COMPOSITE CUT-OFFS FOR DAMS

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Gannett Fleming

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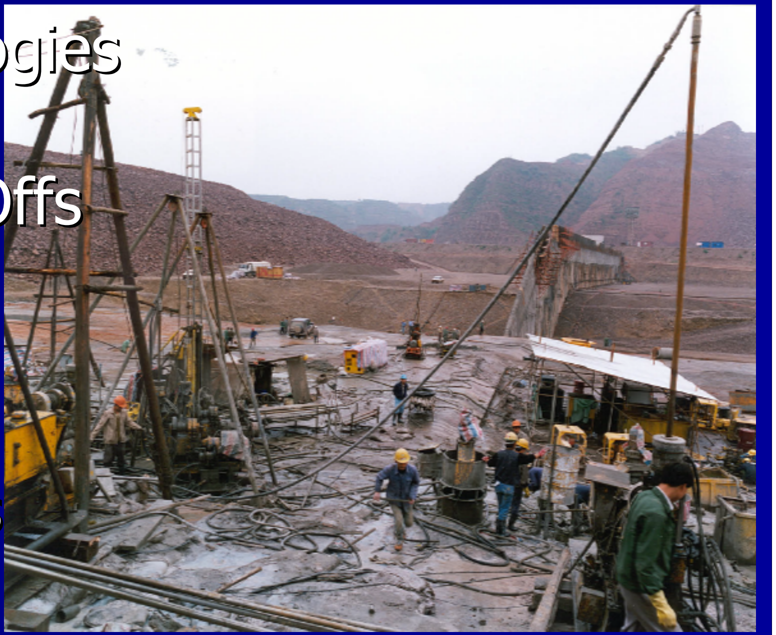

1. Alternative Definitions of "Composite" Cut-Offs

A. By Technology

Using two or more technologies to:

A. Create the cut-off (e.g., concrete cut-off through alluvium with grout curtain in rock below).

B. Permit the construction of a concrete cut-off by pretreating the rock mass.

B. By Material

Using two or more distinct families of grouts to form a multicomponent curtain (e.g., LMG, HMG, polyurethanes and hot bitumen to stop large fast flows).

Note: Cut-offs may be conceived and designed as composite prior to construction, or can become composite, out of necessity, after construction begins.

2. Review of Individual Cut-Off Technologies

Basically there are two groups of Cut-off technologies:

1. Cut-offs comprising some type of concrete wall. Such walls can:
   - be constructed by different methods
     - Diaphragm wall (grab or cutter/mill)
     - Secant pile wall
     - DMM
     - TRD
   - comprise a variety of materials from high strength concrete, to plastic concrete
2. Cut-offs formed by drilling and grouting techniques. Such cut-offs can:
   - be created in rock (fissure or void grouting) or in soil (jet grouting, permeation grouting, hydrofracture grouting)
   - can deploy a wide variety of materials depending on the project goals and conditions

Each family of cut-offs has advantages and disadvantages (both real and perceived). We have traditionally elected to "live with" the consequences of one technology.

Advantages

Concrete Cut-Offs

- "Positive" long-term solution (if constructed properly).
- Low uniform permeability assured through all ground penetrated.
- Simple concept but sophisticated equipment.

Drilled and Grouted

- Excellent recent record in hard fractured rock masses.
- Can focus on targeted zones.
- Smaller equipment, sophisticated methods and materials (responsive).

Disadvantages

Concrete Cut-Offs

- Cost.
- Not "flexible" in response to variable in-ground conditions, i.e., much of wall may be wasted.
- Rock properties (hardness, rippability) pose major controls over feasibility and productivity.
- Can be high risk to dam slurry loss.
- Site logistics and space.
- Alignment.
- Depth limitations.

Drilled and Grouted

- Efficiency will decline in soluble/ erodible conditions.
- Therefore, not perceived as "positive."
- Historical bias.

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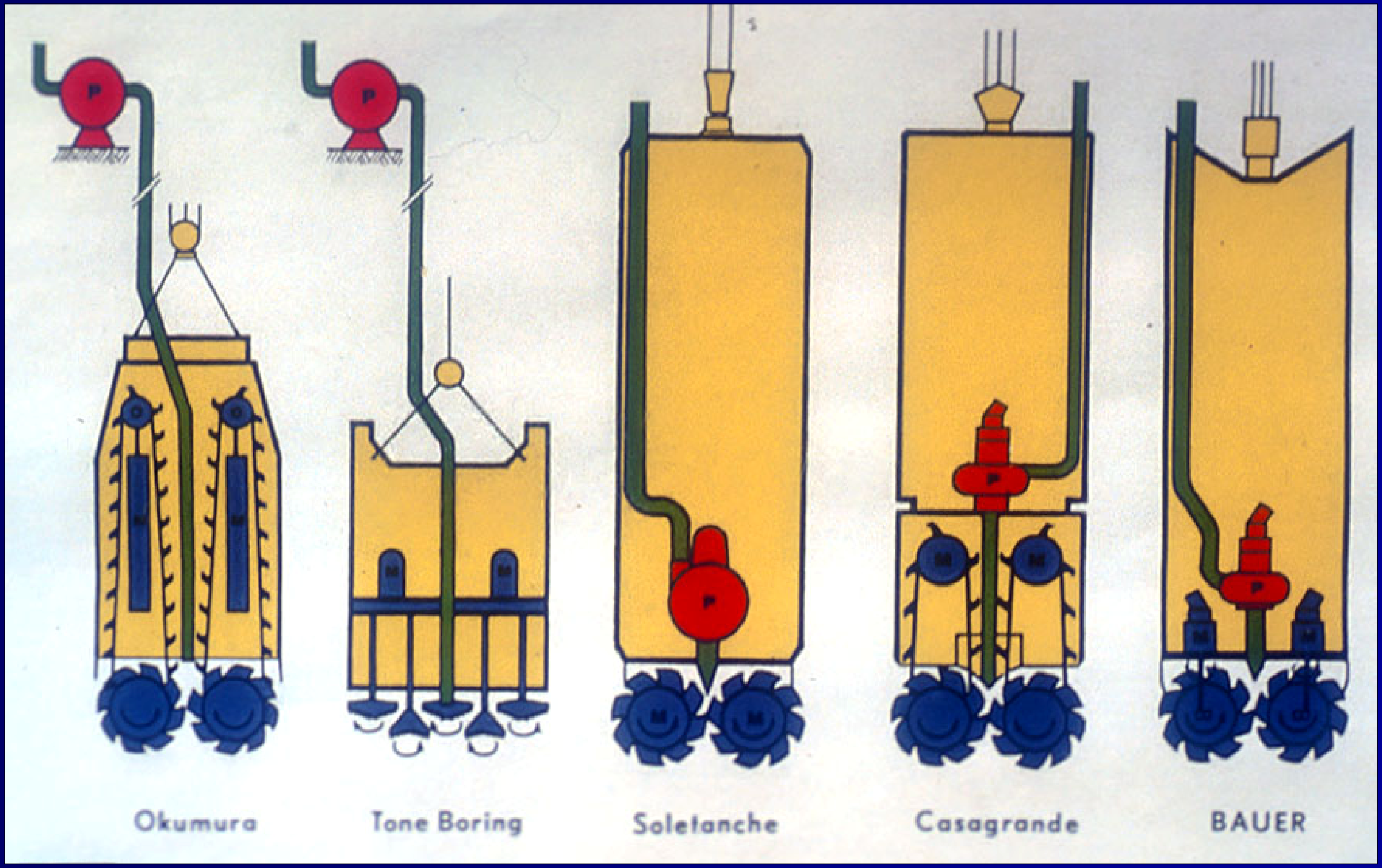
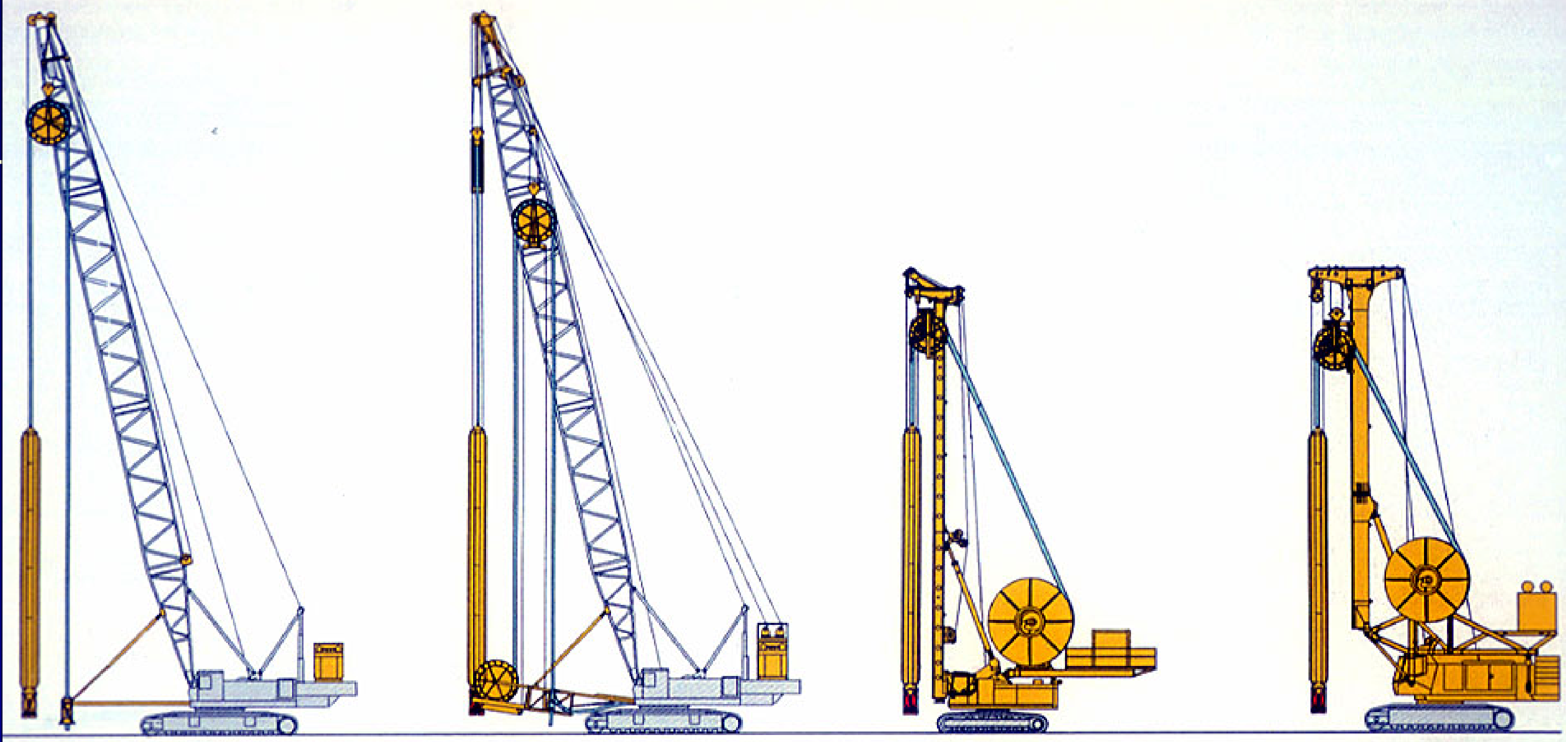
2. Review of Individual Cut-Off Technologies

