BDS 20th March 2017

GENALE DAWA (GD3) MULTI-PURPOSE HYDROPOWER PROJECT ETHIOPIA

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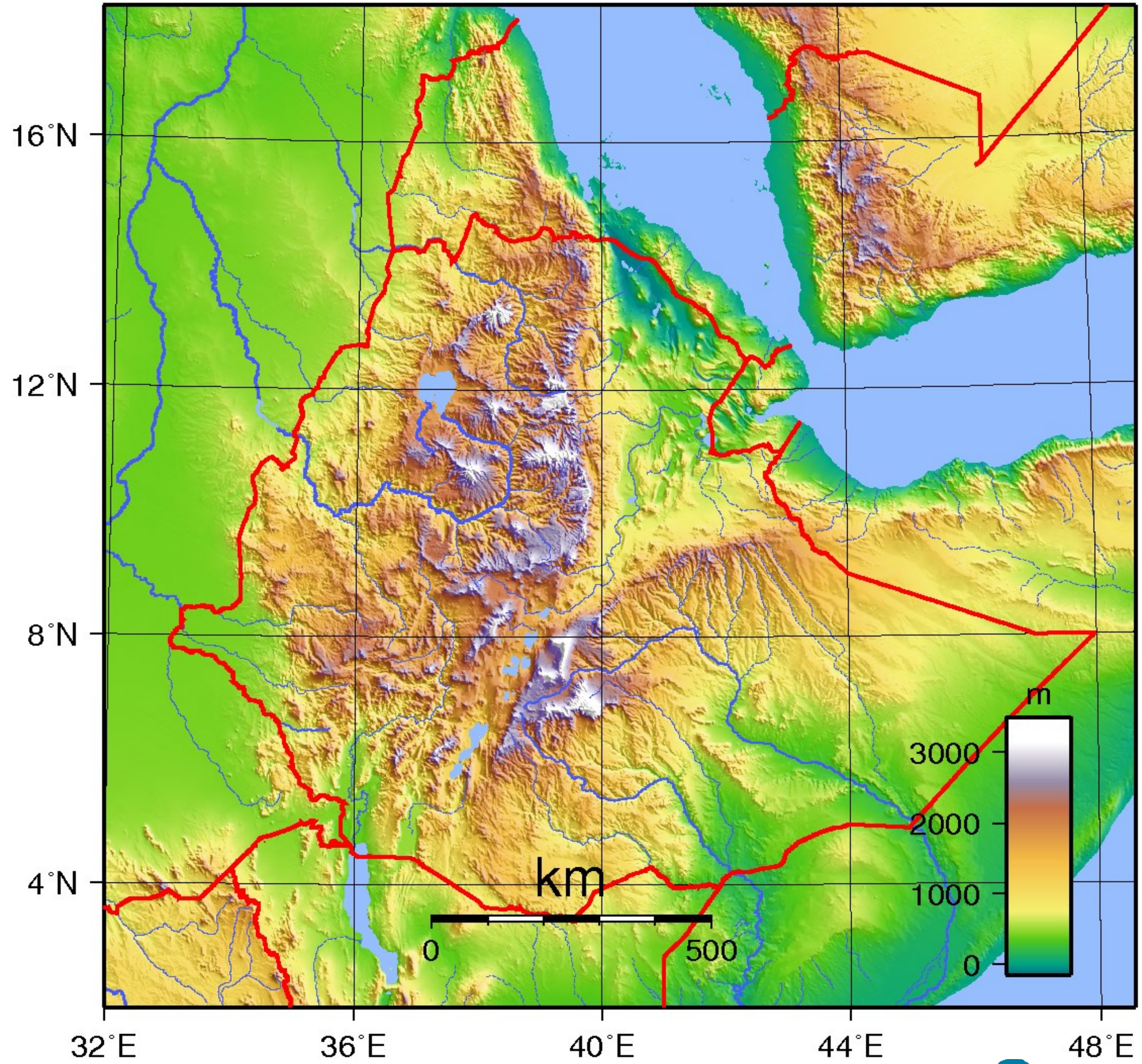
Part 1:	**Ethiopia**
Part 2:	Hydropower In Ethiopia
Part 3:	Genale Dawa (GD3) Scheme
Part 4:	Dam Design & Construction
Part 5:	Appurtenant Structures
Part 6:	Summary
Part 7:	Discussion

EAST AFRICA

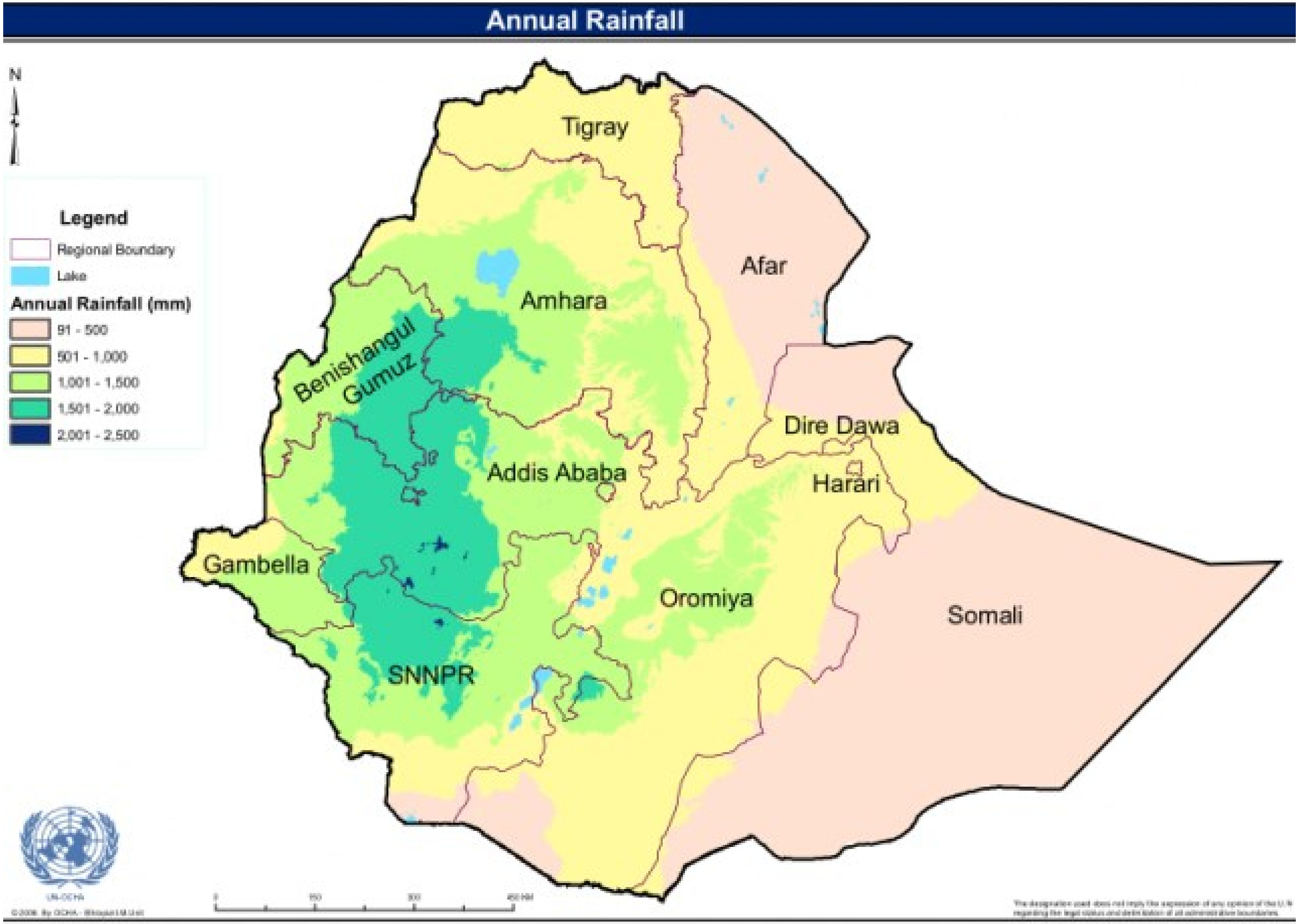
Austria
Kazakhstan
France
Romania
Italy
Uzbekistan
Kyrgyzstan
Spain
Greece
Turkey
Turkmenistan
Portugal
North Atlantic Ocean
Syria
Tunisia
Mediterranean Sea
Iraq
Afghanistan
Iran
Morocco
Pakistan
Algeria
Libya
Egypt
Nepal
Western Sahara
Saudi Arabia
India
Oman
Mauritania
Mali
Niger
Sudan
Chad
Yemen
Burkina Faso
Gulf of Aden
Arabian Sea
Bay of Bengal
Guinea
Nigeria
Ethiopia
Ghana
South Sudan
Laccadive Sea
Gulf of Guinea
Somalia
Kenya
Gabon
DR Congo
Tanzania
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Madagascar
Botswana
Indian Ocean
South Atlantic Ocean
South Africa
Google

THE HORN OF AFRICA

TOPOGRAPHY

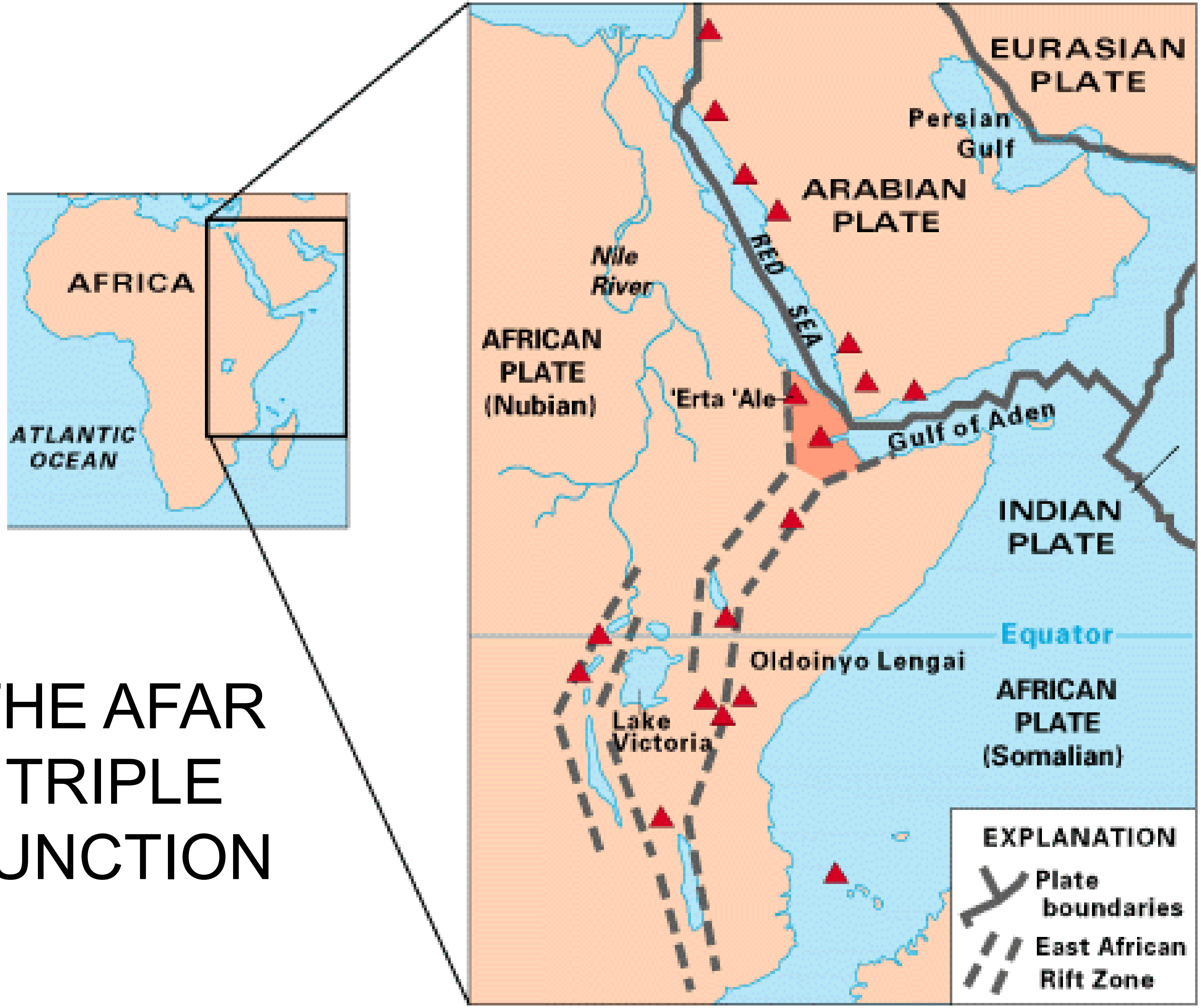


HYDROLOGY



Annual Rainfall
N
Legend
Regional Boundary
Lake
Annual Rainfall (mm)
91 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
Tigray
Afar
Amhara
Benishangul Gumuz
Dire Dawa
Harari
Addis Ababa
Gambella
Oromiya
Somali
SNNPR

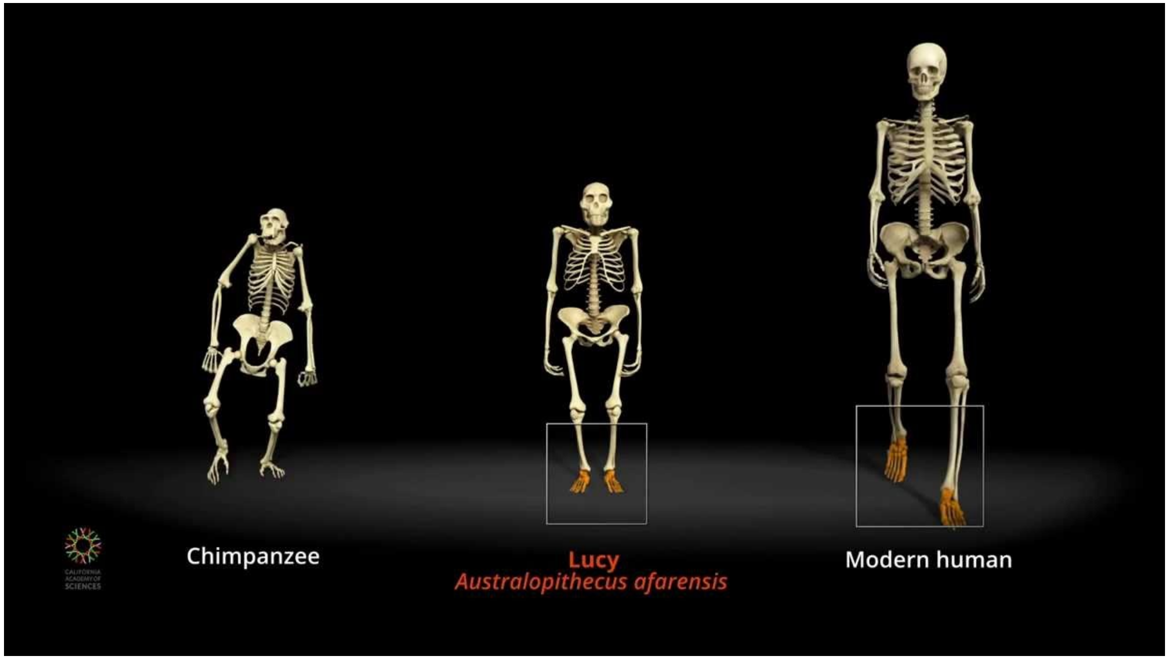
GEOLOGY



THE AFAR TRIPLE JUNCTION

THE GREAT RIFT VALLEY

ARCHEOLOGY



THE BIRTHPLACE OF HUMANITY ?

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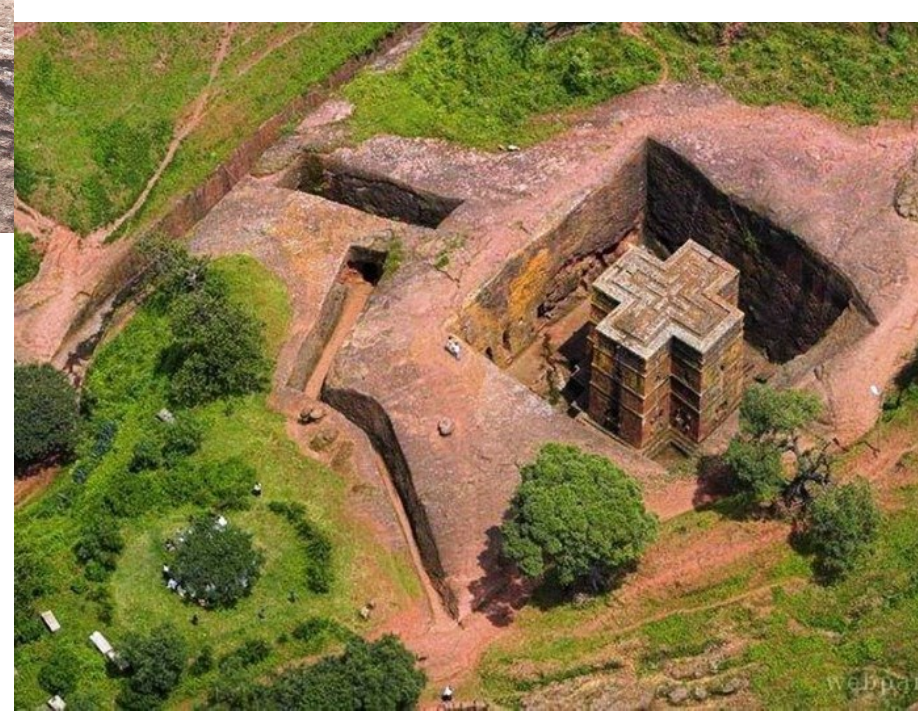
HISTORICAL SITES - AXUM

ANCIENT STELLAE

ST MARY OF ZION CHURCH

ROCK HEWN CHURCHES- BELA



THE BIRTH PLACE OF COFFEE

KAFFA
(SOUTH
ETHIOPIA)

ECONOMY

One of the fastest growing economies in the World

Annual GDP growth has averaged around 10% for the past 10 years

Africa’s second most populous country. 50% under 18

MAIN ECONOMIC SECTORS

Agriculture
Energy
Construction
Manufacturing
Transport
Telecommunications
Tourism
Minerals & Mining

Part 1: Ethiopia

Part 2: Hydropower In Ethiopia

Part 3: Genale Dawa (GD3) Scheme

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POWER DEVELOPMENT IN ETHIOPIA

