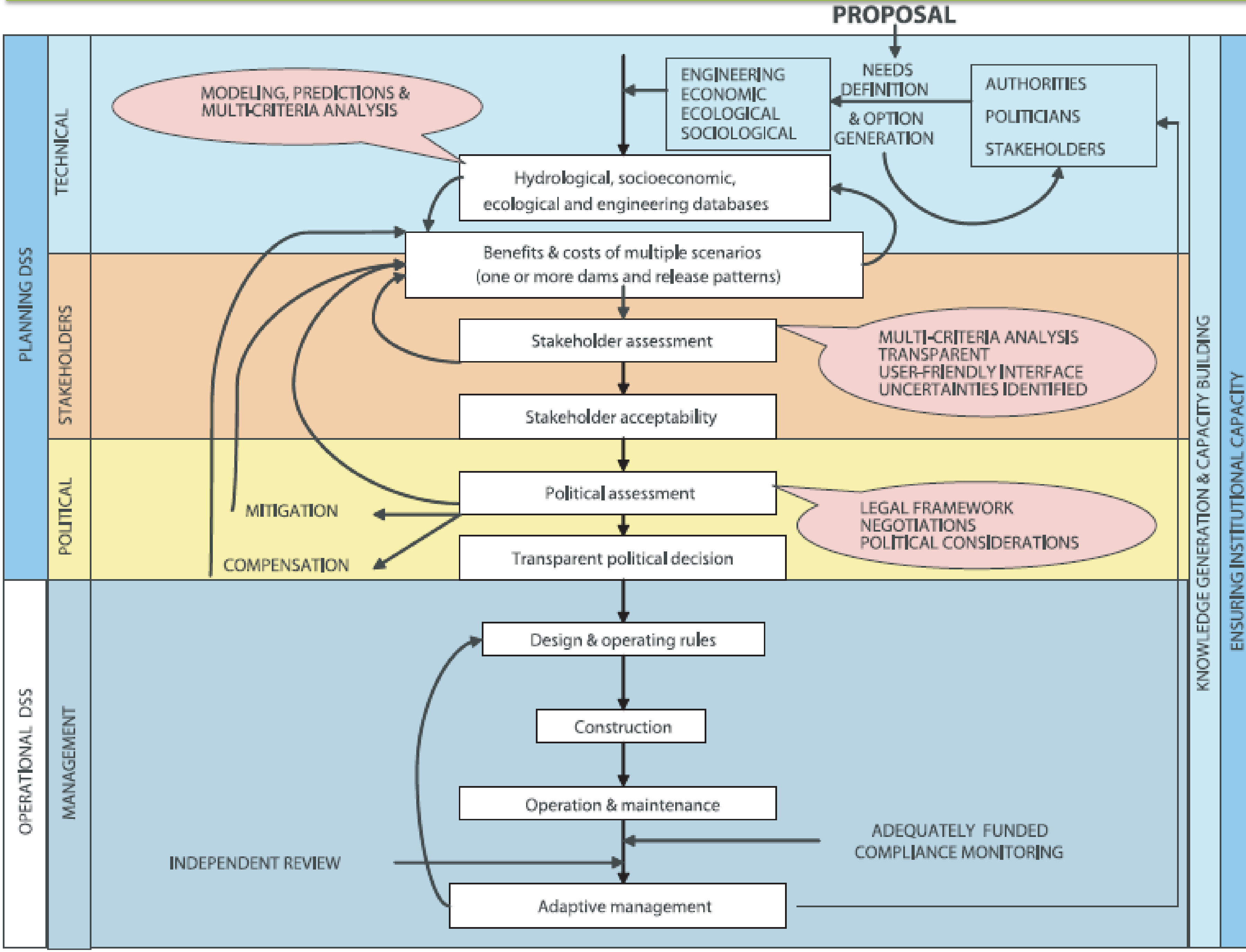
Challenges of Dams

- Resettlement
- Compensation Flows
- Fish migration
- Safety
- Loss of habitat
- Siltation
- Evaporation
- Health (Schistosomiasis)
- Salinisation
- Downstream erosion

Future in Dams and Water Management

- Planning process
- Public involvement & coordination
- Socio-economic issues
- Integrated water management in the watershed or river basin – eg Nile Basin Initiative
- Irrigation in the future
- Further Development of Hydropower
- Flood control
- Inland navigation
- The balance between project benefits and the environment
- Education and awareness of the public

Conceptual framework for decision-making in dam planning and operation (CPWF 2006).



