Appendix A

Photographs

Photo 1

Photo 2

Photo 3

Photo 4


Photo 5


Photo 6

Photo 7

Photo 8

Photo 9

Photo 10

Photo 11

Photo 12

Photo 13

Photo 14

Photo 15

Photo 16


Photo 17

Appendix B

Forms B1 and B2

Form B1

Ministry of Natural Resources
Northeast Region

Pre-Inspection Background Information

Prepared By:	Acres International Limited
Name of Dam:	Crook's Hollow Dam
Latest Construction:	Originally constructed in1913, repaired in the 1970's
Last Inspected:	1993
Access:	From Highway 8 turn north at Crook's Hollow Road and drive about 1.5 km, the dam is located on the right hand side of the road.
Lake Controlled:	Run-of-river, very limited storage.
Lake Area:	Less than 1 km^2
Watershed:	Spencer Creek
Drainage Area:	157.9 km^2
Gauge Info: **(BM; Location, RWL)**	Near station 02HB007 (Spencer Creek at Dundas)
Rule Curves:	Seasonal operation (twice per year)
List of Drawings:	n/a
Geological References:	-
Dam Height (to sill):	6.1 m
Dam Length:	36.6 m
No. of Sluiceways:	4 (3 overflow weirs one stop-log bay)
No. of Stop Logs per Bay:	7, formerly 9

Hydrologic Flows: OTTHYMO model (HCA)

Hydraulic Analysis: Rating curves available

Soils Reports: Peto MacCallum Ltd, 1992

Underwater Inspections: No

Divestment Opportunities: May be a candidate for removal

Known Problems: Leakage, stability problem at high water level

Summary of File:

Form B2

Hamilton Conservation Authority

Dam Inspection Report

Date:	May 27, 2005
Structure:	Crook’s Hollow Dam
District/Area:	City of Hamilton
Location:	Spencer Creek near Crook’s Hollow Road
GPS Coordinates:	43°16’30” 79°59.5’W
Inspected By:	Bruce MacTavish, Ross Zhou, Brain Sinclair
Weather:	Clear sky

---

1. Earth Embankment (including emergency spillway)

N/A

---

2. Concrete Structures (wingwalls, piers, deck, spillways, apron, etc)

Concrete surface of the dam in good/fair conditions. On the upstream face under normal water level, on the north side, there is an area that the concrete surface is falling apart and loose. Repair is needed.
The wall downstream of the dam on the north bank is broken pushed toward the river.
Leakage was observed at the toe of the north bank and south bank.
Most surfaces coated with remedial “shotcrete” in fair condition. Internal concrete mass is reported to be in poor condition.

---

3. Wooden and Metal Structures (decks, gains, railings, conduits, etc)

Deck metal is in good/fair conditions; need painting.

---

4. **Gates and/or Stop Logs** (identified looking downstream left to right)

Removed stop logs were not stored on the damsite. The conditions of the stop logs installed were difficult to evaluate since they are under water.

---

5. **Water Level Gauge** (reading and condition)

Not installed on the damsite.

---

6. **Winches** (type and number)

Fixed winches on the dam locked all the time. The winches are in working conditions but no capacity rating is known for this lifting hardware.

---

7. **Valves** (type and number)

One low level pipe for low flow augment.

---

8. **Boom** (driftwood, chains, anchors)

Not applicable.

---

9. **Erosion** (upstream and downstream)

No sign of erosion on the river banks.

---

10. **Seepage or Leaks**

Seepage is observable on both banks downstream of the dam. The seepage on the north bank through the concrete might come from groundwater behind the concrete cutoff wall (may not come through the dam body). Further investigation is required to confirm the source of the seepage.

---

11. **Access Route** (location of gate keys, winch handles and keys)

Access by drive year-round from Crook's Hollow Road. No gate to prevent public access to the dam.

---

12. Safety Issues (public and operator)

No warning signs are installed on this dam. Public access is easy on both sides of the dam.

---

13. Divestment and/or Decommissioning Opportunities

The dam is currently serving recreational purpose only. No other benefit is gained. The dam may be a candidate for removal.

---

14. General Remarks

The dam is a small structure which is located downstream of the Christie Dam. There is a possibility that the dam cascade fails due to the failure of the Christie Dam, which is a much larger structure. The cascade effect should be evaluated by a detailed dam break simulation.

---

15. Recommendations

Warning signs should be installed in accordance dam safety requirement established by the draft dam safety guidelines (OMNR, 1999)

Appendix C

Dam Operator’s Questionnaire

Dam Safety – General Dam Operator Questionnaire

It is recommended that the dam operator complete this questionnaire for each site at the start of a Dam Safety Review.

This questionnaire will update information on discharge facilities and operating equipment. The information will be used to conduct the Dam Safety Review. The information is broken down into the following categories:

Part I - Site Description
Part II - General Operational Information
Part III - Hydraulic Discharge and Operating Facilities
  A. Discharge Facilities
  B. Operating Equipment
  C. Operating Problems
Part IV Past Dam Incidents
Part V Emergency Preparedness Plan (EPP) Information

Throughout the questionnaire, the following definitions of spillway and sluice apply:

Spillway — A structure over which flood flows are discharged. The discharge is uncontrolled, i.e., an overflow structure.
Sluice — A structure through which flood flows are discharged; the flow is controlled by gates, stop logs or valves.
An emergency — Severe flooding, possible dam failure conditions or a person(s) in danger from a boating accident or drowning.

Office: Hamilton Conservation Authority   Watershed: Spencer Creek   Site: Crooks Hollow

Prepared by: Alex Bouwmeester   Date: May 19, 2005

Person(s) to contact for additional information:

Name: George Stojanovic   Telephone: 905-525-2181, ext 137

Questions	Answers/Observations/Comments
Part I –Site Description (To be completed prior to distributing questionnaire. Data to be reviewed and confirmed by Operating Staff)	
1. Facilities Summary **Type**	**Number**
Sluices –gate N/A	
Sluices –log 1 sluice	3 logs in, 4 to come = 7 (formerly 9) (i.e., 2 logs stolen 3 years ago)
Sluices –valve (Manufacturer, size, type, etc)	Unknown
Debris boom None	
Non-overflow walls – on either side of spillway	
Spillways/overflow walls	2 on right-hand side, 1 on left-hand side (complete with stop log gains that are unused)
Upstream retaining walls	Either side of sluiceways
Downstream retaining walls	Partial (containing earth fill)
Other –	
2. Elevation Datum (Canadian Geodetic Datum (CGD) or other - specify)	? (Staff gauge no longer in place)

Part II - General Operational Information	
3. Please list any major repairs/maintenance since construction that you know of.	- New (approximately 10 years old) steel deck and railings (galvanized) - Shotcrete on all concrete surfaces
4. (a) Who operates this site?	☐ Contractor ☒ Other_ HCA October/November – logs out, May – logs in Contact person HCA Christie Dam staff Legal Agreement in place? n/a
(b) How many staff are normally available to operate the site?	6 (move logs manually across dam)
(c) Is this person/team responsible for operating other sites? (d) If yes, where?	☒Yes ☐No Christie Dam
(e) If answer to (c) is yes, is there sufficient staff to operate these sites simultaneously?	☐Yes ☐No Not necessary
(f) If answer to (e) is no, is other assistance available? (g) If yes, who and from where?	☐Yes ☐No
5. (a) Is an operations log book kept at the dam? (b) Is an operations log book kept elsewhere? (c) If yes to either (a) or (b), where is it located and what information is logged?	☐Yes ☒No ☒Yes at Christie Dam ☐No Stop log movement, minor repairs
(d) Do staff stay at this site during an emergency?	☐ Yes ☒No
(e) How are communications maintained with the area office? (i) at site (ii) traveling to/from site	 Radio or phone Radio and cell phone
6. Most likely means of access under emergency conditions during: (a) Spring (b) Summer/Fall (c) Winter	 ☒Road ☐Boat ☐Snowmobile ☐ATV ☐Helicopter ☐Walk ☒Road ☐Boat ☐Snowmobile ☐ATV ☐Helicopter ☐Walk ☒Road ☐Boat ☐Snowmobile ☐ATV ☐Helicopter ☐Walk