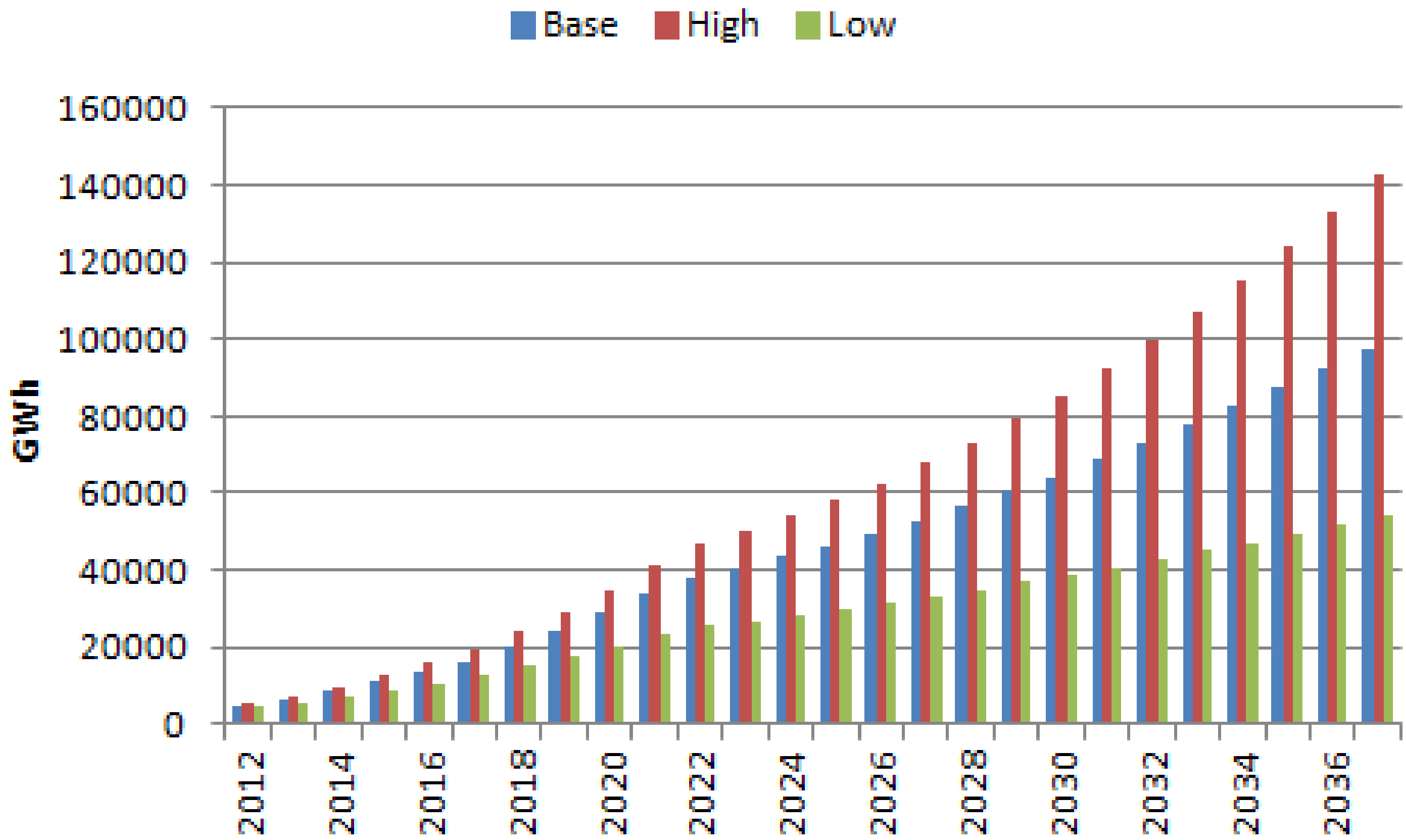
Responsible Bodies

Government of the Federal Democratic Republic of Ethiopia
(*Growth and Transformation Plan*)

Ministry of Water, Irrigation and Electricity

Ethiopian Electric Power

ETHIOPIAN ELECTRICTY DEMAND FORECAST



REASONS FOR GROWTH IN ELECTRICTY DEMAND

High rate of urban development

High rate of industrial development

Rural electrification
(Universal Electricity Access Program)

New railway developments

New large scale irrigation projects

Exportation of Electricity

EXPORTATION OF ELECTRICITY

Country	Capacity (MW)	Start Date
Djibouti	100	since 2011
Sudan	1200	since 2012
Kenya	2000	2018/19
Tanzania	400	2019/20

Possible future connections to Burundi, Egypt, Libya, Rwanda, Uganda, Yemen and beyond through proposed regional interconnectors

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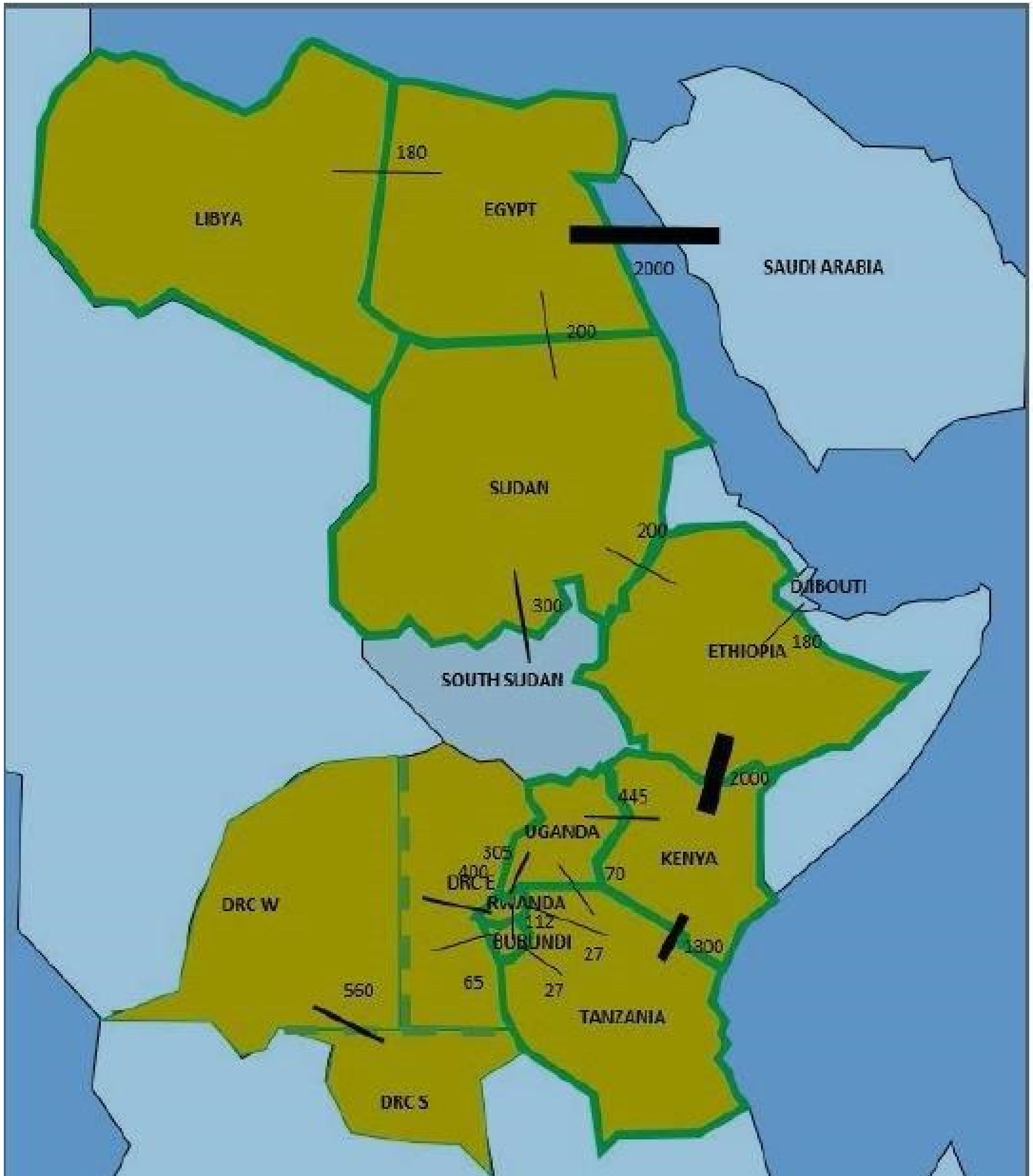
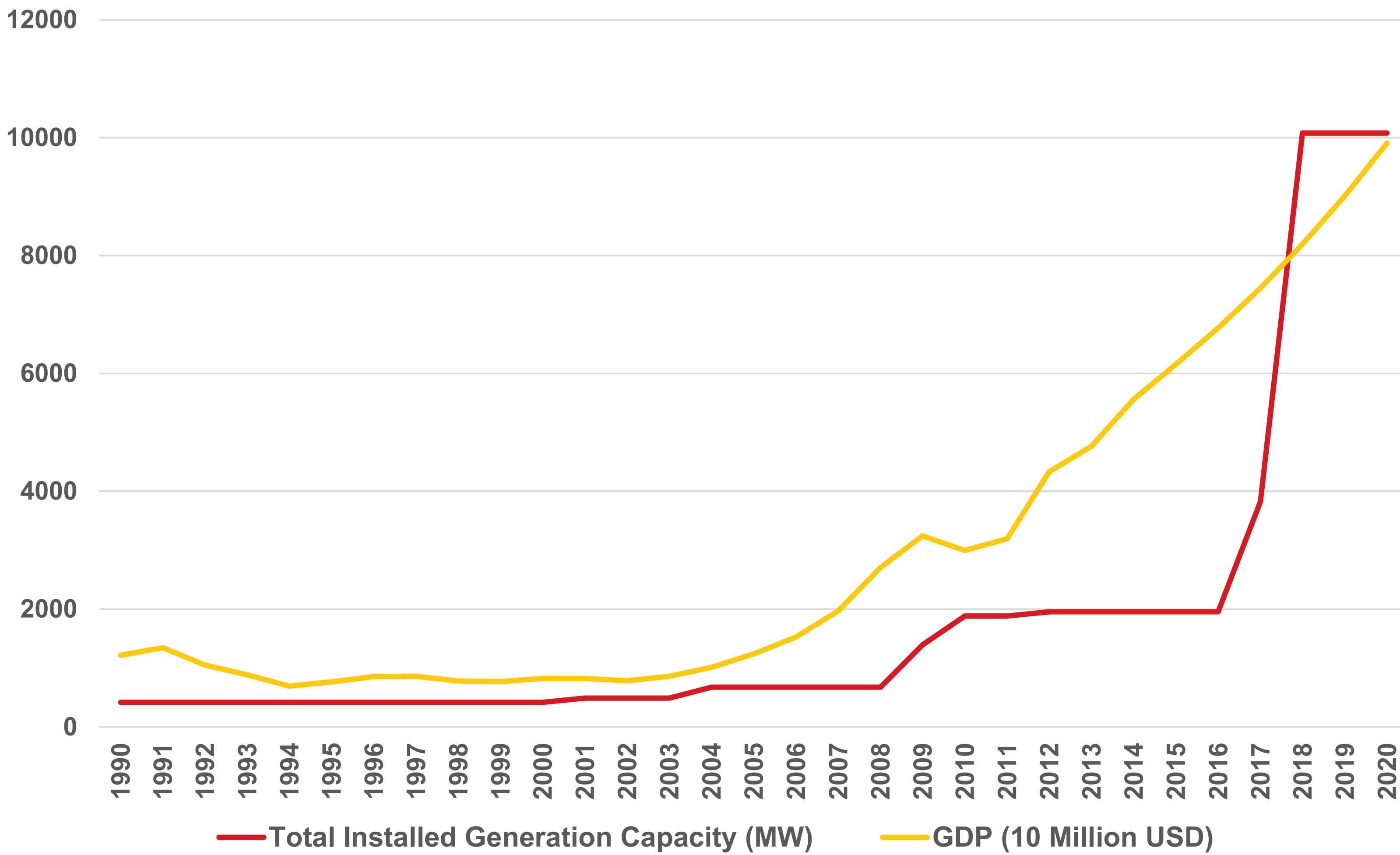
EXPORTATION OF ELECTRICITY



East African Power Pool

(EAPP)

CORRELATION BETWEEN GDP AND HYDROPOWER DEVELOPMENT



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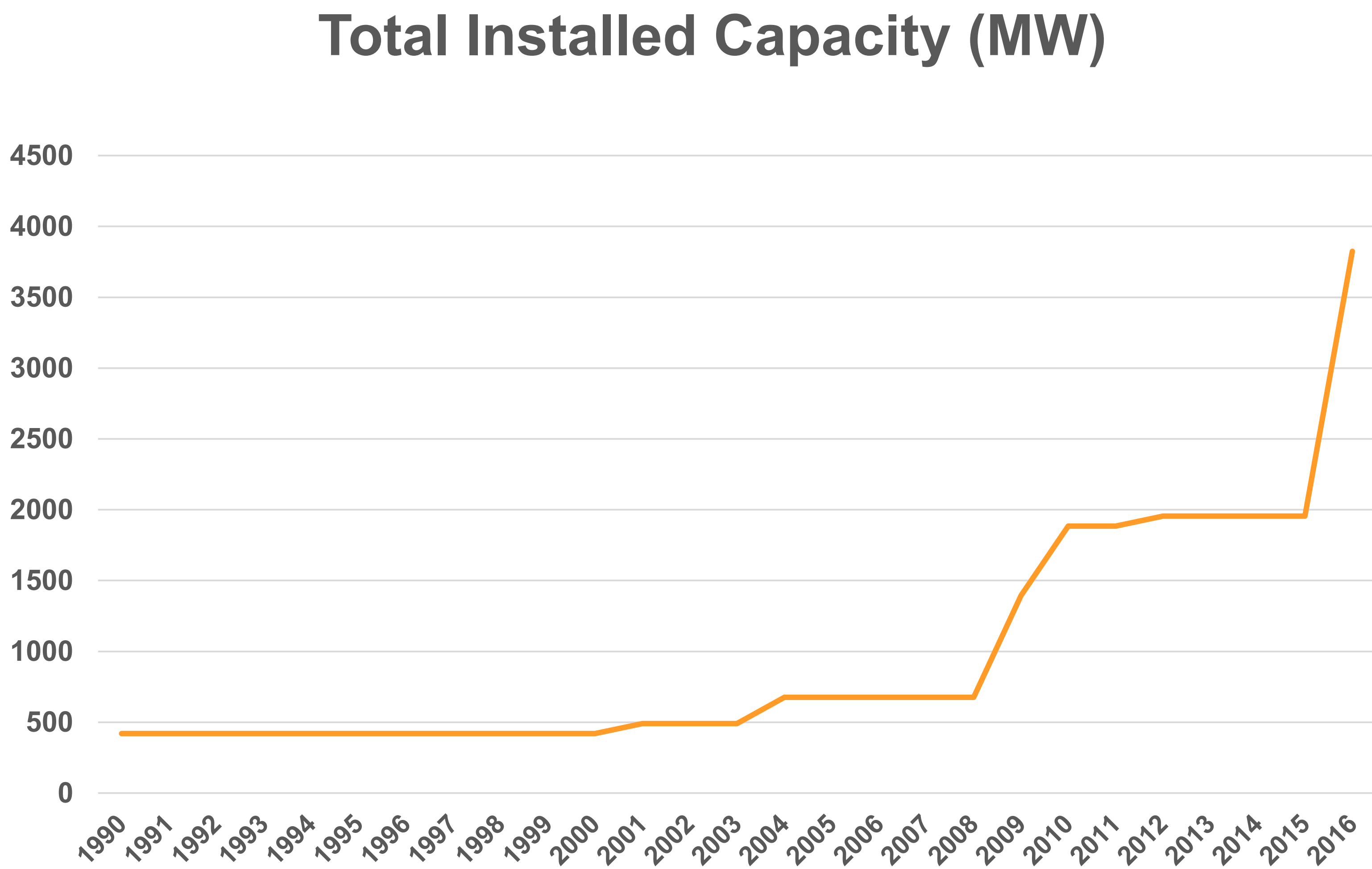
RENEWABLE ENERGY RESOURCES

Hydropower	**45,000 MW**
Wind	**10,000 MW**
Geothermal	**5,000 MW**
Solar	**300 MW**
Waste to Energy	**500 MW**
Cogeneration (Biofuel)	**600 MW**

Ethiopia’s hydropower resources are second only to the Democratic Republic of Congo (DRC) throughout the whole of Africa

HYDROPOWER DEVELOPMENT SINCE 1990



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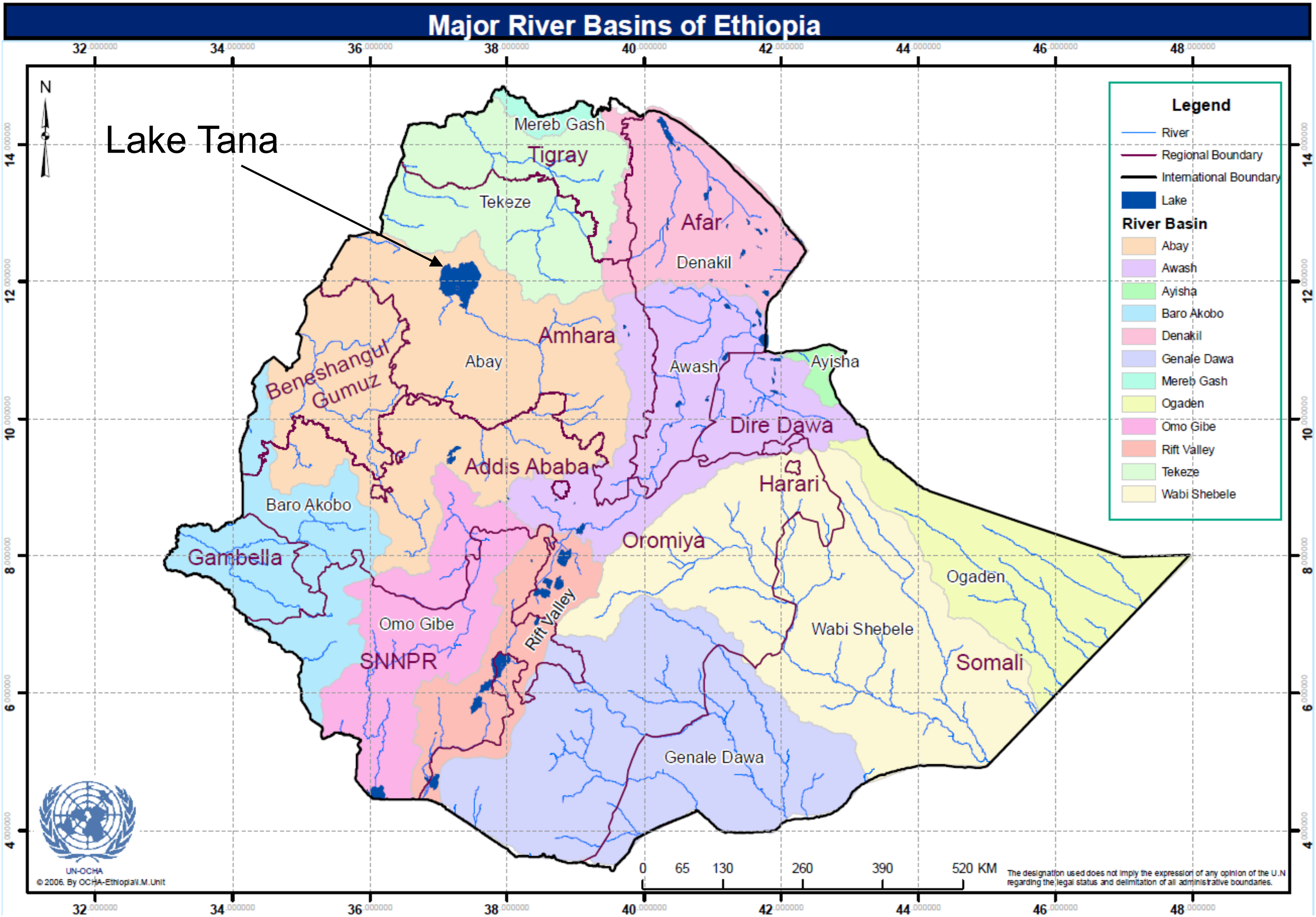
HYDROPOWER DEVELOPMENTS SINCE 2000

Project	Installed Capacity (MW)	Year
Tis Abay II	72	2002
Gilgil Gibe I	184	2004
Tekeze	300	2009
Gilgil Gibe II	420	2009
Tana Beles	460	2010
Finchaa Amerti Neshe	100	2012
Gilgil Gibe III	1870	2016
Genale Dawa (GD3)	254	2018
GERD	6000	2018

HYDROLOGY



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HYDROPOWER PROJECTS IN ETHIOPIA

Tekeze

Double curvature concrete arch

188 m high

300 MW

Completed 2010

HYDROPOWER PROJECTS IN ETHIOPIA

Beles

Intake direct from Lake Tana

460 MW

Completed 2010

HYDROPOWER PROJECTS IN ETHIOPIA

Finchaa Amerti Neshe (FAN)

Earthfill

38m high

100 MW

Completed 2012

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HYDROPOWER PROJECTS IN ETHIOPIA

Gilgel Gibe III

RCC
243 m high
1870 MW
Completed 2016

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HYDROPOWER PROJECTS IN ETHIOPIA

Grand Ethiopian Renaissance Dam

RCC

175 m high

6450 MW

Under construction (2018)

