



EMBANKMENT DAMS AND DYKES OVERTOPPING EROSION

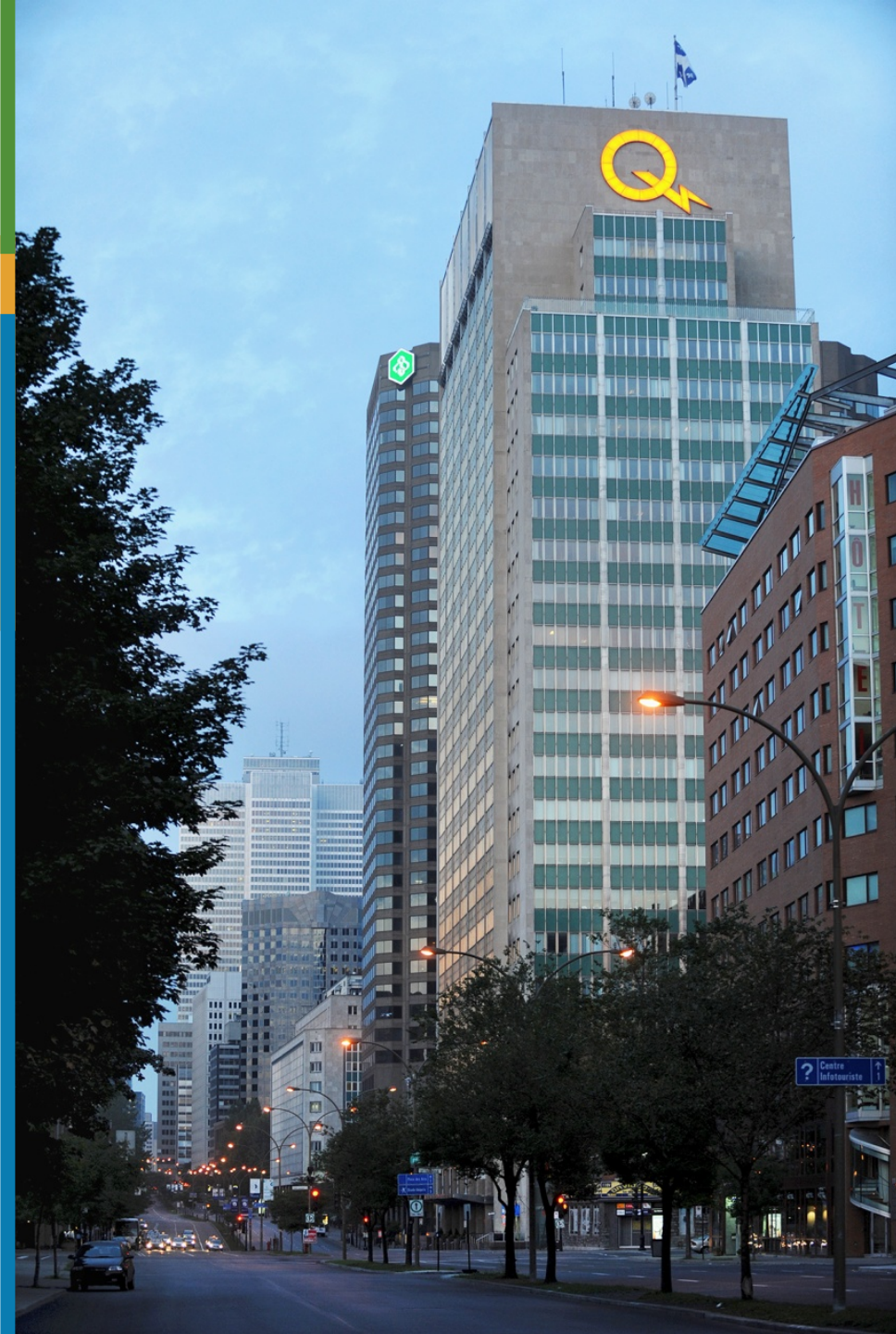
Hydro-Québec Perspectives : Issues and Engineering Needs

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Overview

- ▶ Hydro-Québec generates more than 99% of its electricity from hydro
- ▶ One of the largest electricity companies in Canada and one of the largest producers of renewable energy in the world
- ▶ Nearly 45% of all hydroelectricity in Canada
- ▶ Generation, transmission and distribution of electricity
- ▶ Its sole shareholder is the Québec government