7. Are problems or restrictions for accessing the site in an emergency situation foreseen? (a) Spring (b) Summer/Fall (c) Winter If yes, please describe (e.g., will the access road or a bridge be accessible if there is a major flood?)	 ☐Yes ☒No ☐Yes ☒No ☐Yes ☒No
8. Length of time it will take staff to access the site under emergency conditions.	10 to 15 minutes
(a) Spring	☒Less than 1/2 h ☐1/2 to 2 h ☐2 h to 1/2 d ☐1/2 to 1 d ☐More than 1 d
(b) Summer/Fall	☒Less than 1/2 h ☐1/2 to 2 h ☐2 h to 1/2 d ☐1/2 to 1 d ☐More than 1 d
(c) Winter	☒Less than 1/2 h ☐1/2 to 2 h ☐2 h to 1/2 d ☐1/2 d to 1 d ☐More than 1 d
9. Once at the site, how long will it take staff to achieve maximum spill capacity (assuming headwater level is at Maximum Operating Level)?	☐Less than 1/2 h ☐1/2 to 1 h ☐1 h to 2 h ☐2 h to 1/2 d ☒1/2 d to 1 d ☐2 d ☐3 d ☐More than 3 d
10. How many staff members are required to achieve maximum spill capacity for the above time estimate?	6
11. (a) Are there any emergency procedures in place to deal with a dam accident or extreme flood condition? (b) If yes, what is the name of the document?	☒Yes ☐No Flood operations manual
12. How often is this dam operated?	/month 2 /year
13. (a) Is there a water level gauge at this site? (b) If no, is there a gauge at a dock nearby? (c) What is the location of the gauge (if applicable)? (d) To what is this gauge referenced? (e) Is the gauge metric or imperial?	☐Yes ☒No ☐Yes ☒No ☐CGD ☐Local structure datum ☐ Other datum ☐ Metric ☐ Imperial
14. (a) Are there any recreational activities (such as boating, fishing, canoe portages, hiking or snowmobiling) in close proximity to the dam in either upstream or downstream areas? (b) If yes, please describe.	☒Yes ☐No Fishing, boating (canoe/kayak), swimming (prohibited but……)

15. (a) What other agencies are involved with flow regulation along the river? (b) Who are the contact persons?	None
16. What else may be affected by changes in water levels?	☐ cottagers ☒ recreational boaters ☐ municipal water supply ☐ private water supply ☒ sensitive fisheries/habitat ☐ float plane landing
17. (a) Are there any known operator safety issues or equipment deficiencies? (b) If yes, please explain. (c) Has the Ministry of Labor visited the site? (d) If yes, please list any comments they made.	☒Yes ☐No No rating on chains and hooks associated with the stop log winches ☐Yes ☒No
18. Is the public allowed on the dam?	☒Yes ☐No
19. (a) Are there any public safety concerns? (b) If yes, please explain (c) Is vandalism a problem? Please elaborate.	☒Yes ☐No Public safety signage is nonexistent at dam. Wooden step not level. ☐Yes ☒No
20. What signage is provided at this dam?	☐ Danger – Fast Water ☐ No Trespassing ☐ No Swimming ☐ Other None
21. (a) Is there a debris boom upstream of the dam? (b) If yes, is it chained (logs) or cable-strung (manufactured)? (c) Is it permanent or seasonal? (d) Is there a safety boom upstream? (e) Is it permanent or seasonal?	☐ Yes ☒ No ☐ Chained ☐ Cable strung ☐ Permanent ☐ Seasonal ☐ Yes ☒ No ☐ Permanent ☐ Seasonal
22. What structural aspects of the dam do you inspect during operational visits?	Informal observation only

23. Log Settings	
(a) What is the normal regulated water level	Gauge CGD local
(b) How many logs are usually in for the normal summer setting?	9 logs, lately only 7 logs (12” x 12” Douglas Fir logs)
(c) How many logs are normally removed for the winter drawdown condition?	Leave 3 logs in
(d) How many logs can actually be removed in an emergency?	3 logs normally → but could briefly close Christie Dam to let water slow down; takes approximately 0.5 hours for flow to subside
(e) Is the bottom log fixed in place and not removed?	☐Yes ☒No Practice is to remove all logs in spring to clean sill, then reinstall 7 logs.

Part III - Hydraulic Discharge and Operating Facilities

A Discharge Facilities	
24. (a) Is a rating curve/table available for this site?	☒Yes ☐No
(b) Have any structural or channel modifications been made since the date on the rating table? (e.g., different size stop logs, additional stop logs, shaved stop logs, dredging, etc)	☐Yes ☒No
(c) If yes, please describe these modifications and how they will affect the rating table?	
25. (a) Does fully open represent lifting the gates clear of the deck?	☐Yes ☐No ☒Not applicable
(b) If no, can they be easily lifted clear of the deck during an emergency?	☐Yes ☐No ☒Not applicable
26. (a) Have all log sluices and/or all gate sluices ever been fully opened?	☒Yes ☐No ☐Not applicable
(b) If yes, under what headwater elevation and when?	During low flow following spring freshet [see Item 23 (e)]
(c) If no, what is the constraint?	
B Operating Equipment	
27. Type of equipment used to operate the discharge facilities:	
(a) Sluice Operation	☒crab winch mounted on concrete columns ☐spud winch ☐other - specify with: ☐diesel ☐electric ☒hand ☐other - specify

(b) Log Chutes and other outlet works.	☐crab winch ☐spud winch ☐other - specify with: ☐diesel ☐electric ☐hand ☐other - specify
28. (a) Is primary (pole) power available at the site? (b) Is auxiliary power available? (c) If yes, specify source.	☐Yes ☐No ☒Not applicable ☐Yes ☐No ☒Not applicable
29. (a) Is the discharge facility operating equipment located at the site (keys, winch handles, chain falls, etc)? (b) If no, where are they located? (c) Is there more than one set?	☐Yes ☒No ☐Not applicable Winch handles at Christie Dam ☐Yes ☒No
30. (a) If the gates are automated, is the operation remotely controlled? (b) If yes, from where?	☐Yes ☐No ☐Not applicable
31. (a) Have any backup provisions been made should the equipment fail? (b) If yes, what are the provisions? (c) If yes, is the backup located on site? (d) If no, where is backup located?	☐Yes ☒No ☐Not applicable ☐Yes ☐No
32. If the backup is located off-site, how much more time is required to achieve maximum discharge?	hrs
33. (a) Has the mechanical equipment ever failed? (b) If yes, when did the failure occur? (c) What was the nature and extent of the failure? (d) Has it been satisfactorily repaired?	☐Yes ☒No ☐Not applicable ☐Yes ☐No
C Operating Problems	
34. (a) Are there problems that may reduce the number of stop logs which can be removed or the number of gates that can be opened during normal or flood conditions? (b) If yes, please describe.	☒Yes ☐No ☐Not applicable Log engagement during high flows is difficult, i.e., June 1, 2004 – 150 mm of rain in 1.5 hours

35. (a) Has debris blockage ever occurred at this site? (b) If yes, at what time of the year does blockage occur? (c) What was the nature & extent of the blockage?	☒Yes ☐No ☐Not applicable ☐ All the time ☒ During spring only ☐ During floods only Trees, logs, limbs
36. Is there potential for debris from upstream to interfere with operations at the site under: (a) Normal Operation (b) Flood/Emergency Operation (c) If the answer to (a) or (b) is yes, please describe the situation.	 ☐Yes ☒No ☐Not applicable ☒Yes ☐No ☐Not applicable Potential interference with stop-log removal in an emergency or flood
37. (a) Is there a debris management program in place (e.g. debris boom, regular removal of debris, etc.)? (b) If yes, briefly describe program.	☐Yes ☒No
38. (a) Do ice jams affect this site? (b)Are there special operations to accommodate ice jam inflows? (c) Do ice jams block/hinder discharge facilities? (d) Do ice jams break booms? (e) If answer to any of the above is yes, please describe the situation.	☐Yes ☒No ☐Yes ☒No ☐Yes ☒No ☐Yes ☒No
39. Has an ice sheet formation been observed: (a) in the headpond or reservoir area? (b) against the intake headworks? (c) against the gate sluices? (d) against the log sluices? (e) against gravity walls/bulkheads?	 ☒Yes ☐No ☐Yes ☐No ☒Not applicable ☐Yes ☐No ☒Not applicable ☒Yes ☐No ☐Not applicable ☒Yes ☐No ☐Not applicable
40. (a) Are there any measurements or other estimates of the ice thickness? (b) If yes, please indicate these.	☐Yes ☒No
41. What is the duration of the headpond/reservoir ice cover (months)?	January to March
42. Is the frozen headpond generally covered with snow?	☒Yes ☐No