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GD3 PROJECT DETAILS

Located on Genale River

110 m high CFRD

Reservoir capacity 2,570 Mm^3

Reservoir area 98 km^2 / 8.4 Ha

254 MW

1,600 GWh/year

THE GENALE DAWA RIVER BAS

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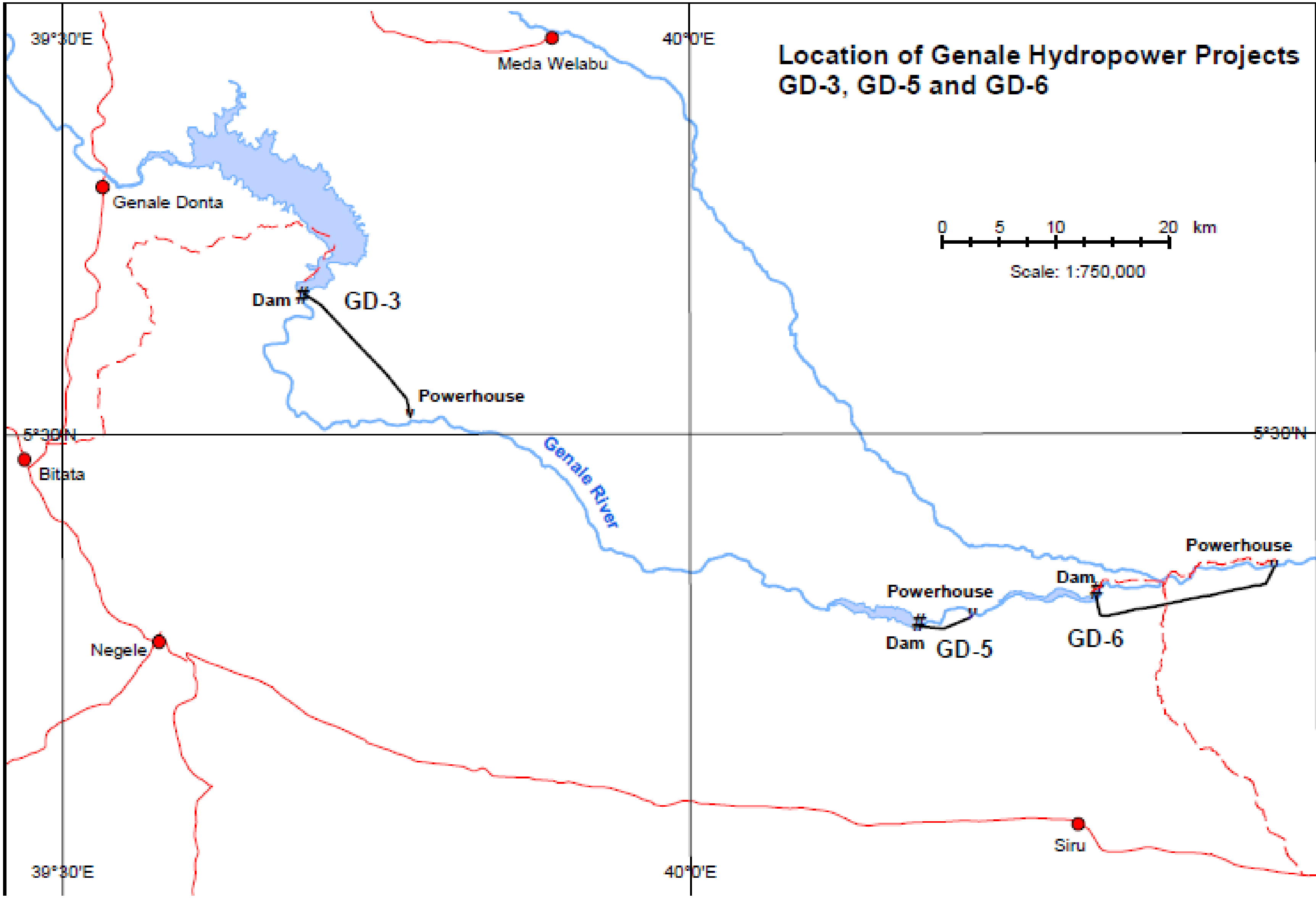
THE GENALE HYDROPOWER CASCADE



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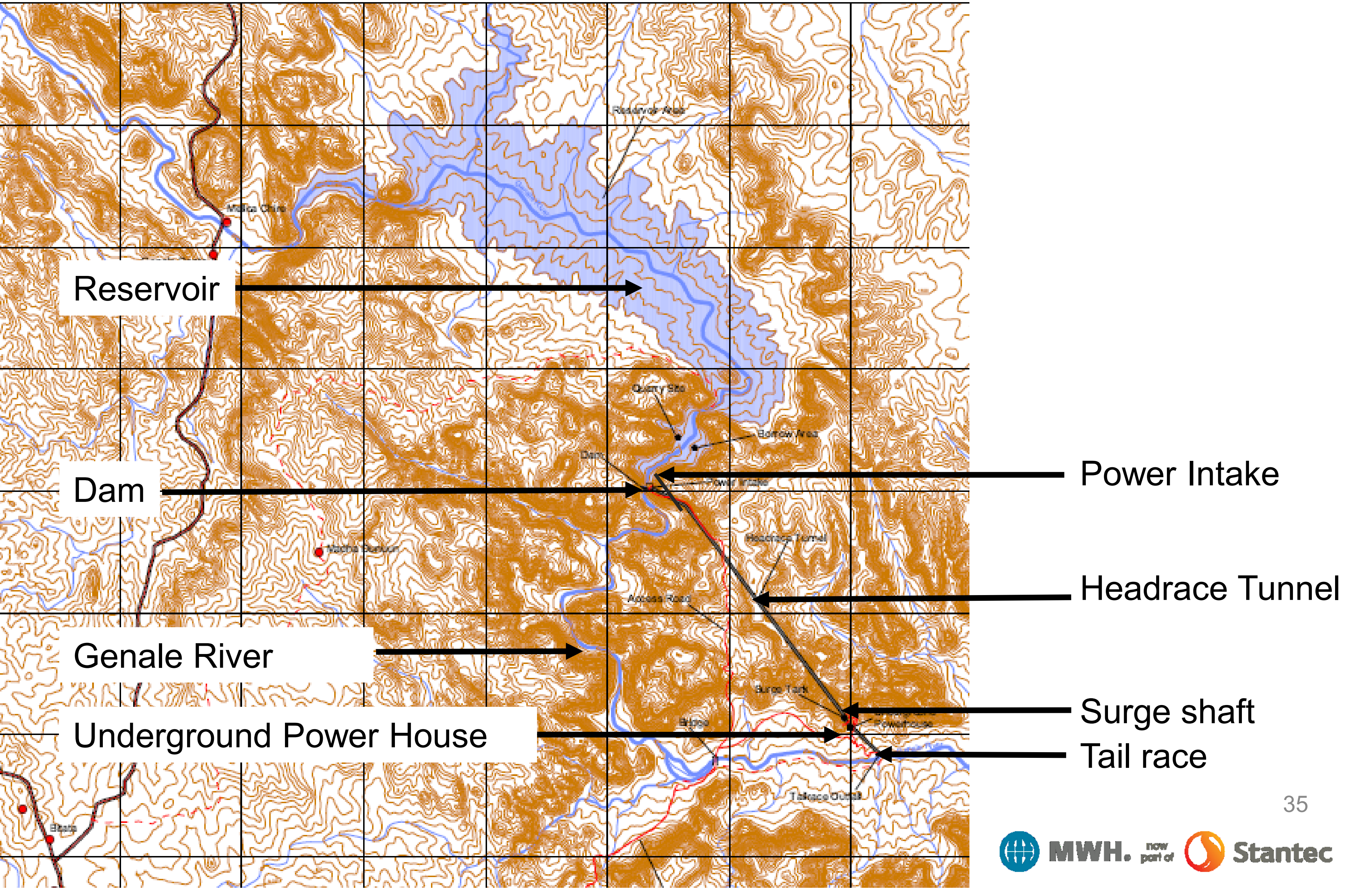
SCHEME LAYOUT



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ORGANISATIONAL STRUCTURE

Ethiopian Electric Power (EEP)

Main Contractor CGGC

Employer's Representative MWH

Mid South Design Institute (MSDI)

Seli (TBM supply and operation)

Integrated Engineering

Acute Engineering

FIDIC 'Silver Book' for EPC/Turnkey Projects

EPC = Engineer Procure Construct

TIMELINE

2007 Aug	Feasibility Lahmeyer Consultants – August 2007
2009 Sep	Award to China Gezhouba Group Corporation (CGGC)
2011 Mar	Basic Design / Start on Site
2013 Jan	River Diverted
2013 Aug	Commencement of TBM drive
2014 Oct	Substantial completion of dam rockfill
2016 Oct	Completion of TBM drive
2017 Mar	Commence impounding
2017 Dec	Commence electricity generation
2018 Mar	Project completion

MAIN PROJECT FEATURES

110m HIGH CFRD

DIVERSION TUNNEL (plugged after start of impoundment)

GATED SPILLWAY (three radial gates)

MID LEVEL OUTLET (radial gate & vert. wheel gate)

INTAKE STRUCTURE (trash rake & vertical wheel gate)

HEADRACE TUNNEL (12.4km long of which 9km by TBM)

SURGE SHAFT (23 m diameter 120m high)

VERTICAL DROP SHAFT (188m high)

STEEL LINED PENSTOCK (various diameters)

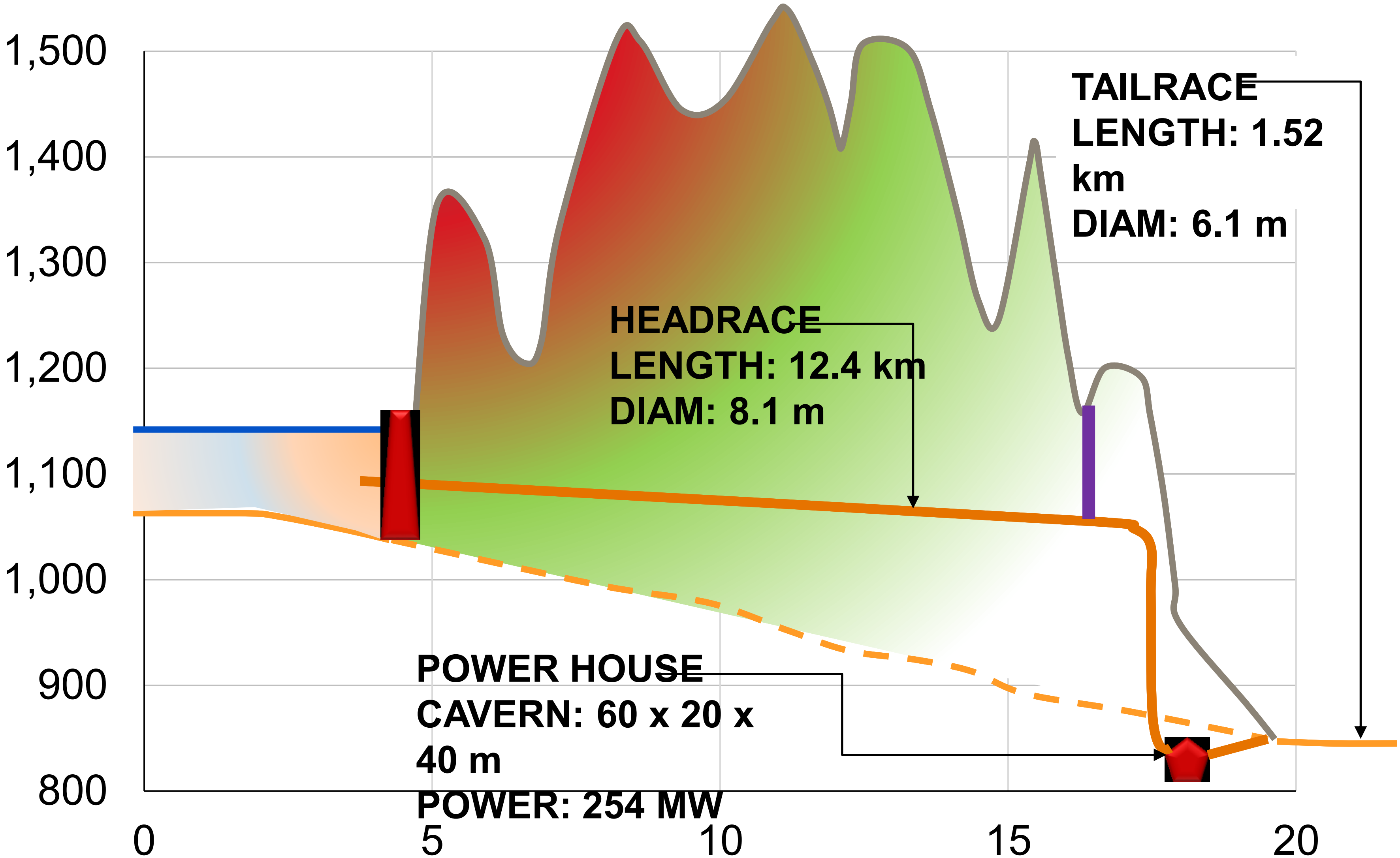
U'GROUND P'HOUSE (three 84.7MW Francis Turbines)

TRANSFORMER CAVERN (immediately d/s of p'house cavern)

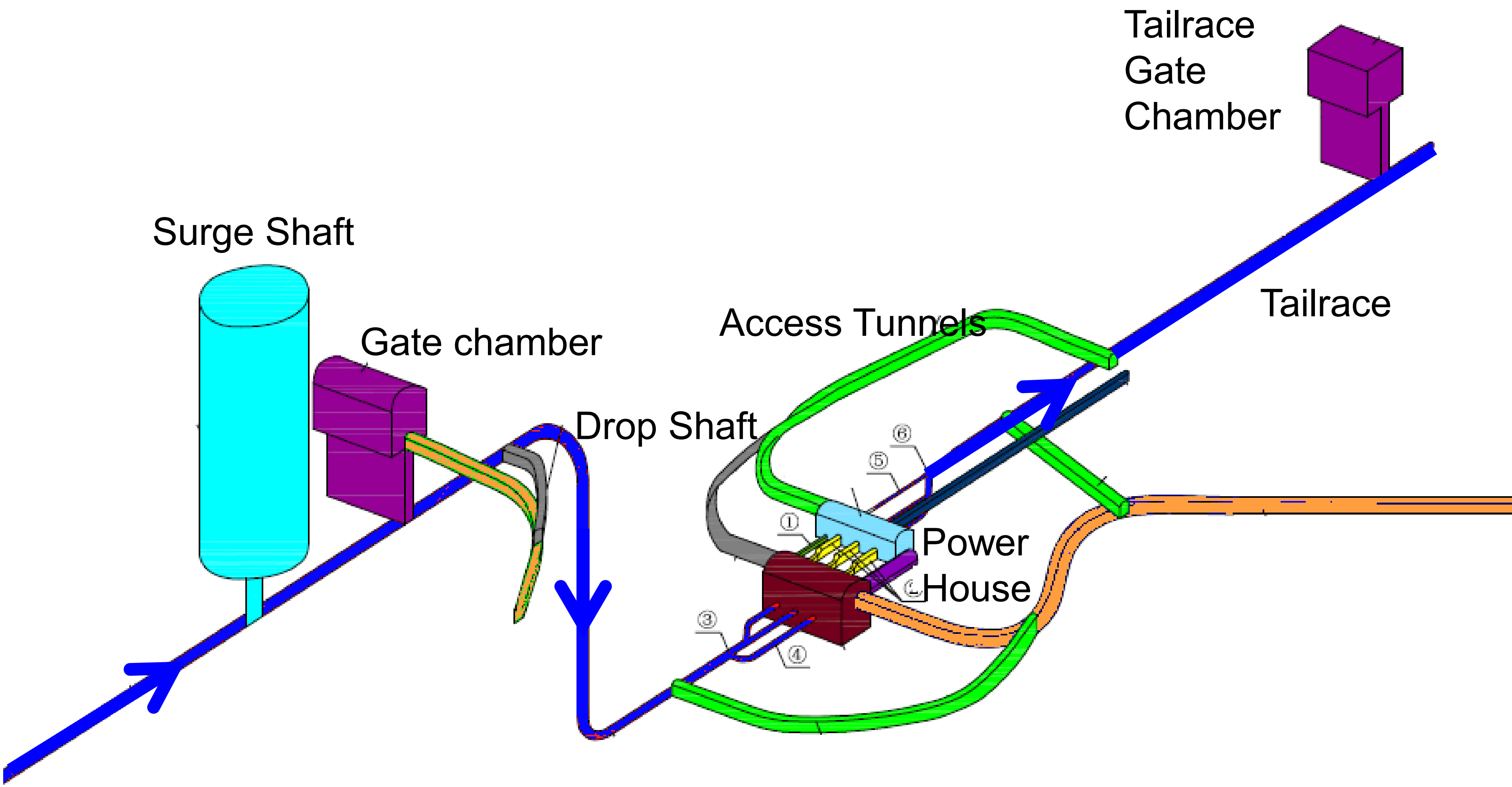
TAILRACE TUNNEL (820m long)

TAILRACE CHANNEL (480m long)

PROJECT IN PROFILE



UNDERGROUND WORKS



POWER INTAKE

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TUNNEL BORING MACHINE

SURGE SHAFT

120m HIGH

23 m DIAMETER

SLIP-FORMED CONCRETE

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POWER HOUSE

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TAILRACE CHANNEL

Genale Dawa (GD3)

Part 1: Ethiopia

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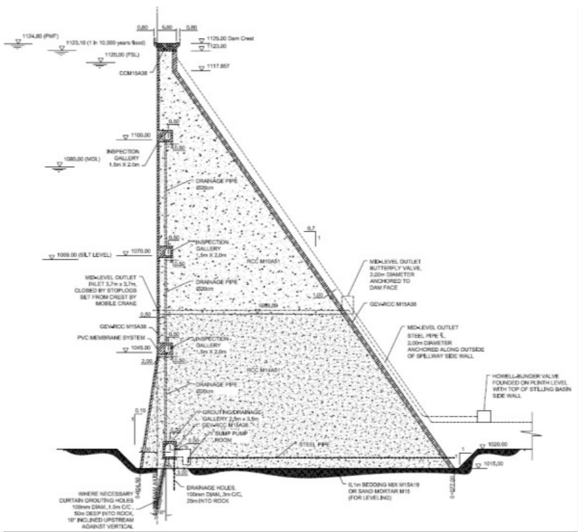
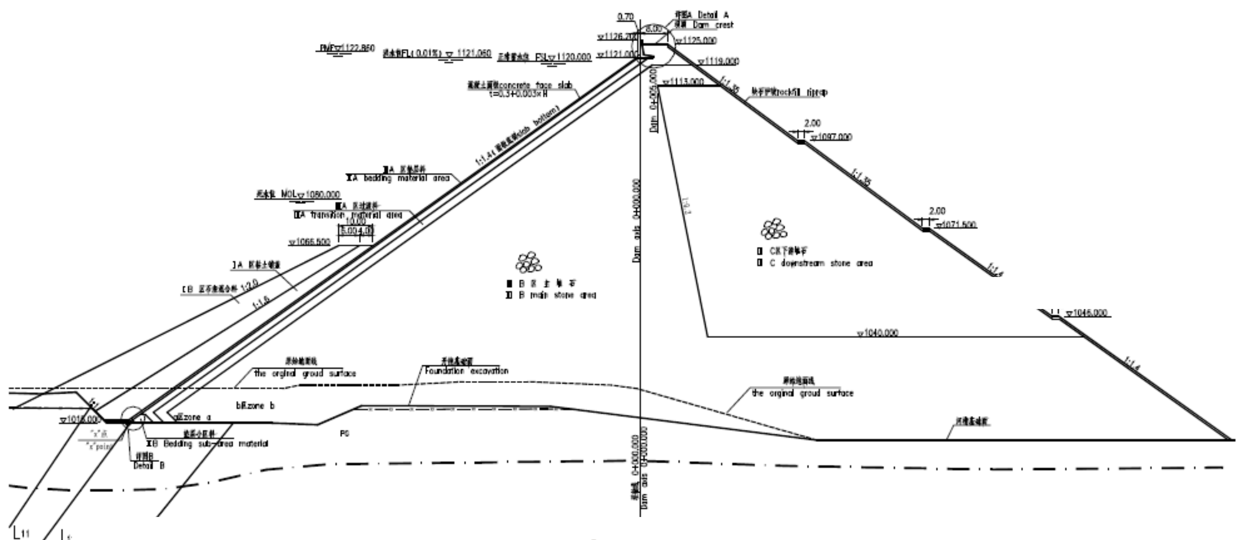
DAM DESIGN