DAM HYDROLOGY AND RESERVOIR PLANNING

1. FLOOD ANALYSIS

- Based on stream flow data at the dam site or design rainfall in the catchment
- Frequency analysis is carried out to determine peak flood discharge corresponding to various return periods

Type of Structure	Project Life (Years)	Return Period (Years)	Safety Factor (Percent)
Storage dams	30	200	86
		100	74
		50	54
Diversion weir and drainage structures	15	50	74
		20	54

2. Determination of Catchment yield

Safe/firm yield

- The maximum of water that can be guaranteed during a critical dry period.

Dependable yield

- Yield that can be guaranteed with certain probability p (e.g. irrigation- 75%, hydropower -90%, water supply 100%)

IF NO FLOW DATA

- The annual runoff for the catchment (the catchment yield in an average year),Y is can be estimated by:

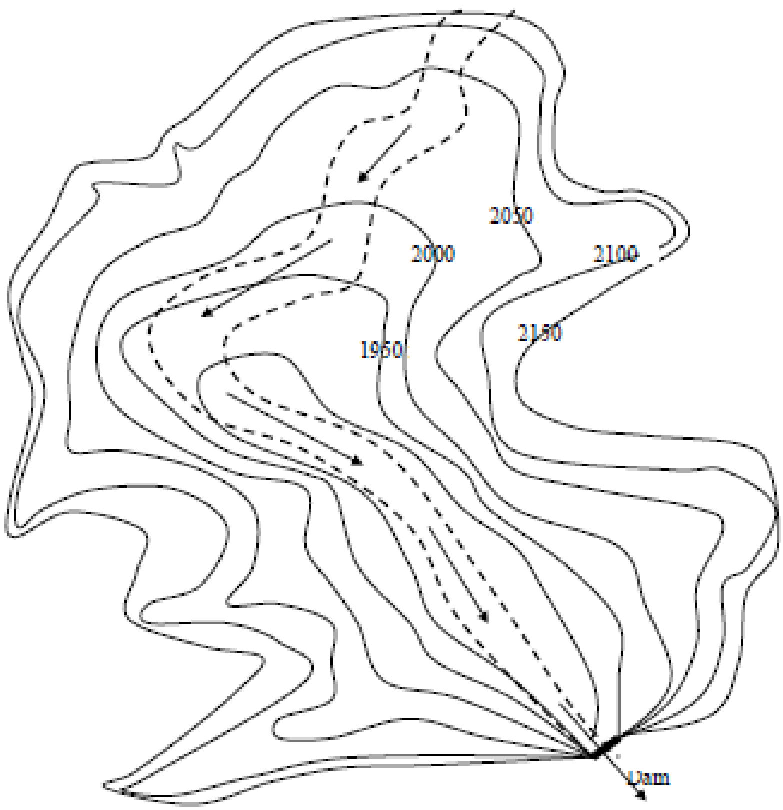
$$Y = C \times A \times R$$

A= catchment area
C= Runoff coefficient
R= Rainfall

3. Reservoir planning

Reservoir sizing (Area-Capacity Relationship)

- A topographic survey of the reservoir area is conducted,
- A contour map of the area is prepared
- the water spread area is determined from the contours