43. (a) Are any photographs of the headpond ice conditions available? (b) If yes, where are they located and when were they taken?	☒Yes ☐No HCA Office
44. (a) Are there any other observations regarding ice cover? (b) If yes, please describe.	☐Yes ☒No
45. (a) What is the deck surface? (b) Describe snow/ice removal concerns.	☐ Concrete ☐ Wood ☒ Metal grating
Part IV – Past Dam Incidents	
46. Describe any past dam incidents (such as seepage, overflow during flooding, sinkholes in the headpond, washout of an abutment, etc.)	None
Part V –EPP Information	
47. Please provide the following emergency contact phone numbers.	Duty Officer System *Name* *Office #* *Home #* *Cell #*
(a) Dam Operator	Bruce Harschnitz (see Flood Operations Manual)
(b) Alternate Dam Operator	Alex Bouwmeester (see Flood Operations Manual)
(c) District Emergency Response Coordinator	---
(d) Regional Engineer	George Stojanovic (905) 525-2181, Ext. 137
(e) Provincial Response Center	MNR – Peterborough, Ontario
(f) OPP	911
(g) Medical Emergencies	911
48. (a) Are there permanent residents living within 0.5 km downstream of the dam? (b) If yes, please indicate their names and phone numbers.	☐Yes ☒No Name Phone #

49.	(a) Is there an access road to this site?	☒Yes ☐No
	(b) Who maintains the access road to the site?	Municipality
	(c) Is this access road plowed in the winter and spring?	☒Yes ☐No ☐Not applicable
50.	(a) Is there emergency equipment available at the site such as life preservers and a first-aid kit?	☐Yes ☒No
	(b) If not available at the site, where are the nearest available ones?	Christie Dam
51.	Note and describe any physical features that use you use to cue yourself that water levels are abnormal (both during flood and drought).	---

Discharge Facilities

(one line for each discharge structure - sluices, spillways, turbines, etc.)

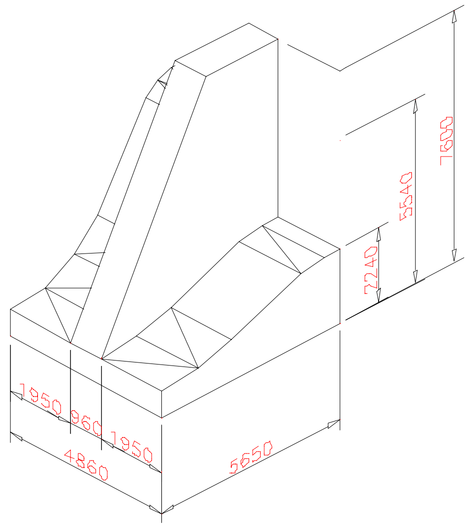
Facility	Structure					Rating Table		Operation			
	Number/ ID	Width (m)	Crest/Sill Elev. (m)	Log Height (m)	Capacity (m^3/s)	Table No.	Date	Log Sluices			Gate Sluices[1] Yes/ Unknown
								Logs Per Sluice	Logs that can be Removed		
									Normal Condition	Emergency Condition	
Sluiceway	2	4.3	214.15	0.305	80	-	-	7 to 9	7	7	-
Sluiceway	1, 3 and 4	3.7	217.32	n/a	22 x 3	-	-	-	-	-	-

1- Can gates be fully opened under emergency conditions? If no, to what percentage can they be opened?

Appendix D

Tabular Results of Stability Analyses

Spillway 2-3



Summary

Load Combinations	Sliding: Acceptance Criteria in Sliding	Sliding: Calculated Factor of Safety	Base Stresses: At Heel (kPa)	Base Stresses: At Toe (kPa)	Location of Resultant
Summer (Usual) Original Water Levels	1.50	0.07	Unstable	Unstable	Outside of base, **Unstable**.
Summer (Usual) Present Water Levels	1.50	1.50	46.58	32.99	Within middle third of base.
Winter (Usual) Original Water Levels	1.50	0.27	Unstable	Unstable	Outside middle third of base, **Unstable**.
Winter (Usual) Present Water Levels	1.50	1.60	44.58	46.96	Within middle third of base.
Earthquake (Summer, 1:100yr)	1.00	1.36	40.93	37.10	Within middle third of base.
Earthquake (Summer, 1:1000yr)	1.00	1.19	33.67	42.03	Within middle third of base.
Earthquake (Winter, 1:100yr)	1.00	1.48	40.15	49.85	Within middle third of base.
Earthquake (Winter, 1:200yr)	1.00	1.44	38.78	50.74	Within middle third of base.
Flood I (1:100yr)	1.30	1.02	19.27	64.75	Within middle third of base.
Flood II (Hazel)	1.30	0.20	Unstable	Unstable	Outside of base, **Unstable**.

Stresses: -ve = tension, +ve = compression
[orange] - Unacceptable Factor of Safety
Unstable - Unstable due to cracking of base

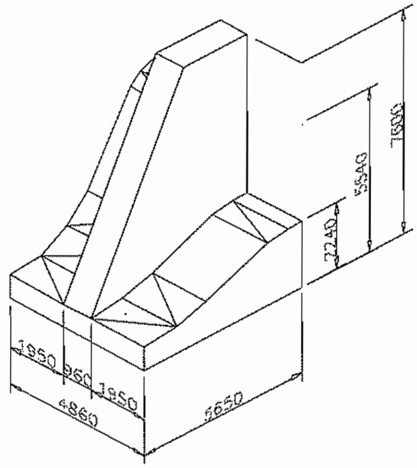
Spillway 2-3

Mass Properties - Concrete Structure

Volume = 78.285 m^3

Centroid from Toe:
X = 3.592 m
Y = 2.245 m

Pier Length = 5.650 m



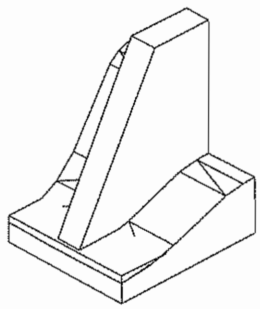
Water Volume Over Section:

Summer
Volume = 1.408 m^3
Centroid from Toe: X = 0.642 m
Y = 0.976 m

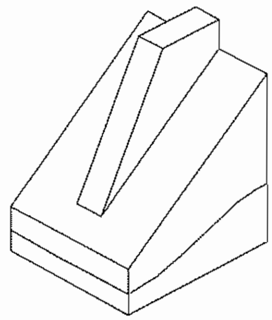
Winter
Volume = 1.408 m^3
Centroid from Toe: X = 0.642 m
Y = 0.976 m

Flood I - 1:100yr
Volume = 42.926 m^3
Centroid from Toe: X = 2.981 m
Y = 3.023 m

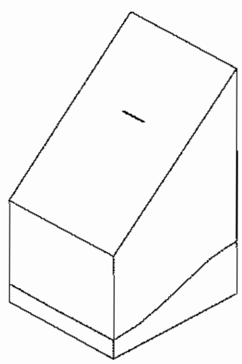
Flood II - Hazel
Volume = 116.533 m^3
Centroid from Toe: X = 2.904 m
Y = 4.704 m



Summer and Winter



1:100yr Flood



Hazel Flood

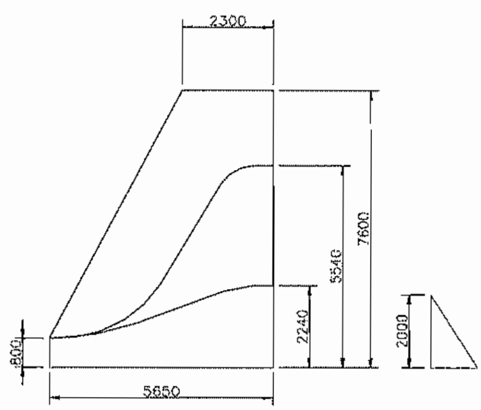
Sediment Load:

γ_{sat} = 14.4 kN/m^3

γ_{sub} = 4.6 kN/m^3

Height of Sediment = 2.0 m

F_H = 44.6 kN
@ y = 0.667 m



Additional Ice Load of Concrete face of Spillway No.3:

Define Units

$kN \equiv 1000N$

$Ice_{add} := 1.95m \cdot \left(73.0\frac{kN}{m} - 29.2\frac{kN}{m}\right)$ $Ice_{add} = 85.41\,kN$ $y_{ice} := 3.03m$ (from spreadsheet)

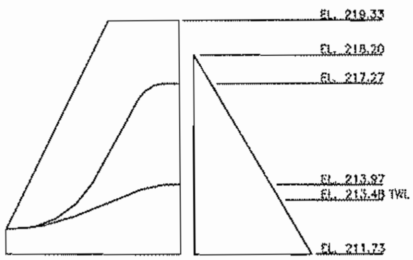
$Sediment := 44.6kN$ $y_{sed} := 0.667m$ (from p. 2 of calc's)

Additional Horizontal loads applied during Winter Load Cases:

$F_{H\_winter} := Ice_{add} + Sediment$ $y_{H\_winter} := \dfrac{Ice_{add} \cdot y_{ice} + Sediment \cdot y_{sed}}{F_{H\_winter}}$

$F_{H\_winter} = 130\,kN$ $y_{H\_winter} = 2.22\ m$

Additional Headwater load on Spillway No.3 during 1:100yr Flood Load Case:
(Caused by the different sill elevations)



$W_{add\_100} := \left(\dfrac{0.93m + 4.23m}{2}\right) \cdot 9.81\dfrac{kN}{m^3} \cdot (4.23m - 0.93m) \cdot 1.95m$

$W_{add\_100} = 162.87\,kN$

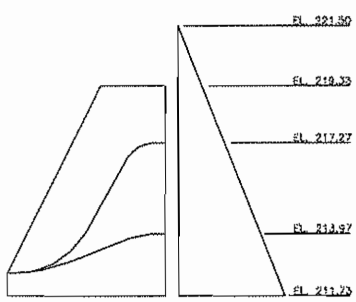
$y_{water\_100} := 3.538m$

Additional Horizontal loads applied during Flood Load Cases:

$F_{H\_flood\_100} := W_{add\_100} + Sediment$ $y_{H\_flood\_100} := \dfrac{W_{add\_100} \cdot y_{water\_100} + Sediment \cdot y_{sed}}{F_{H\_flood\_100}}$

$F_{H\_flood\_100} = 207.5\,kN$ $y_{H\_flood\_100} = 2.92\ m$

Additional Headwater load on Spillway No.3 during Hazel Flood Load Case:
(Caused by the different sill elevations)



$W_{add\_H} := \left(\dfrac{4.23m + 7.53m}{2}\right) \cdot 9.81\dfrac{kN}{m^3} \cdot (7.53m - 4.23m) \cdot 1.95m$

$W_{add\_H} = 371.19\,kN$

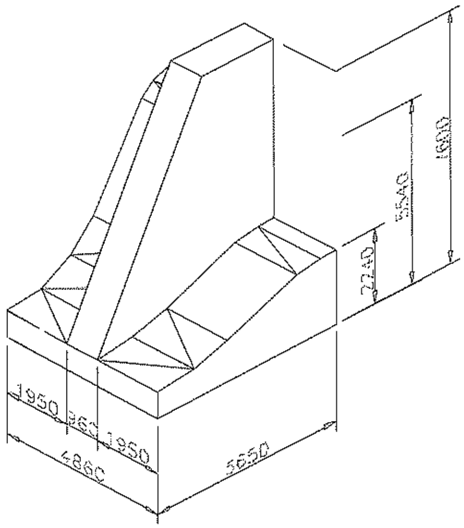
$y_{water\_H} := 3.736m$

Additional Horizontal loads applied during Flood Load Cases:

$F_{H\_flood\_H} := W_{add\_H} + Sediment$ $y_{H\_flood\_H} := \dfrac{W_{add\_H} \cdot y_{water\_H} + Sediment \cdot y_{sed}}{F_{H\_flood\_H}}$

$F_{H\_flood\_H} = 415.8\,kN$ $y_{H\_flood\_H} = 3.41\ m$

Spillway 2-3



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	217.270	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I, 1:100yr)	213.970	m
H.W.L. (Flood I. 1:100yr)	218.200	m
T.W.L. (Flood I, 1:100yr)	213.480	m
Log Top Elevation (Flood II, Hazel)	213.970	m
H.W.L. (Flood II, Hazel)	221.500	m
T.W.L. (Flood II, Hazel)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	78.29	m^3
Centre of Gravity X	3.592	m
Centre of Gravity Y	2.245	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_B	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	9.13	4.89	-	kN	Westergaards Force
y	-	-	-	-	-	1.67	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	655.61	493.51	264.34	1168.60	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	1.38	1.52	1.11	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	130.00	44.60	130.00	207.50	44.60	130.00	415.80	kN	Other Horizontal Force
y	0.67	2.22	0.67	2.22	2.92	0.67	2.22	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.986				2.801			
Stress at Heel	kPa	-46.58				-44.58			
Cracked		NO				NO			
Stress at Toe	kPa	-32.99				-46.96			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		1.97				2.13			
F.S. Sliding ϕ= 25		1.00				1.07			
F.S. Sliding ϕ= 30		1.24				1.32			
F.S. Sliding ϕ= 35		**1.50**				**1.60**			
F.S. Sliding ϕ= 40		1.80				1.92			
F.S. Sliding ϕ= 45		2.15				2.29			
Accepted F.S. Sliding		1.50				1.50			

		Load Case #4 - Flood I				Load Case #6 - Flood II			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1107.12				2631.77			
Effective Base	%	100.0				0.0			
Length of Base in Compression	m	5.65				0.00			
Resultant	m	2.315				-1.680			
Stress at Heel	kPa	-19.27				Unstable			
Cracked		NO				YES			
Stress at Toe	kPa	-64.75				Unstable			
Allowable Stress at Toe	kPa	-3077				-3077			
F.S. Overturning		1.51				0.95			
F.S. Sliding ϕ= 25		0.68				0.13			
F.S. Sliding ϕ= 30		0.84				0.17			
F.S. Sliding ϕ= 35		**1.02**				**0.20**			
F.S. Sliding ϕ= 40		1.23				0.24			
F.S. Sliding ϕ= 45		1.46				0.29			
Accepted F.S. Sliding		1.30				1.30			

Input Summary

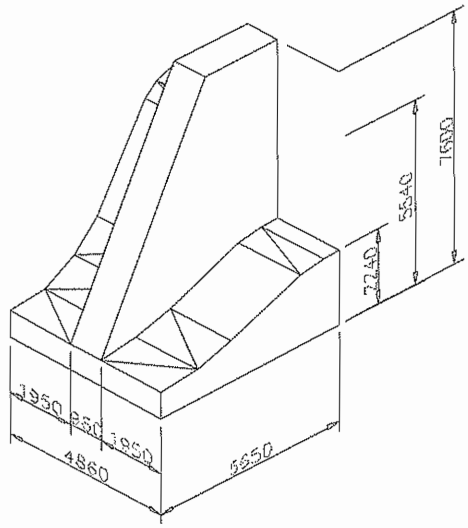
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	9.13	4.89	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	655.61	493.51	264.34	1168.60	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	1.38	1.52	1.11	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	130.00	44.60	130.00	207.50	44.60	130.00	415.80	kN	Other Horizontal Force
y	0.67	2.22	0.67	2.22	2.92	0.67	2.22	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.986				2.801			
Stress at Heel	kPa	-46.58				-44.58			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-32.99				-46.96			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		1.97				2.13			
F.S. Sliding ϕ= 25		1.00				1.07			
F.S. Sliding ϕ= 30		1.24				1.32			
F.S. Sliding ϕ= 35		**1.50**				**1.60**			
F.S. Sliding ϕ= 40		1.80				1.92			
F.S. Sliding ϕ= 45		2.15				2.29			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.871				2.724			
Stress at Heel	kPa	-40.93				-40.15			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-37.10				-49.85			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		1.87				2.02			
F.S. Sliding ϕ= 25		0.91				0.98			
F.S. Sliding ϕ= 30		1.12				1.22			
F.S. Sliding ϕ= 35		**1.36**				**1.48**			
F.S. Sliding ϕ= 40		1.63				1.77			
F.S. Sliding ϕ= 45		1.95				2.11			
Accepted F.S. Sliding		1.00				1.00			