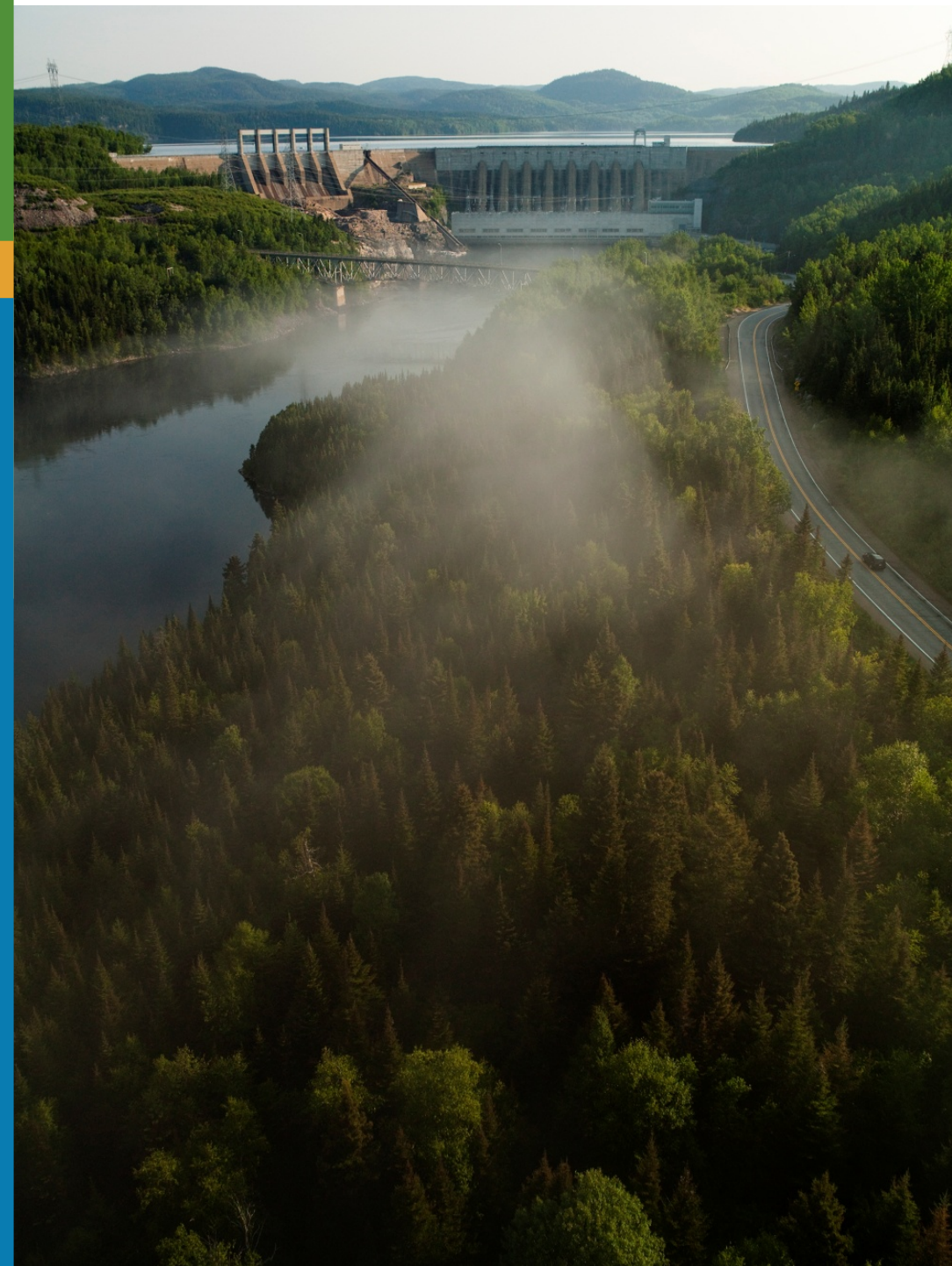


Map

