Trapping large magnitude debris flows induced by massive rock avalanche collapses: The Cheekye debris barrier (Squamish, British Columbia, Canada)

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Séminaire MecaPhyGeo – IRSTEA
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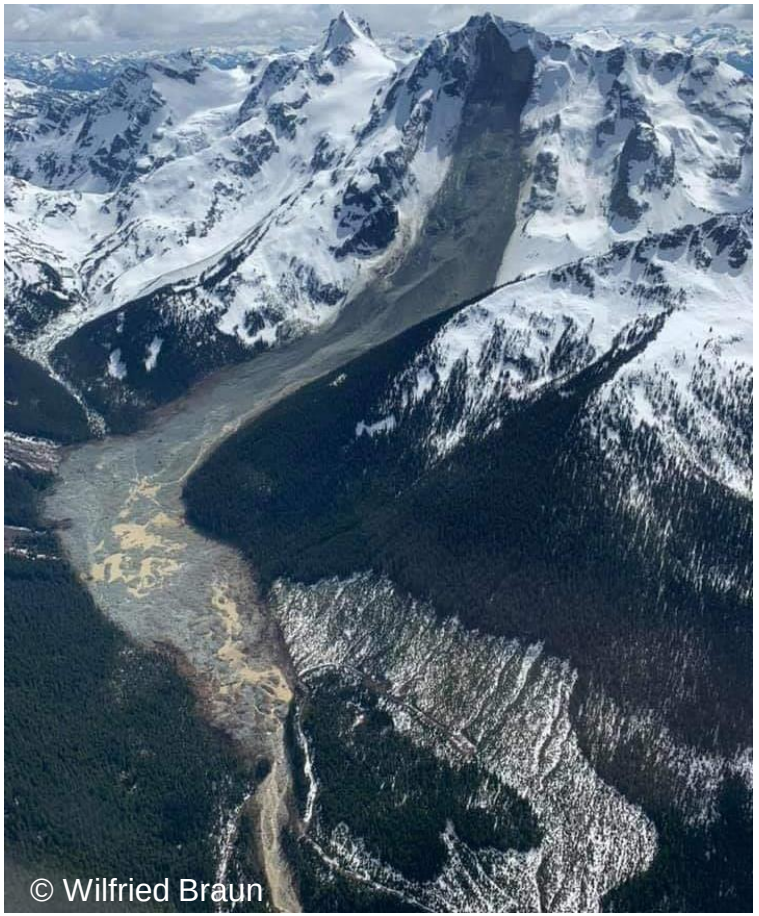
Recent large collapses in British Columbia

Mount Meager collapse: Aug. 2010
(~120 km north to Cheekye)

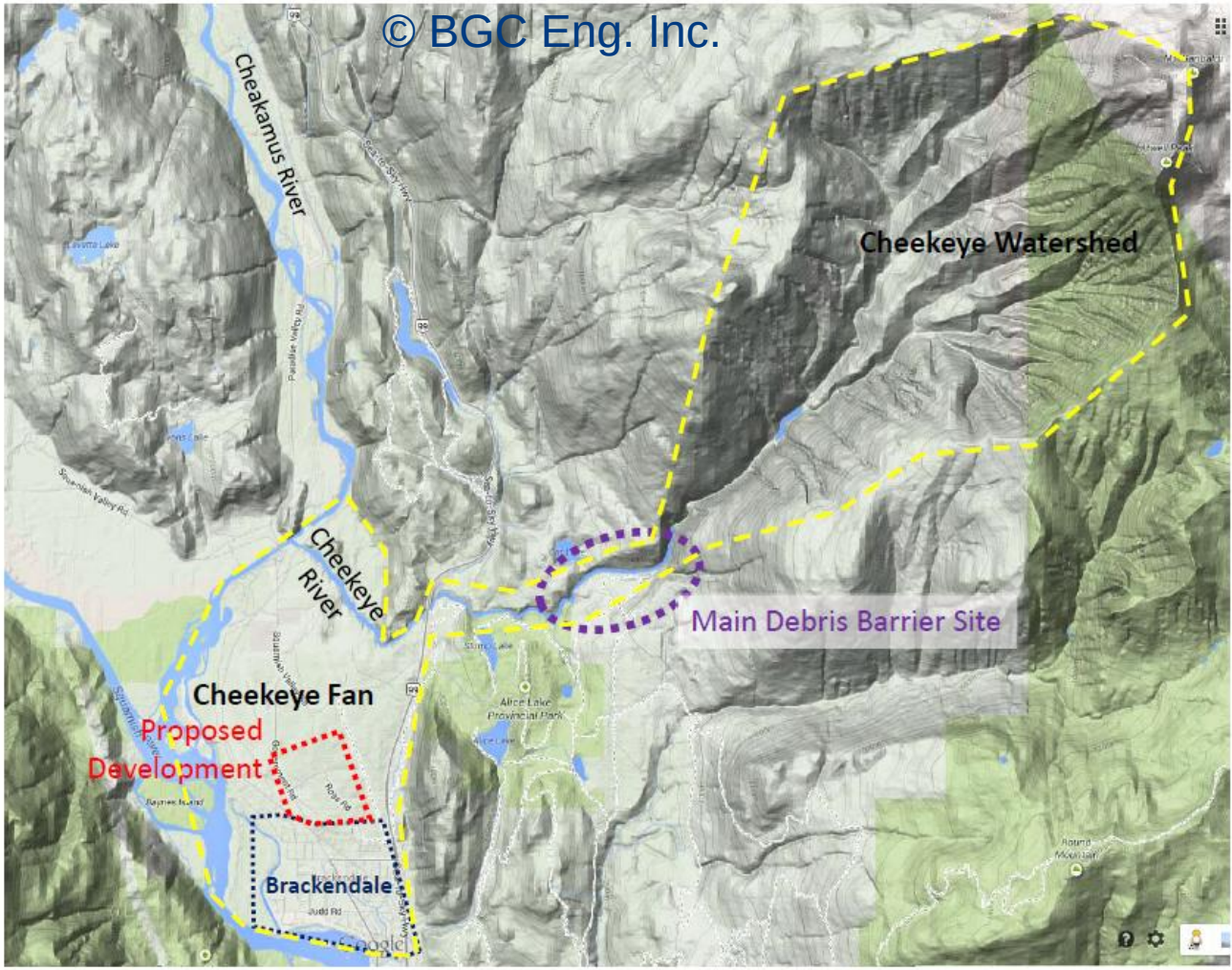


Joffre Peak collapse: May 2019
(~50 km north to Cheekye)

Site map

~ 50 KM NORTH TO VANCOUVER (BRITISH COLUMBIA, CANADA)

© Jakob & Friele (2010 Geomorphology 114: 382–395)

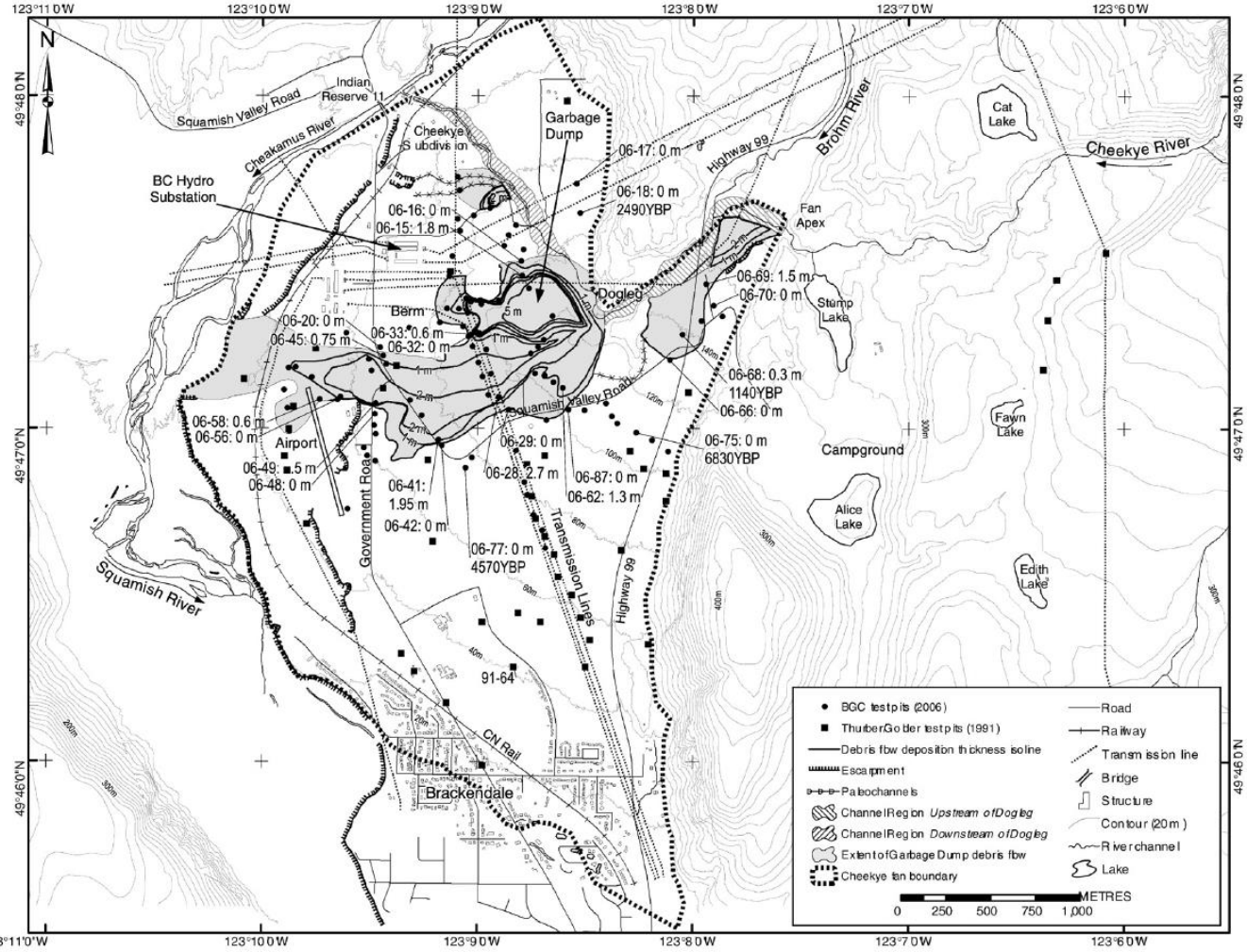


Squamish city

Large scale event during the middle age

COLLAPSE AND DEBRIS FLOW: VOLUME 2.1 Mm^3

© Jakob & Friele (2010 Geomorphology 114: 382–395)