1. Diaphragm Wall Techniques

– Cutters/Mills



Development of Trench Cutters



BC 30 on 130 to base machine

Height: 39 m
Cutting depth: 60 m
Operating weight: 35 + 135 to
Installed power: 430 kW

BC 30 on 150 to base machine

Height: 39 m
Cutting depth: 100 m
Operating weight: 35 + 165 to
Installed power: 430 kW

BC 30 with hose drum system on drilling rig BG 40

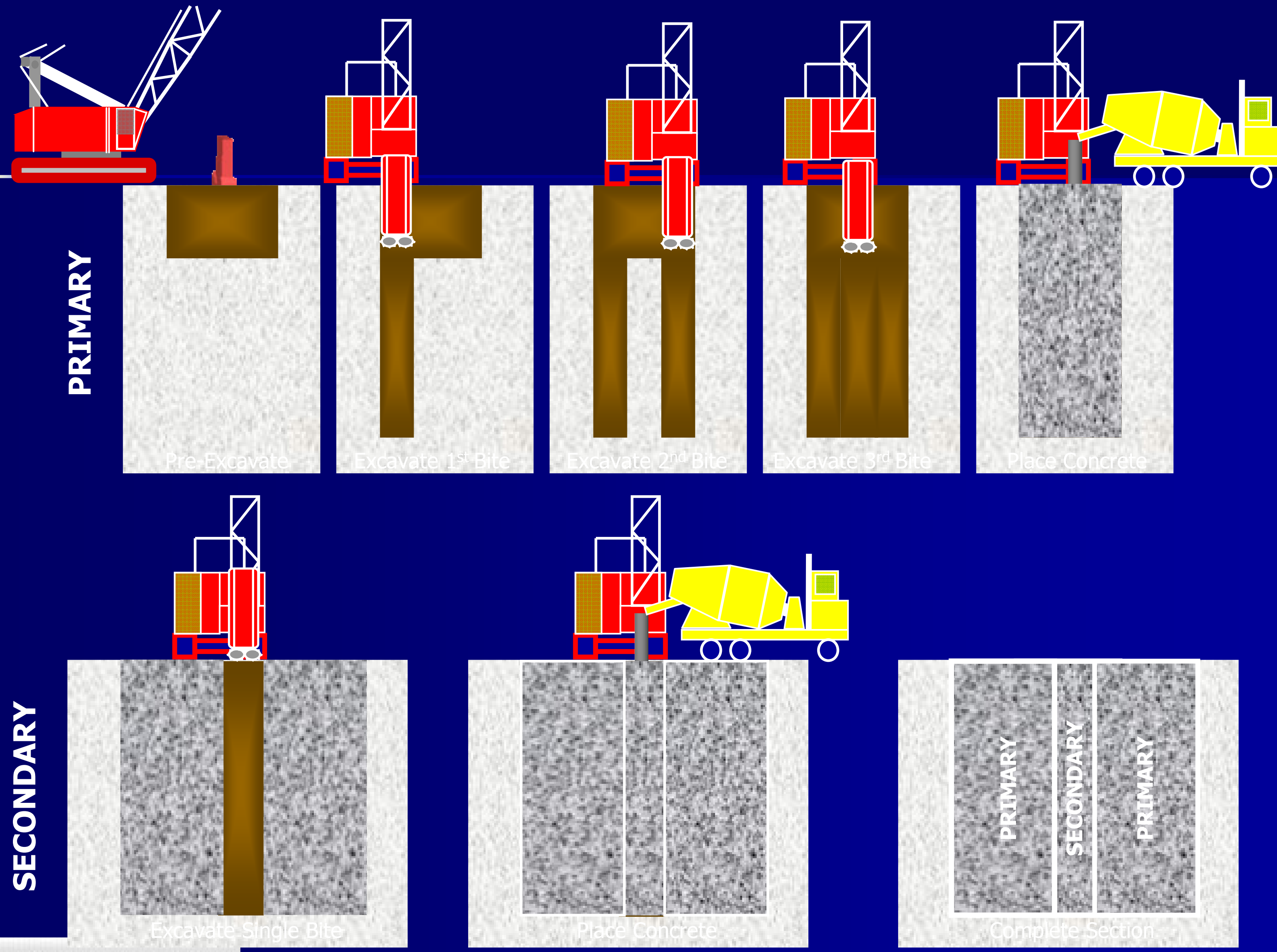
Height: 24 m
Cutting depth: 80 m
Operating weight: 35 + 115 to
Installed power: 300 + 265 kW

BC 30 with cutter base system and hose drum system on 120 to base machine

Height: 24 m
Cutting depth: 150 m
Operating weight: 35 + 155 to
Installed power: 634 kW

Development of Bauer Trench Cutters

Diaphragm Wall Panel Construction Sequence



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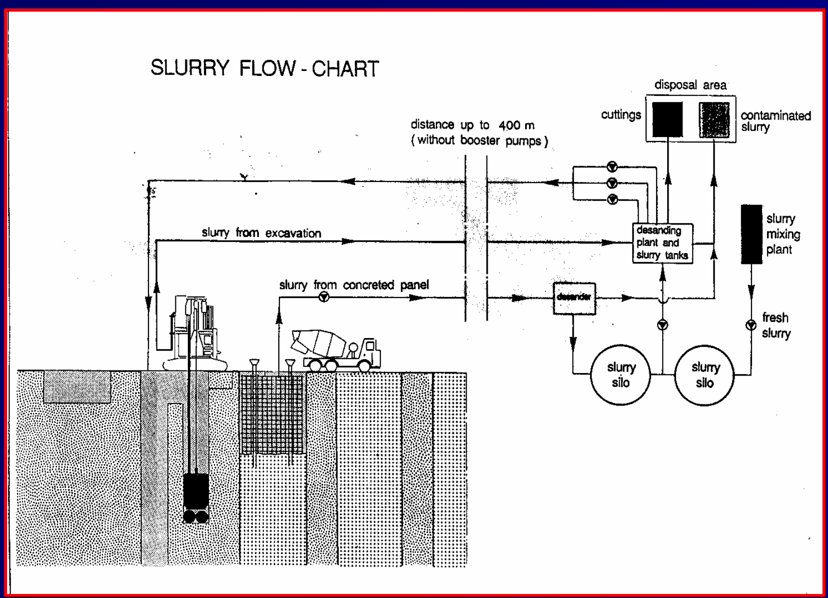
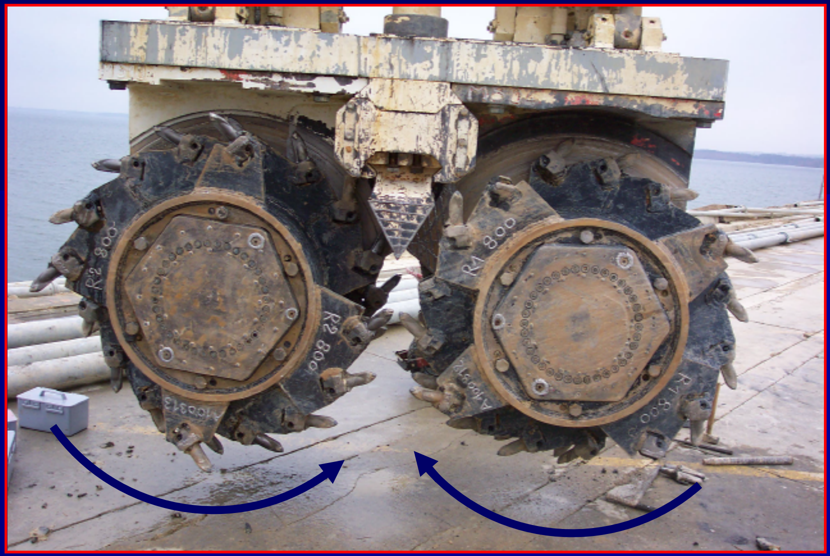
Panel Excavation

The cutters continuously remove the soil from the bottom of the trench, breaks it up and mixes it with a bentonite slurry in the trench.





The slurry charged with soil particles is pumped through a pipe to the de-sanding plant where it is cleaned and returned into the trench.

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2. Review of Individual Cut-Off Technologies

- Conventional grabs (cable or hydraulic)

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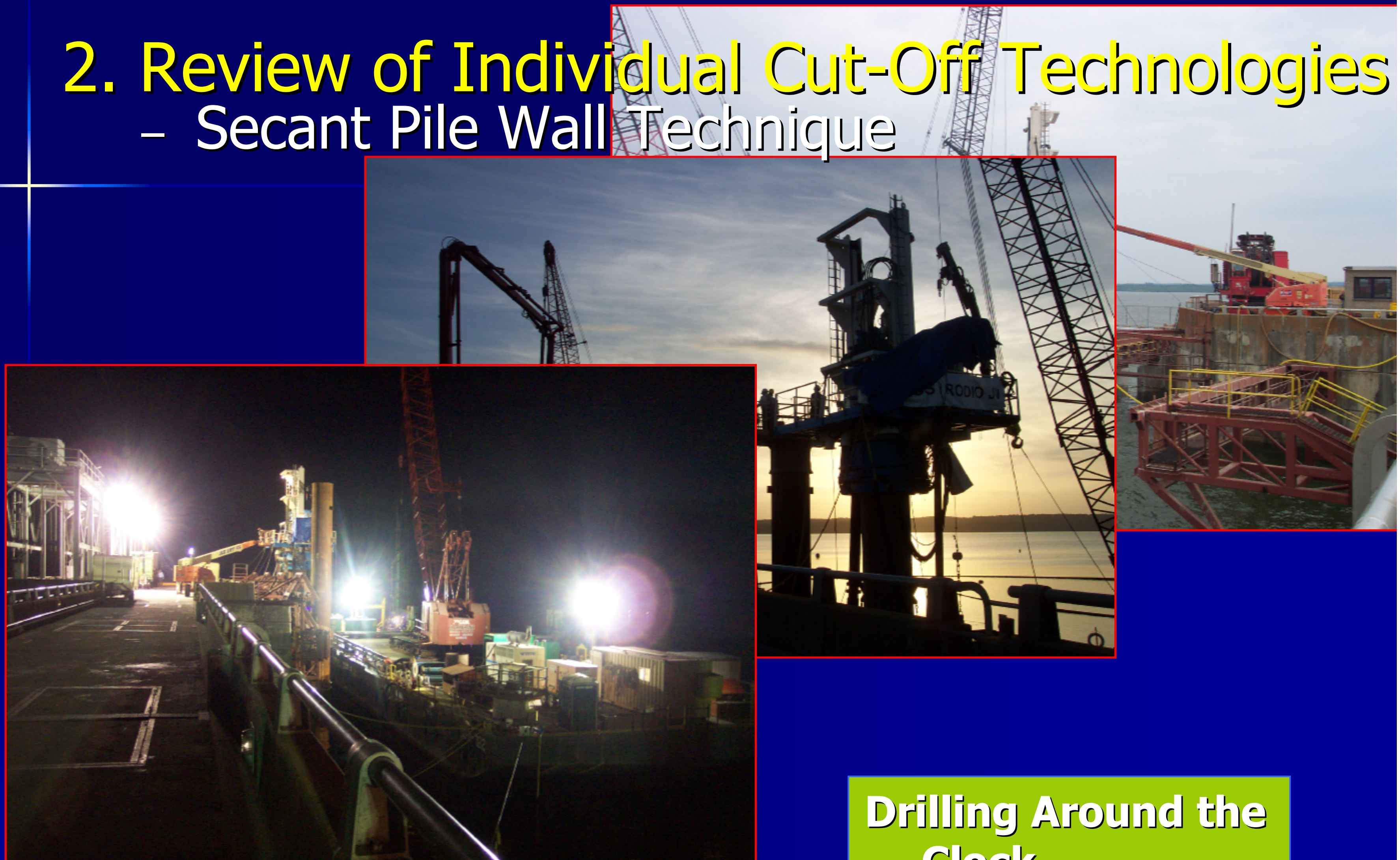
2. Review of Individual Cut-Off Technologies