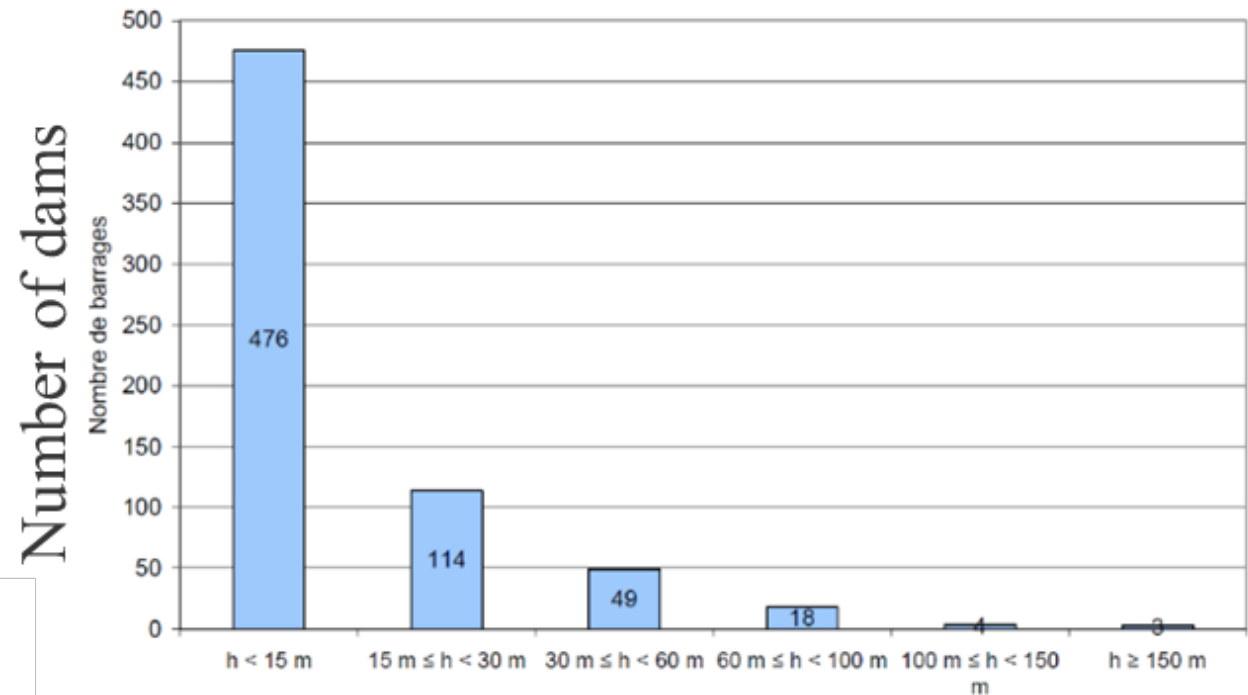
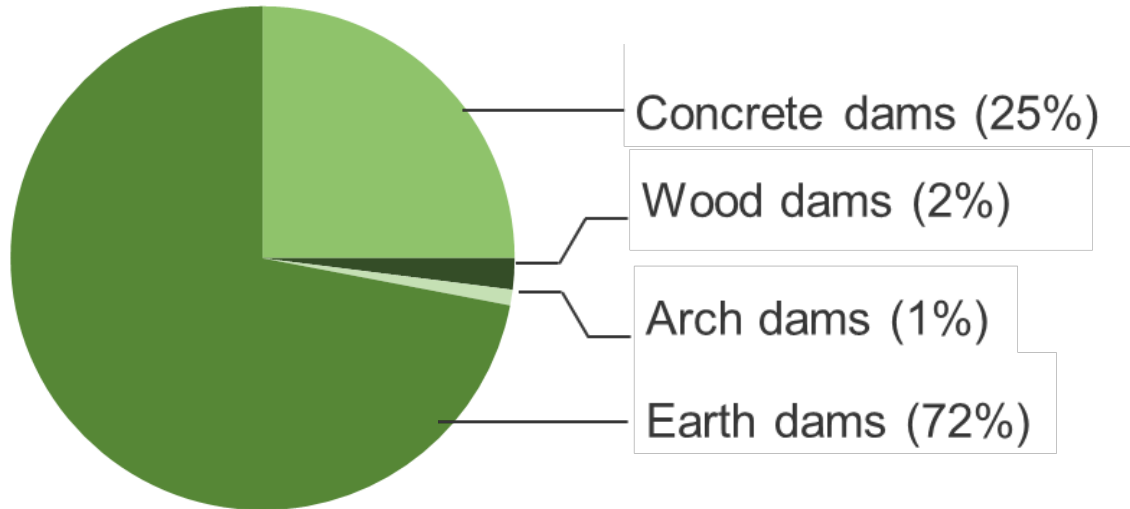