Historical event analysis

UNTIL LAST GLACIATION

5 500 000 m³

Tools:

Sedimentology (fan+side lakes)

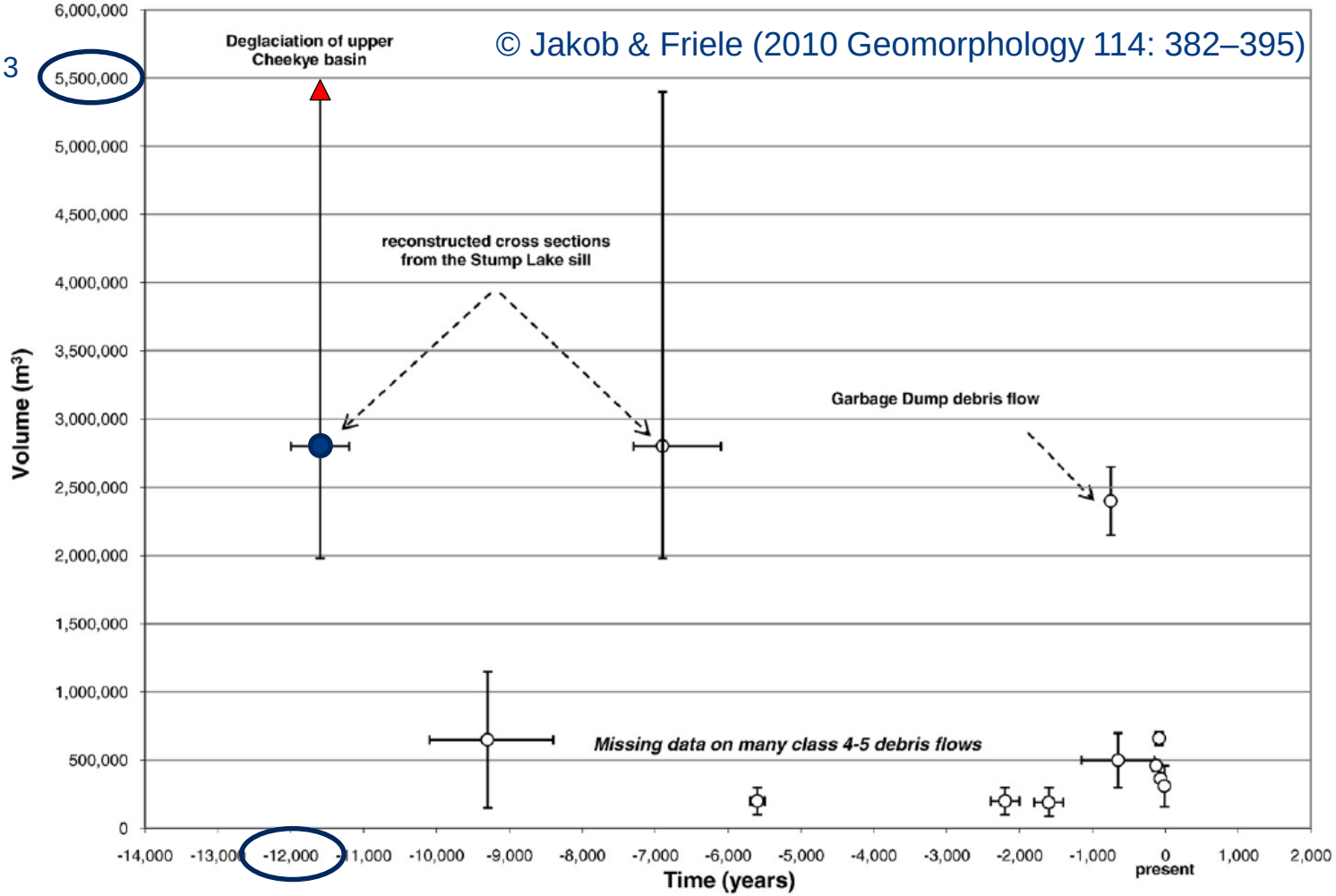
Geophysics

Test pits (100⁺)