Feasibility Study[1] Recommended Roller Compacted Concrete (RCC)

Contractor changed to Concrete Faced Rockfill Dam (CFRD)



RCC

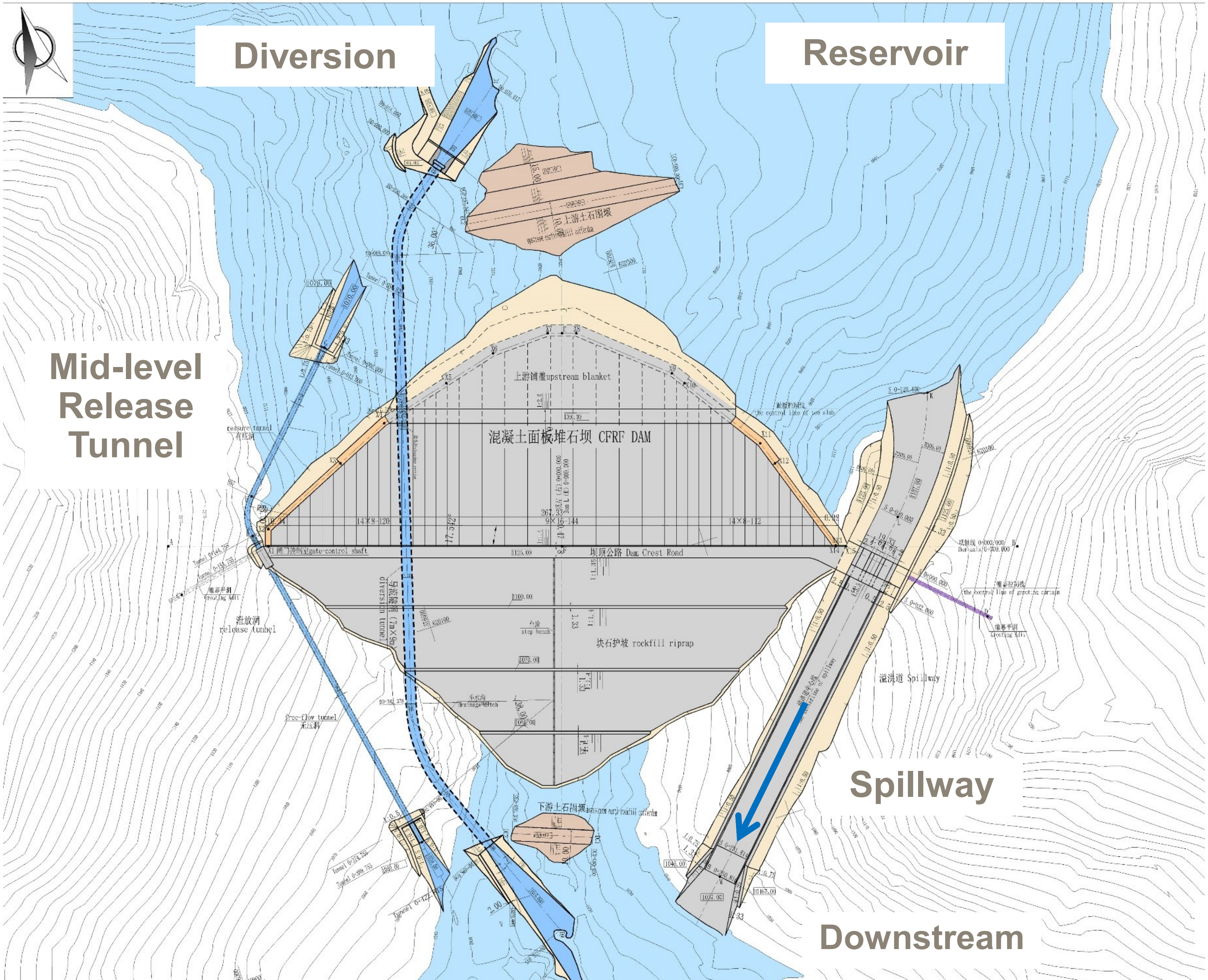


CFRD

WHY?

[1] Lahmeyer International, August 2007

DESIGN – DAM SITE LAYOUT



RESERVOIR / DAM DETAILS

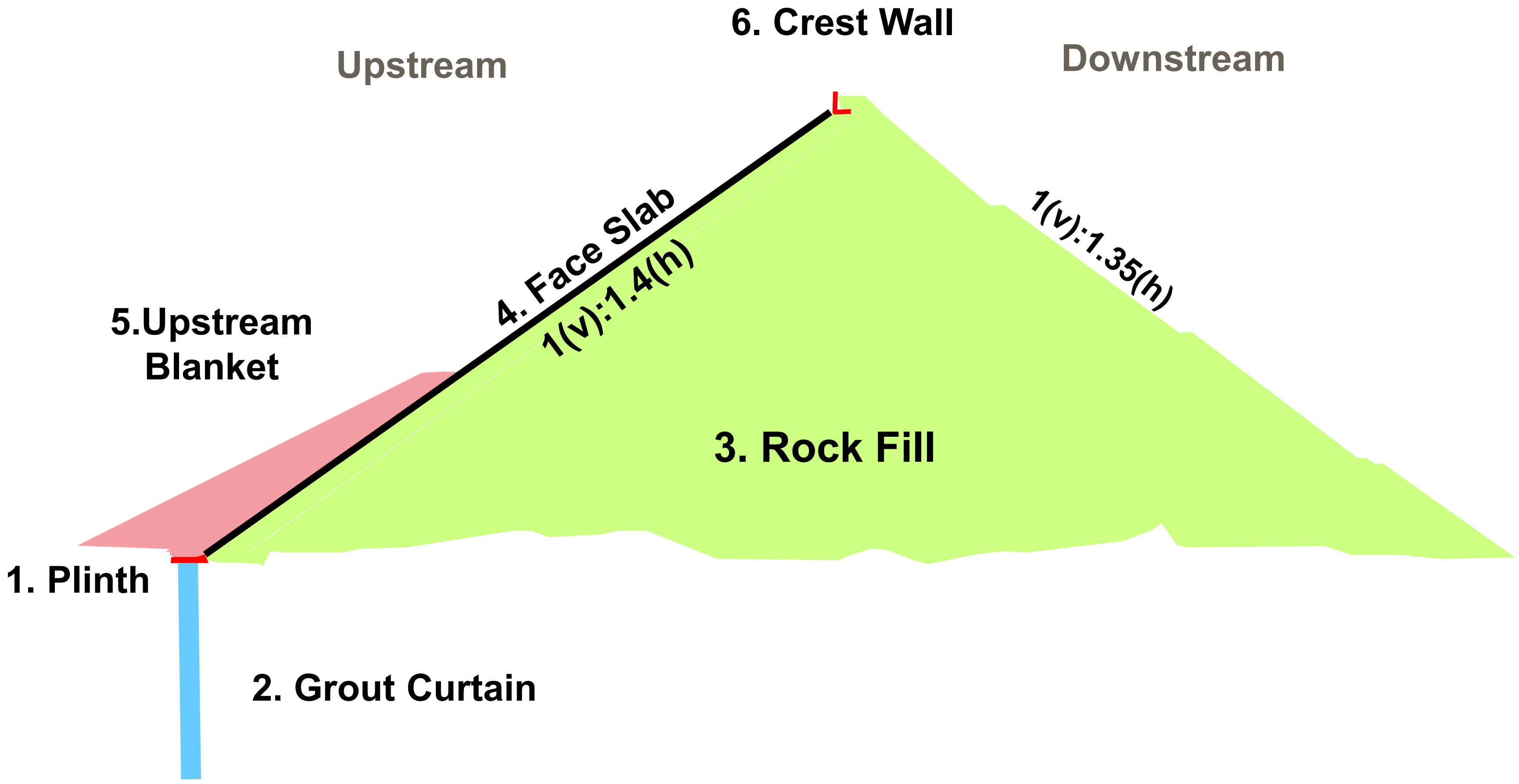
Reservoir

Catchment area:	10,445 km^2
Reservoir area:	98 km^2
Mean Inflow:	92.6 m^3/s
Storage (Live / Dead):	2,570 / 2,310 Mm^3
Loss of live storage after 50 years:	2.1%
Lifetime:	> 1000 years

Dam

Type:	CFRD
Geology / Rockfill material:	Granite
Height:	110 m
Length:	450 m
Fill volume:	3 Mm^3

TYPICAL CFRD SECTION



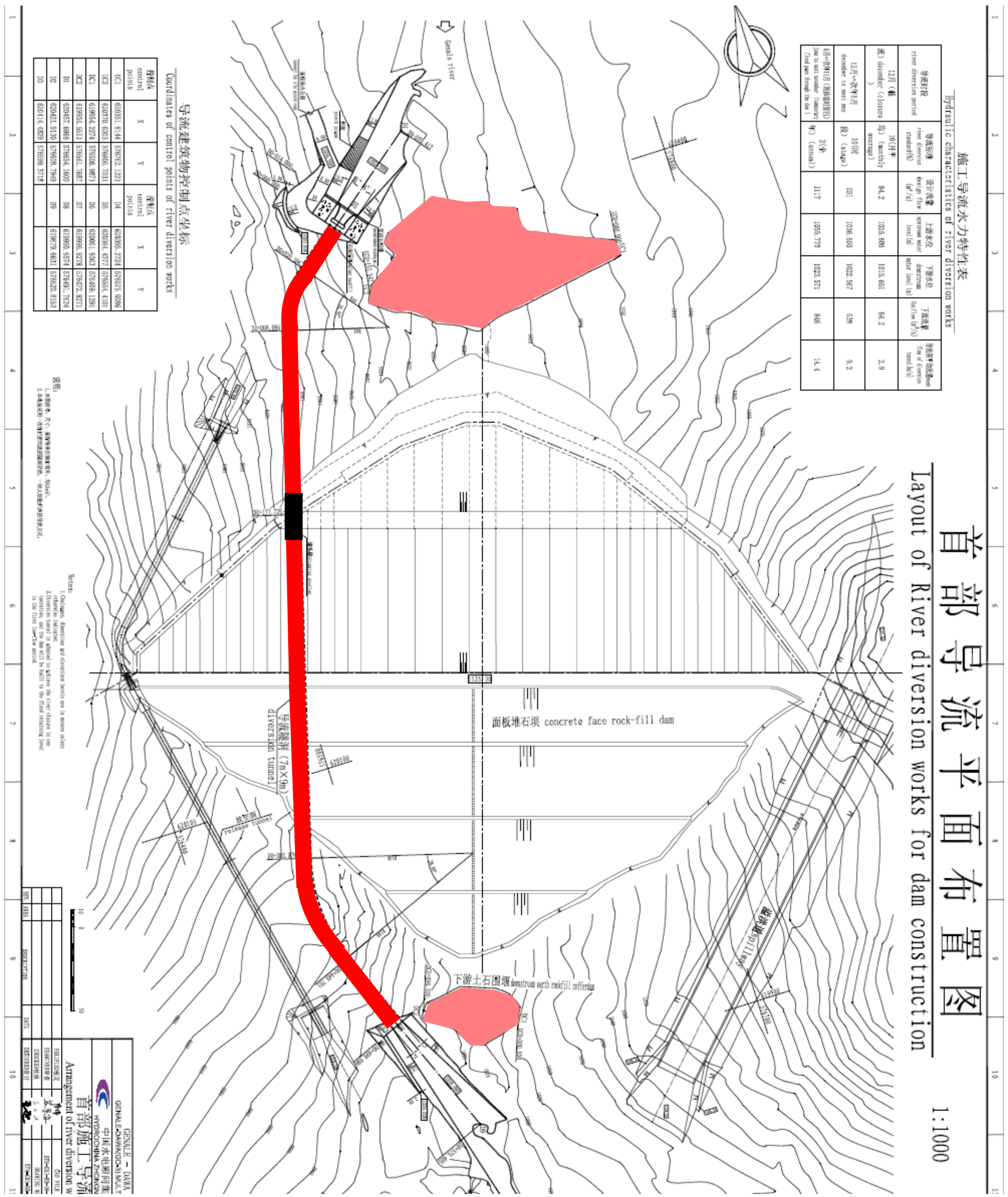
EVOLUTION OF CFRD's

Mid to late 1800s	**Dumped rockfill with timber facing / steep slopes**
1890's	**First use of concrete in 1890s (height < 25 m)**
1920s-1960s	**Dumped in high lifts and sluiced. Use of upstream rockfill zone. Dam heights 80m - 100m. Result in face slab cracking / high leakage. CFRD's go out of fashion. . .**
From late 60s	**Rockfill placed in 1 - 2 metre lifts, watered and compacted. Reduction in particle size and improvements to plinth and face slab design = Improved performance. CFRDs popular again.**
2010	**Standard design formalised in ICOLD Bulletin 141.**

Summarised from p.590 of Geotechnical Engineering of Dams, 2005, Taylor and Francis Group PLC

CONSTRUCTION – EARLY DAYS

DESIGN – DIVERSION

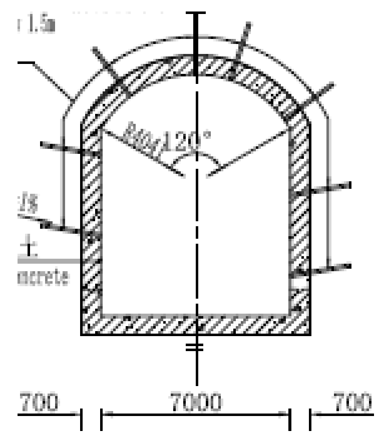


Diversion system sized for 1 in 10 year flood event (551 m^3/s)

Low consequence of overtopping of cofferdams

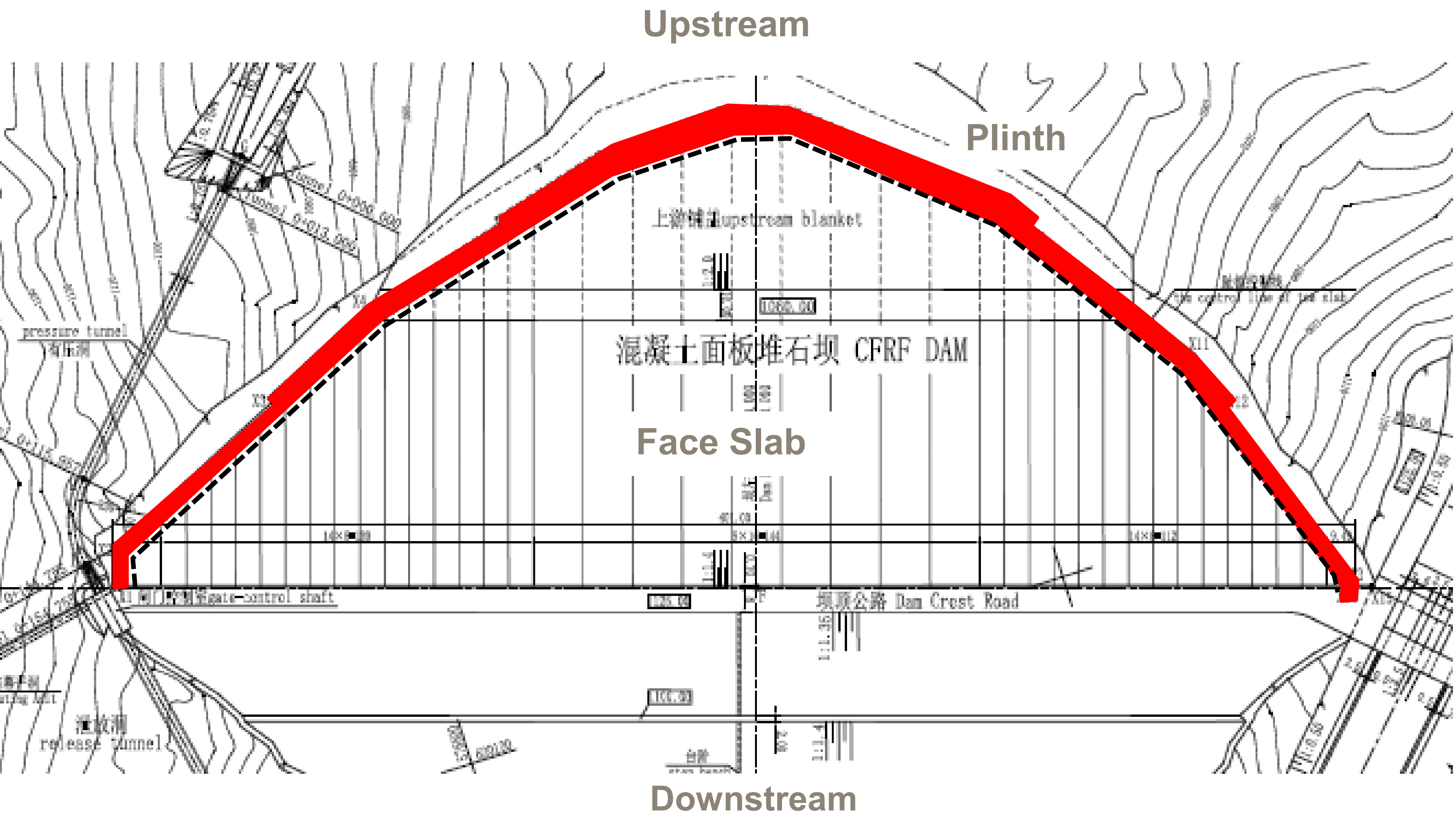
500 m long drill and blast tunnel

20 m long concrete plug to be installed upon completion



DIVERSION WORKS (JAN 2013)