– Secant Pile Wall Technique



Drilling Around the Clock

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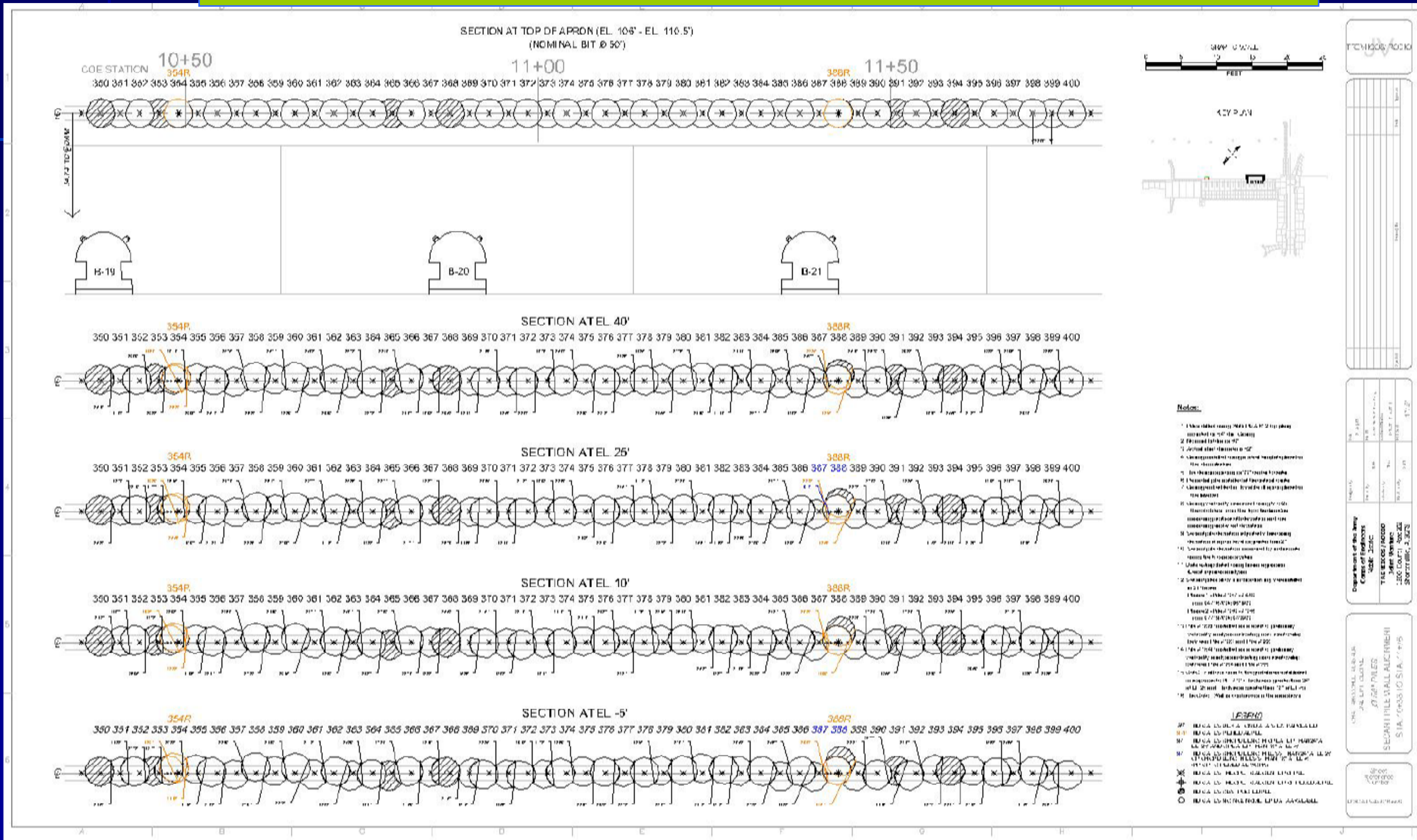
Verification of Cut-Off Wall Design Criteria At Various Elevations



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Beaver Dam, AR

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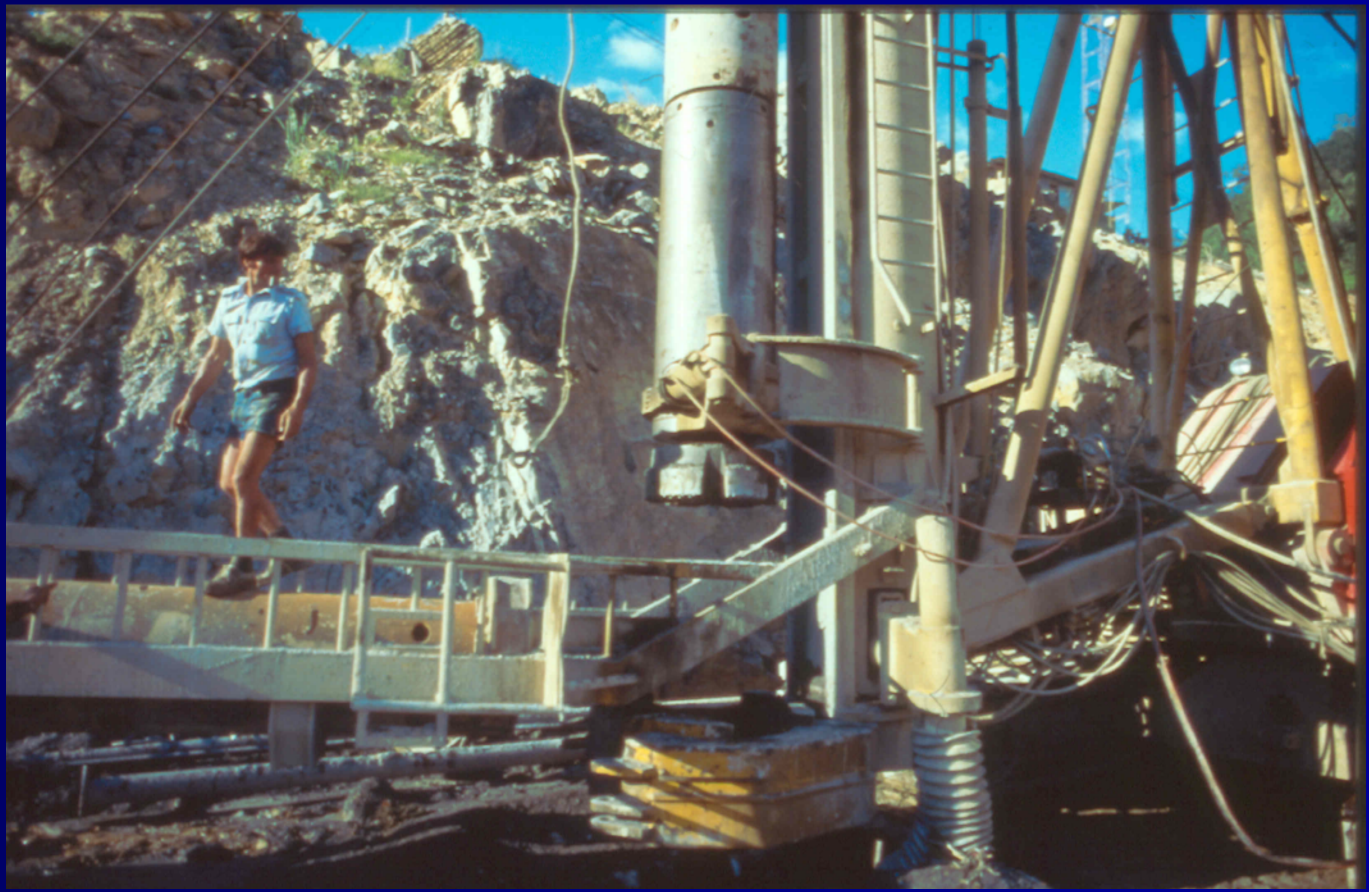
Khao Laem Dam, Thailand



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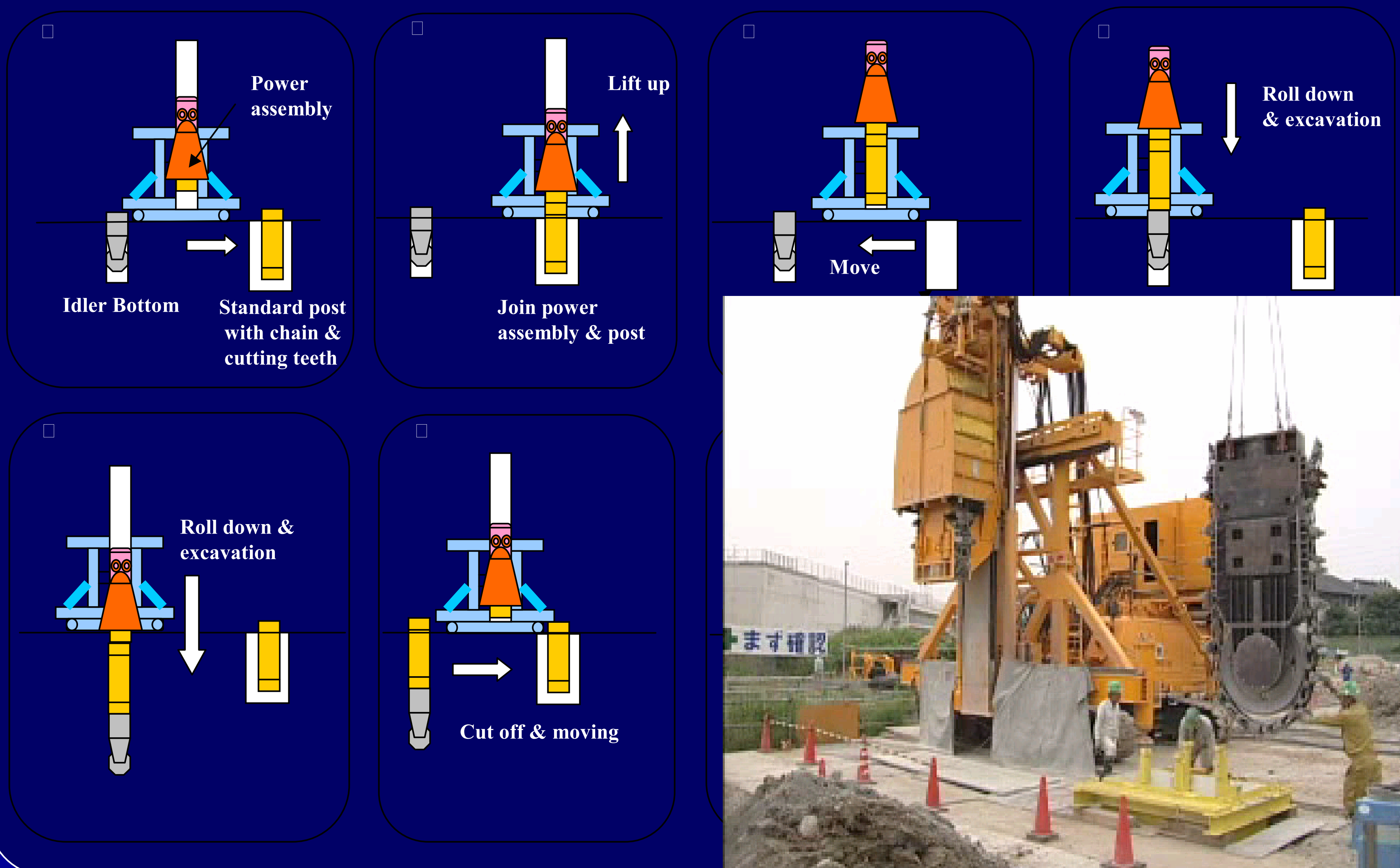
DMM Method at Jackson Lake Dam, WY