Radiocarbon dating

Dendrochronology

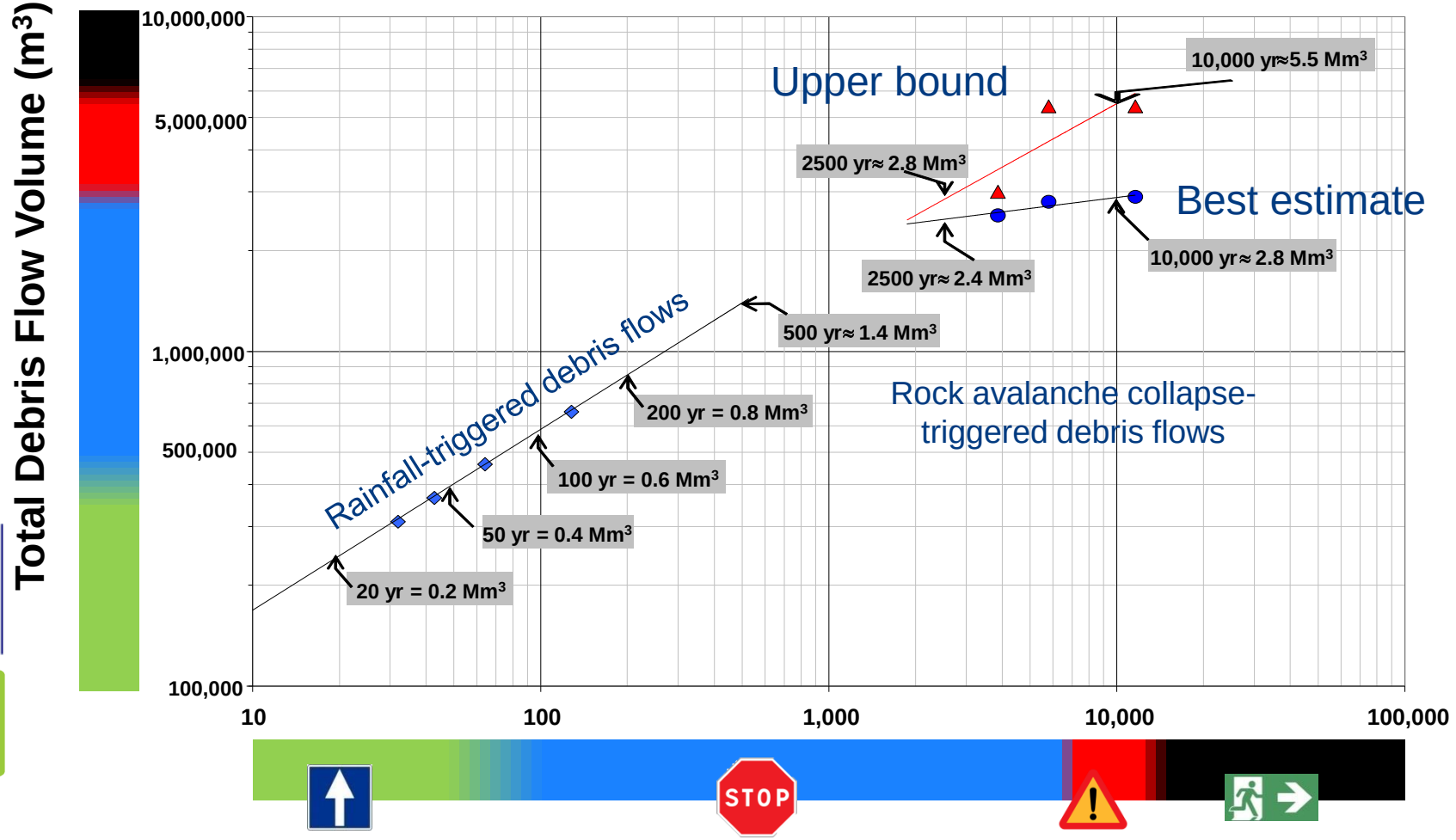
Modelling



-12 000 yr

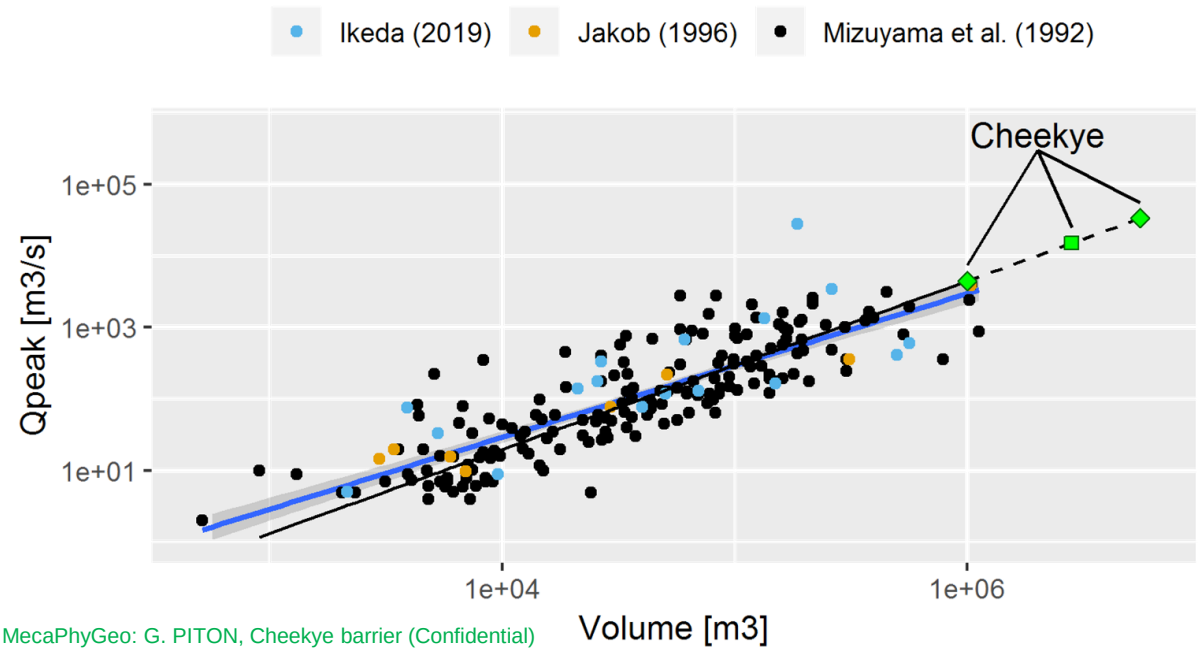
Frequency - magnitude

ADAPTED FROM BGC ENG.



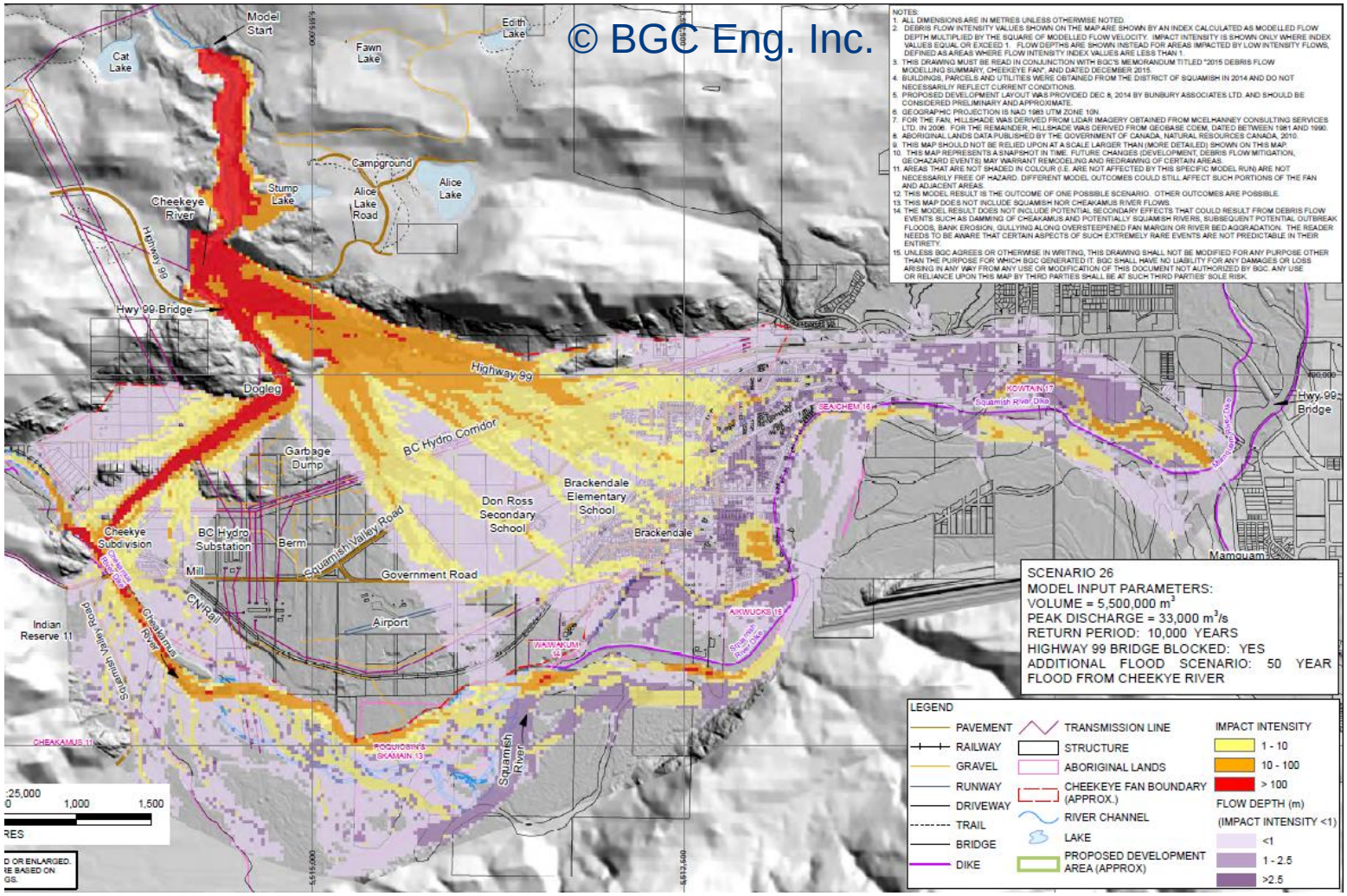
Frequency – magnitude peak discharge

Scenario Name		Scenario Characteristics	
Volume Class	Return period class (years)	Event volume (Mm^3)	Peak discharge (m^3/s)
1	10 to 30	0.2	800
2	30 to 100	0.4	1,600
3	100 to 300	0.8	3,400
4	300 to 1000	1.4	6,600
5	1000 to 3000	2.2	11,000
6	3000 to 10,000	2.8	15,000
6	10,000 – best estimate	2.8[2]	15,000
7	10,000 – upper bound	5.5	33,000



Debris flow spreading 2D modelling

UNCERTAINTIES: RHEOLOGY (3) & AVULSION POINT (4)



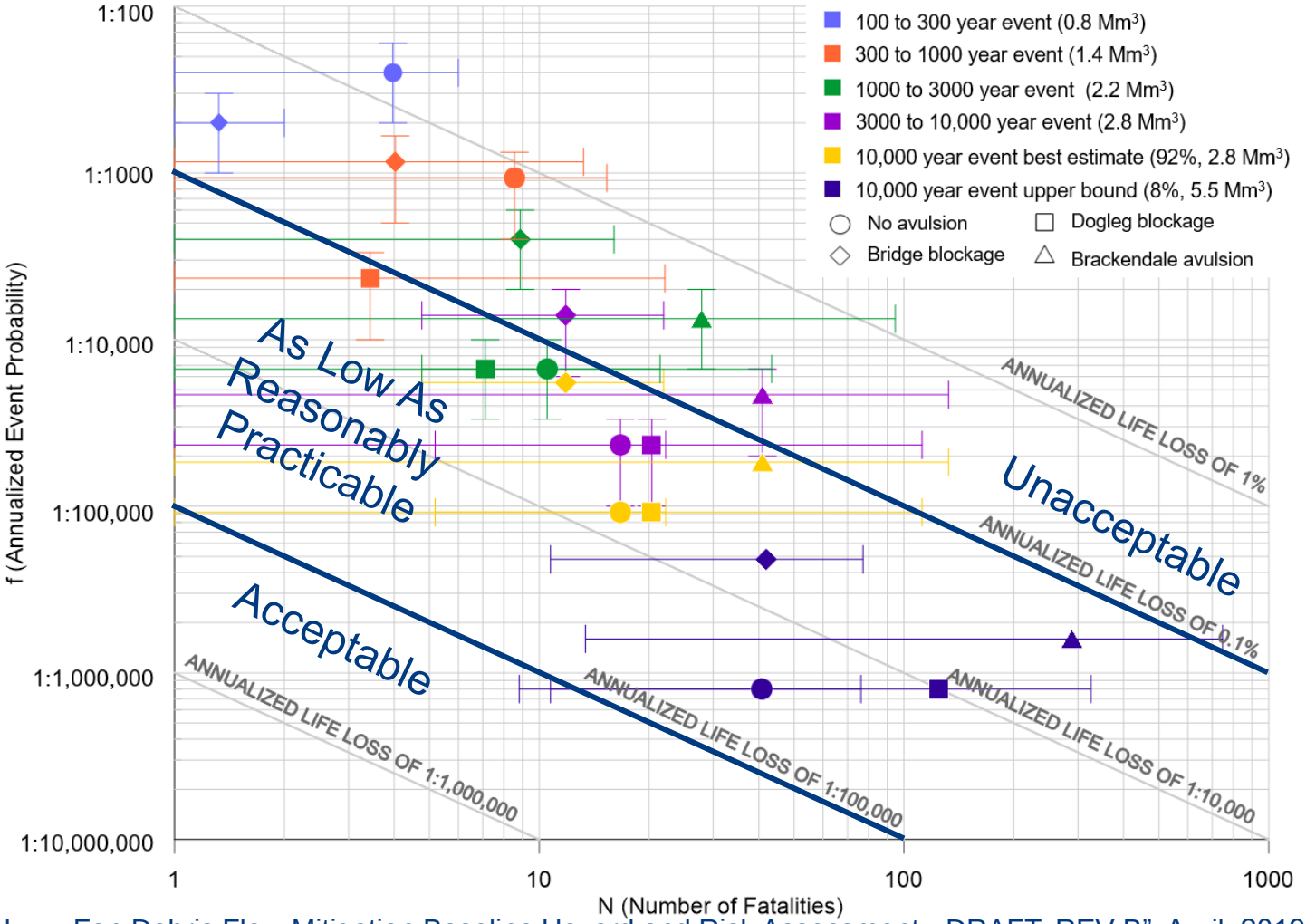
Risk-based assessment: safety approach

INCLUDING PROBABILISTIC UNCERTAINTY PROPAGATION

Uncertainties:

-Rheology (error bars)

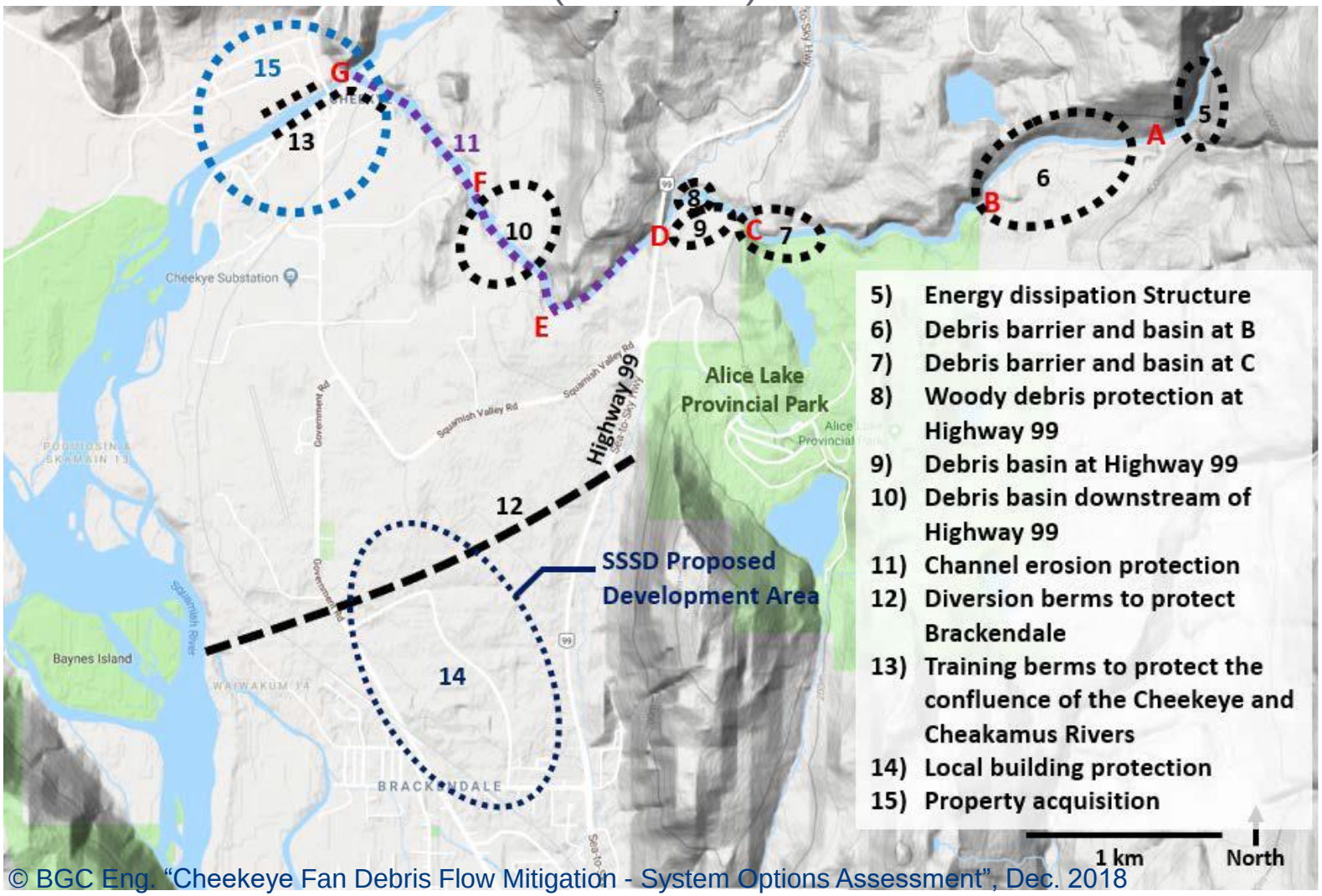
-Avulsion point (dot shape)



© BGC Eng. “Cheekeye Fan Debris Flow Mitigation Baseline Hazard and Risk Assessment - DRAFT, REV B”, April. 2019

15 debris flow mitigation measures considered

→ BEST OPTION: BARRIER (OPTION 6)



© BGC Eng. "Cheekeye Fan Debris Flow Mitigation - System Options Assessment", Dec. 2018