PLINTH - DESIGN



PLAN

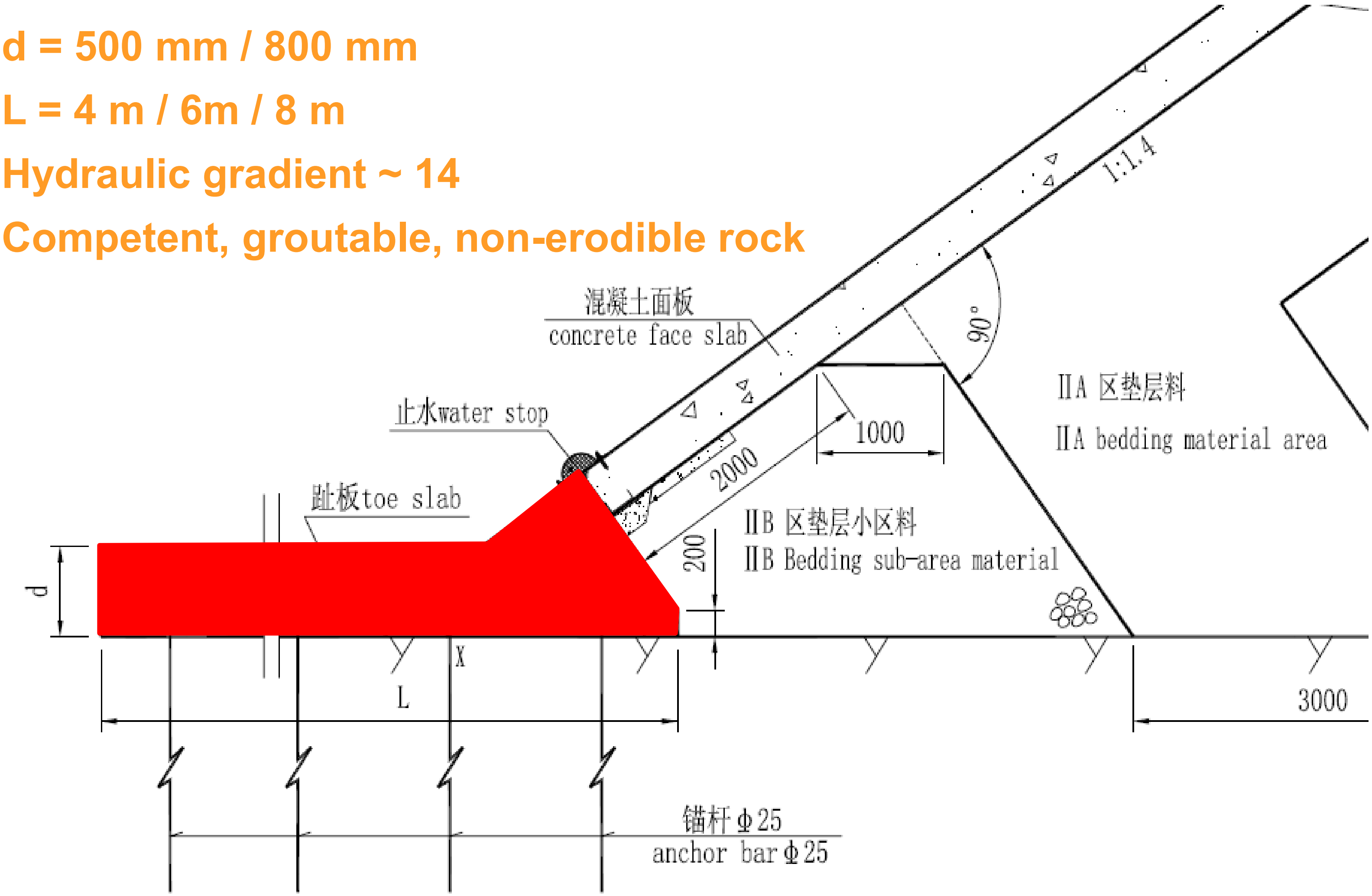
PLINTH – DESIGN

d = 500 mm / 800 mm

L = 4 m / 6m / 8 m

Hydraulic gradient ~ 14

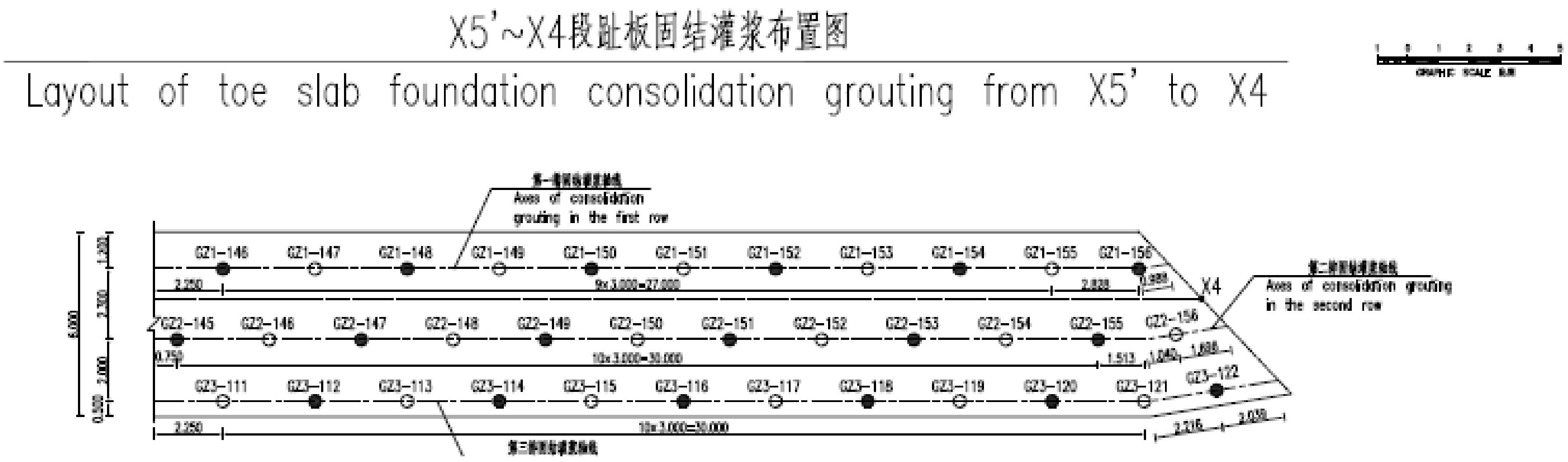
Competent, groutable, non-erodible rock

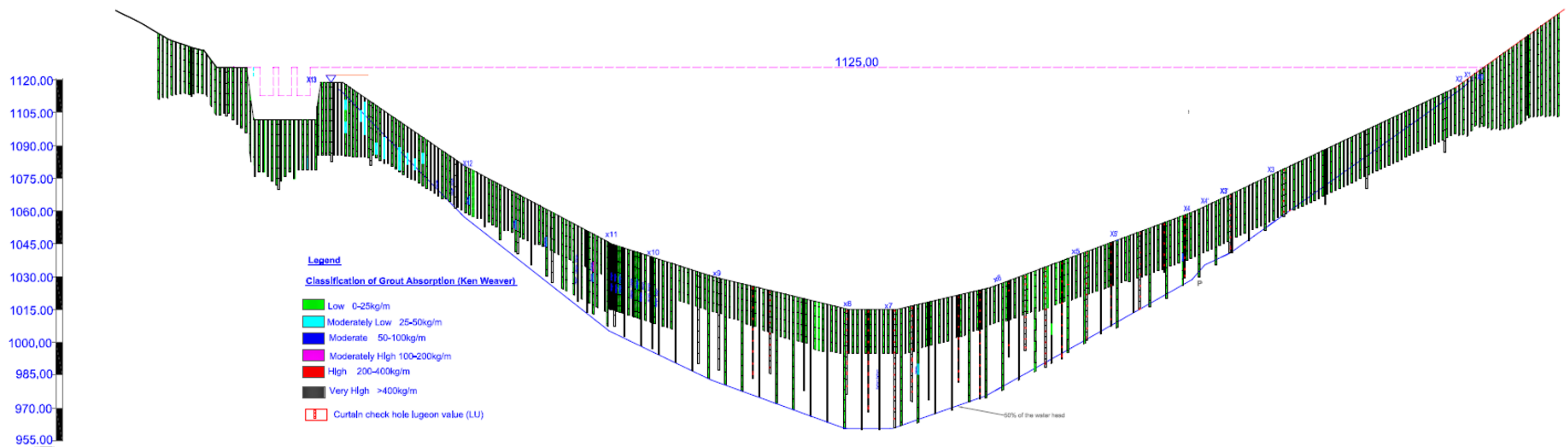


PLINTH

PLINTH FOUNDATION PREPARATION

CURTAIN GROUTING





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CURTAIN GROUTING

EMBANKMENT STABILITY

2D and 3D Dynamic Finite Element Analysis.
Scenarios:

1. Completion – dam constructed to crest
2. Normal water level
3. Highest flood water level
4. Lowest water level
5. Normal water level with earthquake

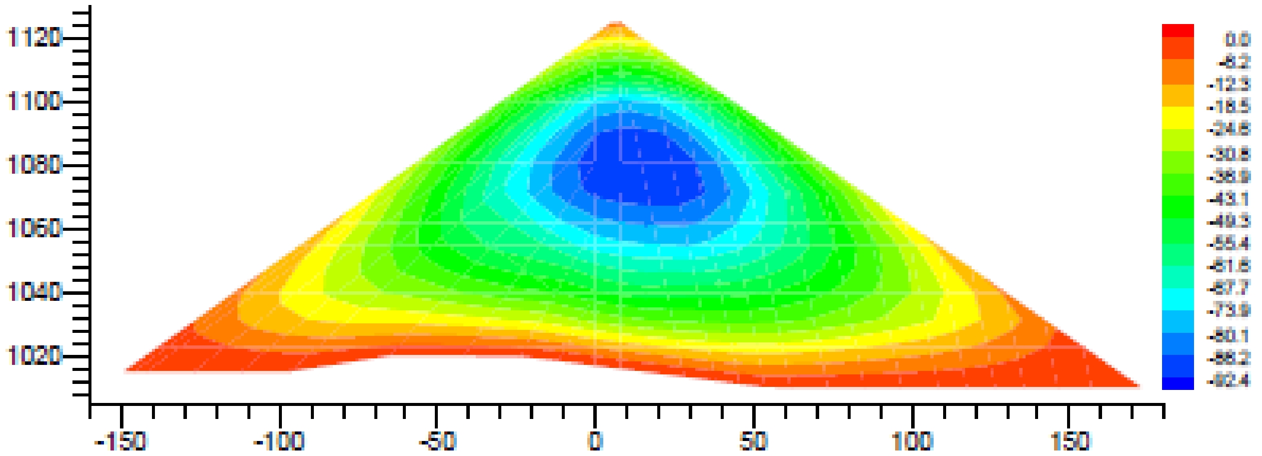

Fig. 4.4.2 The vertical displacement nephogram of the typical section at the time of completion (unit: cm)

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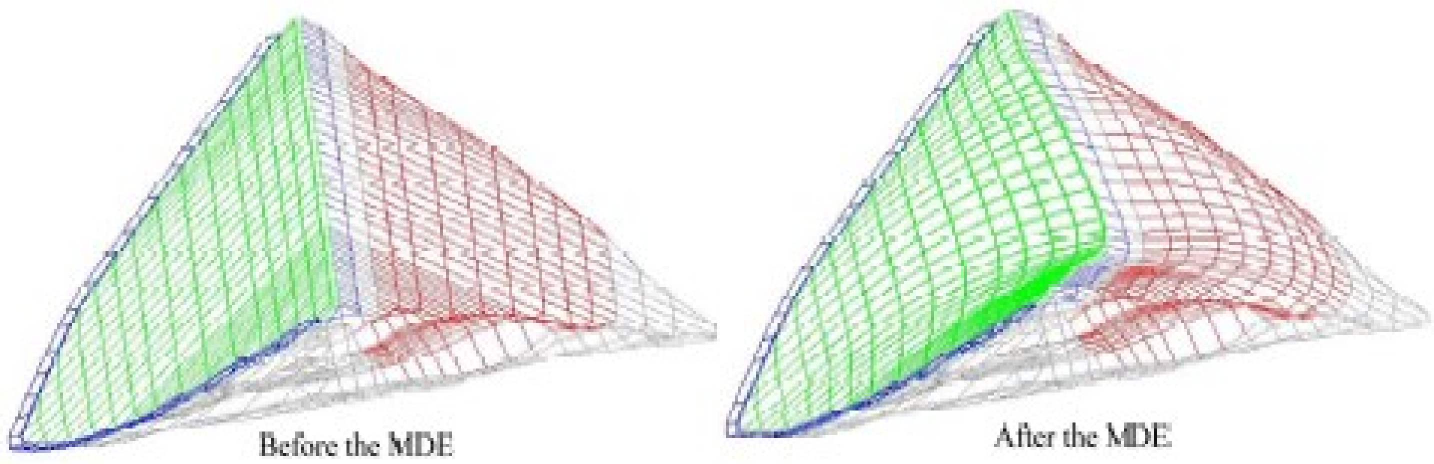
EMBANKMENT DESIGN – SEISMIC

GD3 dam site is located in an area of low seismic hazard (Hazard Class I).

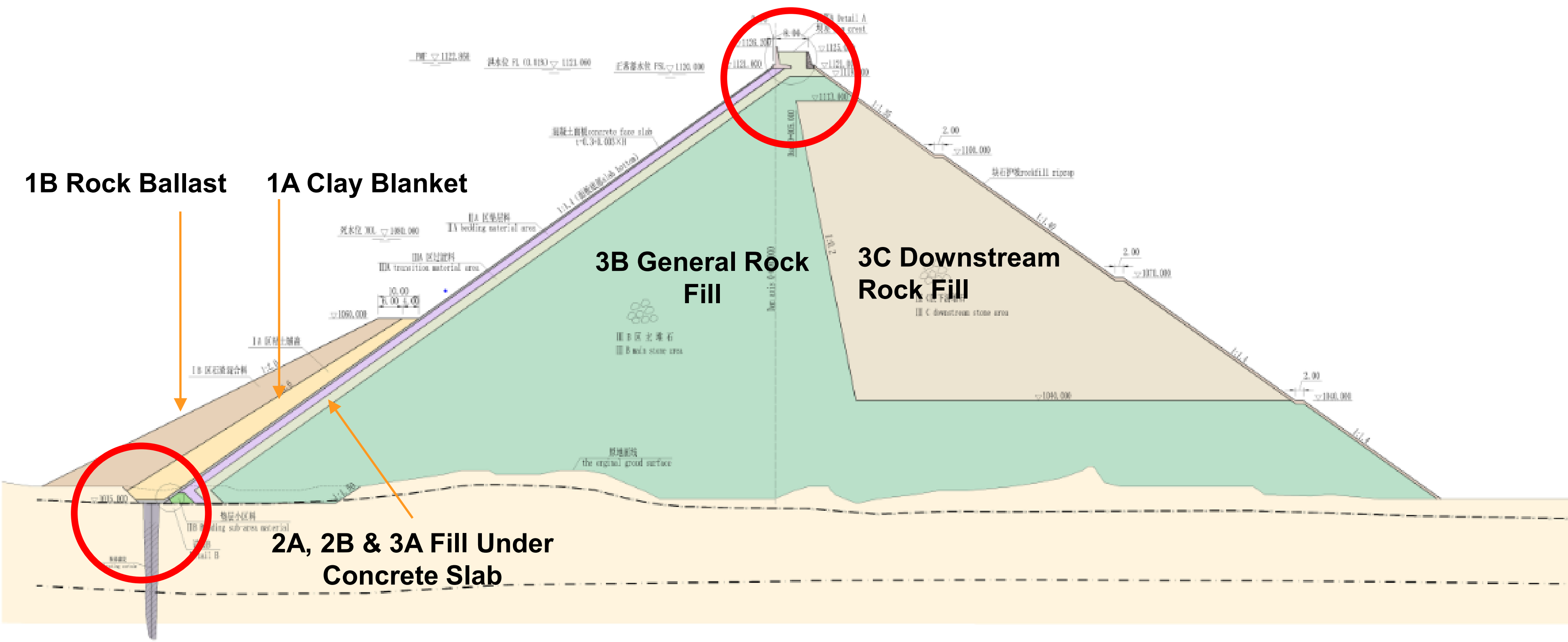
Peak ground accelerations:

Maximum design earthquake (MDE): 0.12 g

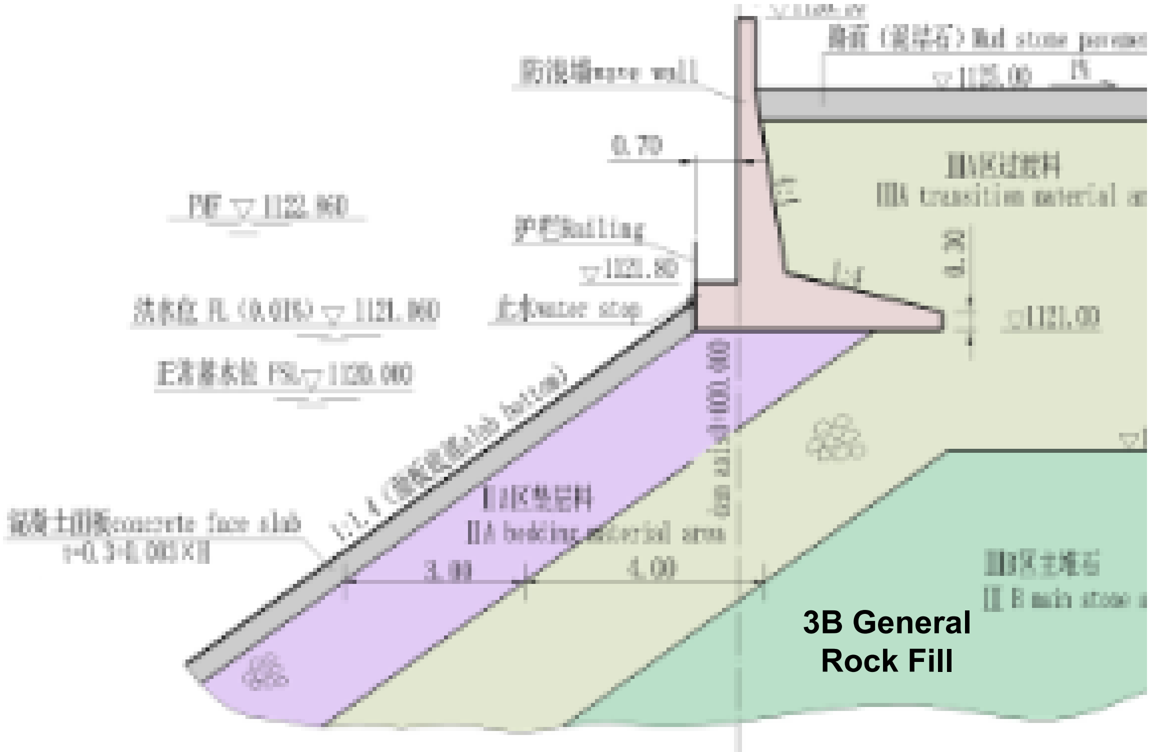
Operating basis earthquake (OBE): 0.06 g

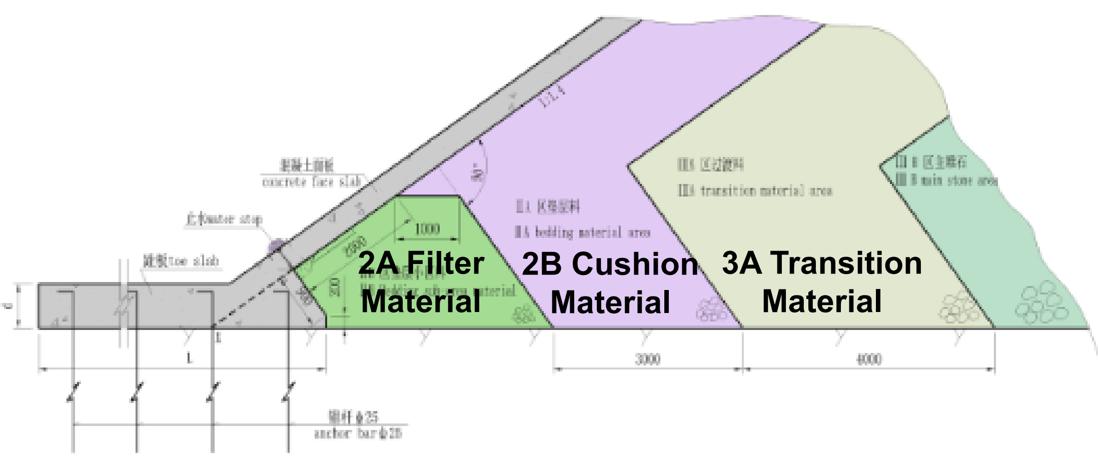


DESIGN – DAM SECTION



DESIGN – DAM SECTION





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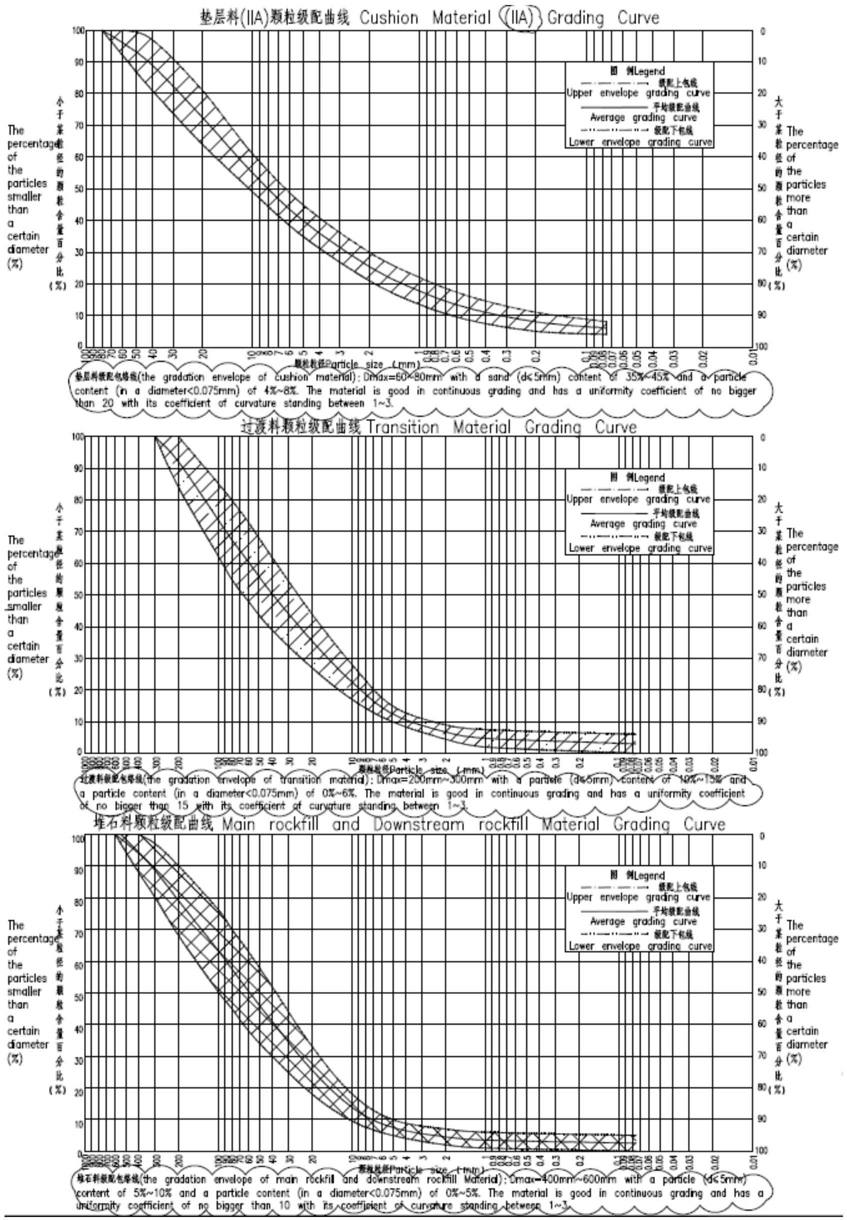
MATERIALS