Production – 2016

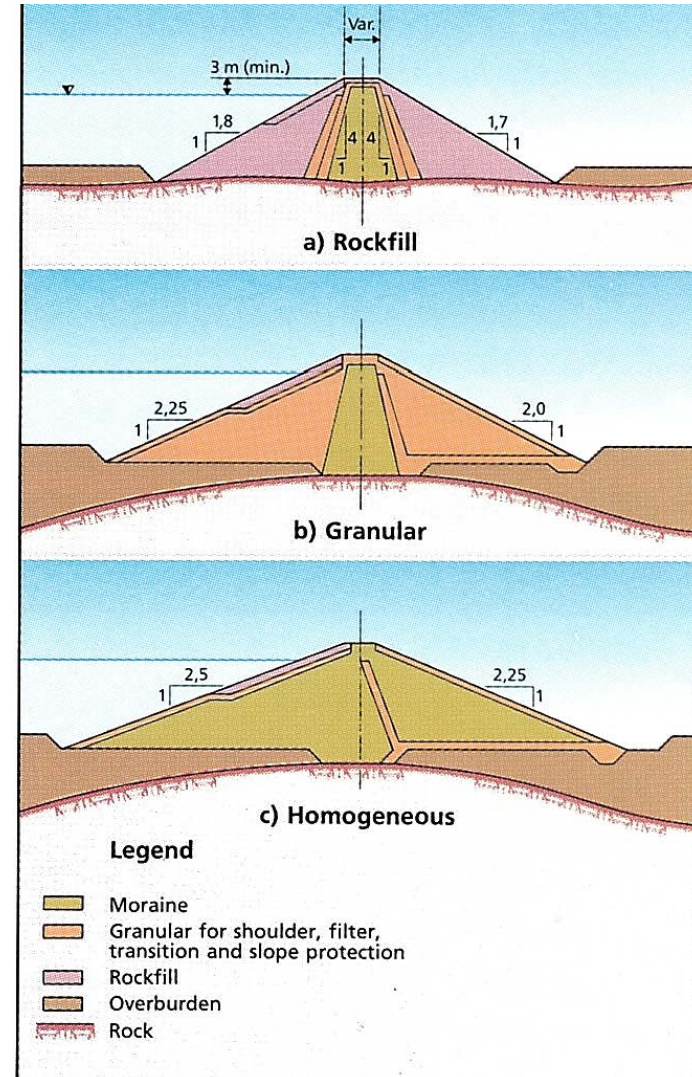
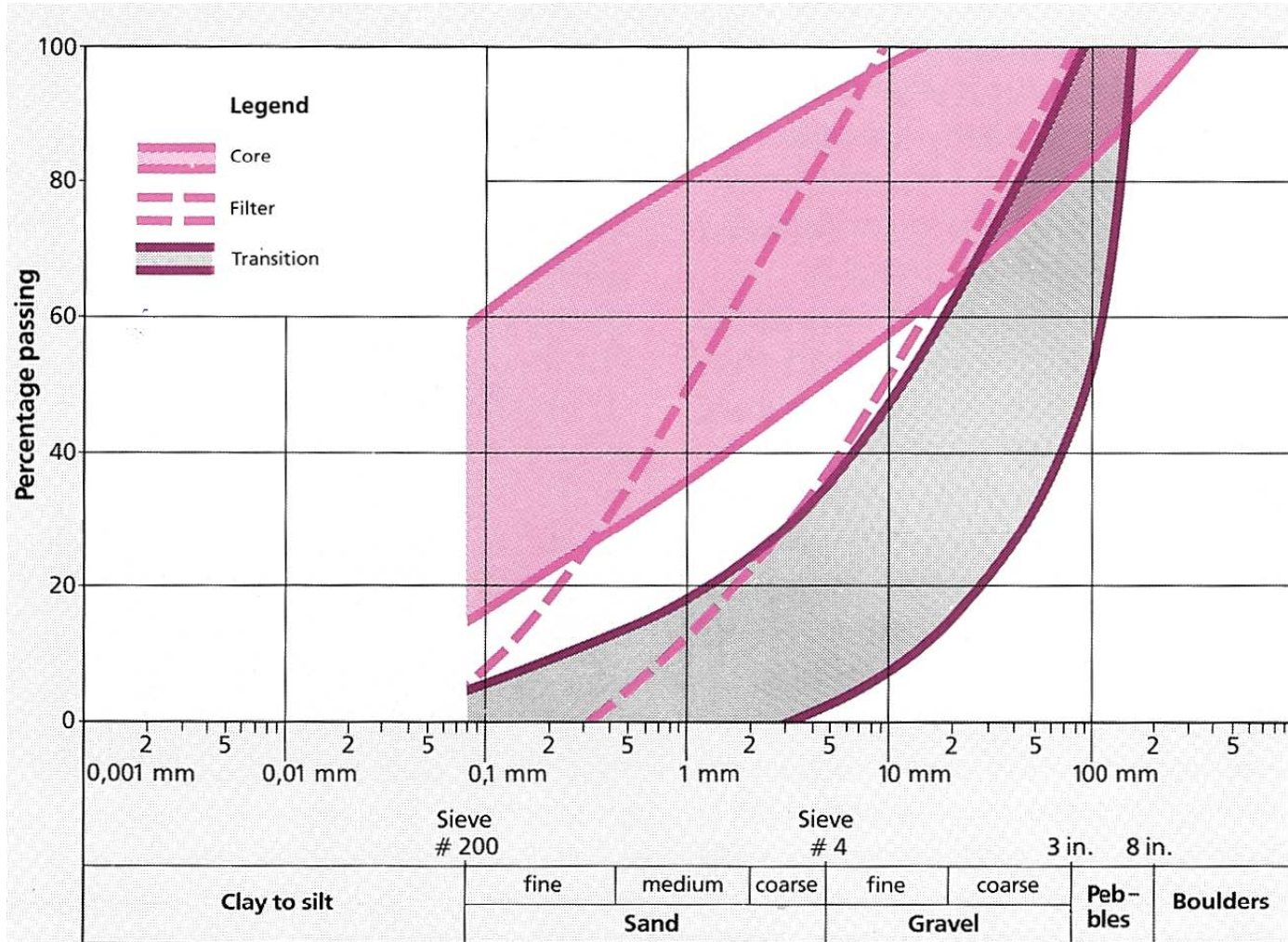
- ▶ Generates power for the Québec market and sells electricity on wholesale markets
- ▶ > 60 hydroelectric generating stations
- ▶ > 600 dams
- ▶ 27 reservoirs with a storage capacity of 176 TWh/year
- ▶ Total installed capacity : 36,3 GW
- ▶ Assets : 33 B\$
- ▶ Annual investments in property, plant and equipment and intangible assets : 906 M\$



Heights and Types of Dams



Embankment Dams Materials



Laws and Regulations

- ▶ The Dam Safety Act and its attendant Regulation came into effect in Quebec province on April 11, 2002.
- ▶ The Dam Safety Act :
 - ▶ Construction, change and operation of high-capacity dams
 - ▶ Maintain dams in good condition and repair
 - ▶ Emergency Action Plan
 - ▶ Safety review by an engineer to verify their safety and compliance with today's standards

Dam Safety Regulation

- ▶ 25. The crest of an erodible dam at its lowest point must not be less than 1 m above the safety check flood level, unless ...