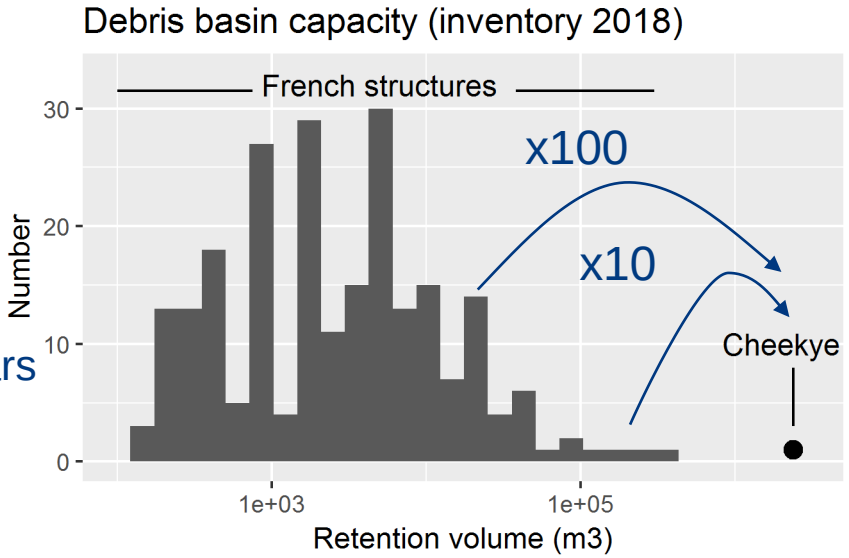
A (very large) barrier

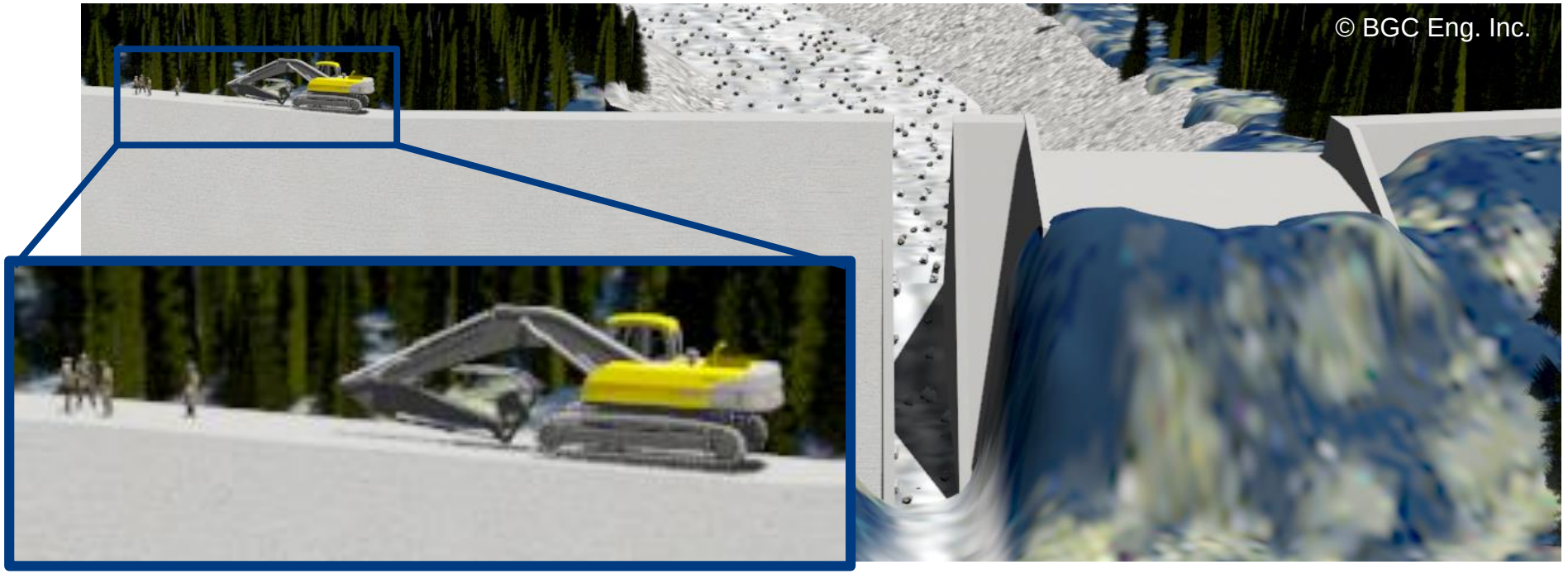
BIGGEST IN NORTH AMERICA

Project design event exceedance probability
1:3 000 -1:10 000 years

Project design event volume 2.8 Mm^3

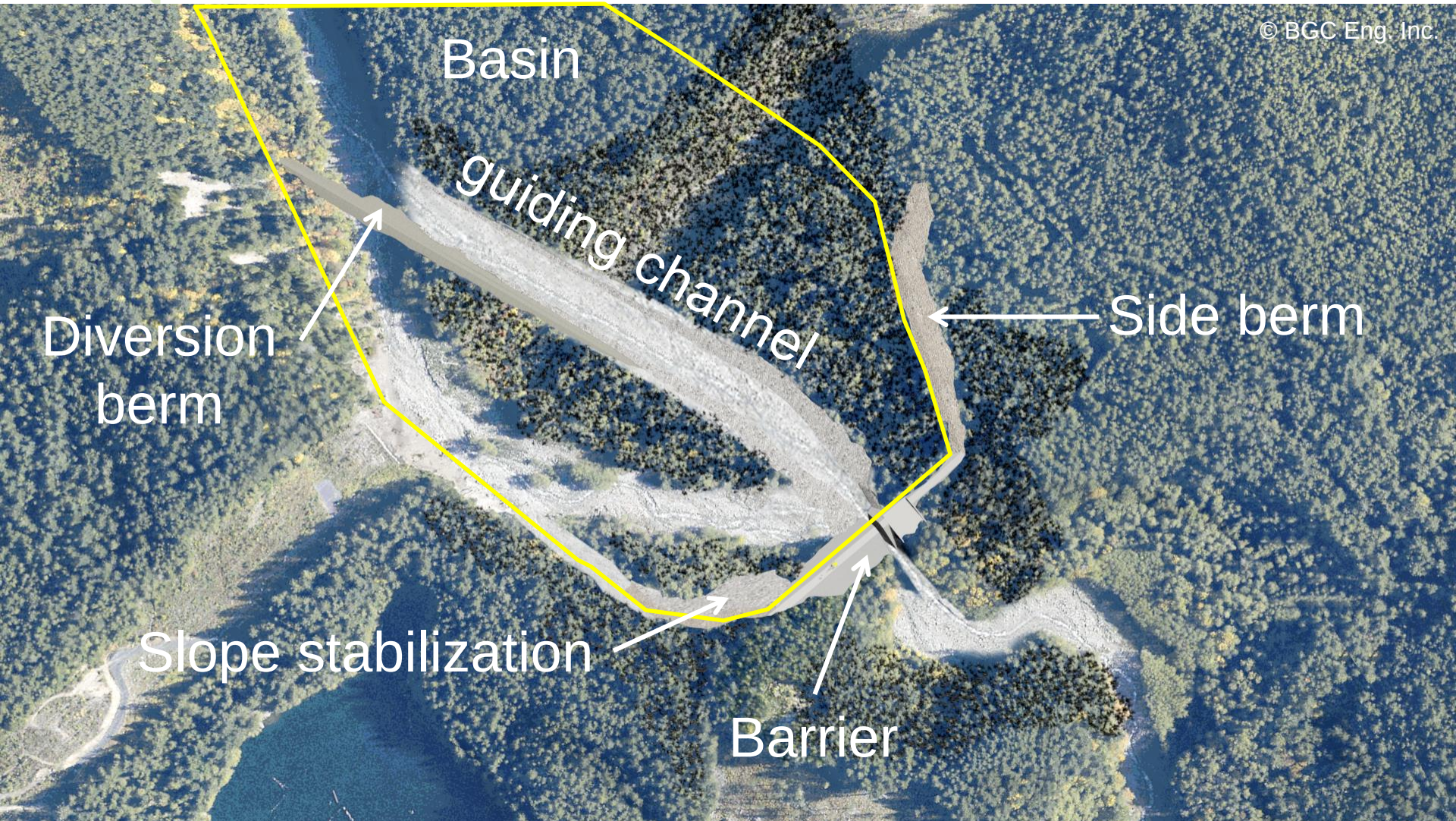
Dam height 25 – 35 m





Draft 3D view – Preliminary design

AERIAL VIEW

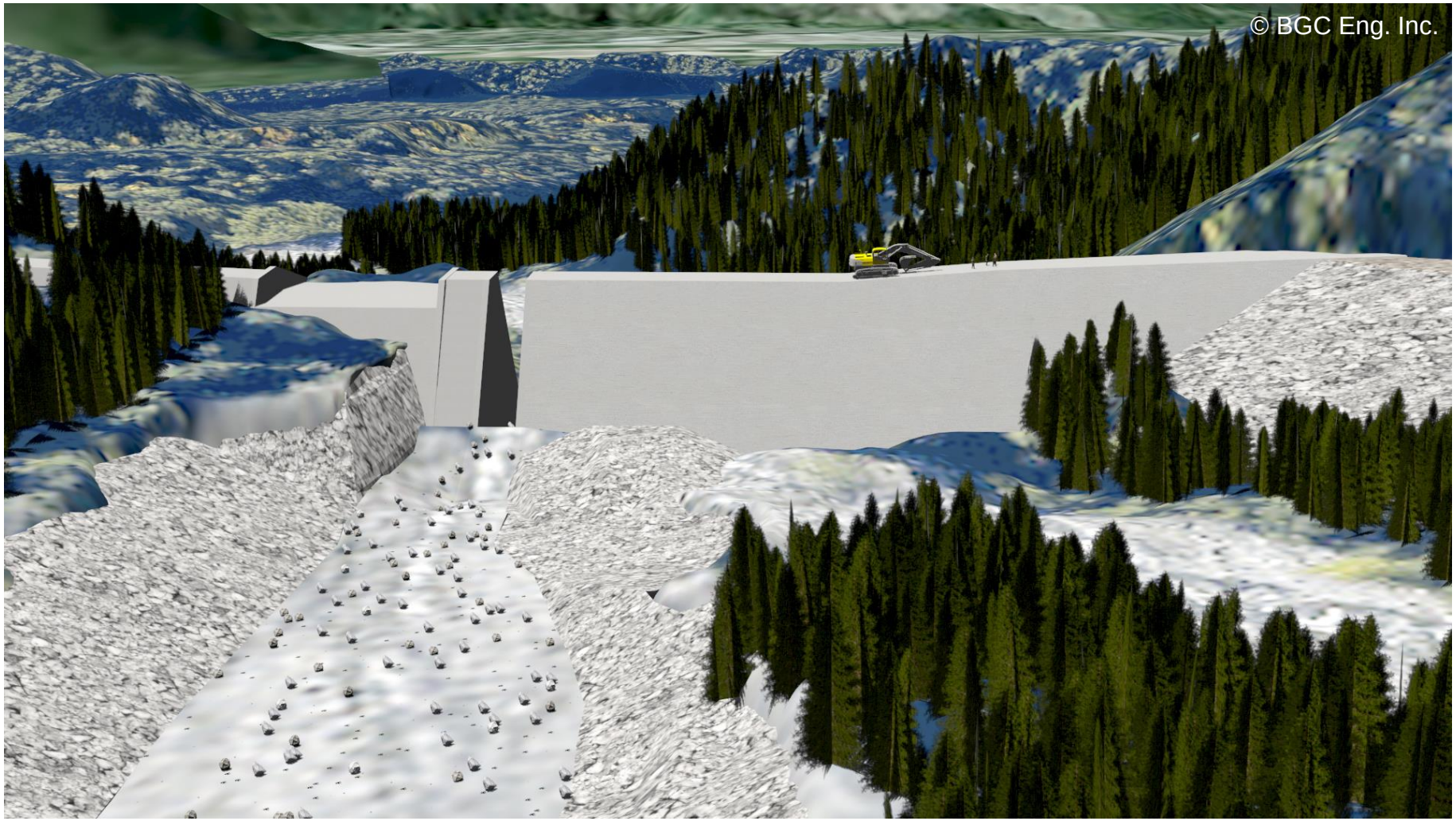


Draft 3D view – Preliminary design

BASIN AND BARRIER VIEW

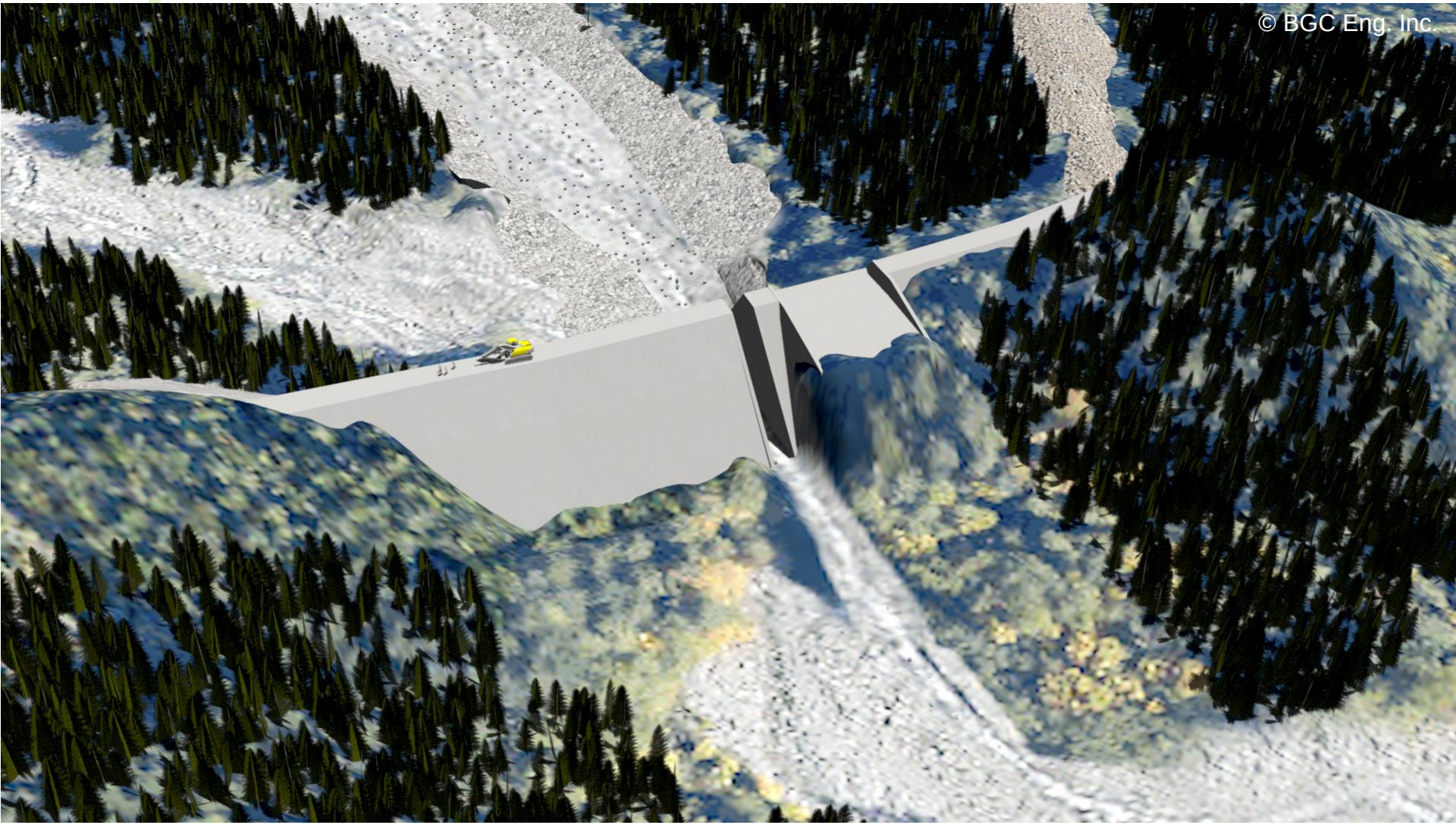
Draft 3D view – Preliminary design

VIEW FROM UPSTREAM