TRD Method
Trench cutting & Re-mixing
Deep wall method since 1993
Up to July 2003,
Number of job sites : over than 220,
Max. depth : about 53m(170 ft.)
September, 2003
M.Aoi &
K.Tsujimoto
1
Blue print

Process of insertion



40m(131 ft) depth takes normally about 16-20 hours.

2. Drilling and Grouting Techniques
2.1 Rock Fissure Drilling and Grouting

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2. Drilling and Grouting Techniques
2.2 Rock Void Drilling for Grout Holes

2. Drilling and Grouting Techniques
2.3 Treatment of Soil by Permeation

2. Drilling and Grouting Techniques
2.3 Treatment of Soil by Hydrofracture

2. Drilling and Grouting Techniques
2.3 Treatment of Soil by Jet Grouting

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3. Illustrative Case Histories

	Designed as Composites (Two Components: as Facilitation: Materials)					
	Wall Type		Grouting Type			
	Diaphragm (Mill/Cutter)	Secant	Rock Fissure	Rock Void	Permeation/ Hydrofracture	Jet
1. Papadia, Greece		✓	✓			
2. Diavik, NWT	✓					✓
3. W.F. George, AL	✓	✓	✓			
4. Clearwater, MO	✓		✓	✓		
5. Tims Ford, TN			✓	✓		
6. Cape Girardeau, MO			✓	✓		
	Modified during construction to become composites.					
7. Mud Mountain, WA	✓				✓	
8. Mississenewa Dam, IN	✓		✓	✓		
9. Peixe Dam, Brazil			✓			✓

1. Papadia Dam, Greece

Plastic concrete cut-off in alluvium, grouting in underlying rock.

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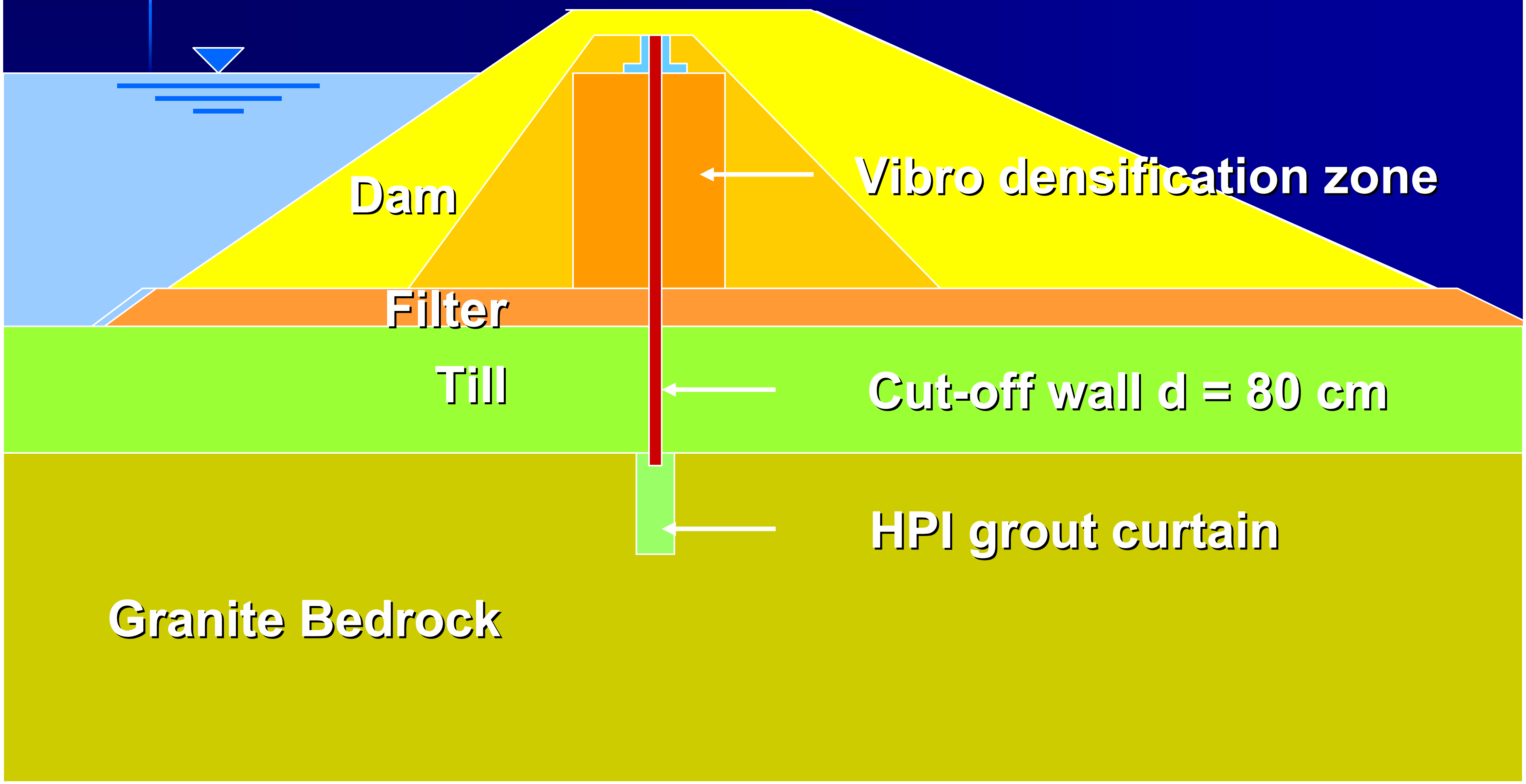
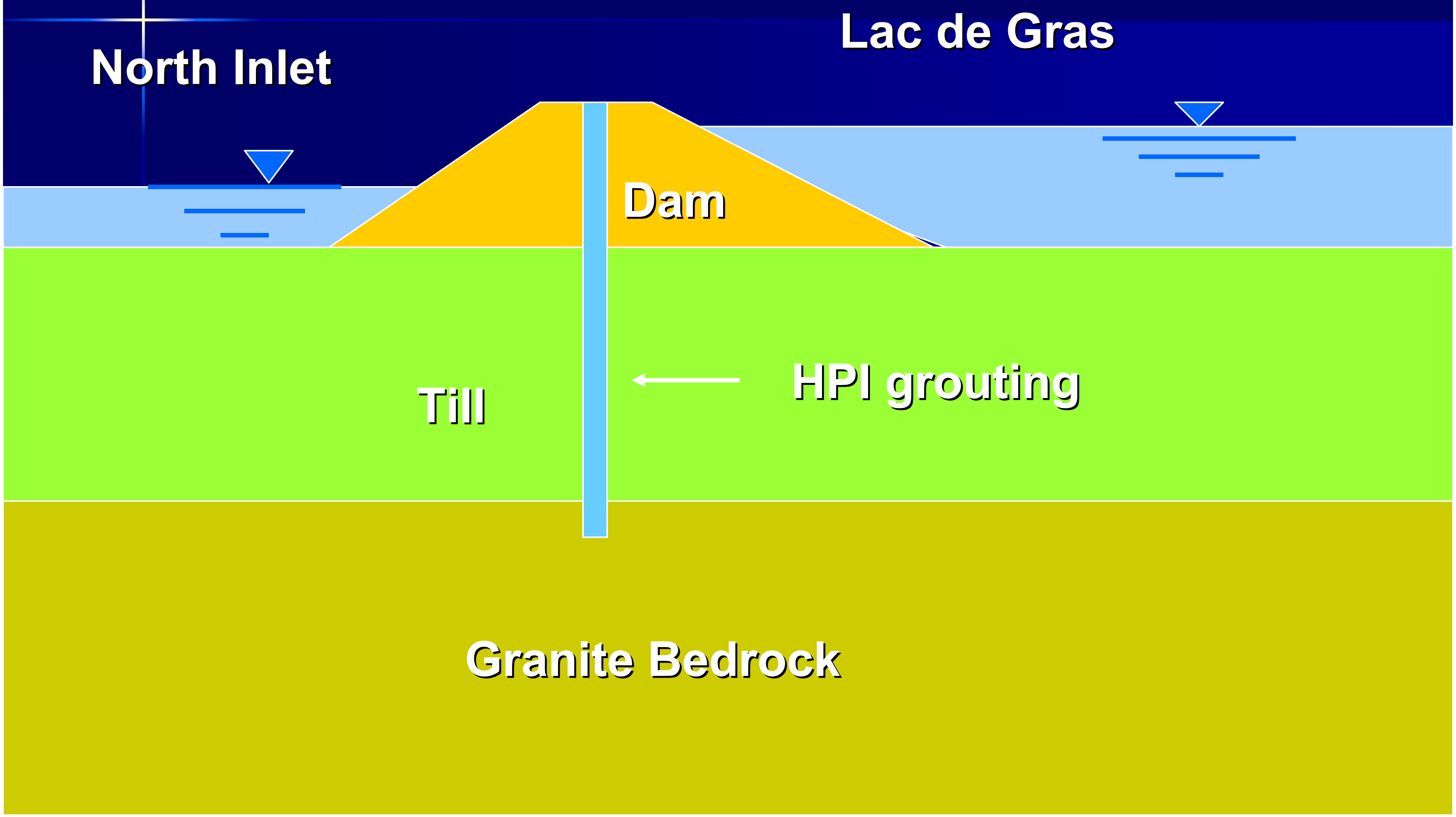
2. DIAVIK Diamond Mines, Project in year 2018

DIAVIK Project
Dam Section



DIAVIK Project
North Inlet Dike



Cut-off wall data:

- *max depth* — *35 m*
  thickness — *800 mm*
- ***artificial fill dam :*** — *22.000 m²*
  main equipment — *grab*
  av. performance — *15 m²/h*
- ***till and frozen till:*** — *11.000 m²*
  (cohesive with stones and boulders)
  main equipment — *1 cutter, 2 grabs, chisel*
  av. performance — *2,5 m²/h*
  big boulders — *1 m²/h*