Spillway 2-3



Geometrical Definitions		
Base Elevation	211.730	m
Log Top Elevation (Summer)	217.270	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I)	213.970	m
H.W.L. (Flood I)	218.200	m
T.W.L. (Flood I)	213.480	m
Log Top Elevation (Flood II)	213.970	m
H.W.L. (Flood II)	221.500	m
T.W.L. (Flood II)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	78.29	m^3
Centre of Gravity X	3.592	m
Centre of Gravity Y	2.245	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	$(0.05fc')$
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

2.89	%g	Vertical Ground Acceleration (Summer)
4.33	%g	Horizontal Ground Acceleration (Summer)
1.51	%g	Vertical Ground Acceleration (Winter, DEice)
2.27	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

Input Summary

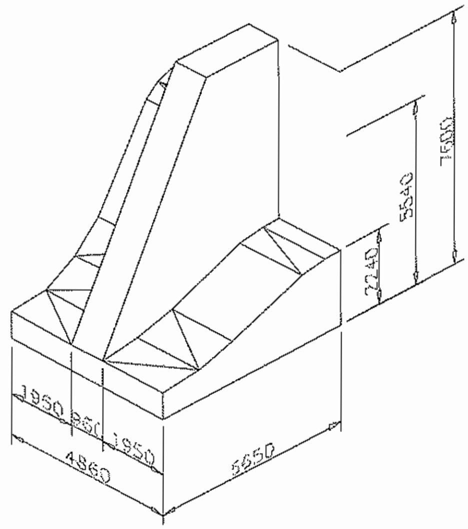
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.53	m^3	Volume of Water Over Section
M_2	13.83	13.83	13.83	13.83	421.14	13.83	13.83	1143.16	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	22.82	6.39	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	4.33	2.27	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	2.89	1.51	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	655.61	493.51	264.34	1168.60	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	1.38	1.52	1.11	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	130.00	44.60	130.00	207.50	44.60	130.00	415.80	kN	Other Horizontal Force
y	0.67	2.22	0.67	2.22	2.92	0.67	2.22	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.966				2.800			
Stress at Heel	kPa	-45.76				-44.58			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-33.81				-46.96			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		1.97				2.13			
F.S. Sliding ϕ= 25		1.00				1.07			
F.S. Sliding ϕ= 30		1.24				1.32			
F.S. Sliding ϕ= 35		**1.50**				**1.60**			
F.S. Sliding ϕ= 40		1.80				1.92			
F.S. Sliding ϕ= 45		2.15				2.29			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.721				2.699			
Stress at Heel	kPa	-33.67				-38.78			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-42.03				-50.74			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		1.74				1.99			
F.S. Sliding ϕ= 25		0.79				0.96			
F.S. Sliding ϕ= 30		0.98				1.19			
F.S. Sliding ϕ= 35		**1.19**				**1.44**			
F.S. Sliding ϕ= 40		1.43				1.73			
F.S. Sliding ϕ= 45		1.70				2.06			
Accepted F.S. Sliding		1.00				1.00			

Spillway 2-3



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	218.240	m
H.W.L. (Summer)	218.240	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	218.240	m
H.W.L. (Winter)	217.270	m
T.W.L. (Winter)	212.830	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	216.970	m
Volume of Section	78.29	m^3
Centre of Gravity X	3.592	m
Centre of Gravity Y	2.245	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

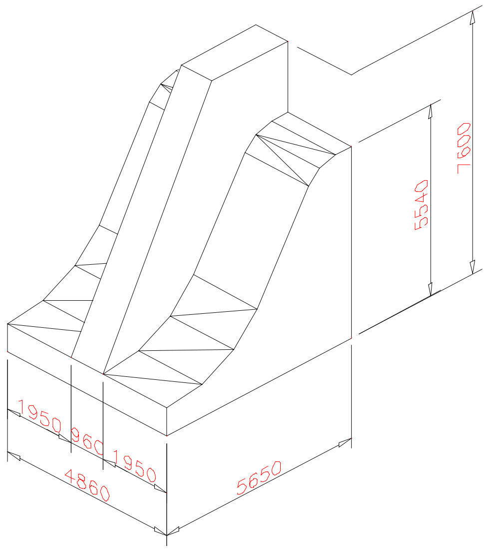
Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.53	m^3	Volume of Water Over Section
M_2	13.83	13.83	13.83	13.83	421.14	13.83	13.83	1143.16	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	5.24	-	5.24	-	-	5.24	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	18.69	13.53	-	kN	Westergaards Force
y	-	-	-	-	-	2.68	2.28	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	1010.27	731.64	1010.27	731.64	655.61	1010.27	731.64	1168.60	kN	Hydrostatic Pressure From Headwater
y	2.17	1.85	2.17	1.85	1.38	2.17	1.85	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	207.50	44.60	44.60	415.80	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	2.92	0.67	0.67	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1753.62				1492.33			
Effective Base	%	0.0				0.0			
Length of Base in Compression	m	0.00				0.00			
Resultant	m	-5.488				0.186			
Stress at Heel	kPa	Unstable				Unstable			
Cracked		YES				YES			
Stress at Toe	kPa	Unstable				Unstable			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		0.92				1.01			
F.S. Sliding ϕ= 25		0.05				0.18			
F.S. Sliding ϕ= 30		0.06				0.22			
F.S. Sliding ϕ= 35		0.07				0.27			
F.S. Sliding ϕ= 40		0.08				0.33			
F.S. Sliding ϕ= 45		0.10				0.39			
Accepted F.S. Sliding		1.50				1.50			

Spillway 3-4



Summary

Load Combinations	Sliding: Acceptance Criteria in Sliding	Sliding: Calculated Factor of Safety	Base Stresses: At Heel (kPa)	Base Stresses: At Toe (kPa)	Location of Resultant
Summer (Usual) Original Water Levels	1.50	0.80	4.94	80.97	Within middle third of base.
Summer (Usual) Present Water Levels	1.50	1.98	80.00	25.13	Within middle third of base.
Winter (Usual) Original Water Levels	1.50	0.26	Unstable	Unstable	Outside of base, **Unstable**.
Winter (Usual) Present Water Levels	1.50	1.77	68.00	49.11	Within middle third of base.
Earthquake (Summer, 1:100yr)	1.00	1.78	73.18	30.11	Within middle third of base.
Earthquake (Summer, 1:1000yr)	1.00	1.54	64.18	36.35	Within middle third of base.
Earthquake (Winter, 1:100yr)	1.00	1.63	62.40	52.86	Within middle third of base.
Earthquake (Winter, 1:200yr)	1.00	1.60	60.67	54.02	Within middle third of base.
Flood I (1:100yr)	1.30	1.00	16.46	82.49	Within middle third of base.
Flood II (Hazel)	1.30	0.26	Unstable	Unstable	Outside of base, **Unstable**.

Stresses: -ve = tension, +ve = compression
- Unacceptable Factor of Safety
Unstable - Unstable due to cracking of base

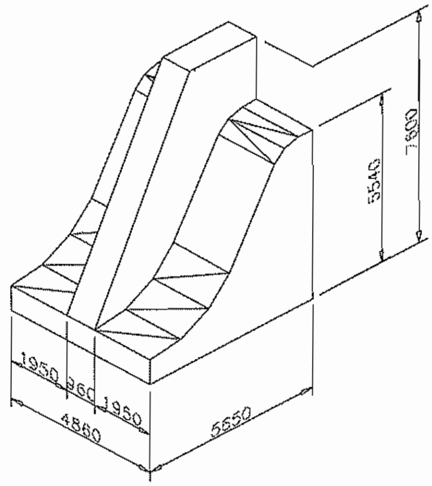
Spillway 3-4

Mass Properties - Concrete Structure

Volume = 93.252 m^3

Centroid from Toe:
X = 3.712 m
Y = 2.417 m

Pier Length = 5.650 m



Water Volume Over Section:

Summer

Volume = 1.327 m^3
Centroid from Toe: X = 0.582 m
Y = 0.972 m

Winter

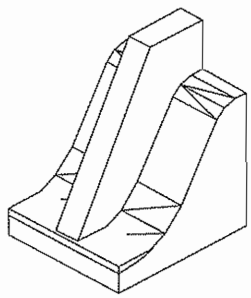
Volume = 1.327 m^3
Centroid from Toe: X = 0.582 m
Y = 0.972 m