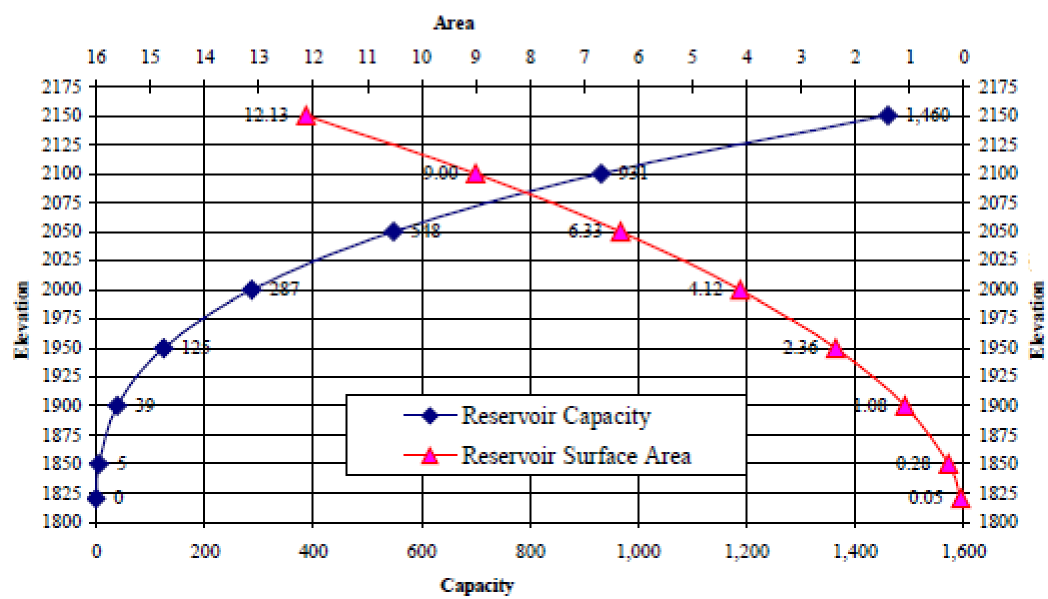


contour map

- The storage capacity is calculated different using formulae

For example
Trapezoidal formula

$$\Delta V_1 = \frac{h}{2}(A_1 + A_2)$$



Elevation-area curve and elevation-storage curve

Determination of Required Reservoir Capacity

- Capacity required for a reservoir depends upon the inflow available and demand
- Sometimes topography can dictate the capacity

Methods

- Graphical method, using mass curves
- Analytical method
- Flow-duration curves method

Analytical method

- The capacity of the reservoir is determined from the net inflow and demand

Adjusted inflow = Stream inflow + Precipitation - Evaporation – D/S Discharge

Storage required = Adjusted inflow - Demand

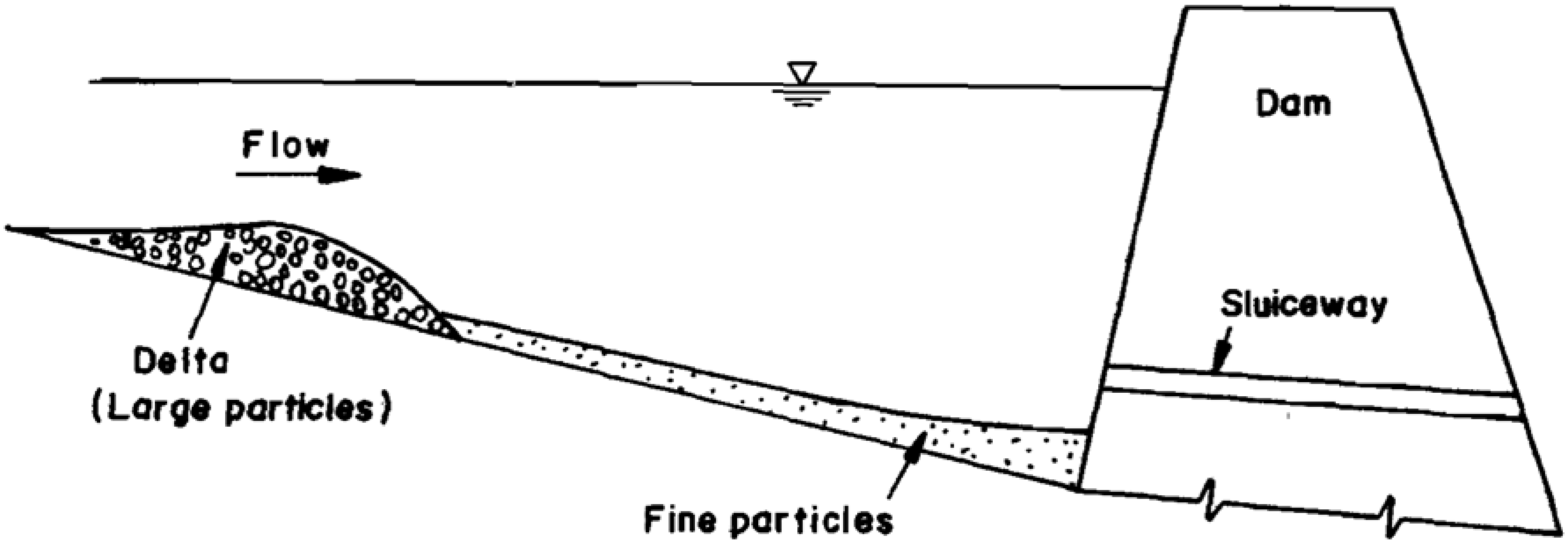
Sedimentation in Reservoirs

Sediments → eventually fill all reservoirs
determine the useful life of reservoirs
important factor in planning

- Rivers carry some **suspended sediment** and move **bed load** (larger solids along the bed).