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DIAVIK Project

High Pressure Grout

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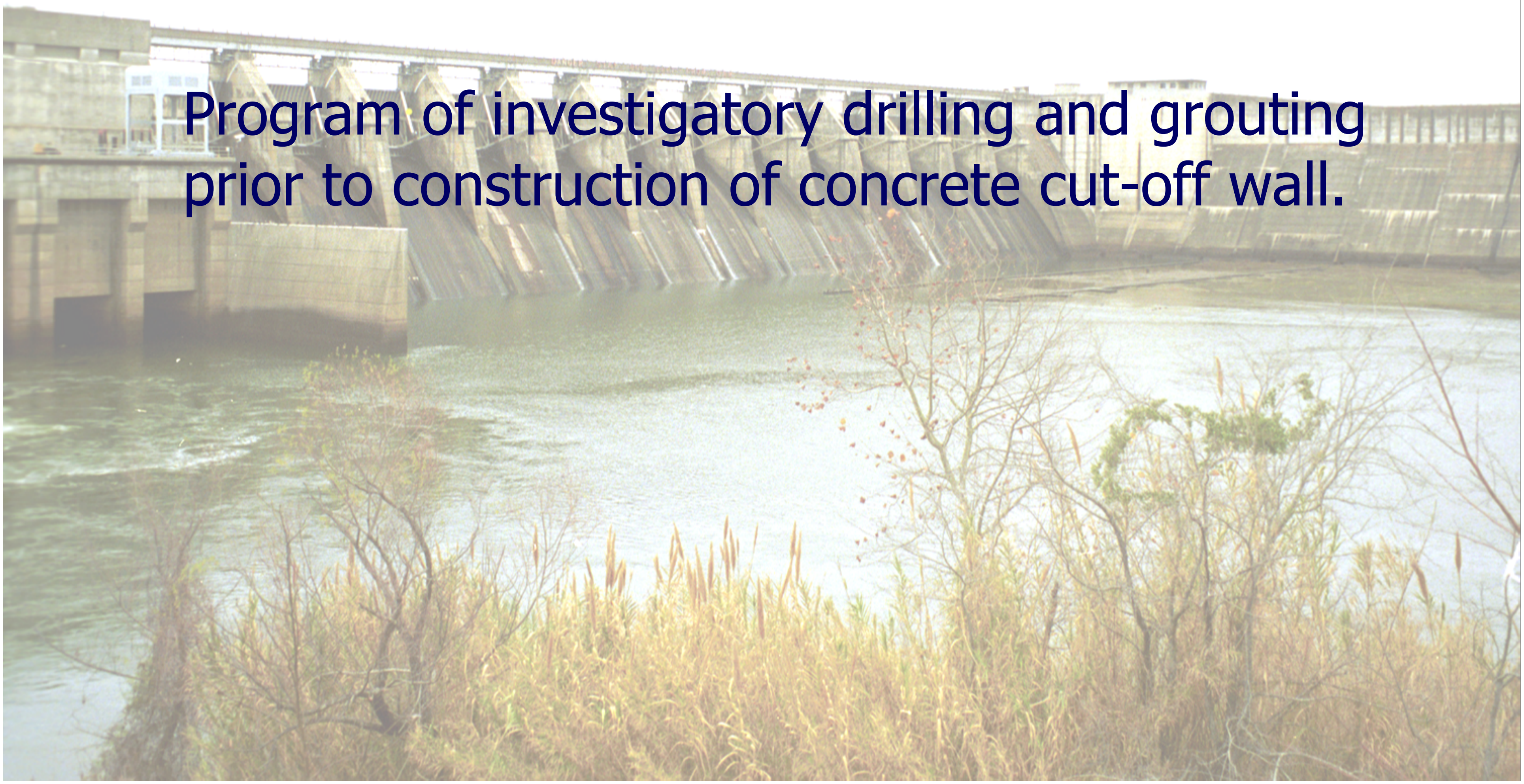
JOINT VENTURE

3. W.F. George Dam, AL



Program of investigatory drilling and grouting prior to construction of concrete cut-off wall.

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JOINT VENTURE

Exploratory Holes and Grouting

- Drilling
  - 11,800 lft
  - 102 Holes
- Coring
  - 1,900 lft
  - 13 Holes
- Grouting
  - 450 cy

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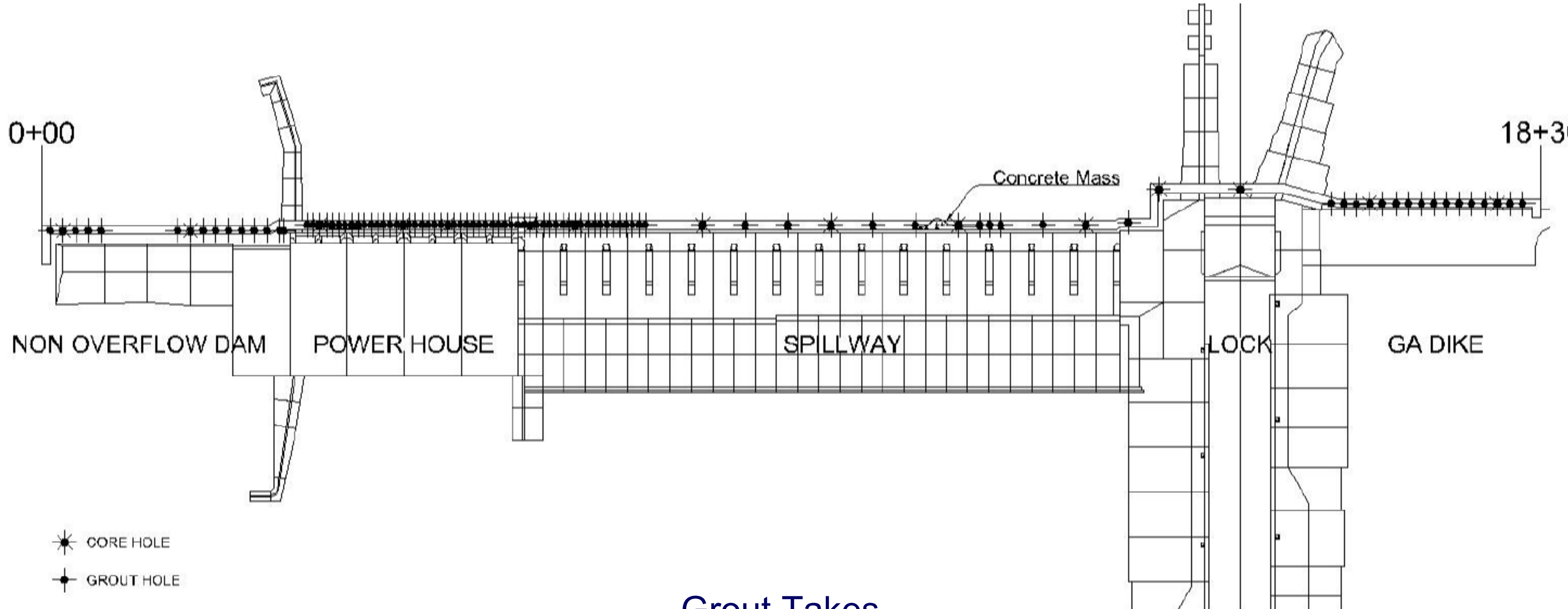
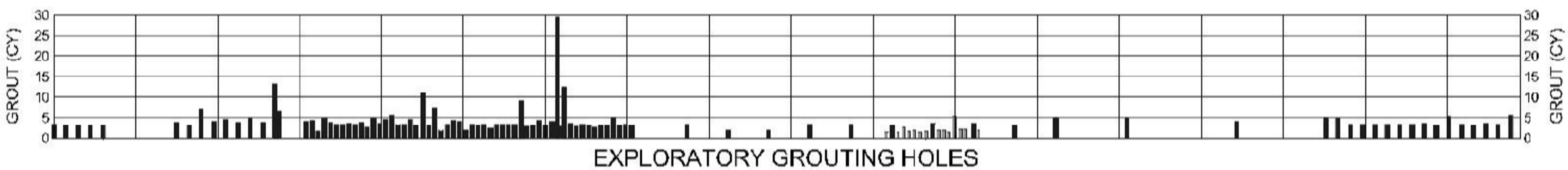
JOINT VENTURE

Exploratory Grouting Layout



Grout Takes



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JOINT VENTURE

Drilling and Coring Using an SM-405 Rig on Flexi-Floats

PRELIMINARY INVESTIGATION

By conducting an extensive exploratory campaign the JV gained vital information which allowed it to plan the work ahead even when confronted with situations at variance from what the contract documents showed.

Advance information is relatively cheap to acquire and it pays for itself many times over in avoiding or mitigating delays and extra costs during the performance of the work.

THERE IS NO SUCH THING AS TOO MUCH INFORMATION, ESPECIALLY OF UNDERGROUND CONDITIONS!

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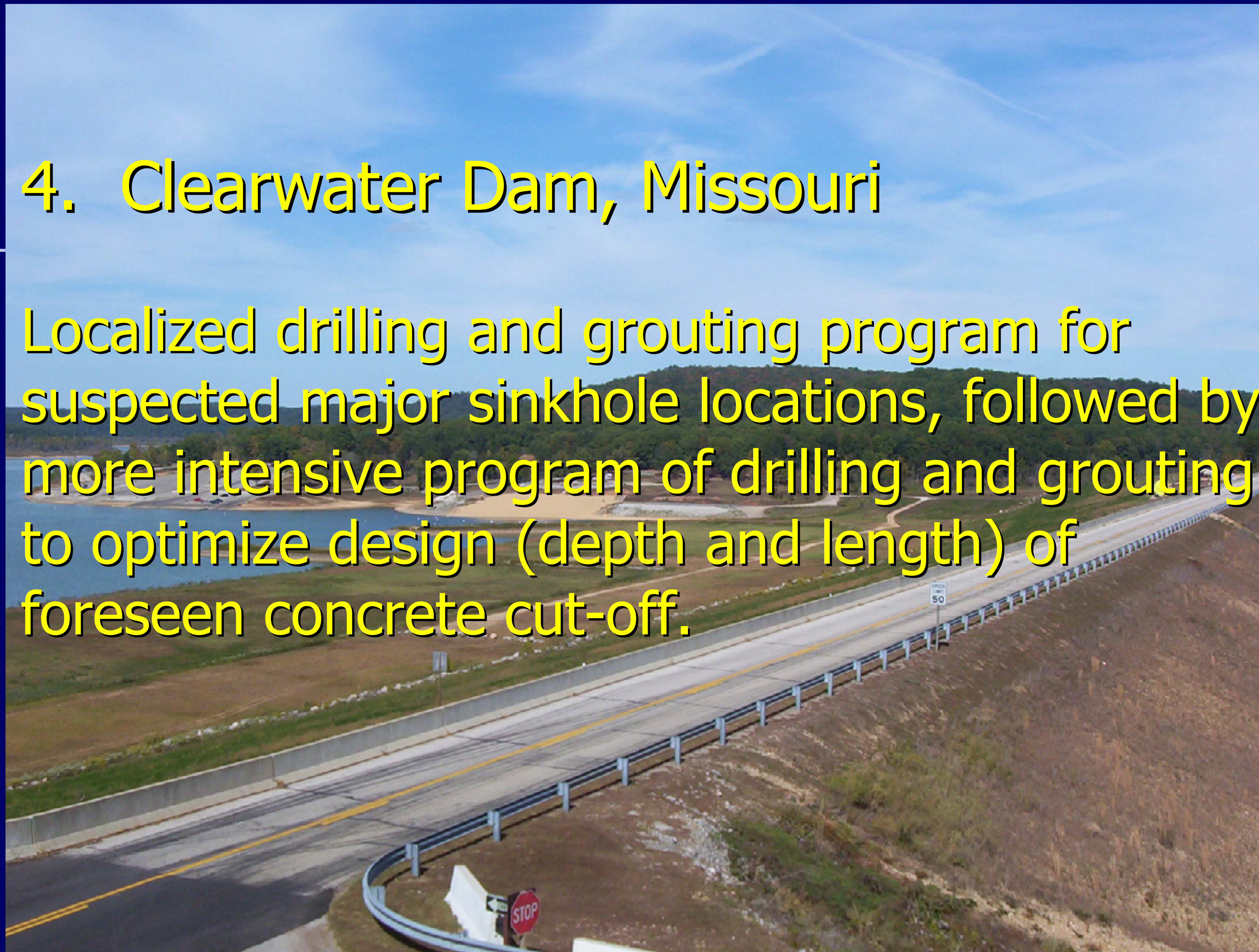
Happy Lake Dwellers