Flood I - 1:100yr

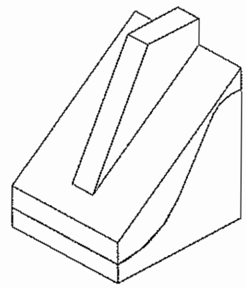
Volume = 27.955 m^3
Centroid from Toe: X = 2.255 m
Y = 2.867 m

Flood II - Hazel

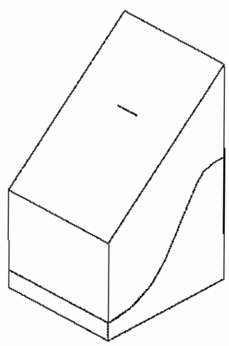
Volume = 101.562 m^3
Centroid from Toe: X = 2.692 m
Y = 4.909 m



Summer and Winter



1:100yr Flood



Hazel Flood

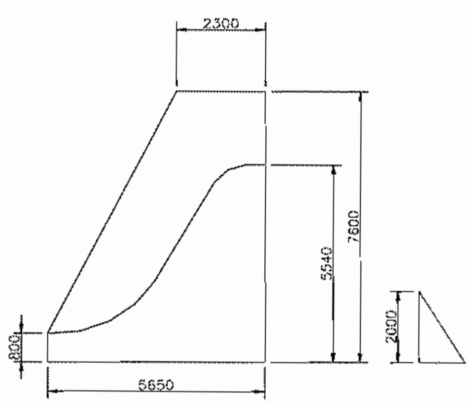
Sediment Load:

γ_{sat} = 14.4 kN/m^3

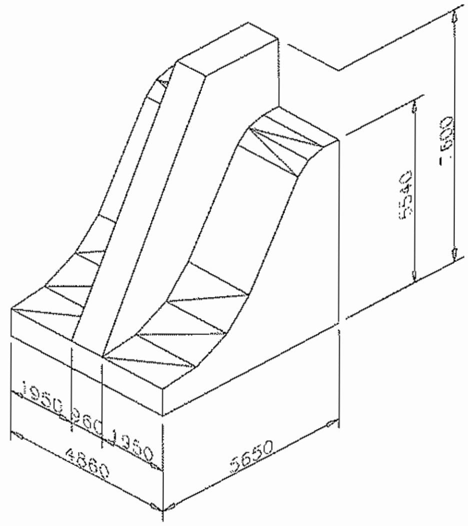
γ_{sub} = 4.6 kN/m^3

Height of Sediment = 2.0 m

F_H = 44.6 kN
@ y = 0.667 m



Spillway 3-4



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	217.270	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I)	217.270	m
H.W.L. (Flood I)	218.200	m
T.W.L. (Flood I)	213.480	m
Log Top Elevation (Flood II)	217.270	m
H.W.L. (Flood II)	221.500	m
T.W.L. (Flood II)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	93.25	m^3
Centre of Gravity X	3.712	m
Centre of Gravity Y	2.417	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_b	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
73	kN/m	Ice Force on Logs/Gates

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	kN	Weight of Section
V_{water}	1.33	1.33	1.33	1.33	27.96	1.33	1.33	101.56	m^3	Volume of Water Over Section
M_2	13.02	13.02	13.02	13.02	274.24	13.02	13.02	996.32	kN	Weight of Water Over Section
x	0.58	0.58	0.58	0.58	2.26	0.58	0.58	2.69	m	Location of Water Force Along X-Axis
ICE	-	354.78	-	354.78	-	-	354.78	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	9.13	4.89	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	981.35	493.51	264.34	1910.98	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.09	1.52	1.11	2.54	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	465.71	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	44.60	44.60	44.60	44.60	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.316				2.977			
Stress at Heel	kPa	-80.00				-68.00			
Cracked		NO				NO			
Stress at Toe	kPa	-25.13				-49.11			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		2.42				2.42			
F.S. Sliding ϕ= 25		1.32				1.18			
F.S. Sliding ϕ= 30		1.64				1.46			
F.S. Sliding ϕ= 35		**1.98**				**1.77**			
F.S. Sliding ϕ= 40		2.38				2.12			
F.S. Sliding ϕ= 45		2.83				2.53			
Accepted F.S. Sliding		1.50				1.50			

		Load Case #4 - Flood I				Load Case #6 - Flood II			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1107.12				2631.77			
Effective Base	%	100.0				0.0			
Length of Base in Compression	m	5.65				0.00			
Resultant	m	2.197				-1.454			
Stress at Heel	kPa	-16.46				Unstable			
Cracked		NO				YES			
Stress at Toe	kPa	-82.49				Unstable			
Allowable Stress at Toe	kPa	-3077				-3077			
F.S. Overturning		1.51				0.93			
F.S. Sliding ϕ= 25		0.66				0.17			
F.S. Sliding ϕ= 30		0.82				0.22			
F.S. Sliding ϕ= 35		**1.00**				**0.26**			
F.S. Sliding ϕ= 40		1.20				0.31			
F.S. Sliding ϕ= 45		1.43				0.37			
Accepted F.S. Sliding		1.30				1.30			

Input Summary

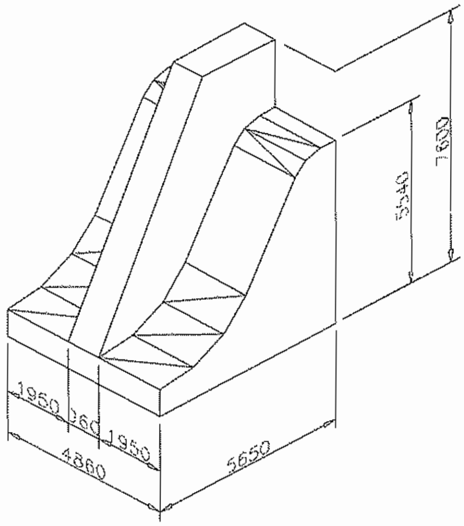
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	kN	Weight of Section
V_{water}	1.33	1.33	1.33	1.33	27.96	1.33	1.33	101.56	m^3	Volume of Water Over Section
M_2	13.02	13.02	13.02	13.02	274.24	13.02	13.02	996.32	kN	Weight of Water Over Section
x	0.58	0.58	0.58	0.58	2.26	0.58	0.58	2.69	m	Location of Water Force Along X-Axis
ICE	-	354.78	-	354.78	-	-	354.78	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	9.13	4.89	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	981.35	493.51	264.34	1910.98	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.09	1.52	1.11	2.54	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	465.71	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	44.60	44.60	44.60	44.60	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.316				2.977			
Stress at Heel	kPa	-80.00				-68.00			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-25.13				-49.11			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		2.42				2.42			
F.S. Sliding ϕ= 25		1.32				1.18			
F.S. Sliding ϕ= 30		1.64				1.46			
F.S. Sliding ϕ= 35		**1.98**				**1.77**			
F.S. Sliding ϕ= 40		2.38				2.12			
F.S. Sliding ϕ= 45		2.83				2.53			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.218				2.903			
Stress at Heel	kPa	-73.18				-62.40			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-30.11				-52.86			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		2.27				2.28			
F.S. Sliding ϕ= 25		1.19				1.09			
F.S. Sliding ϕ= 30		1.47				1.35			
F.S. Sliding ϕ= 35		**1.78**				**1.63**			
F.S. Sliding ϕ= 40		2.14				1.96			
F.S. Sliding ϕ= 45		2.55				2.33			
Accepted F.S. Sliding		1.00				1.00			

Spillway 3-4



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	217.270	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I)	217.270	m
H.W.L. (Flood I)	218.200	m
T.W.L. (Flood I)	213.480	m
Log Top Elevation (Flood II)	217.270	m
H.W.L. (Flood II)	221.500	m
T.W.L. (Flood II)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	93.25	m^3
Centre of Gravity X	3.712	m
Centre of Gravity Y	2.417	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

2.89	%g	Vertical Ground Acceleration (Summer)
4.33	%g	Horizontal Ground Acceleration (Summer)
1.51	%g	Vertical Ground Acceleration (Winter, DEice)
2.27	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
73	kN/m	Ice Force on Logs/Gates