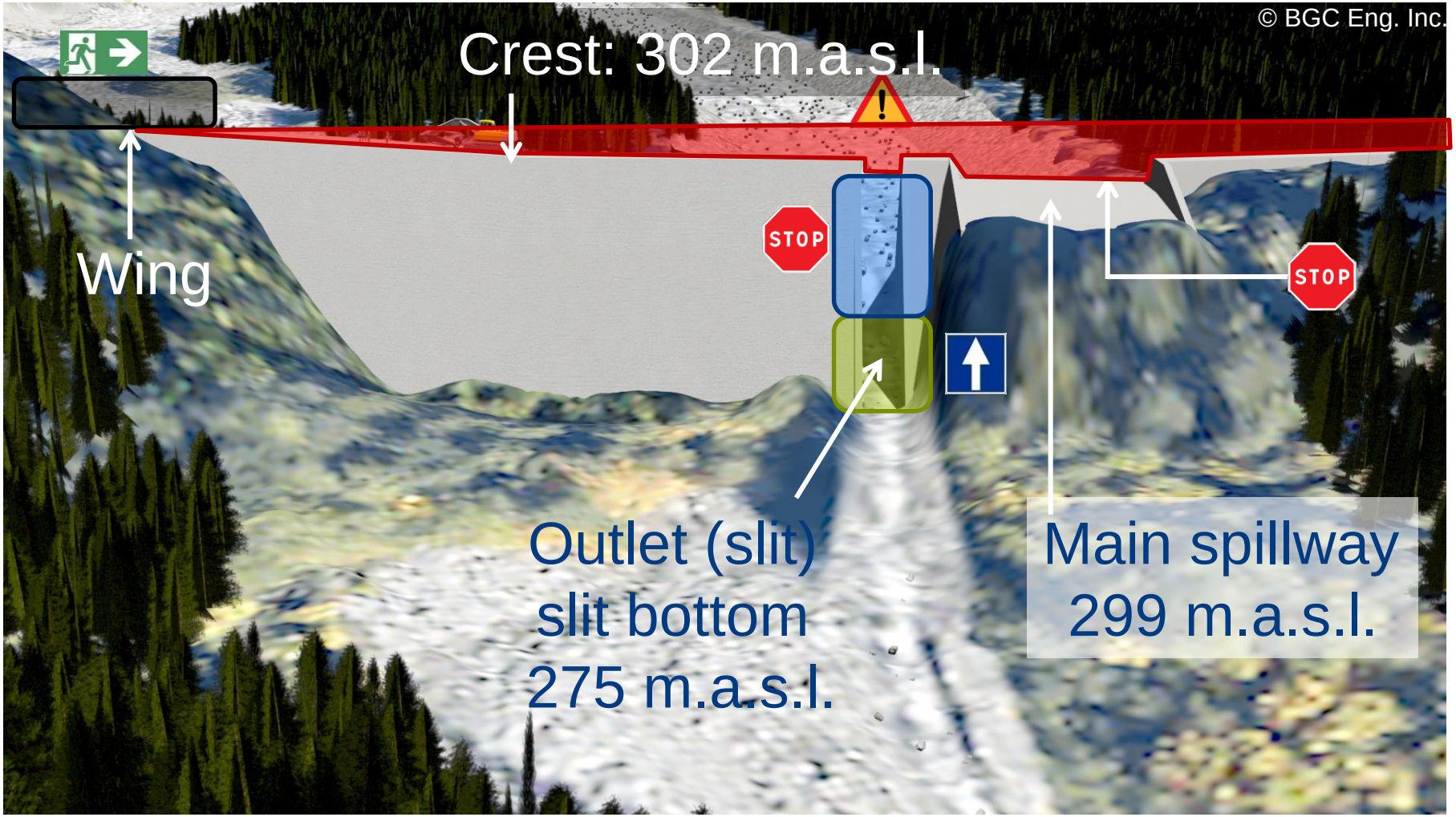
Draft 3D view – Preliminary design

VIEW FROM DOWNSTREAM



Draft 3D view – Preliminary design

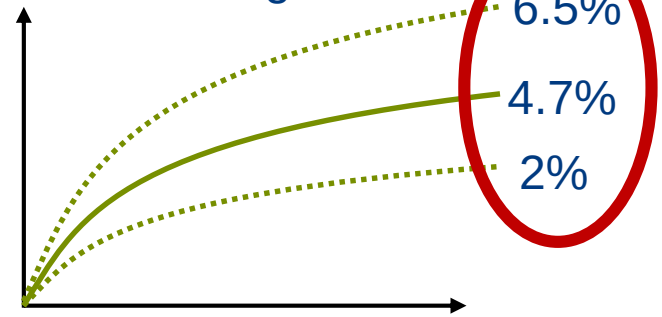
VIEW FROM DOWNSTREAM

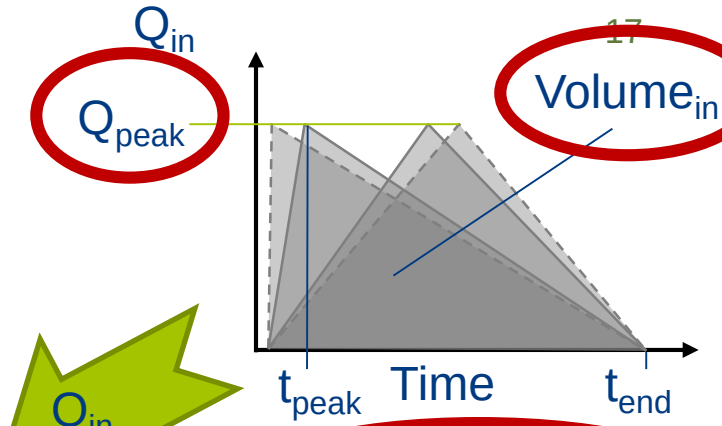


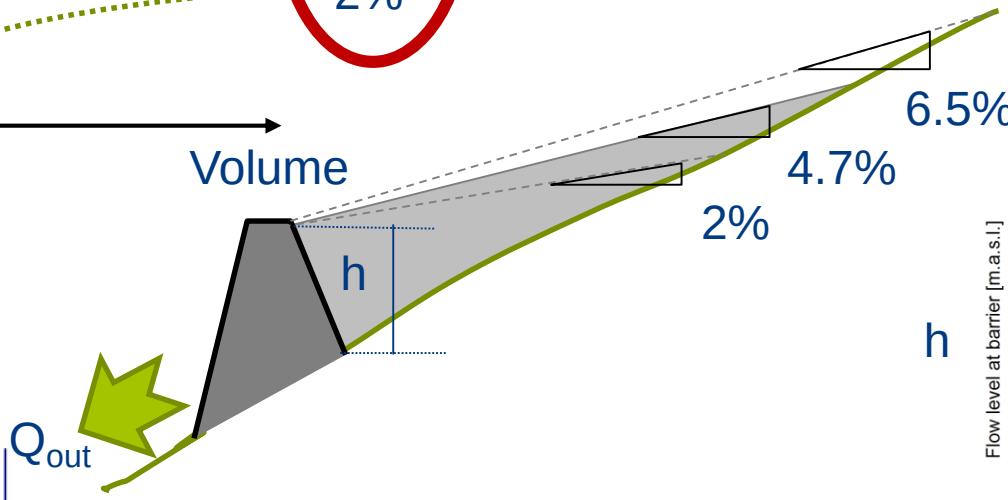
Flow buffering model

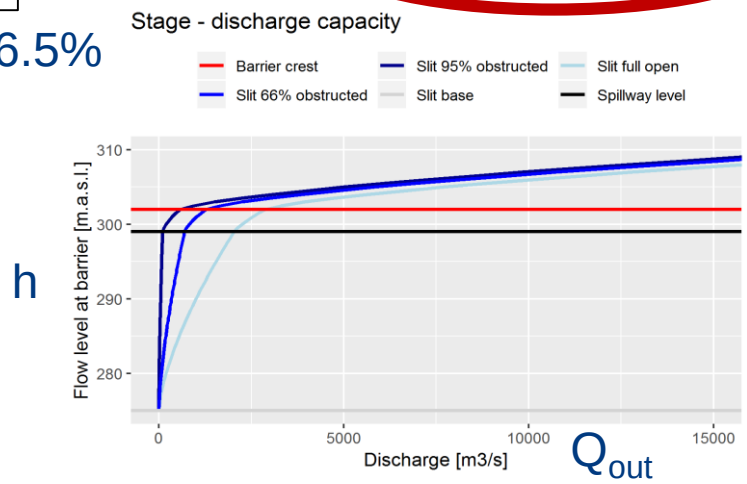
RESERVOIR MODEL

h: Flow height









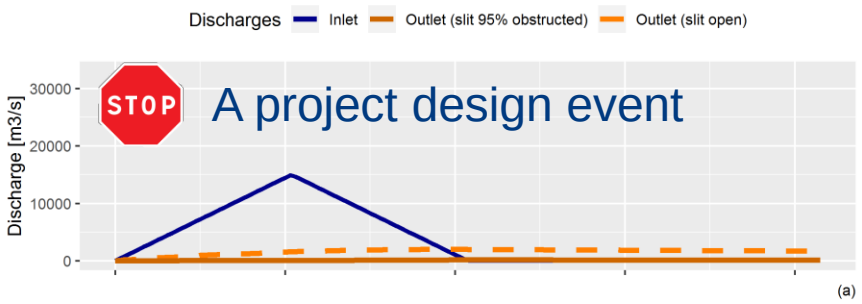
$$Q_{out} \propto W_{slt}(1+\alpha_{slt})\sqrt{h^3} + W_{spillway}(1+\alpha_{spw})\sqrt{(h-h_{spw})^3} + W_{crt}(1+\alpha_{crt})\sqrt{(h-h_{crt})^3}$$