2A Filter < 40 mm

2B Cushion < 80 mm

3A Transition < 300 mm

3B General < 600 mm

3C General < 700 mm

2A Processed and blended

2B Processed and blended

3A Quarry direct / tunnelling

3B Quarry direct

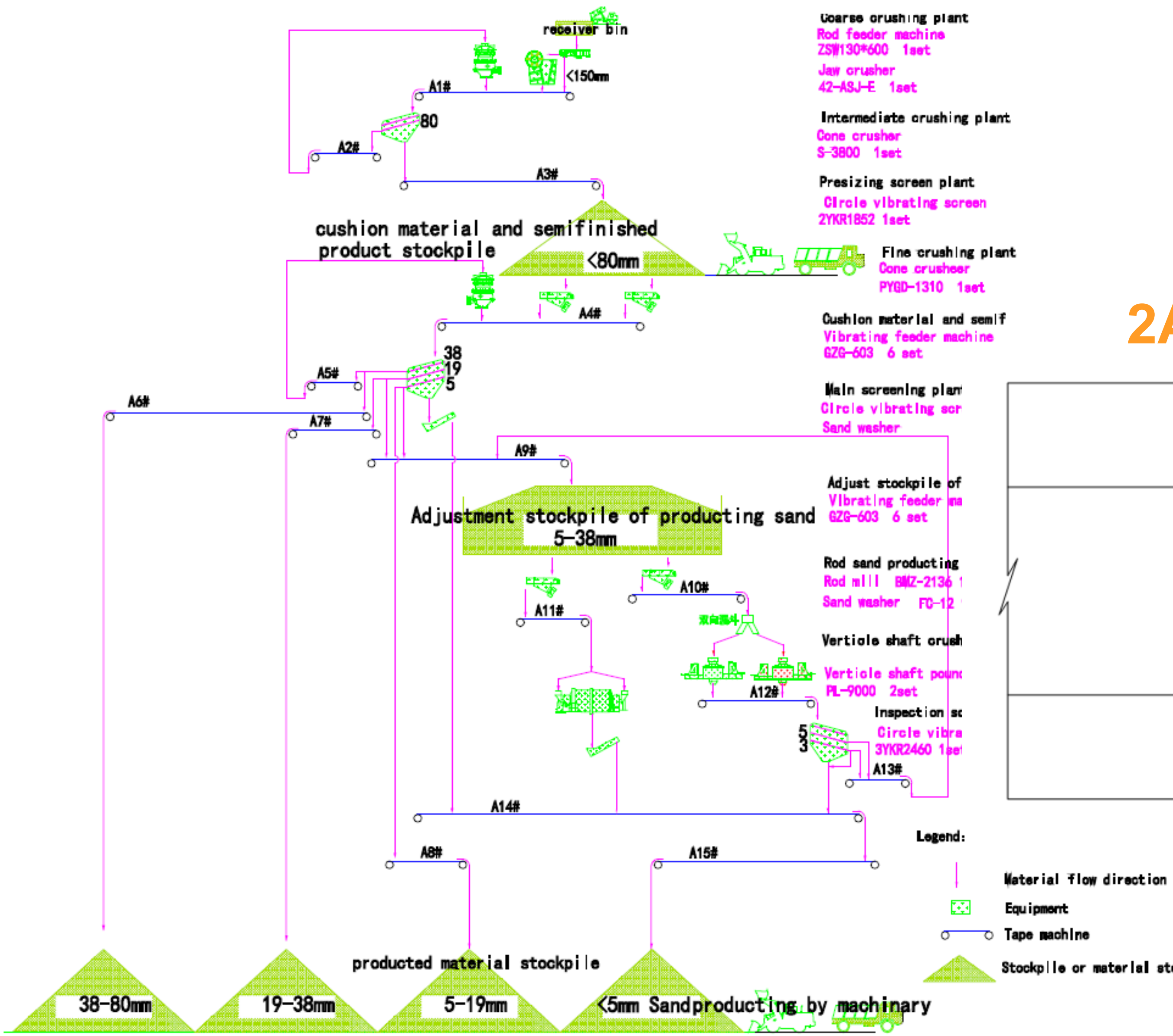
3C Quarry direct

MATERIALS

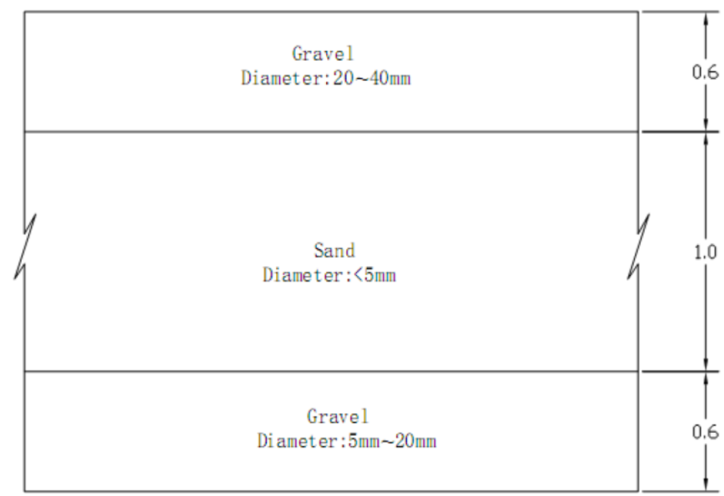
QUARRY

CRUSHING, SCREENING AND BATCHING

PROCESSED MATERIALS



2A Blending



GENERAL ROCKFILL - CONSTRUCTION

Blast at quarry
⇩
Load (selectively)
⇩
Transport / Unload
⇩
Sluice / Water
⇩
Spread
⇩
Compact
⇩
Test
⇩
Repeat

- Abutment cleaning
- Control Layer thickness
- Control Segregation
- Test (prove density & grading)

~~EXCESSIVE / DIFFERENTIAL~~
SETTLEMENT

ROCKFILL – EXTRUDED KERB

2A FILTER / 2B CUSHION FILL

DENSITY ASTM D5030 / GRADING

AND REPEAT . . .

3B/3C GENERAL ROCKFILL ZONES

3B/3C GENERAL ROCKFILL ZONES

DOWNSTREAM SLOPE

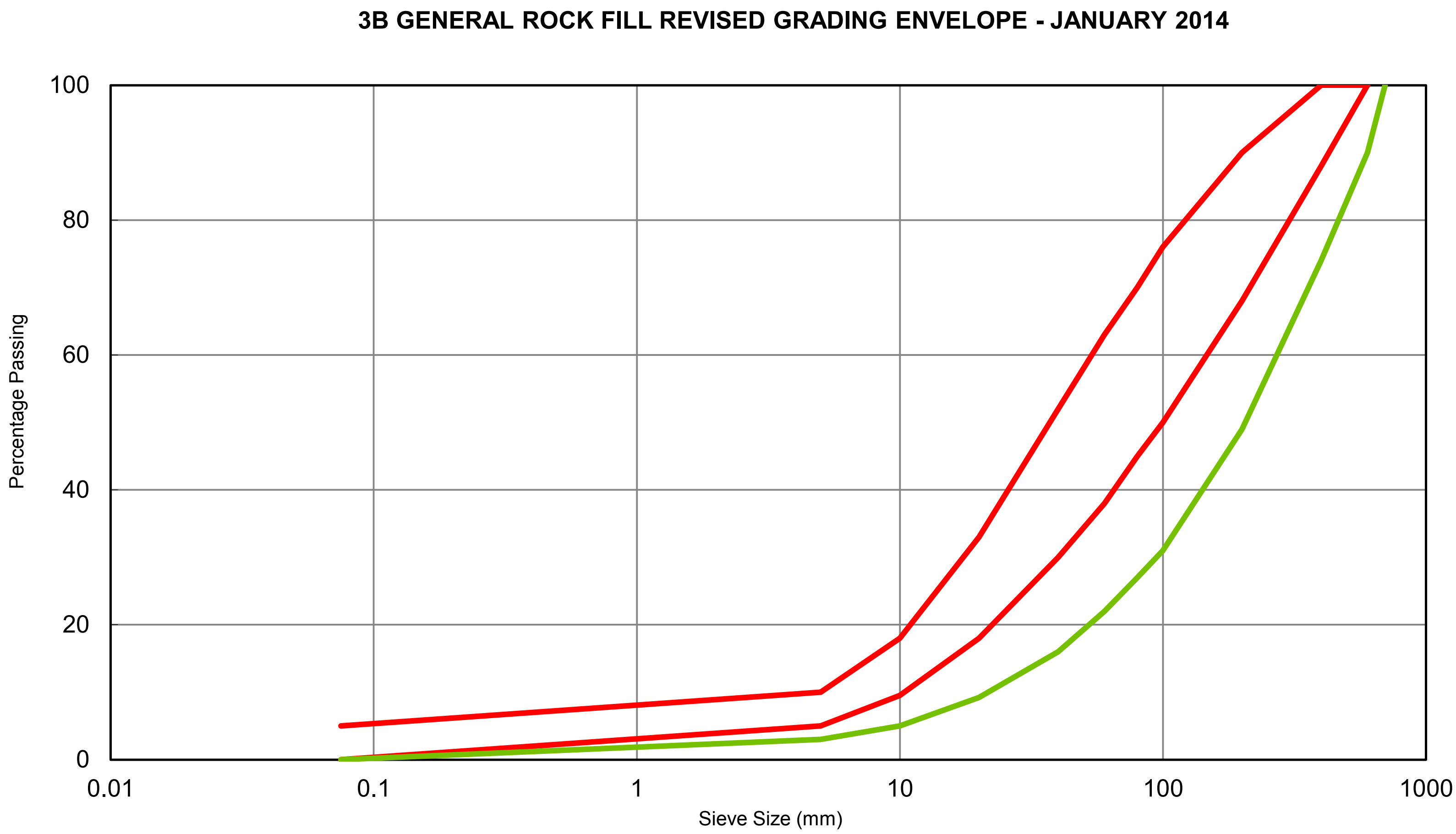
OCTOBER 2013

QUALITY CONCERNS . . .

QUARRY OPERATIONS

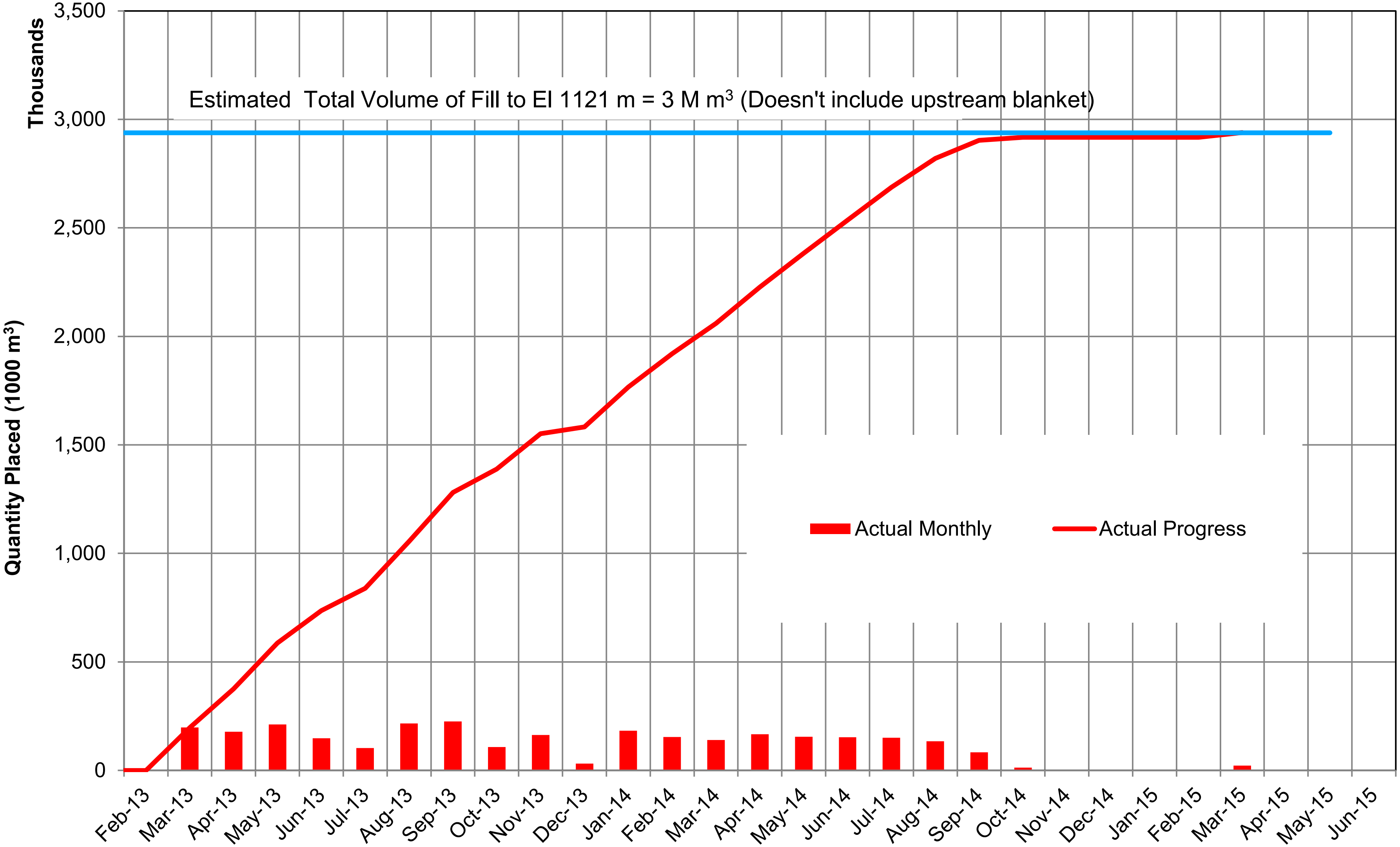
Secondary Blasting ?

A WAY FORWARD . . .



IMPROVED SUPERVISION

ROCKFILL PROGRESS



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DIVERSION WORKS OCTOBER 2014

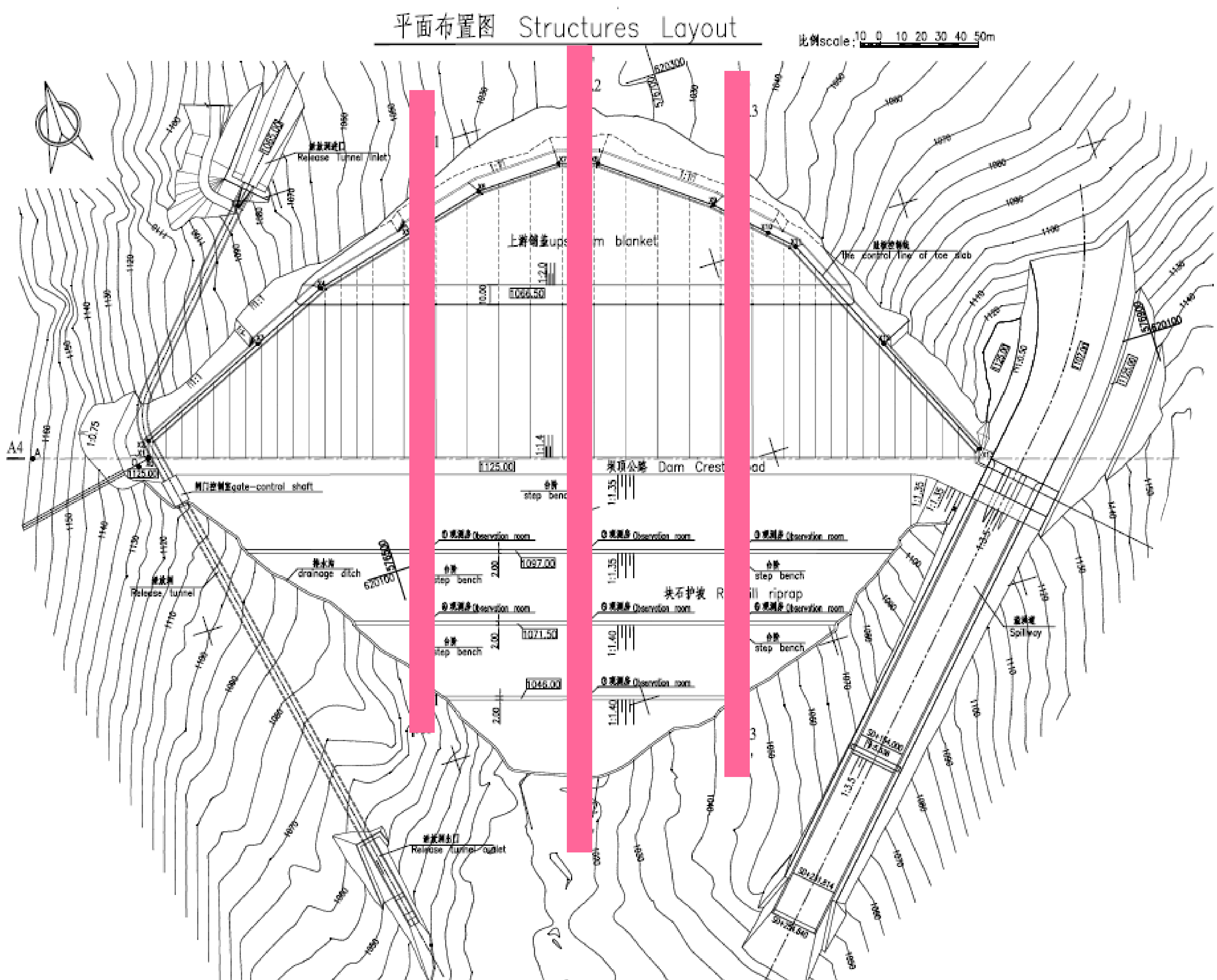
TOKWE-MUKOSI DAM – FEB 2014

Tokwe-Mukosi dam wall breached (Pictures: David Coltart Facebook)