Input Summary

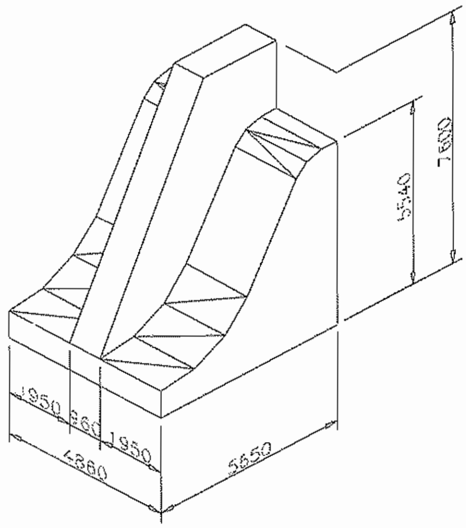
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	kN	Weight of Section
V_{water}	1.33	1.33	1.33	1.33	27.96	1.33	1.33	101.56	m^3	Volume of Water Over Section
M_2	13.02	13.02	13.02	13.02	274.24	13.02	13.02	996.32	kN	Weight of Water Over Section
x	0.58	0.58	0.58	0.58	2.26	0.58	0.58	2.69	m	Location of Water Force Along X-Axis
ICE	-	354.78	-	354.78	-	-	354.78	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	22.82	6.39	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	4.33	2.27	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	2.89	1.51	-	%g	Vertical Seismic Coefficient
w_1	493.51	264.34	493.51	264.34	981.35	493.51	264.34	1910.98	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.09	1.52	1.11	2.54	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	465.71	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	44.60	44.60	44.60	44.60	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.316				2.977			
Stress at Heel	kPa	-80.00				-68.00			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-25.13				-49.11			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		2.42				2.42			
F.S. Sliding ϕ= 25		1.32				1.18			
F.S. Sliding ϕ= 30		1.64				1.46			
F.S. Sliding ϕ= 35		**1.98**				**1.77**			
F.S. Sliding ϕ= 40		2.38				2.12			
F.S. Sliding ϕ= 45		2.83				2.53			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	760.98				596.66			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.086				2.880			
Stress at Heel	kPa	-64.18				-60.67			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-36.35				-54.02			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		2.08				2.24			
F.S. Sliding ϕ= 25		1.03				1.06			
F.S. Sliding ϕ= 30		1.27				1.32			
F.S. Sliding ϕ= 35		**1.54**				**1.60**			
F.S. Sliding ϕ= 40		1.85				1.91			
F.S. Sliding ϕ= 45		2.20				2.28			
Accepted F.S. Sliding		1.00				1.00			

Spillway 3-4



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	218.240	m
H.W.L. (Summer)	218.240	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	218.240	m
H.W.L. (Winter)	218.240	m
T.W.L. (Winter)	212.830	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	217.940	m
Volume of Section	93.25	m^3
Centre of Gravity X	3.712	m
Centre of Gravity Y	2.417	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	$(0.05fc')$
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

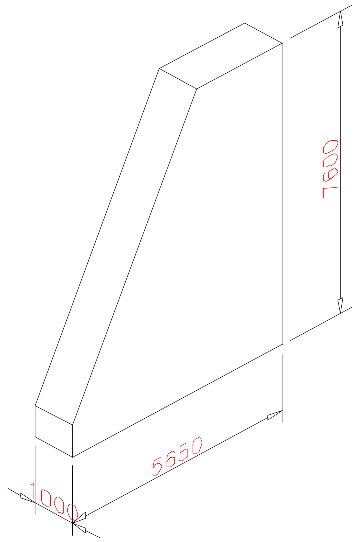
Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	2191.42	kN	Weight of Section
V_{water}	1.33	1.33	1.33	1.33	27.96	1.33	1.33	101.56	m^3	Volume of Water Over Section
M_2	13.02	13.02	13.02	13.02	274.24	13.02	13.02	996.32	kN	Weight of Water Over Section
x	0.58	0.58	0.58	0.58	2.26	0.58	0.58	2.69	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	6.21	-	6.21	-	-	6.21	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	18.69	18.69	-	kN	Westergaards Force
y	-	-	-	-	-	2.68	2.68	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	1010.27	1010.27	1010.27	1010.27	981.35	1010.27	1010.27	1910.98	kN	Hydrostatic Pressure From Headwater
y	2.17	2.17	2.17	2.17	2.09	2.17	2.17	2.54	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	465.71	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	44.60	44.60	44.60	44.60	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1024.96				1753.62			
Effective Base	%	100.0				0.0			
Length of Base in Compression	m	5.65				0.00			
Resultant	m	1.992				-0.367			
Stress at Heel	kPa	-4.94				Unstable			
Cracked		NO				YES			
Stress at Toe	kPa	-80.97				Unstable			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		1.40				0.98			
F.S. Sliding ϕ= 25		0.54				0.17			
F.S. Sliding ϕ= 30		0.66				0.22			
F.S. Sliding ϕ= 35		0.80				0.26			
F.S. Sliding ϕ= 40		0.96				0.31			
F.S. Sliding ϕ= 45		1.15				0.37			
Accepted F.S. Sliding		1.50				1.50			

Buttress



Summary

Load Combinations	Sliding: Acceptance Criteria in Sliding	Sliding: Calculated Factor of Safety	Base Stresses: At Heel (kPa)	Base Stresses: At Toe (kPa)	Location of Resultant
Summer (Usual) Original Water Levels	1.50	1.51	67.74	120.13	Within middle third of base.
Summer (Usual) Present Water Levels	1.50	3.91	142.81	64.29	Within middle third of base.
Winter (Usual) Original Water Levels	1.50	1.26	0.00	207.94	Outside middle third of base, crack developed.
Winter (Usual) Present Water Levels	1.50	3.32	130.80	88.27	Within middle third of base.
Earthquake (Summer, 1:100yr)	1.00	3.38	130.98	73.09	Within middle third of base.
Earthquake (Summer, 1:1000yr)	1.00	2.79	114.46	85.06	Within middle third of base.
Earthquake (Winter, 1:100yr)	1.00	2.96	120.19	95.85	Within middle third of base.
Earthquake (Winter, 1:200yr)	1.00	2.86	116.93	98.18	Within middle third of base.
Flood I (1:100yr)	1.30	1.82	69.87	113.25	Within middle third of base.
Flood II (Hazel)	1.30	0.55	Unstable	Unstable	Outside middle third of base, **Unstable**.

Stresses: -ve = tension, +ve = compression

(orange) - Unacceptable Factor of Safety

Unstable - Unstable due to cracking of base

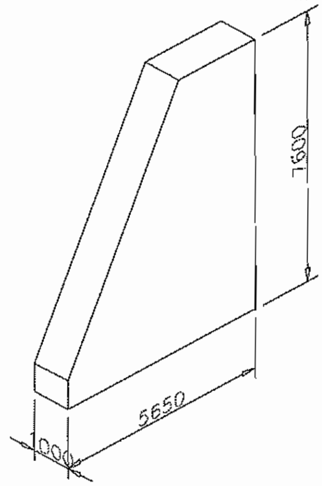
Buttress

Mass Properties - Concrete Structure

Volume = 31.550 m^3

Centroid from Toe:
X = 3.442 m
Y = 3.246 m

Pier Length = 5.650 m



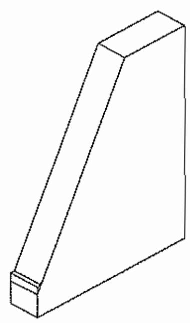
Water Volume Over Section:

Summer
Volume = 0.022 m^3
Centroid from Toe: X = 0.049 m
Y = 1.000 m

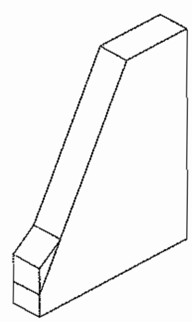
Winter
Volume = 0.022 m^3
Centroid from Toe: X = 0.049 m
Y = 1.000 m

Flood I - 1:100yr
Volume = 0.378 m^3
Centroid from Toe: X = 0.265 m
Y = 1.655 m

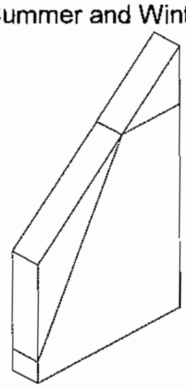
Flood II - Hazel
Volume = 8.568 m^3
Centroid from Toe: X = 2.213 m
Y = 5.450 m