$$Volume(t) = \int_0^t \left(Q_{in}(t) - Q_{out}(t)\right)dt$$

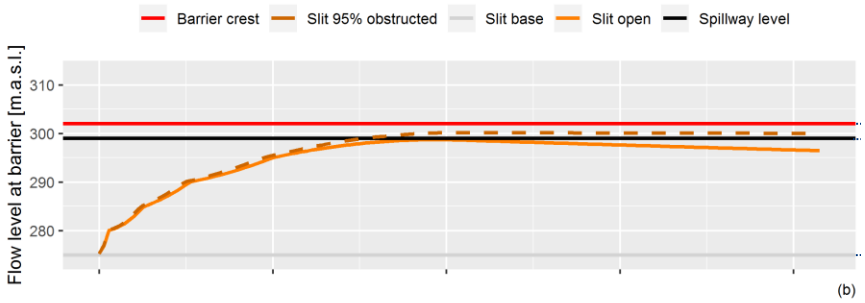
Flow buffering model

RESULTS

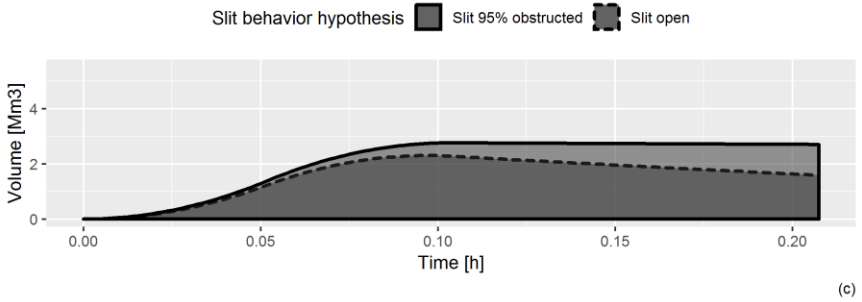
Max discharge released = 200 - 2000 m3/s, i.e., buffering = 87 - 99 %



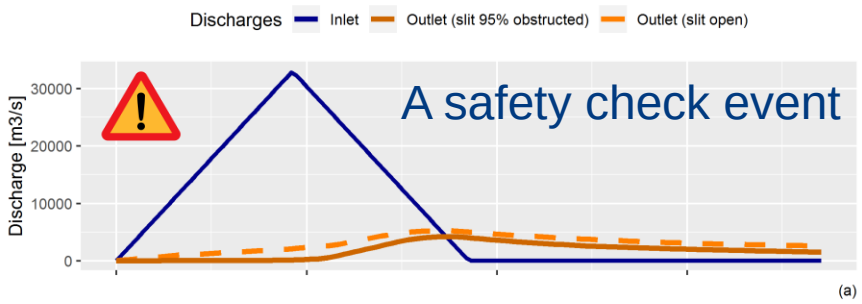
Max level at barrier = 298.71 - 300.13 m.a.s.l.



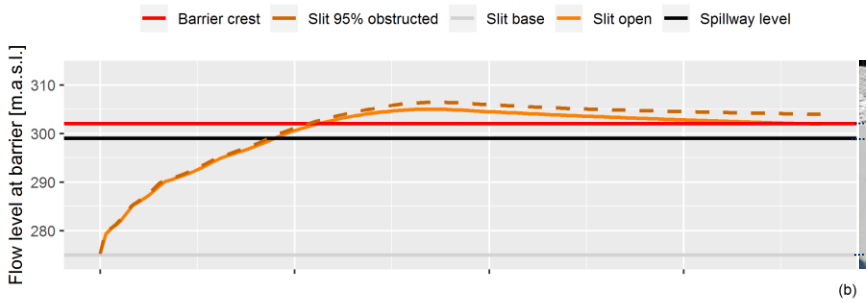
Max stored volume = 2.3 - 2.76 Mm3

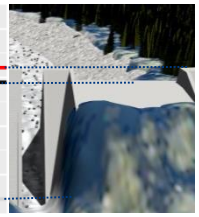


Max discharge released = 4200 - 5200 m3/s, i.e., buffering = 84 - 87 %

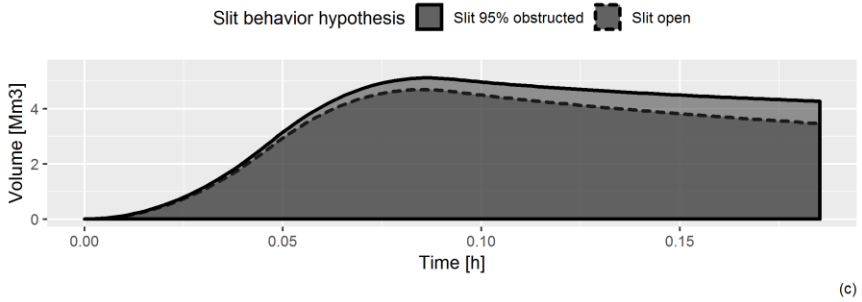


Max level at barrier = 304.97 - 306.4 m.a.s.l.





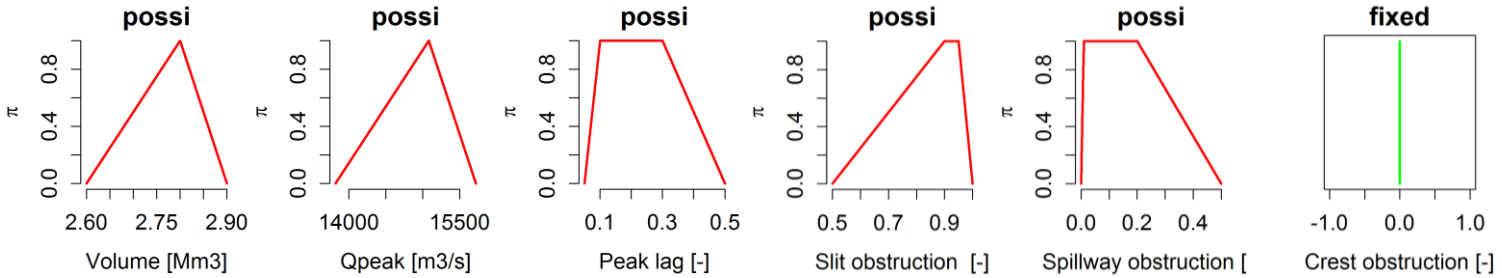
Max stored volume = 4.69 - 5.12 Mm3



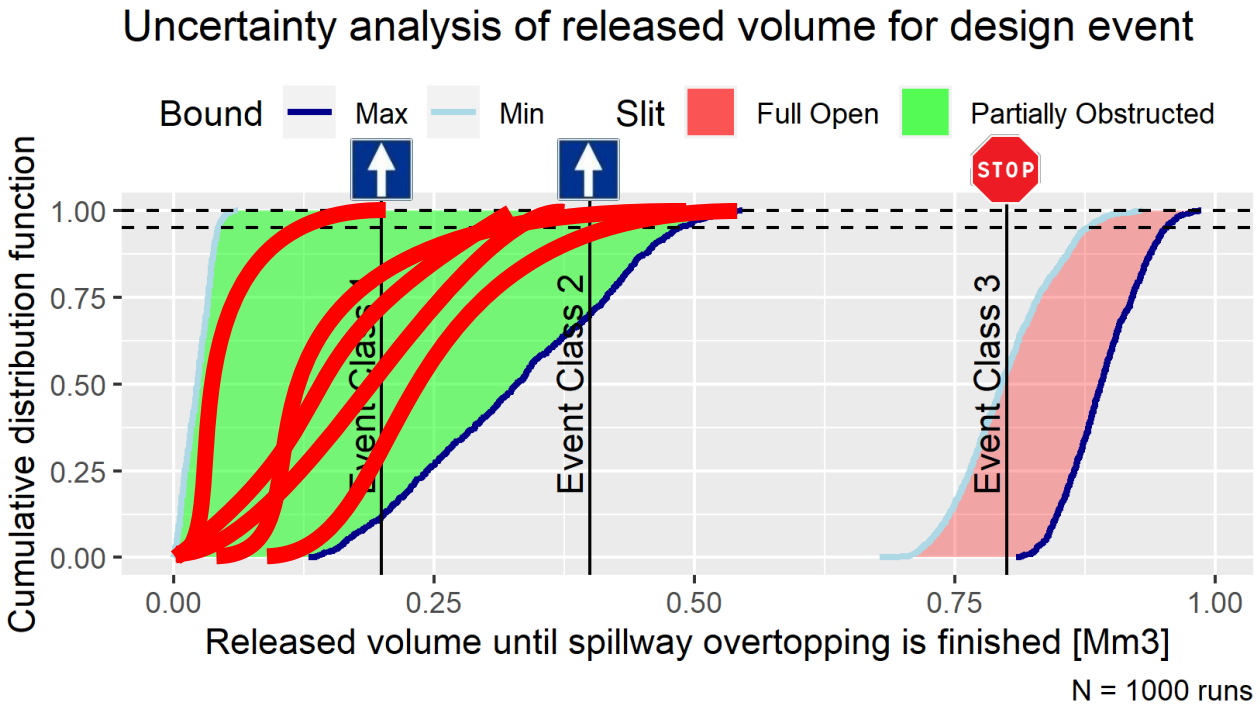
[Design event]

How much volume can be released?