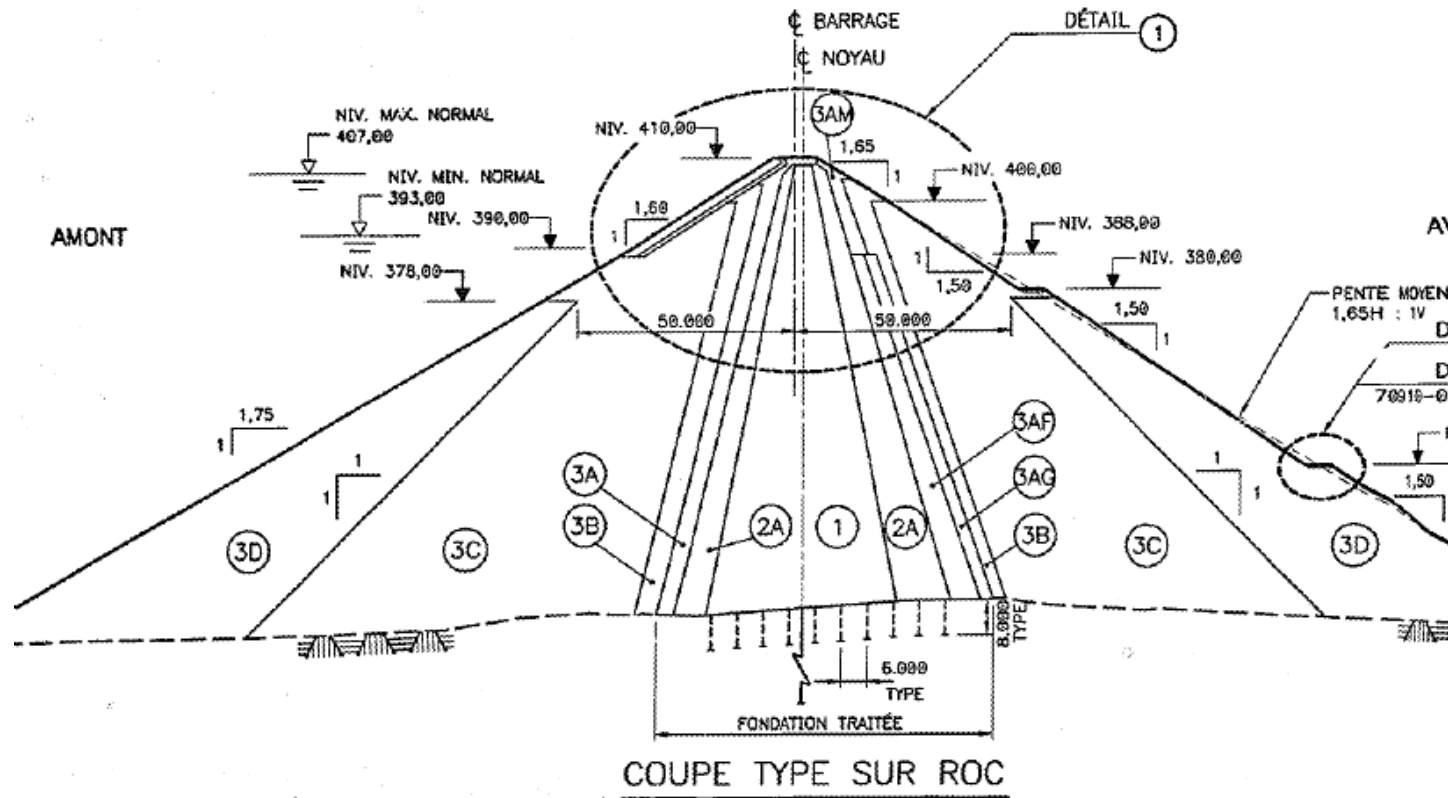
...

This section does not apply to dams designed to withstand a “probable maximum flood”.

- ▶ 26. Any impervious component of an erodible dam must be at least as high as the safety check flood level.

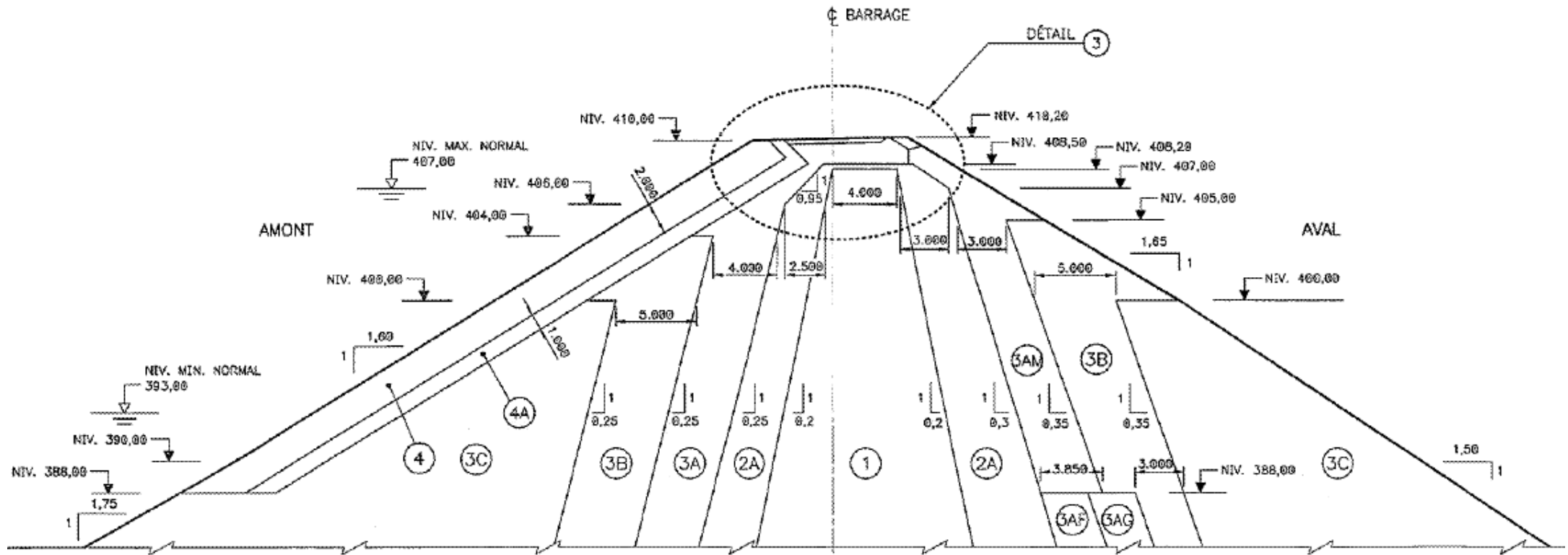
This section does not apply to existing dams.