4. Clearwater Dam, Missouri

Localized drilling and grouting program for suspected major sinkhole locations, followed by more intensive program of drilling and grouting to optimize design (depth and length) of foreseen concrete cut-off.



5. Tims Ford Dam, TN

Remedial grout curtain in karst employing three families of grout materials – HMG, Polyurethane, LMG.

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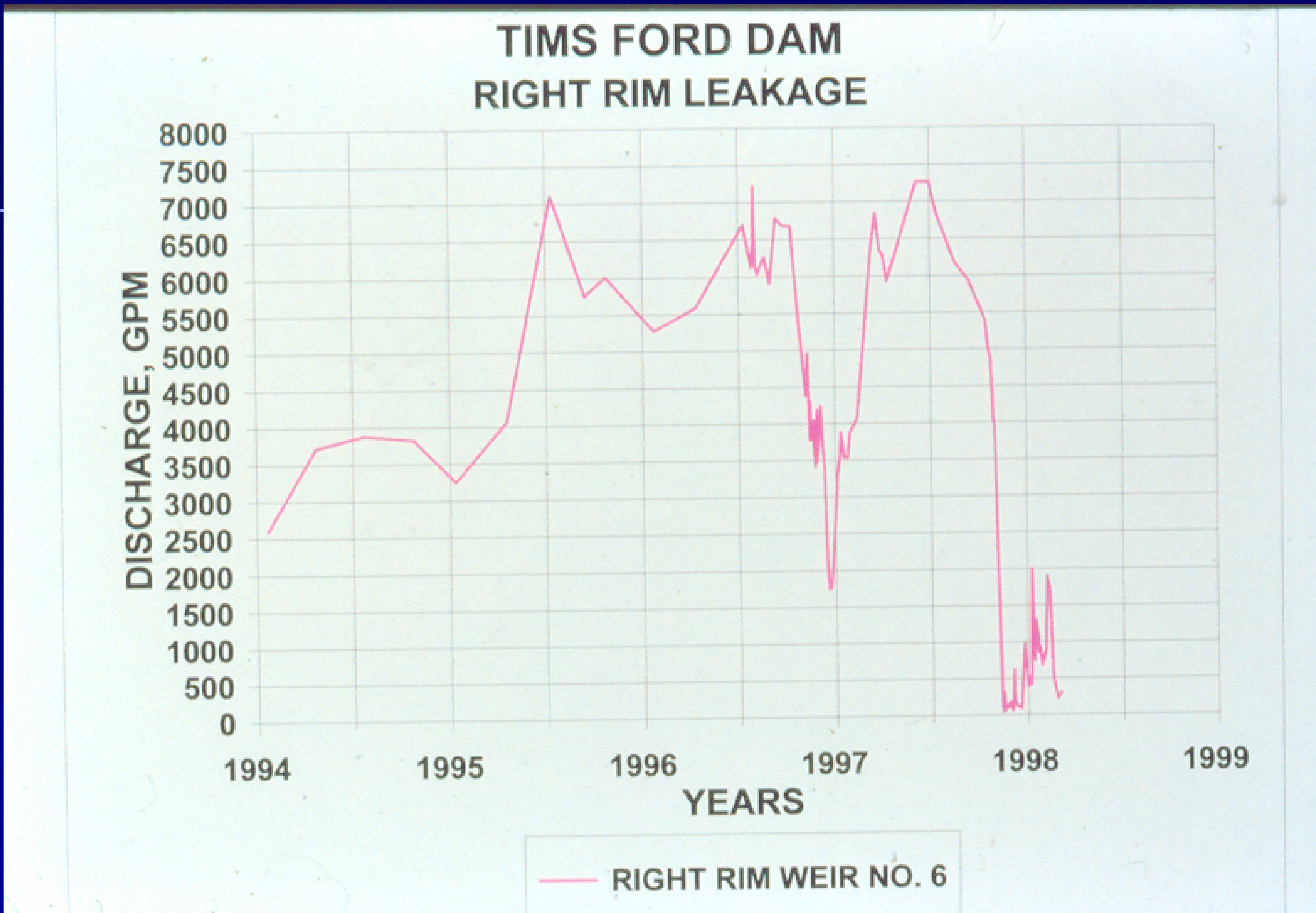

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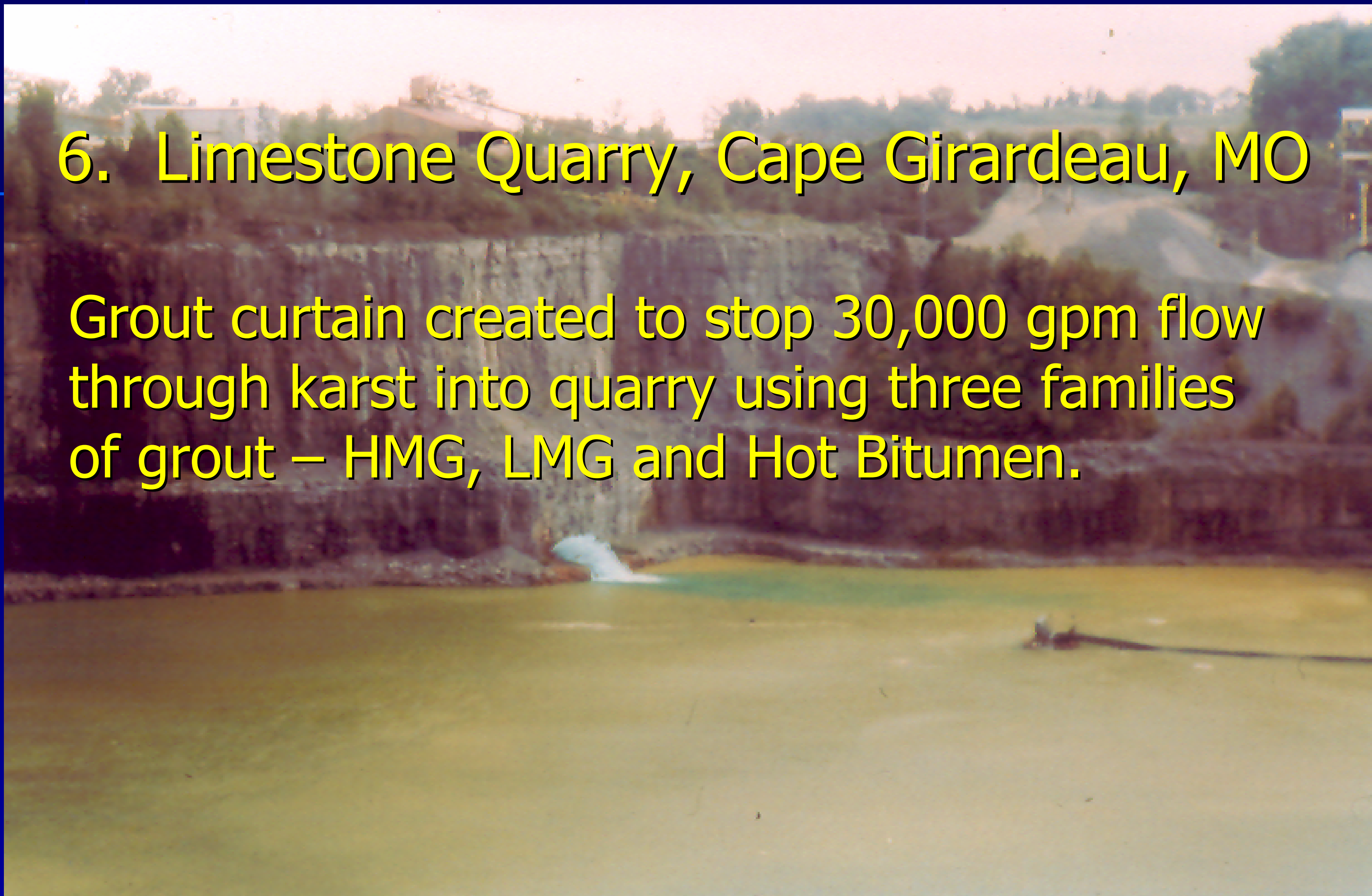
6. Limestone Quarry, Cape Girardeau, MO

Grout curtain created to stop 30,000 gpm flow through karst into quarry using three families of grout – HMG, LMG and Hot Bitumen.