- Large suspended particles **+** bed loads → deposited at the head of the reservoir & form **delta.**

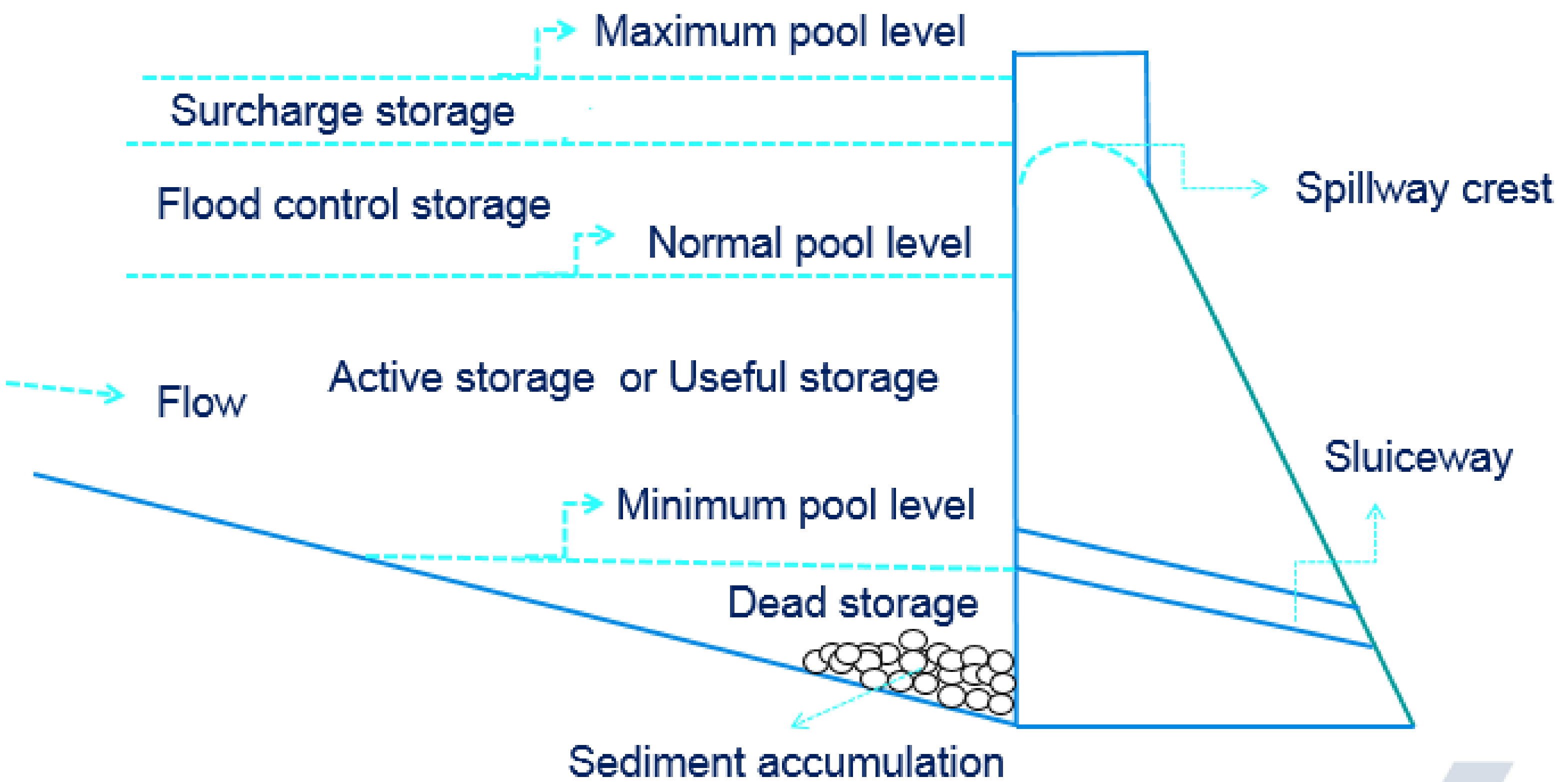
- Small particles → suspend in the reservoir *or* flow over the dam.