Design and Safety Reviews



- ▶ Flood and Seismic Resistance
- ▶ Stability

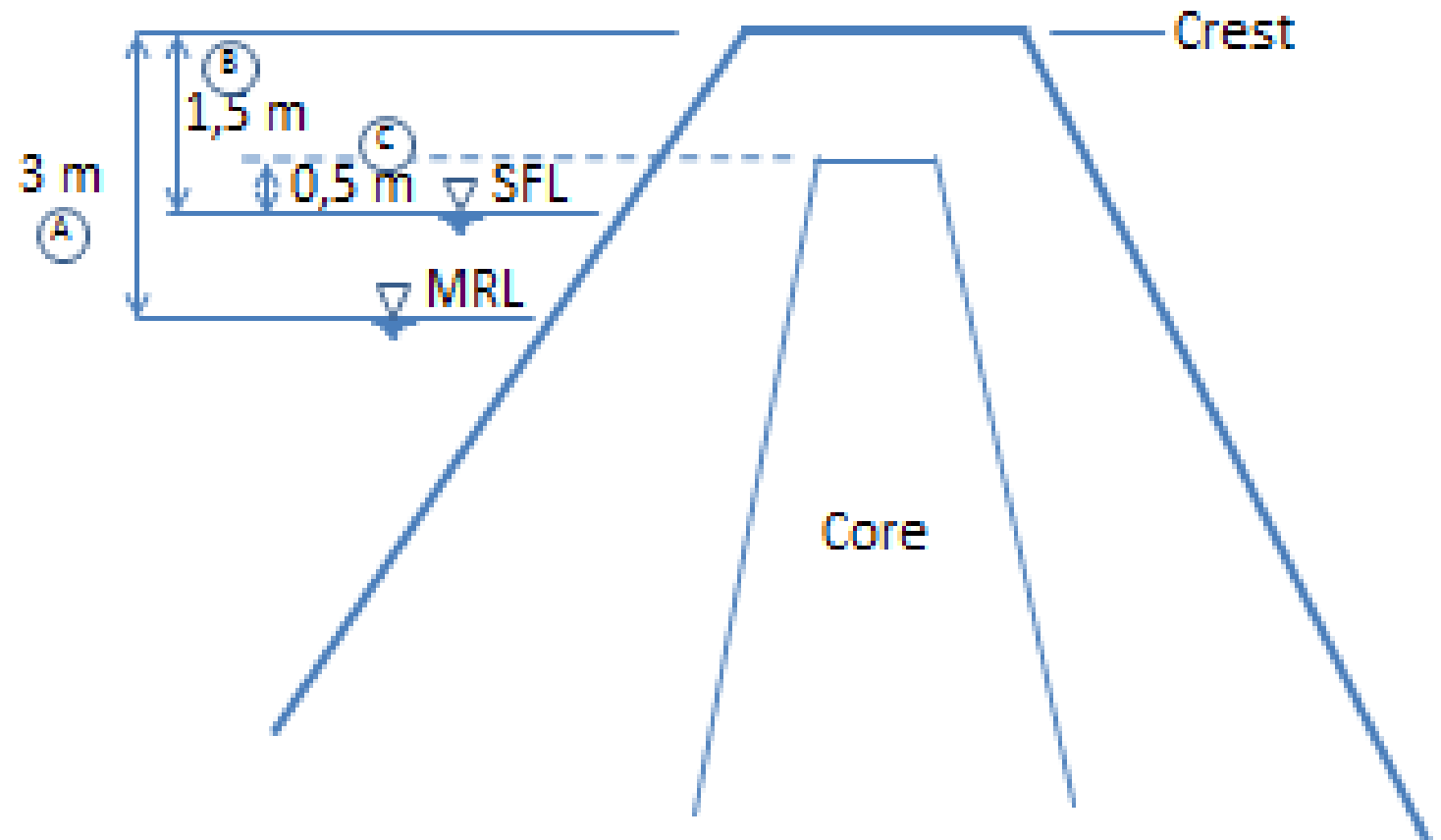
Crest details



- ▶ New Dams: Laws and Regulations, ..., Quantity Optimization
- ▶ Existing Dams: Dam Safety Reviews considering today's standards