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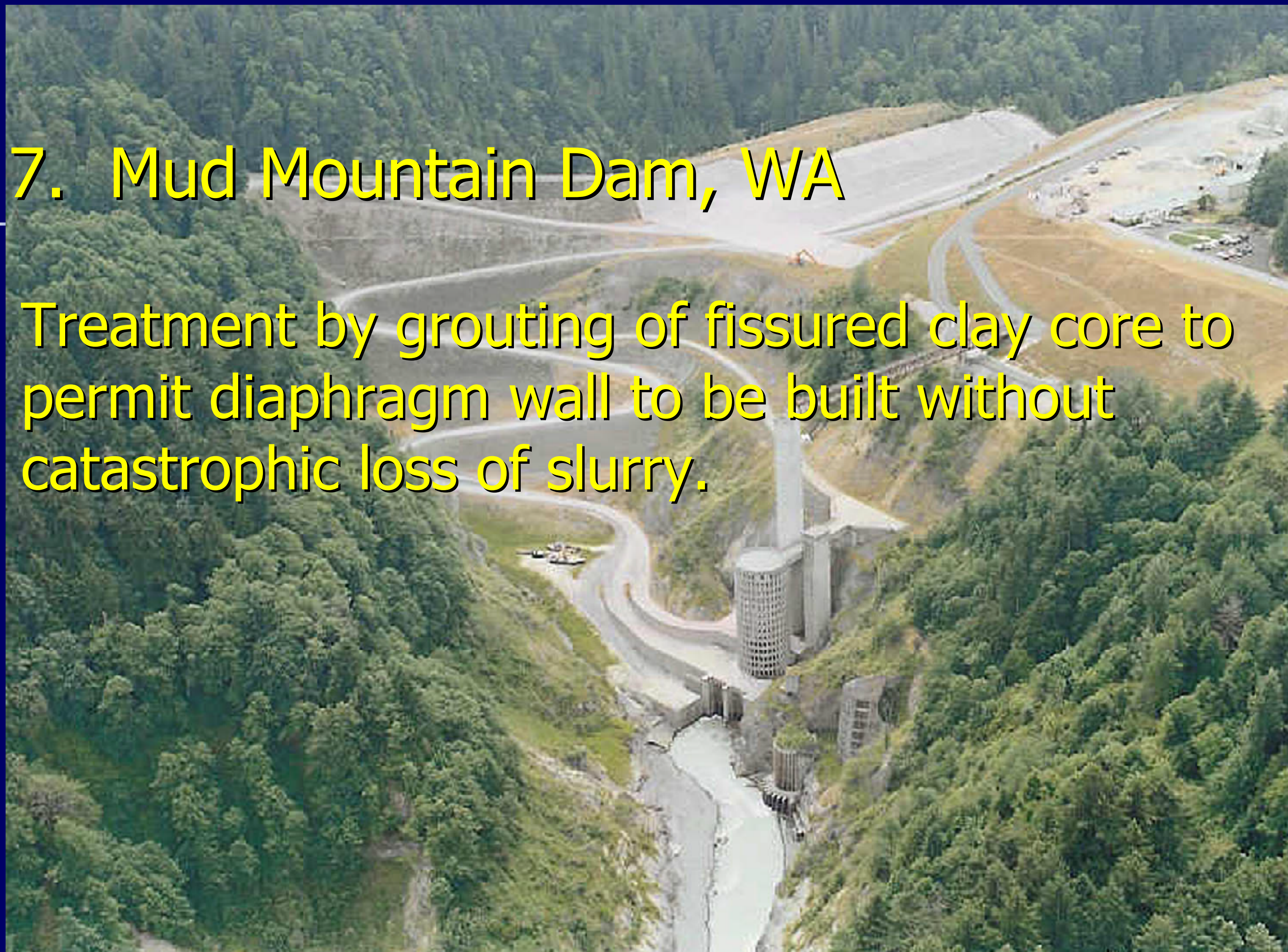
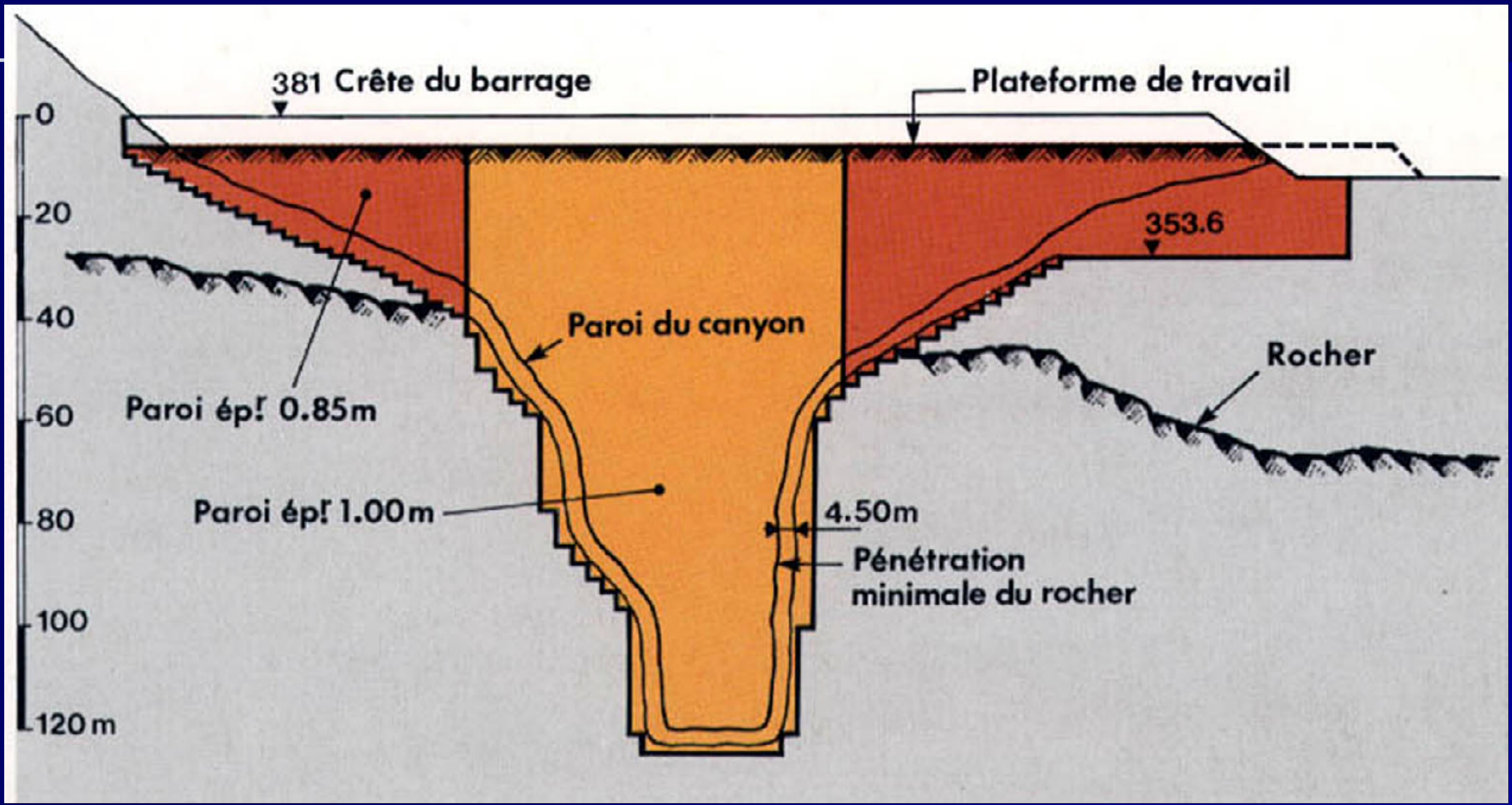
7. Mud Mountain Dam, WA



Treatment by grouting of fissured clay core to permit diaphragm wall to be built without catastrophic loss of slurry.


381 Crête du barrage
Plateforme de travail
0
20
40
60
80
100
120 m
353.6
Paroi du canyon
Rocher
Paroi ép! 0.85m
Paroi ép! 1.00m
4.50m
Pénétration
minimale du rocher

MUD MOUNTAIN

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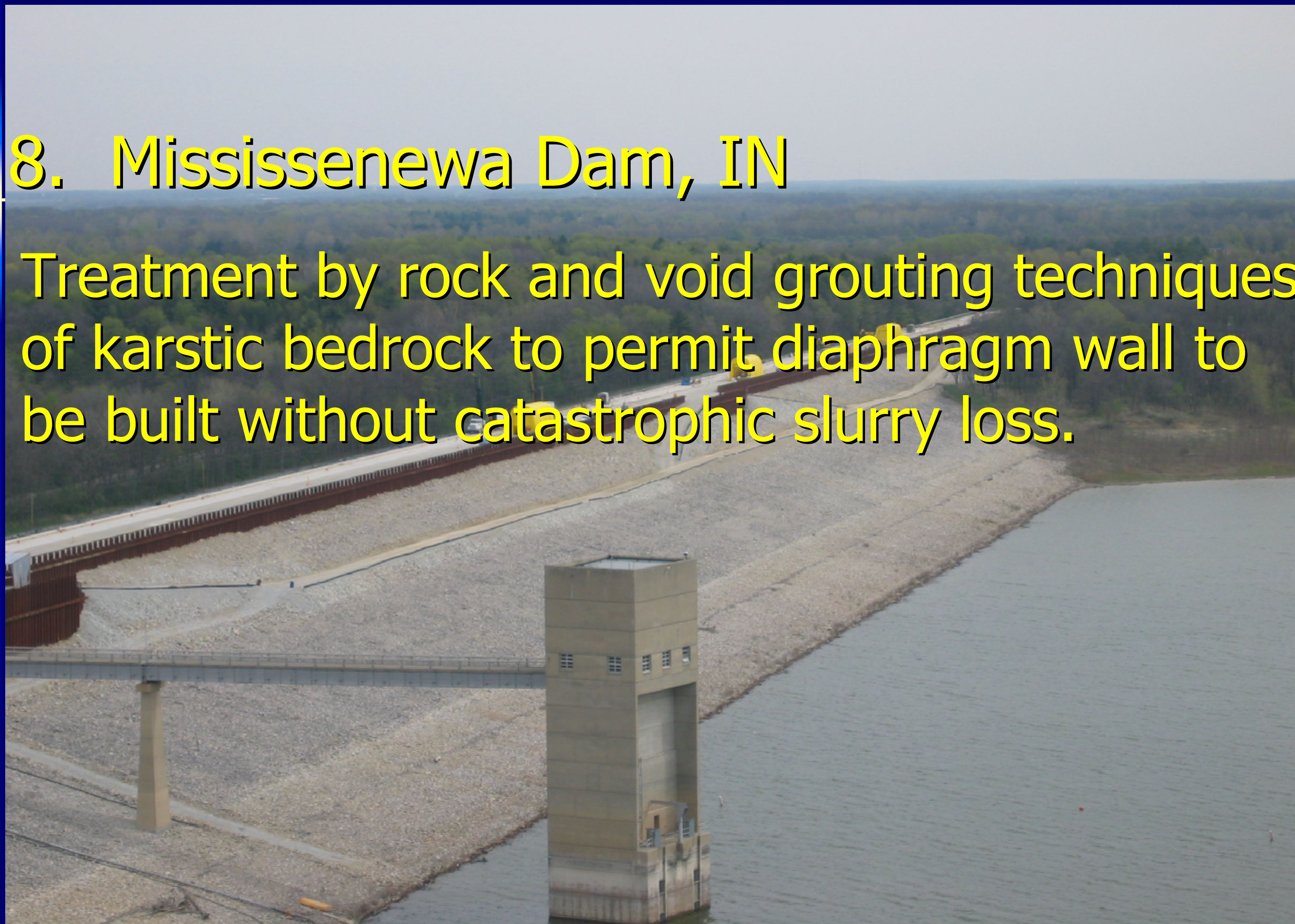
8. Mississenewa Dam, IN

Treatment by rock and void grouting techniques of karstic bedrock to permit diaphragm wall to be built without catastrophic slurry loss.



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Clear example of equivalent performance of grouting to concrete cut-off wall construction.

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9. Peixe Dam, Brazil

Rock grouting used in voided/fissured karstic limestone inlier. Jet grouting required to treat weathered, soil-like materials lying above fresher rock.