Sediment accumulation in a reservoir

Design of Reservoirs for Sedimentation

- providing a "dead storage" to accommodate the deposits during the life of the dam



Storage zones in a reservoir

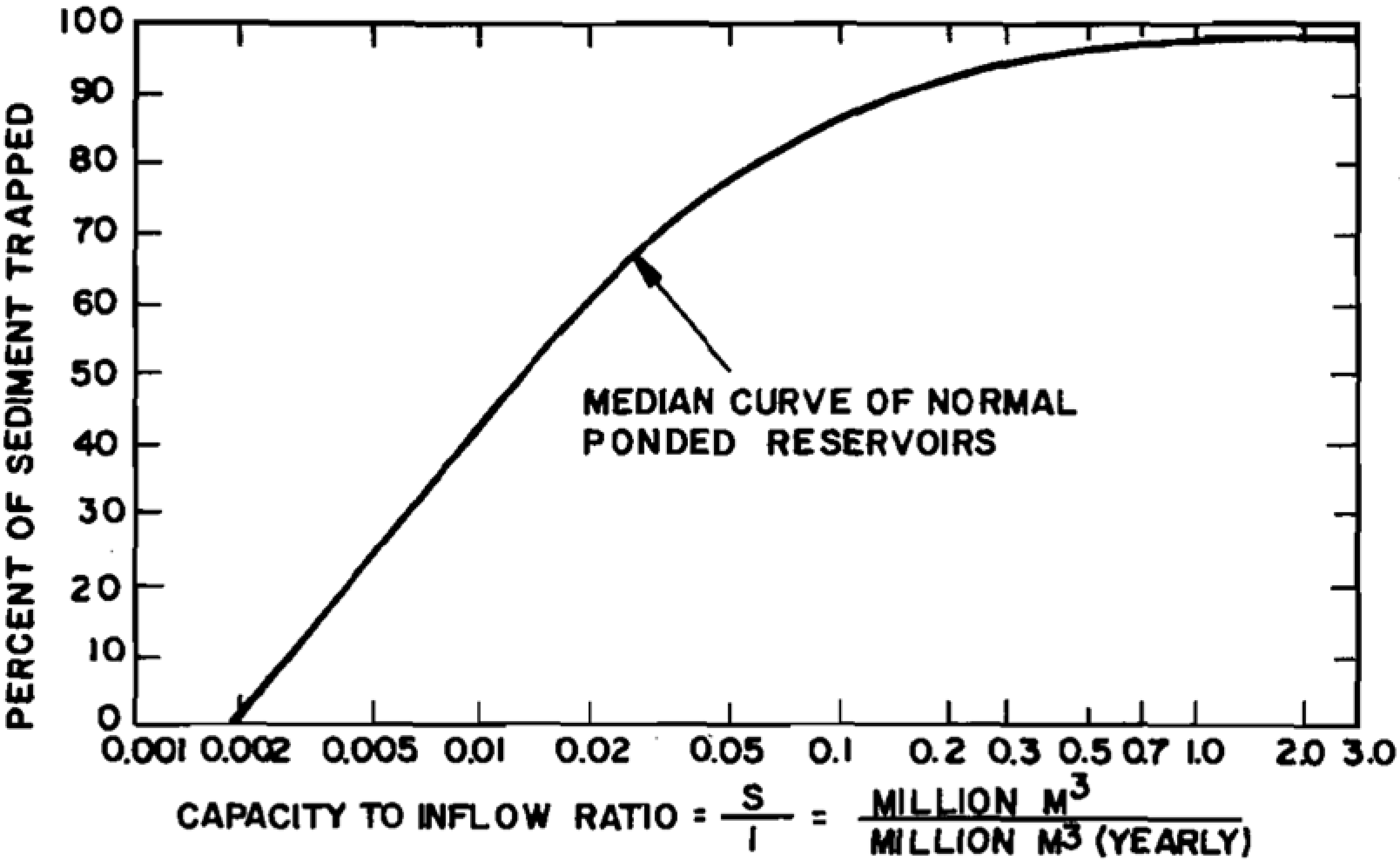
RESERVOIR SEDIMENTATION RATE

- based on **survey** of existing reservoirs, containing

  * Specific weight of the settled sediments
  * % of entering sediment which is deposited

TRAP EFFICIENCY

- % of inflowing sediment retained in the reservoir
- function of the ratio of reservoir capacity to total inflow.



Sediment trap efficiency and capacity / inflow relation
(Brune, 1953).

Example

The monthly inflow,precipitation,demand and pan-evaporation during a critical dry year at the site of a proposed reservoir are given below. The net increase in pool area is 500 ha and the prior rights require the release of the full stream flow or 10 ha-m, whichever is less. Determine the storage capacity. Take pan coefficient as 0.80.

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Inflow (ha-m)	10	10	4	2	1	200	2000	4000	1500	100	15	10
Pan evaporation (cm)	8	10	10	12	15	20	15	15	15	12	10	8
Precipitation (cm)	1.2	0	0	0	0	18	24	27	24	6	0	1.2
Demand (ha-m)	150	150	50	50	50	50	50	50	150	150	150	150