Freeboard

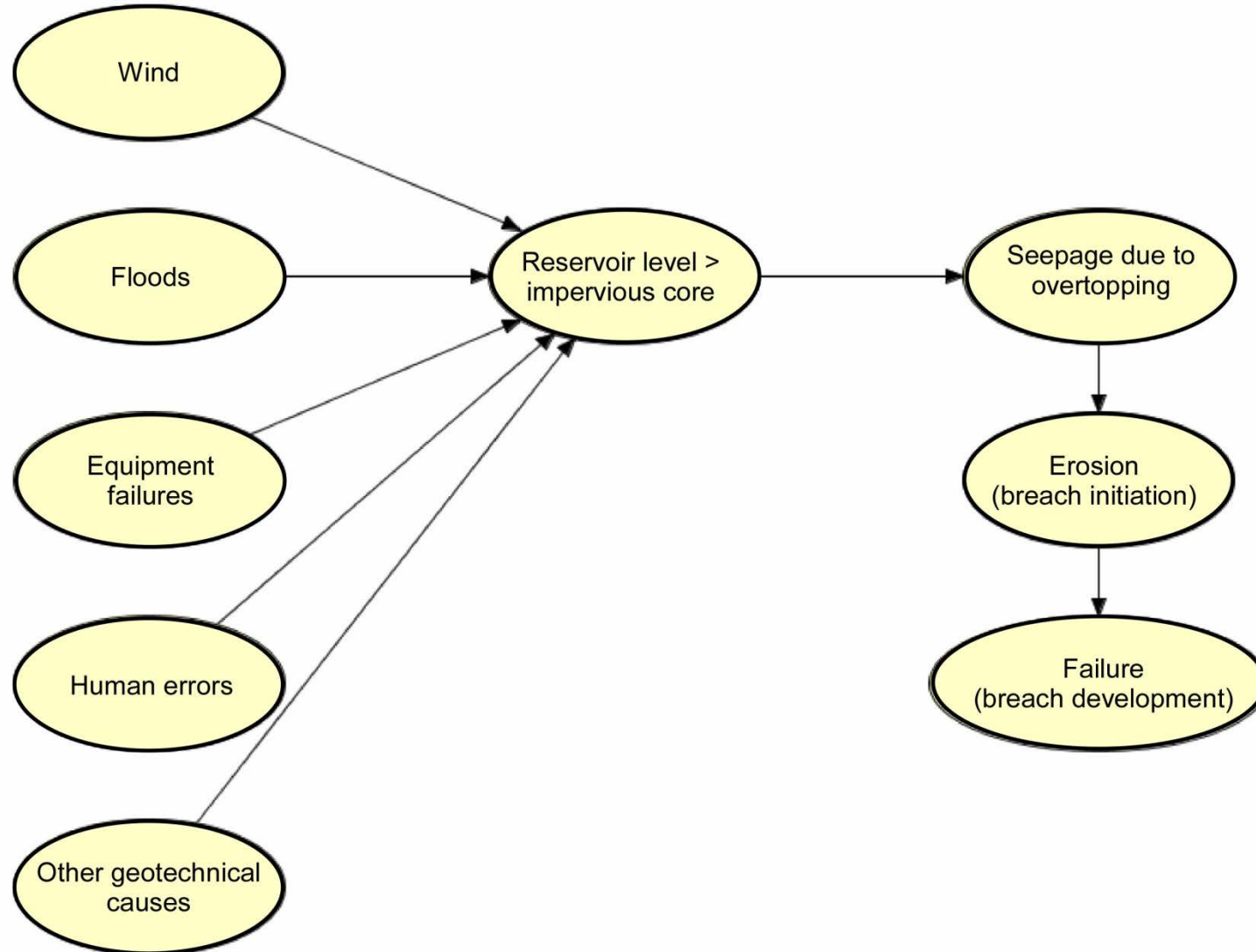
- Ⓐ Highest value between hydraulic freeboard and frost depth
- Ⓑ Depending of the spillway capacity
- Ⓒ To avoid core overtopping



Hydraulic Freeboard

Safety check flood	Recurrence of the wind used
CMP	20 years
10 000 years	100 years
1 000 years and less	1 000 years

Failure Mechanism (global) - Core Overtopping

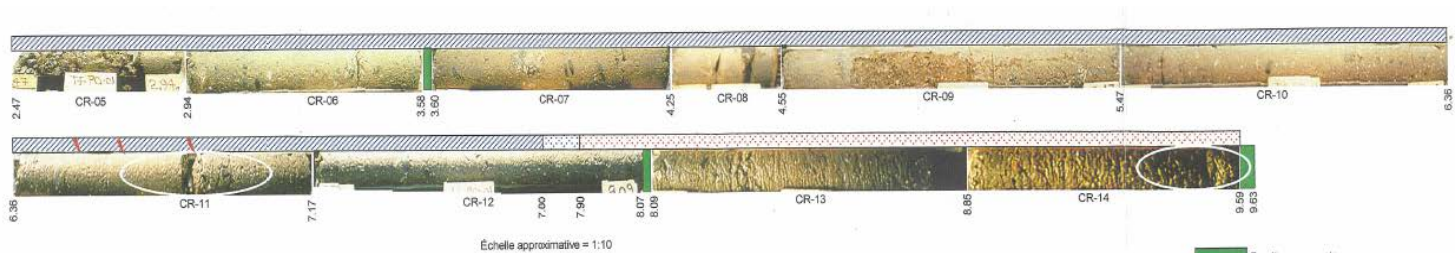


Smith, 2010

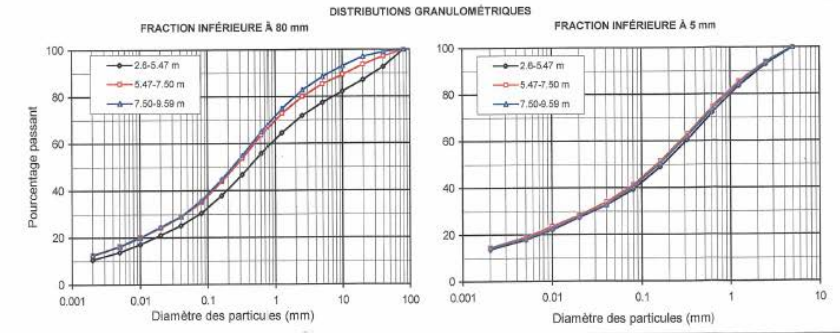
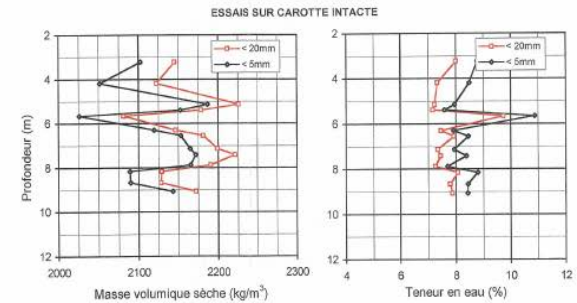
Riprap Design