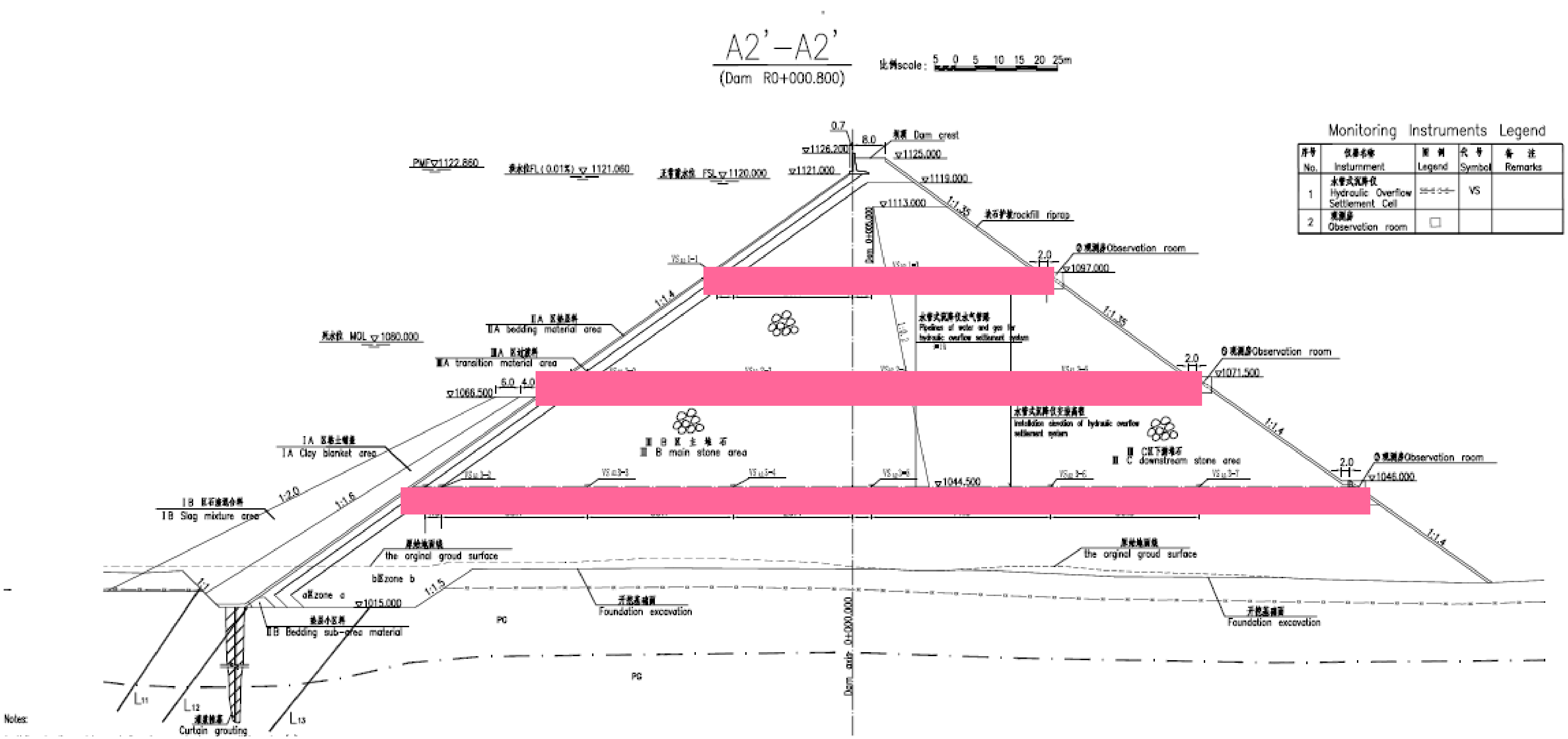
INSTRUMENTATION

- Piezometers in dam foundation
- Settlement Meters
- Horizontal Displacement Meters
- Abutment Strain Gauges
- Observation holes in abutments (seepage)
- Surface Monitoring Network
- Seepage flow measurement weir at D/S toe
- Res Water level and water temperature
- Weather station
- Seismic (right bank, crest, mid-berm and D/S)

ROCKFILL INSTRUMENTATION



ROCKFILL INSTRUMENTATION



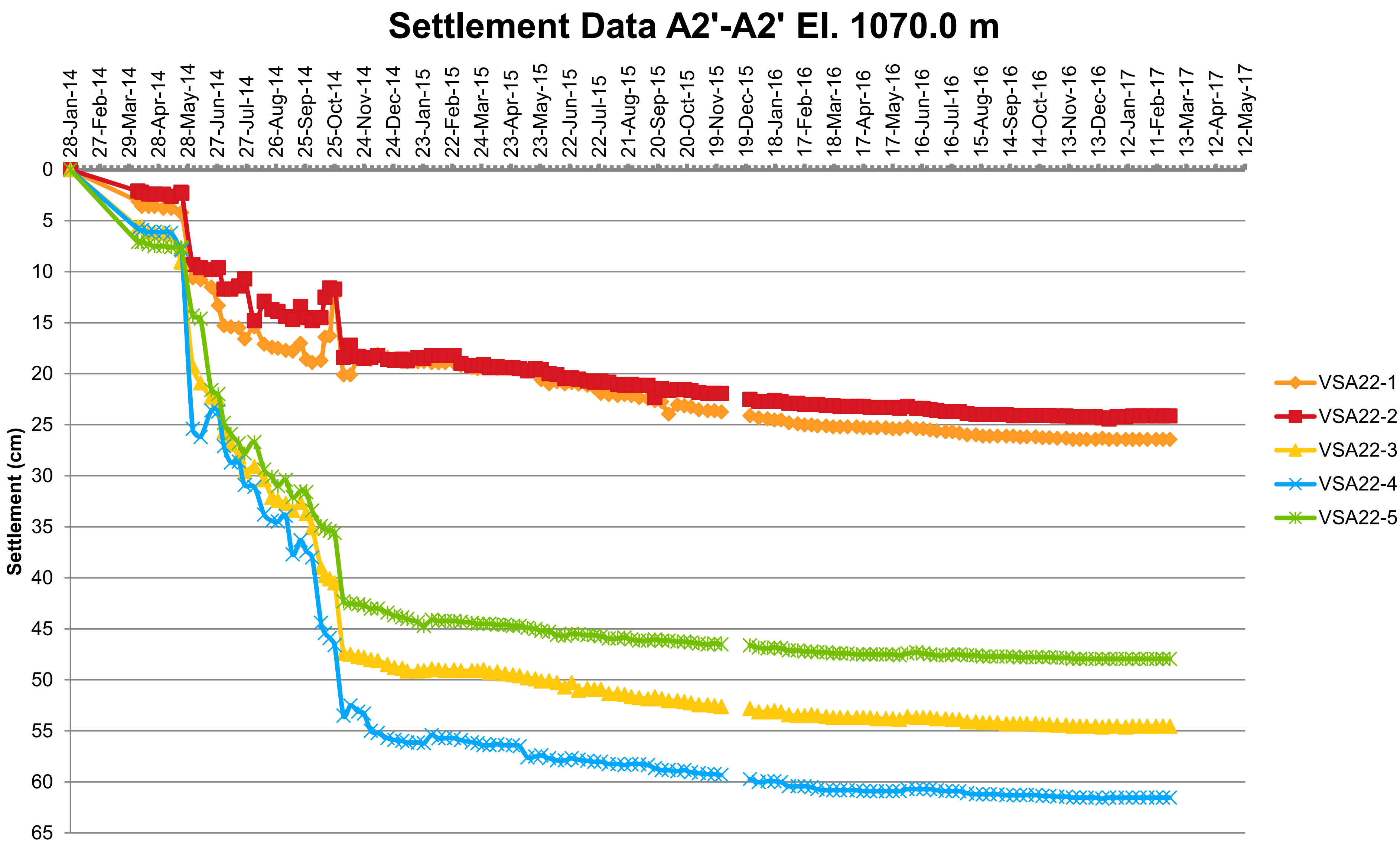
ROCKFILL INSTRUMENTATION

ROCKFILL INSTRUMENTATION

ROCKFILL INSTRUMENTATION

ROCKFILL INSTRUMENTATION

ROCKFILL SETTLEMENT



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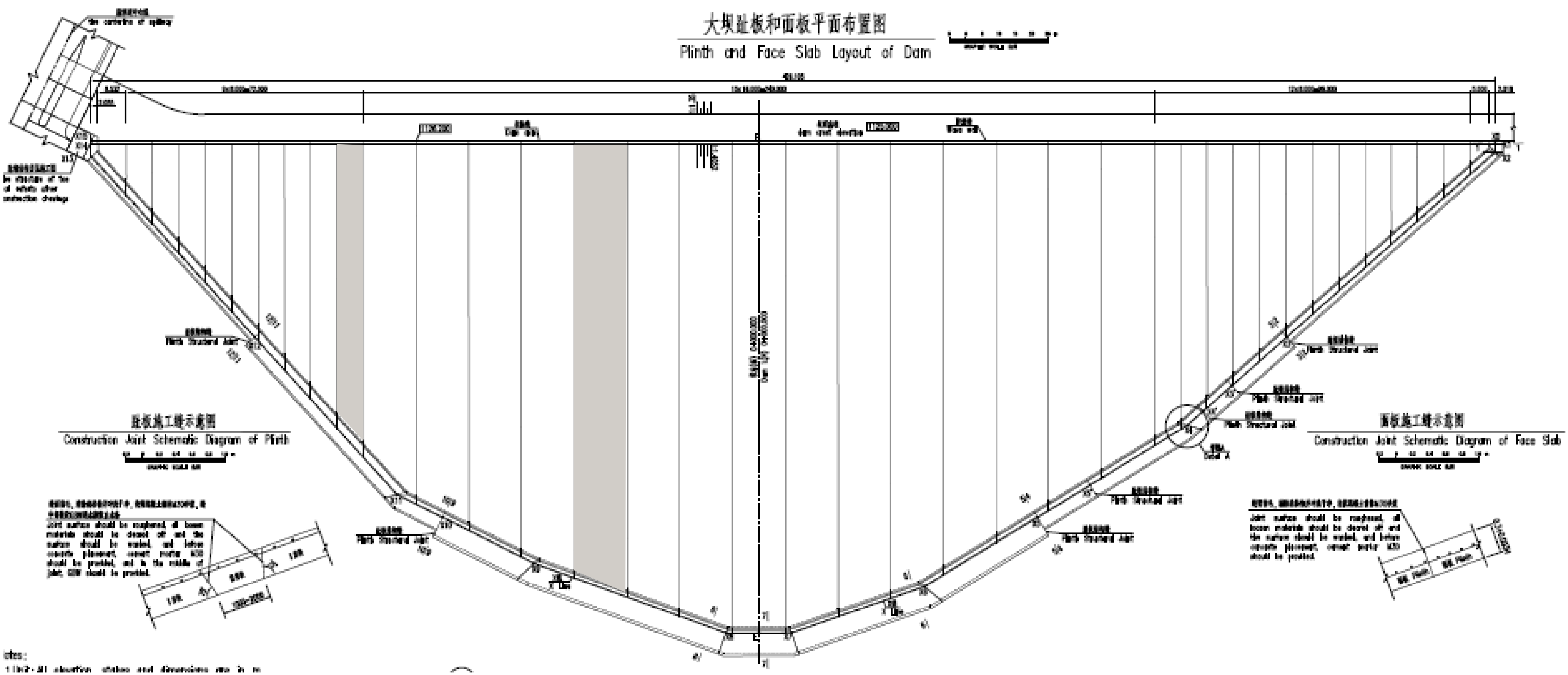
FACE SLAB – DESIGN

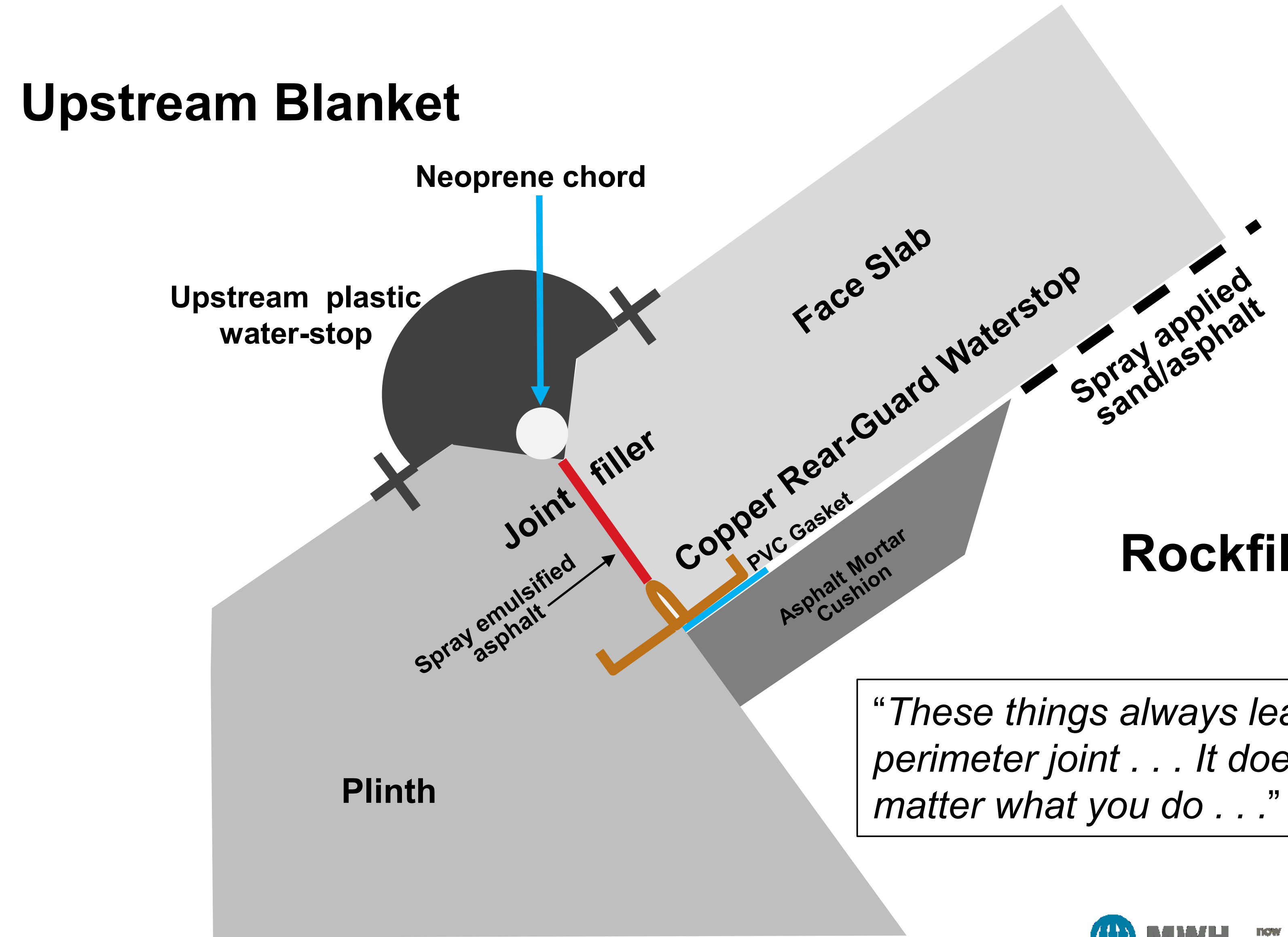
8 m wide and 16 m wide panels

300 mm – 600 mm thick

2 layers of reinforcement



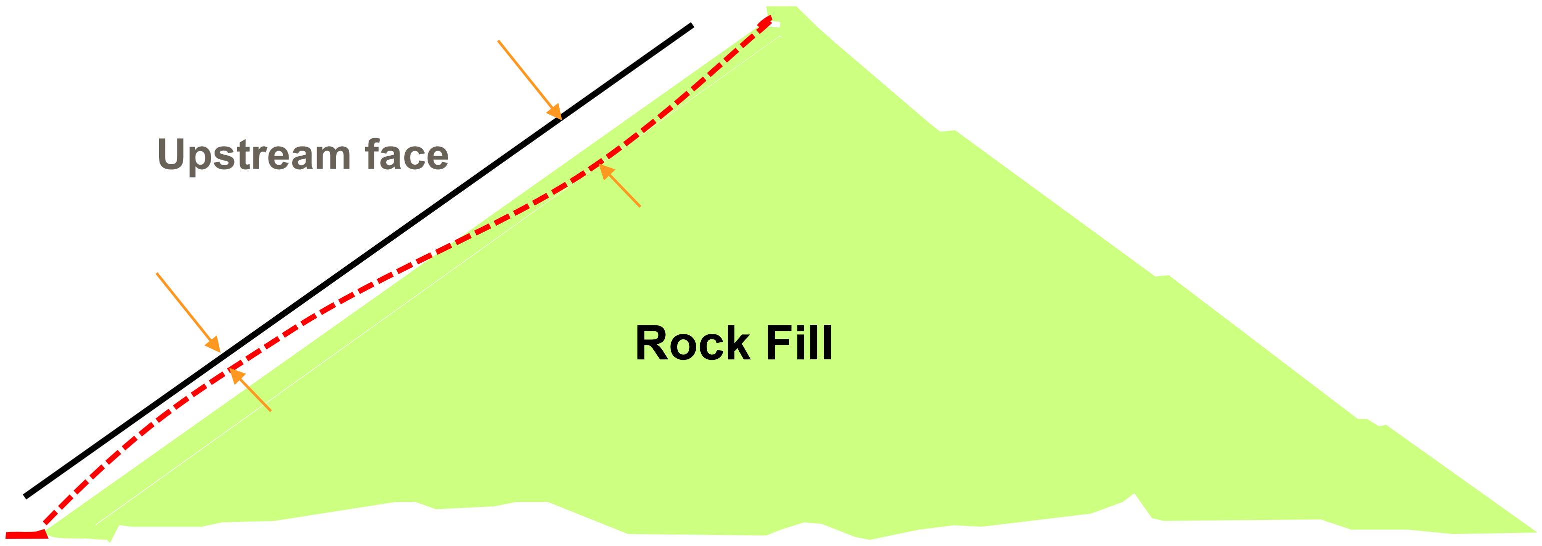
PERIMETER JOINT



"These things always leak at the perimeter joint . . . It doesn't matter what you do . . ." Anon

FACE SLAB PREPARATION

DAM DEFORMATION



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FACE SLAB
PREPARATION
Mortar Cushions