FOR SLIT WIDTH DESIGN VERIFICATION



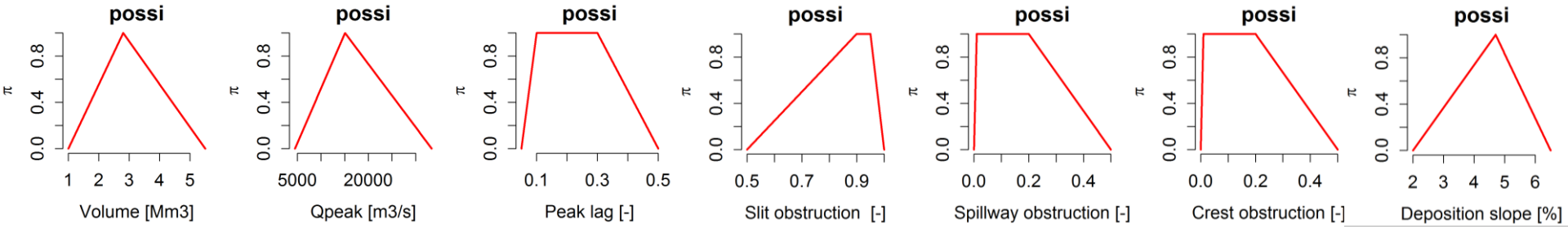
Baudrit et al. (2006) IEEE Transactions On Fuzzy Systems, 14(5):593-608

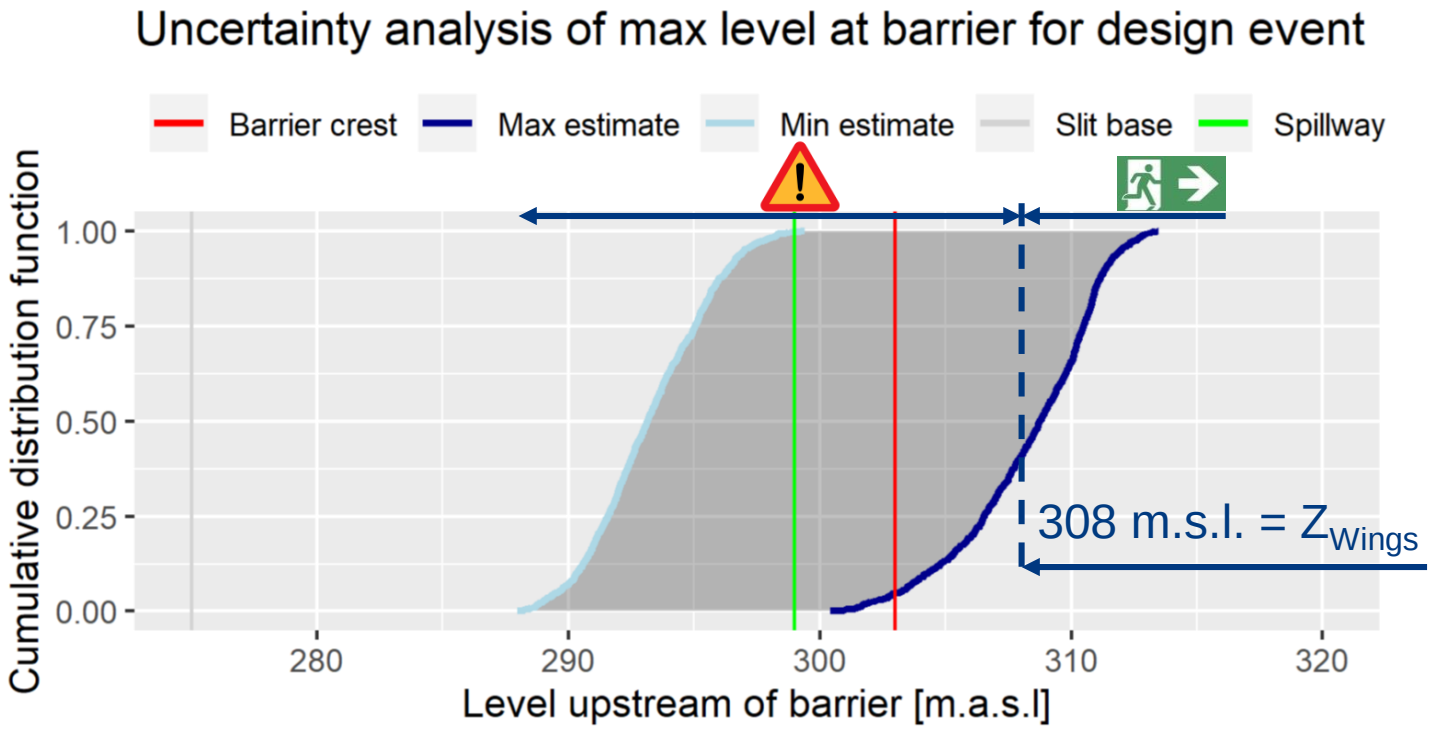


[Safety check & danger events]

How high will debris flow level rise?

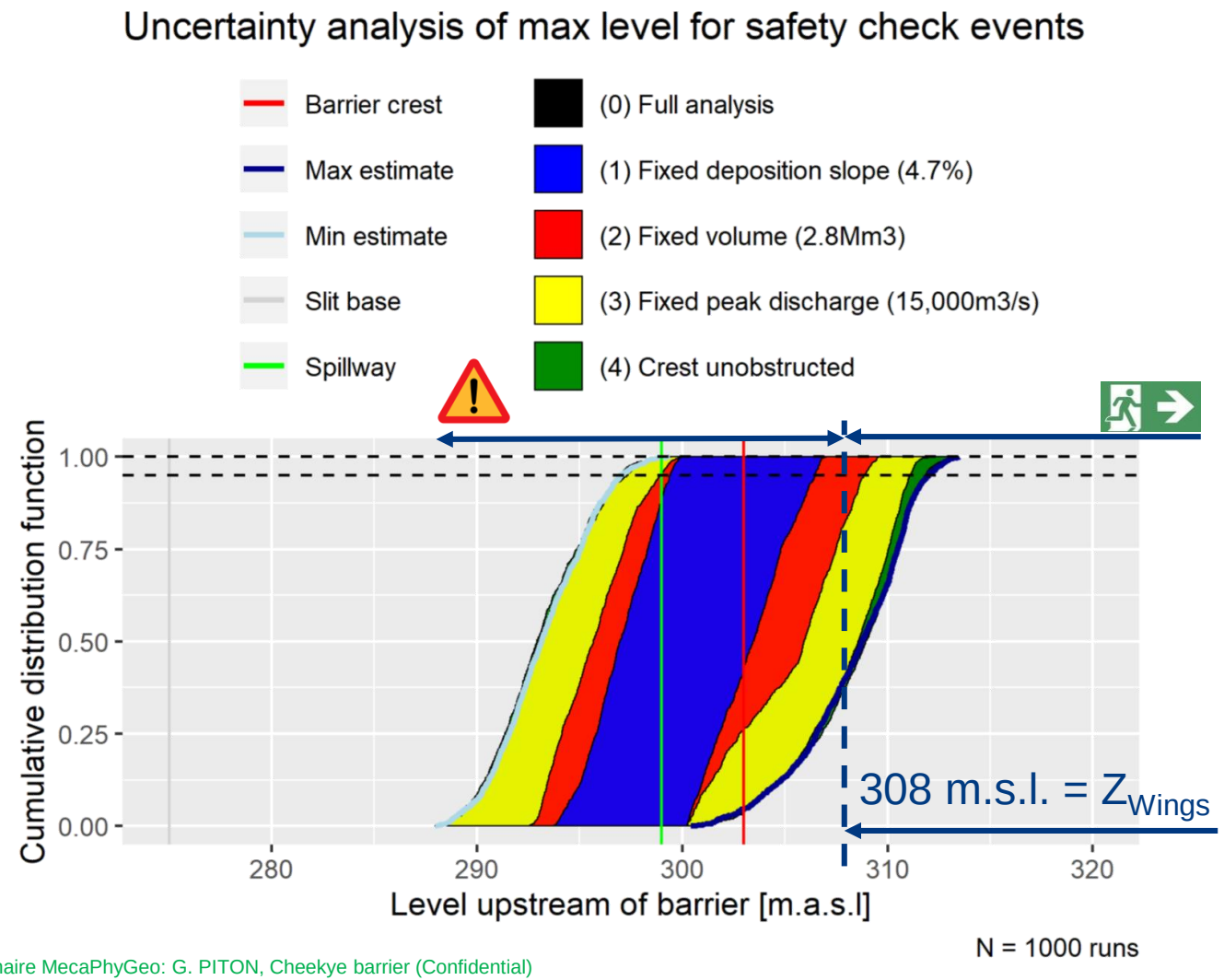
FOR WING DESIGN AND OUTFLANKING FAILURE ANALYSIS





How high will debris flow level rise?

FOR WING DESIGN AND OUTFLANKING FAILURE ANALYSIS



Conclusion

Most studied alluvial fan in Canada

Development project for residential purpose

Evidences of large scale debris flow events (“silent witnesses”)

Risk based approach demonstrating unacceptable risk (current & project)

Debris flow barrier best option → biggest barrier in North America

IRSTEA: scientific advisor → review functional design & implement hybrid uncertainty propagation methods