Frozen Till – Dam Core Drilling



SYNTHÈSE DES OPÉRATIONS ET DU CAROTTAGE														
Course No	Forage		Récupération				Longueurs (cm)				Profond. estimée		Carotte manquante	
	de	à	Photo No	de	à	Individuelle forée	Cumulative récup.	Individuelle forée	Cumulative récup.	de	à	Long. (cm)		
CR-05	2.47	2.94	F-01-01	2.47	2.94	47	47	47	47					
CR-06	2.94	3.60	F-01-03	2.94	3.58	66	64	113	111	3.58	3.60	2	Usée au forage.	
CR-07	3.60	4.25	F-01-04	3.60	4.25	65	65	178	176					
CR-08	4.25	4.55	F-01-06	4.25	4.55	30	30	208	205					
CR-09	4.55	5.47	F-01-07	4.55	5.47	92	92	300	298					
CR-10	5.47	6.36	F-01-08	5.47	6.36	89	89	389	387					
CR-11	6.36	7.23	F-01-09	6.36	7.17	87	81	476	468	8.07	8.09	2	Laissée au fond et détruite.	
CR-12	7.23	8.09	F-01-11	7.17	8.07	86	90	562	558					
CR-13	8.09	8.95	F-01-12	8.09	8.85	86	76	645	634					
CR-14	8.95	9.63	F-01-13	8.85	9.59	88	74	716	708	9.59	9.63	4	Laissée au fond du forage.	

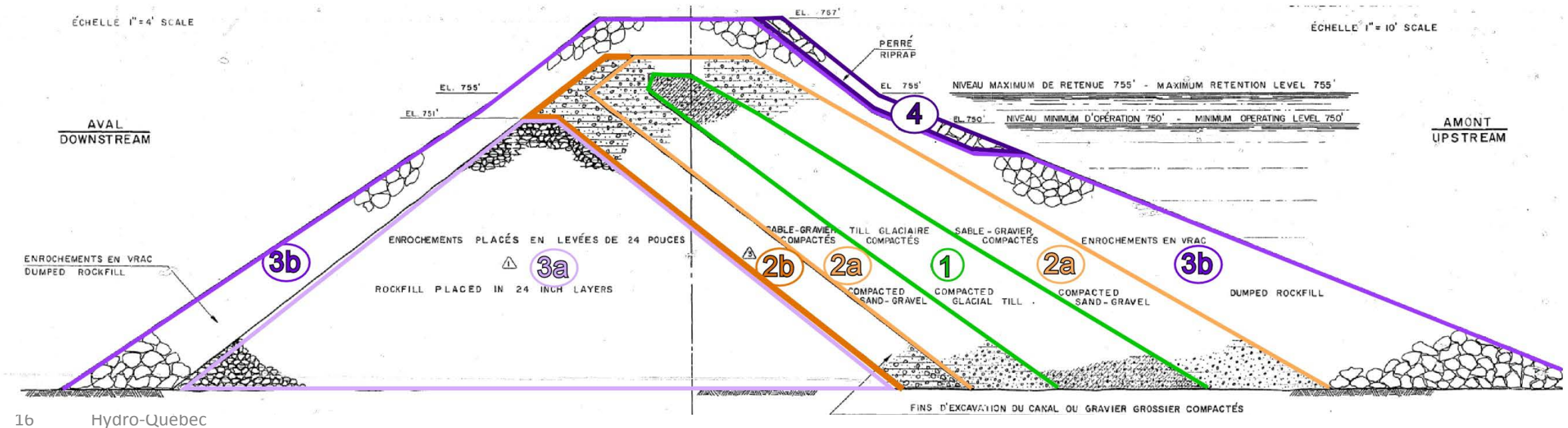


TECHMAT	QUÉFORMAT
CANIAPISCAU	
FORAGE F-01 BARRAGE KA-3	
PHOTOGRAPHIES DES CAROTTES SYNTHÈSE DES OPÉRATIONS ET PRINCIPAUX RÉSULTATS D'ESSAIS	
Juillet 2000	Planche no 6



Core Overtopping (1991)

- ▶ Rockfill dam – Till core
- ▶ Length 500 m
- ▶ Height 33 m
- ▶ Foundation : rock (gneiss) and concrete



Core Overtopping

- ▶ Core overtopping : water level went up to the top of the filters but not in the rockfill (< 1m over the core for < 19 hrs)
- ▶ Inspections during and after the event showed :
 - no deformation or instability;
 - inflow of 3-4L/s.

Issues and Engineering Needs

- ▶ Wind, flood, earthquake, frost, equipment failures, human errors, ...
- ▶ Design, Regulations, Inspection, Safety Reviews, Rehabilitation, ...
- ▶ Research projects: laboratory tests and numerical models