FACE SLAB JOINTS

FACE SLAB CONSTRUCTION

FACE SLAB CONSTRUCTION

FACE SLAB INSTRUMENTATION

FACE SLAB CONSTRUCTION

FACE SLAB CONSTRUCTION

FACE SLAB CONSTRUCTION

FACE SLAB

CREST WALL CONSTRUCTION

TOP WATER-STOP

UPSTREAM BLANKET

Part 1: Ethiopia

Part 2: Hydropower In Ethiopia

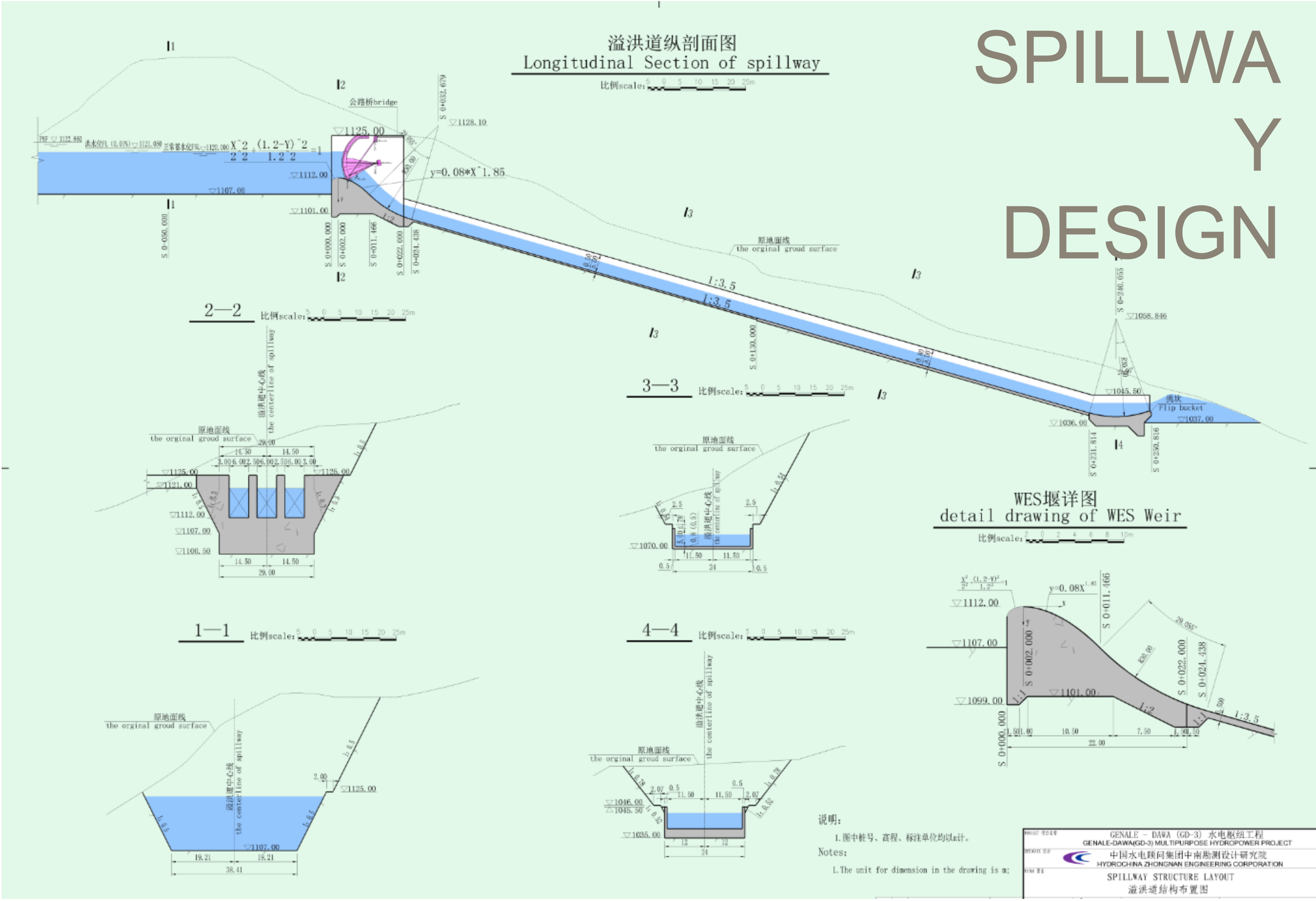
Part 3: Genale Dawa (GD3) Scheme

Part 4: Dam Design & Construction

Part 5: Appurtenant Structures

Part 6: Summary

SPILLWAY DESIGN



SPILLWAY DESIGN

SPILLWAY EXCAVATION

GATE SECTION CONSTRUCTION

CHUTE CONSTRUCTION

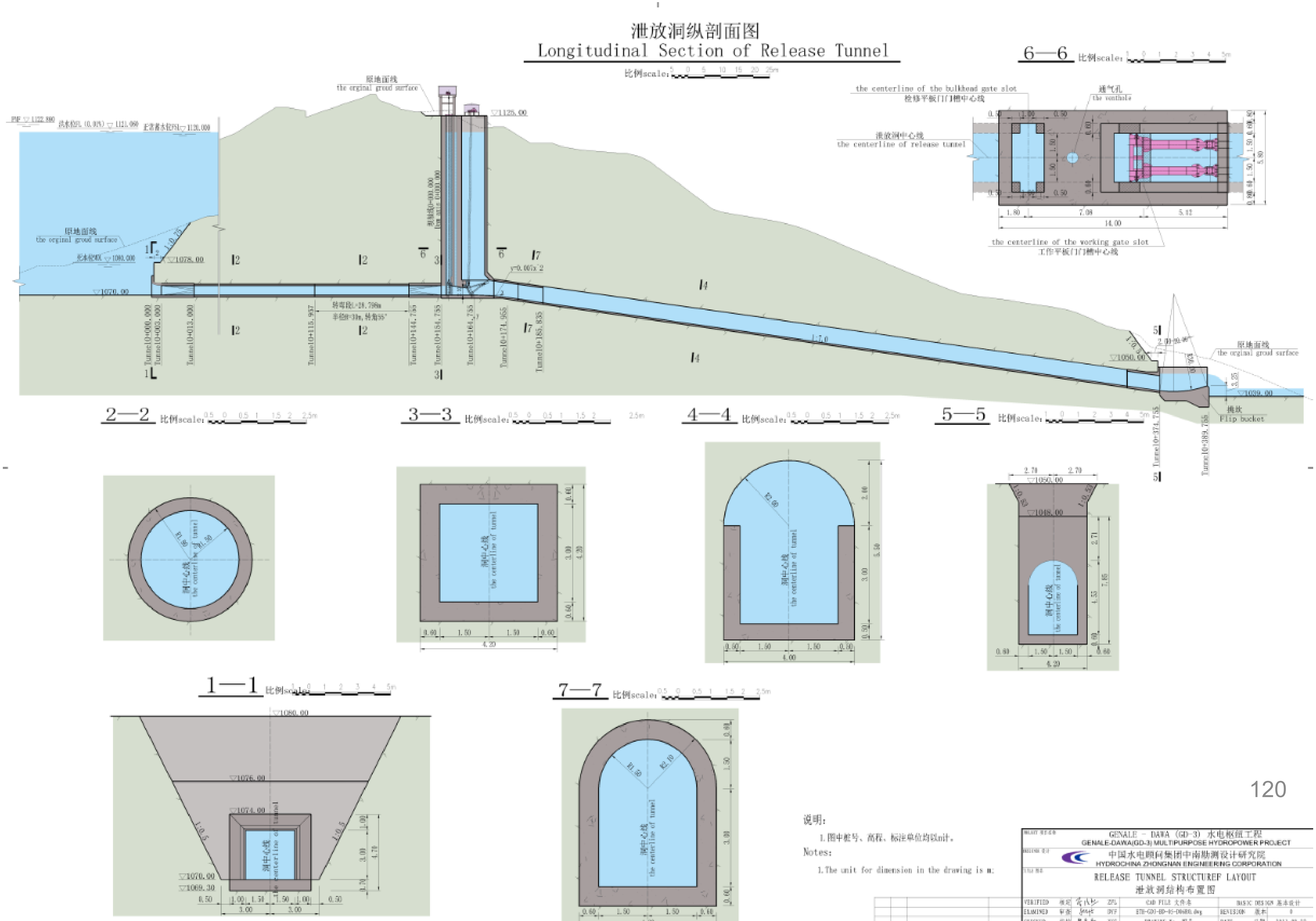
AERATION TOWERS

FLIP-BUCKET CONSTRUCTION

SPILLWAY CONSTRUCTION

SPILLWAY CONSTRUCTION

RELEASE TUNNEL DESIGN



RELEASE TUNNEL DESIGN

SPILLWAY / RELEASE TUNNEL COMBINED

RIVER BED ‘PLUNGE’ MODEL

RELEASE TUNNEL INLET

RELEASE TUNNEL GATE SHAFT

RELEASE TUNNEL GATE

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Genale Dawa (GD3)

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QUALITY CONTROL

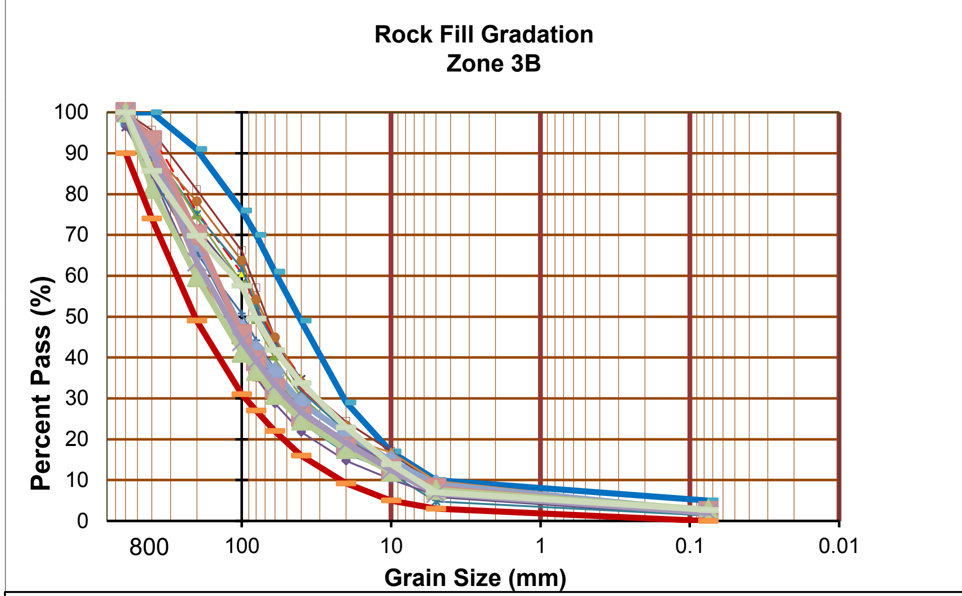
GD-3 PROJECT SITE LABORATORY

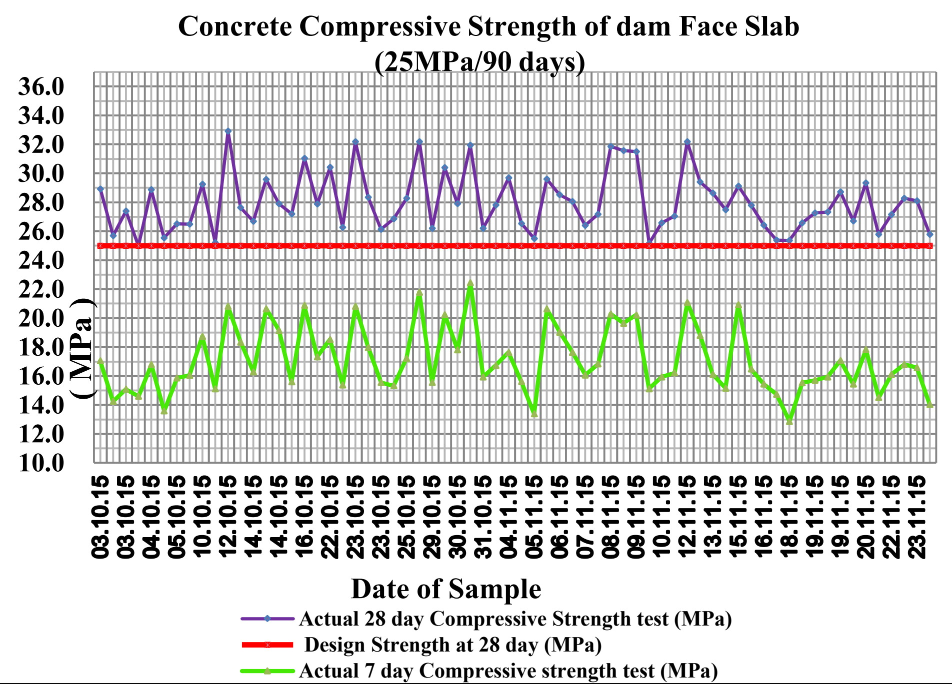
Test Record of Compressive Strength of Concrete

Location of Concrete Represented: Plinth ▽1011.2～▽1012.5		
Make Specimens Method: ASTM C31	Lab No.: ZC04	
Test Method: ASTM C39	Design Strength: 21MPa	

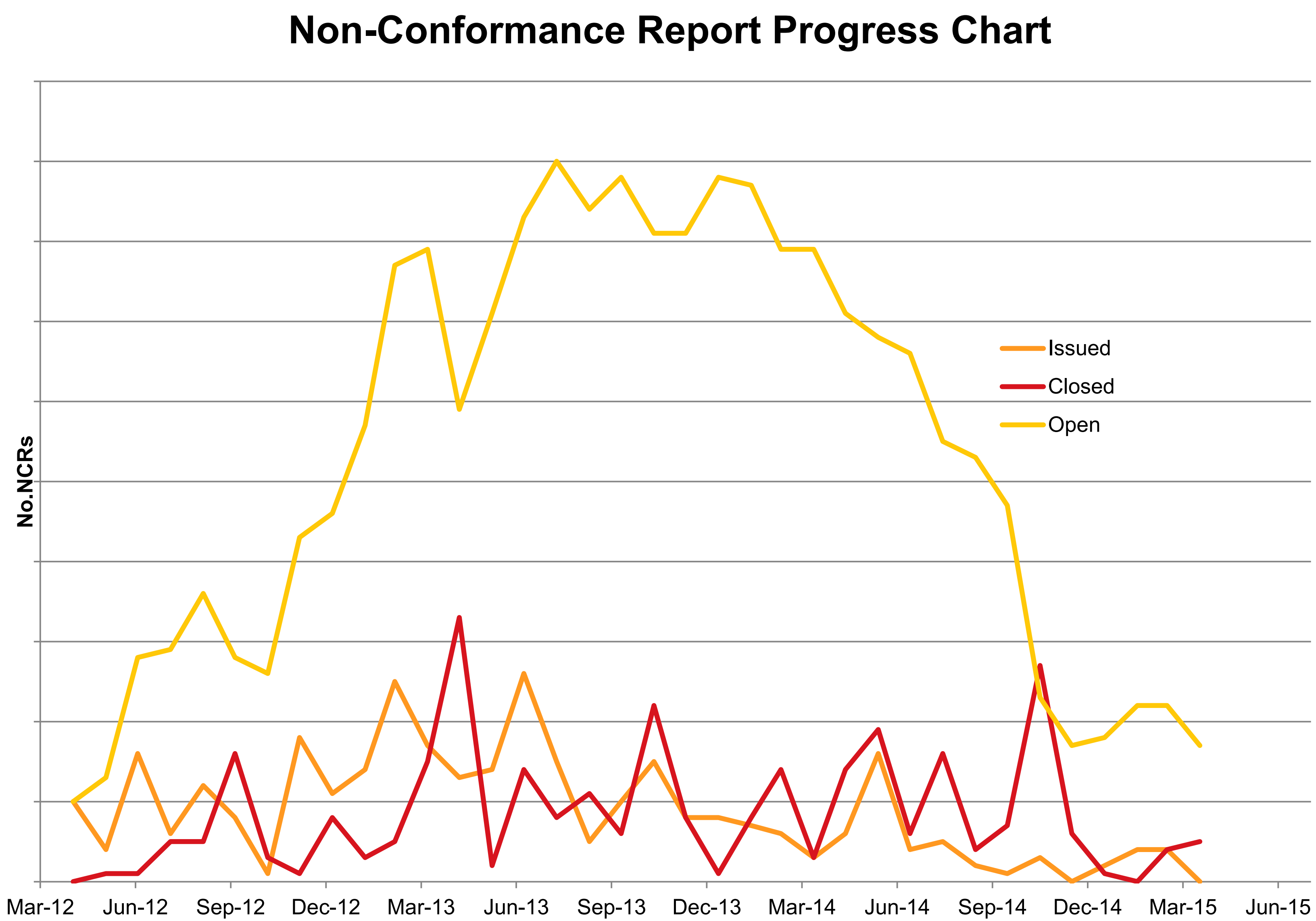
Item	Age								
	3Days			7Days			28Days		
Cylinder No.	/	/	/	/	/	/	ZC04-2	ZC04-2	ZC04-2
Date of Casting	/			/			2013.03.02		
Date of Testing	/			/			2013.03.30		
Dimension of cube (cm)	/			/			15		
Area (cm^2)	/			/			225		
Volume of Cylinder (cm^3)	/			/			3375		
Weight of Cylinder (kg)	/	/	/	/	/	/	8.107	8.183	8.162
Density of Concrete (kg/m^3)	/	/	/	/	/	/	2402	2425	2418
Failure Load (KN)	/	/	/	/	/	/	753.25	718.33	721.84
Compressive Strength (Mpa)	/	/	/	/	/	/	33.5	31.9	32.1
Average Compressive strength (Mpa)	/			/			32.5		
Correct factor	0.8			0.8			0.8		
Axial Compressive strength (Mpa)	/			/			26.0		
Remarks									

Checked By: 魏 [signature]　　Tested By: 郭世海





QUALITY ASSURANCE



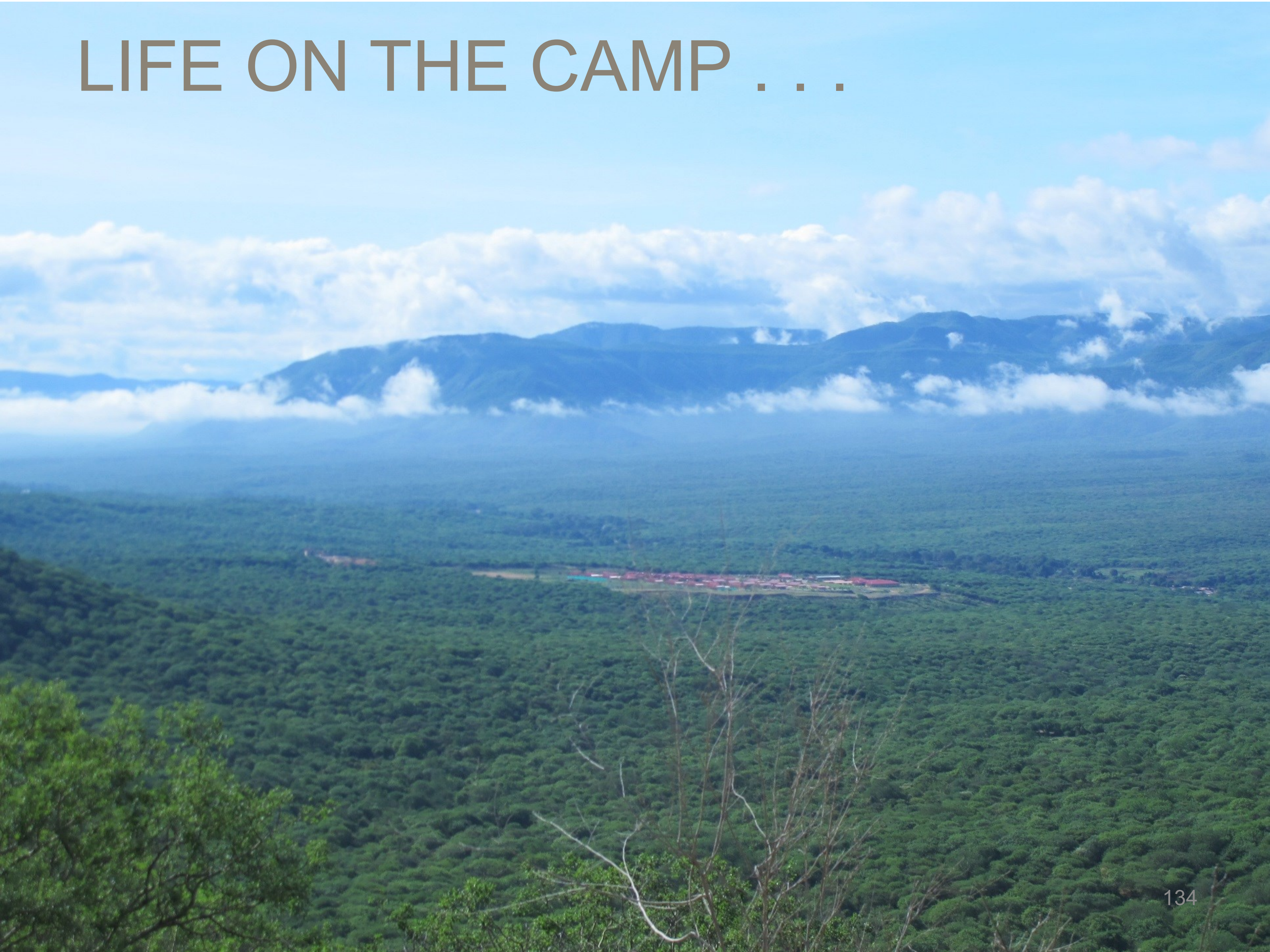
CHALLENGES . . .

COMPLETION (FROM UPSTREAM)

COMPLETION (DOWNSTREAM)

IMPOUNDING . . .

LIFE ON THE CAMP . . .



THE CAMP . . .

THE BEAUTIFUL GAME . . .

DINNER PARTIES . . .

EASTER FUN RUN . . .

HOPE SCHOOL

QUESTIONS ? ?