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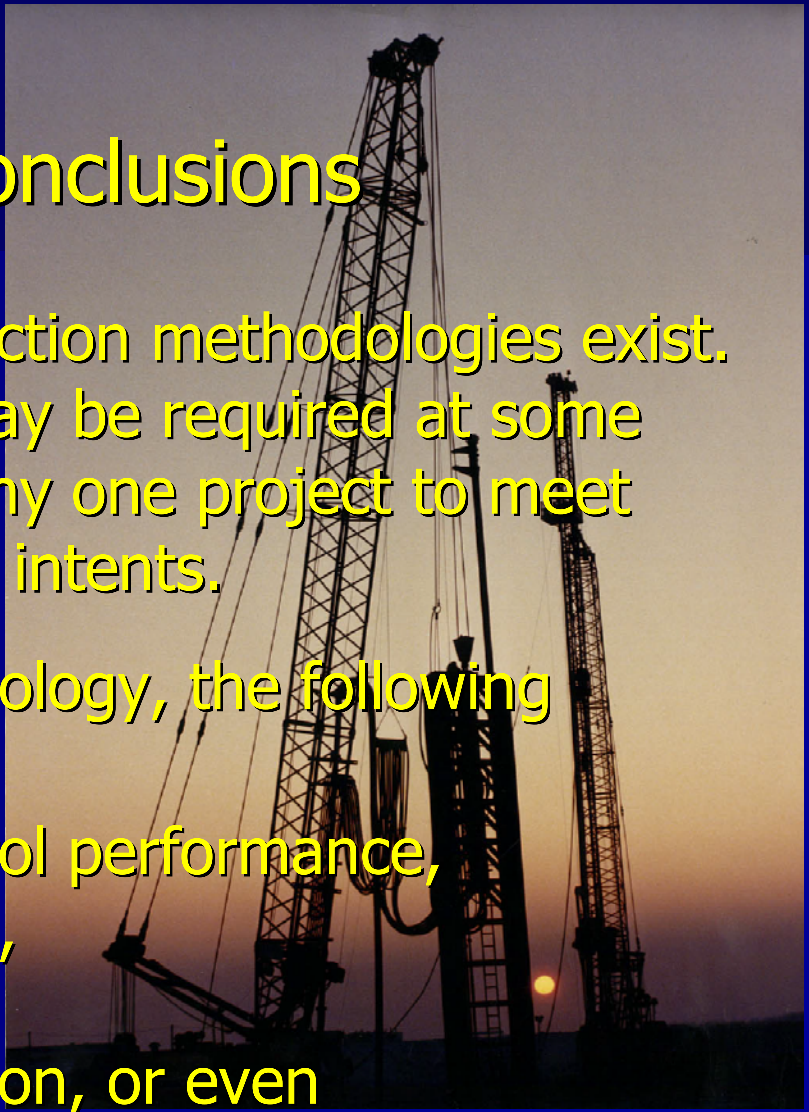
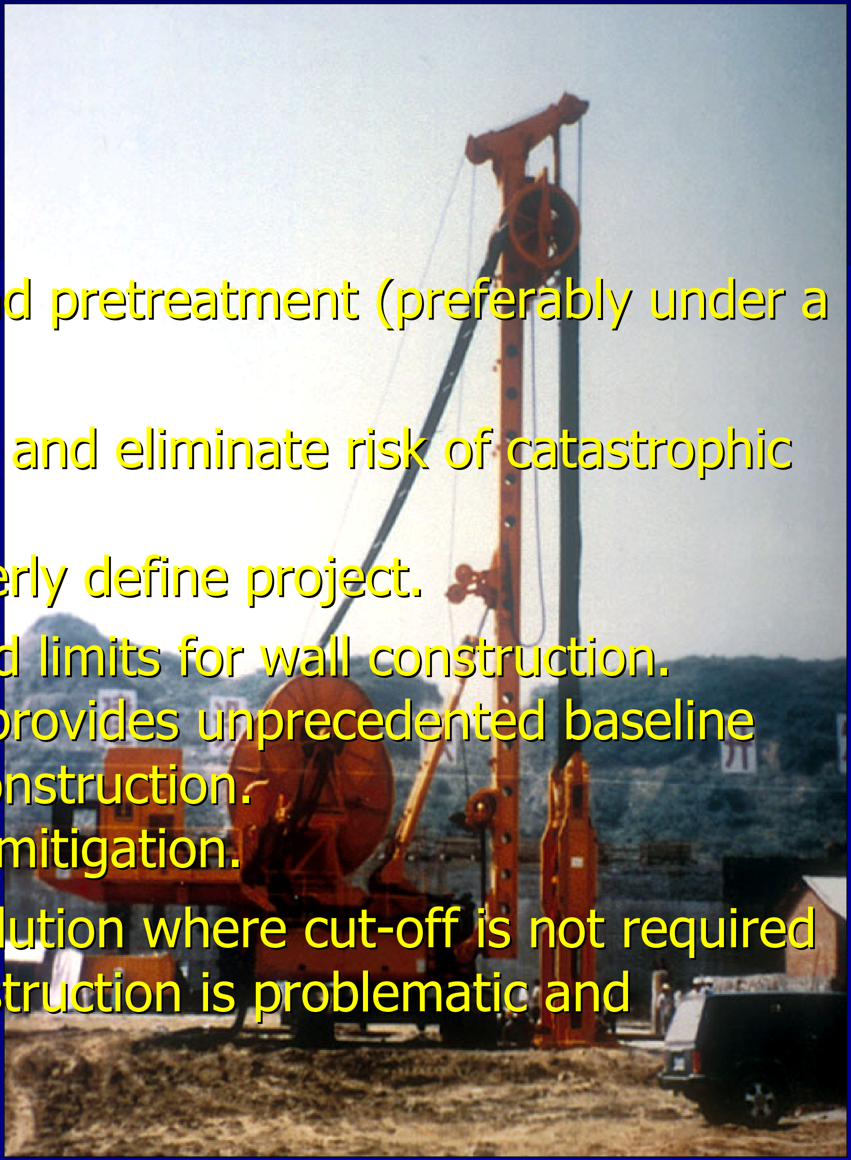
4. Observations and Conclusions



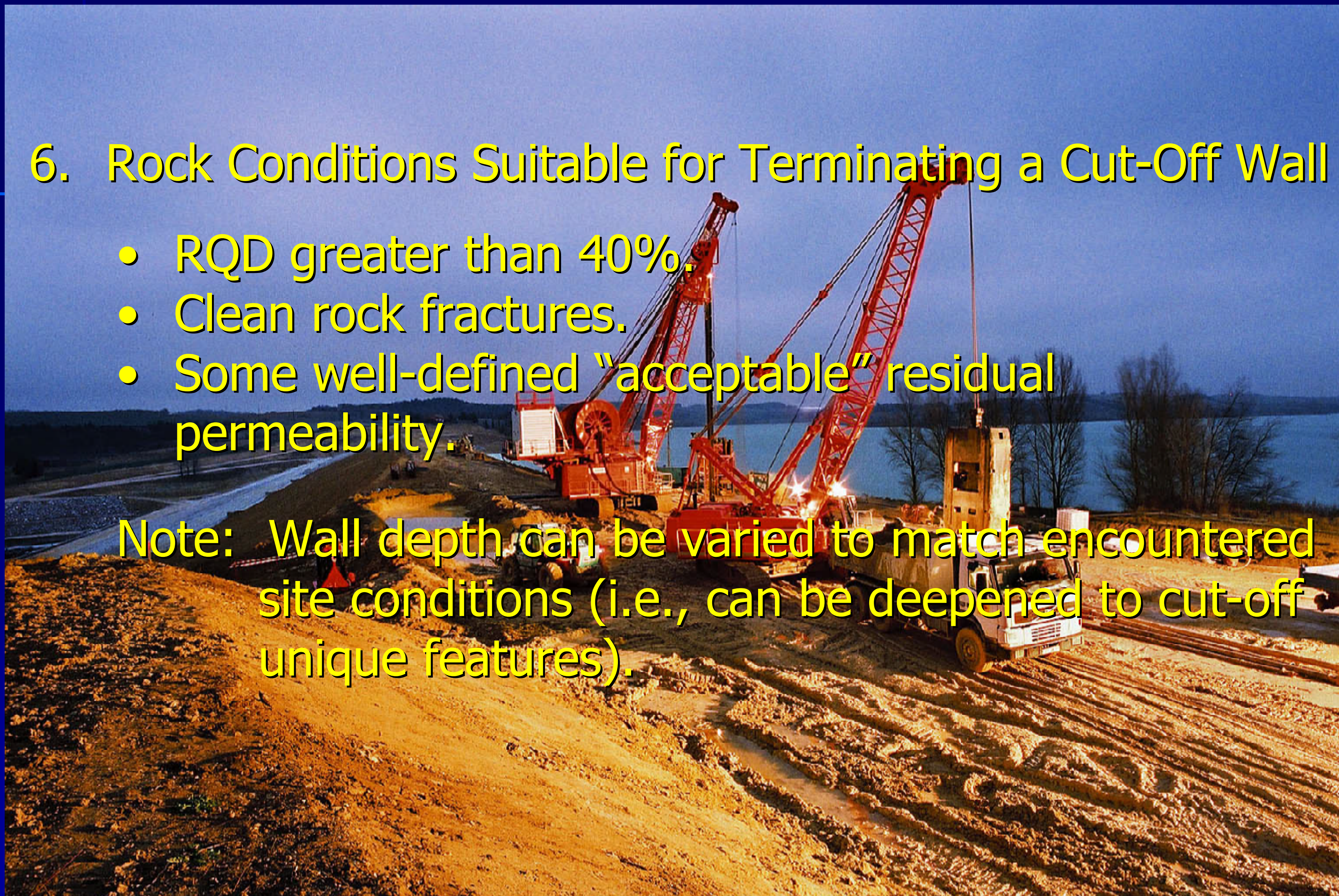
1. Numerous excellent construction methodologies exist. However, more than one may be required at some time, or some location on any one project to meet the design and construction intents.
2. By "shoehorning" one technology, the following outcomes often occur:
   - Ineffective seepage control performance,
   - Large construction claims,
   - Damage to structure,
   - Need for future remediation, or even
   - Abandonment of remediation efforts.

3. If water is lost in substantial amounts during initial subsurface investigations, circulation fluid (slurry, water or air) will be lost during subsequent wall construction if remediation is not carried out in advance.

4. Intensive site investigation and pretreatment (preferably under a separate contract) will:
    - Prepare the site of cut-off and eliminate risk of catastrophic slurry loss.
    - Explore the site and properly define project.
        - Used to define required limits for wall construction.
        - Information obtained provides unprecedented baseline data for cut-off wall construction.
        - Claims avoidance and mitigation.
    - Can provide lower cost solution where cut-off is not required at depths where wall construction is problematic and increasingly expensive.



5. Configurations for Compatible Performance of Cut-Off Wall and Permanent Grouting
   - Two fully grouted lines at 5 to 10 feet spacing.
   - Grouting in stages to absolute refusal with balanced stable grouts.
   - Verification holes along centerline (core and water pressure test).



6. Rock Conditions Suitable for Terminating a Cut-Off Wall

- RQD greater than 40%.
- Clean rock fractures.
- Some well-defined "acceptable" residual permeability.

Note: Wall depth can be varied to match encountered site conditions (i.e., can be deepened to cut-off unique features).

Acknowledgements

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