Summer and Winter



1:100yr Flood



Hazel Flood

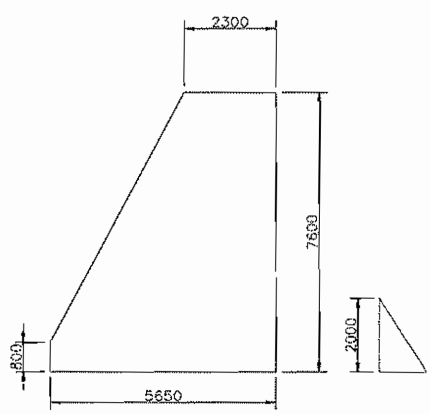
Sediment Load:

γ_{sat} = 14.4 kN/m^3

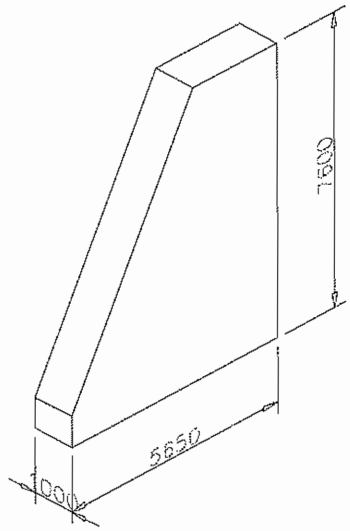
γ_{sub} = 4.6 kN/m^3

Height of Sediment = 2.0 m

F_H = 9.2 kN/m
@ y = 0.667 m



Buttress



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	219.330	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	219.330	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I, 1:100yr)	219.330	m
H.W.L. (Flood I. 1:100yr)	218.200	m
T.W.L. (Flood I, 1:100yr)	213.480	m
Log Top Elevation (Flood II, Hazel)	219.330	m
H.W.L. (Flood II, Hazel)	221.500	m
T.W.L. (Flood II, Hazel)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	31.55	m^3
Centre of Gravity X	3.442	m
Centre of Gravity Y	3.246	m
Length of Pier Section	5.650	m
Width of Pier Section	1.000	m
Length of Sluiceway #1 Section	0.000	m
Width of Sluiceway #1 Section	0.000	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	0.000	m
Width of Sluiceway #2 Section	0.000	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_B	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
73	kN/m	Ice Force on Logs/Gates

Input Summary

	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
	Load Case									
M_1	741.43	741.43	741.43	741.43	741.43	741.43	741.43	741.43	kN	Weight of Section
V_{water}	0.02	0.02	0.02	0.02	0.38	0.02	0.02	8.57	m^3	Volume of Water Over Section
M_2	0.22	0.22	0.22	0.22	3.71	0.22	0.22	84.07	kN	Weight of Water Over Section
x	0.05	0.05	0.05	0.05	0.27	0.05	0.05	2.21	m	Location of Water Force Along X-Axis
ICE	-	73.00	-	73.00	-	-	73.00	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	1.88	1.01	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	101.55	54.39	101.55	54.39	205.33	101.55	54.39	445.10	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.16	1.52	1.11	2.99	m	Location of Headwater Force Along Y-Axis
w_2	5.94	5.94	5.94	5.94	15.02	5.94	5.94	95.83	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	156.58				122.77			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.182				3.008			
Stress at Heel	kPa	-142.81				-130.80			
Cracked		NO				NO			
Stress at Toe	kPa	-64.29				-88.27			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		3.69				3.69			
F.S. Sliding ϕ= 25		2.60				2.21			
F.S. Sliding ϕ= 30		3.22				2.73			
F.S. Sliding ϕ= 35		**3.91**				**3.32**			
F.S. Sliding ϕ= 40		4.68				3.97			
F.S. Sliding ϕ= 45		5.58				4.74			
Accepted F.S. Sliding		1.50				1.50			

		Load Case #4 - Flood I				Load Case #6 - Flood II			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	227.80				541.52			
Effective Base	%	100.0				0.0			
Length of Base in Compression	m	5.65				0.00			
Resultant	m	2.602				0.038			
Stress at Heel	kPa	-69.87				Unstable			
Cracked		NO				YES			
Stress at Toe	kPa	-113.25				Unstable			
Allowable Stress at Toe	kPa	-3077				-3077			
F.S. Overturning		2.11				1.00			
F.S. Sliding ϕ= 25		1.21				0.37			
F.S. Sliding ϕ= 30		1.50				0.46			
F.S. Sliding ϕ= 35		**1.82**				**0.55**			
F.S. Sliding ϕ= 40		2.18				0.66			
F.S. Sliding ϕ= 45		2.59				0.79			
Accepted F.S. Sliding		1.30				1.30			

Input Summary

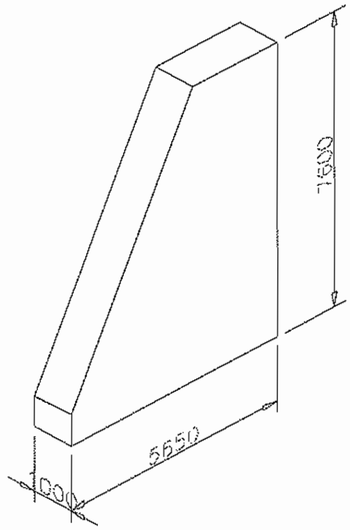
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	741.43	741.43	741.43	741.43	741.43	741.43	741.43	741.43	kN	Weight of Section
V_{water}	0.02	0.02	0.02	0.02	0.38	0.02	0.02	8.57	m^3	Volume of Water Over Section
M_2	0.22	0.22	0.22	0.22	3.71	0.22	0.22	84.07	kN	Weight of Water Over Section
x	0.05	0.05	0.05	0.05	0.27	0.05	0.05	2.21	m	Location of Water Force Along X-Axis
ICE	-	73.00	-	73.00	-	-	73.00	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	1.88	1.01	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	101.55	54.39	101.55	54.39	205.33	101.55	54.39	445.10	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.16	1.52	1.11	2.99	m	Location of Headwater Force Along Y-Axis
w_2	5.94	5.94	5.94	5.94	15.02	5.94	5.94	95.83	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	156.58				122.77			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.182				3.008			
Stress at Heel	kPa	-142.81				-130.80			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-64.29				-88.27			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		3.69				3.69			
F.S. Sliding ϕ= 25		2.60				2.21			
F.S. Sliding ϕ= 30		3.22				2.73			
F.S. Sliding ϕ= 35		**3.91**				**3.32**			
F.S. Sliding ϕ= 40		4.68				3.97			
F.S. Sliding ϕ= 45		5.58				4.74			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	156.58				122.77			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.092				2.931			
Stress at Heel	kPa	-130.98				-120.19			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-73.09				-95.85			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		3.33				3.33			
F.S. Sliding ϕ= 25		2.25				1.97			
F.S. Sliding ϕ= 30		2.78				2.44			
F.S. Sliding ϕ= 35		**3.38**				**2.96**			
F.S. Sliding ϕ= 40		4.05				3.54			
F.S. Sliding ϕ= 45		4.82				4.22			
Accepted F.S. Sliding		1.00				1.00			

Buttress



Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	219.330	m
H.W.L. (Summer)	216.280	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	219.330	m
H.W.L. (Winter)	215.060	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I, 1:100yr)	219.330	m
H.W.L. (Flood I, 1:100yr)	218.200	m
T.W.L. (Flood I, 1:100yr)	213.480	m
Log Top Elevation (Flood II, Hazel)	219.330	m
H.W.L. (Flood II, Hazel)	221.500	m
T.W.L. (Flood II, Hazel)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	214.760	m
Volume of Section	31.55	m^3
Centre of Gravity X	3.442	m
Centre of Gravity Y	3.246	m
Length of Pier Section	5.650	m
Width of Pier Section	1.000	m
Length of Sluiceway #1 Section	0.000	m
Width of Sluiceway #1 Section	0.000	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	0.000	m
Width of Sluiceway #2 Section	0.000	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

2.89	%g	Vertical Ground Acceleration (Summer)
4.33	%g	Horizontal Ground Acceleration (Summer)
1.51	%g	Vertical Ground Acceleration (Winter, DEice)
2.27	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
73	kN/m	Ice Force on Logs/Gates

Input Summary

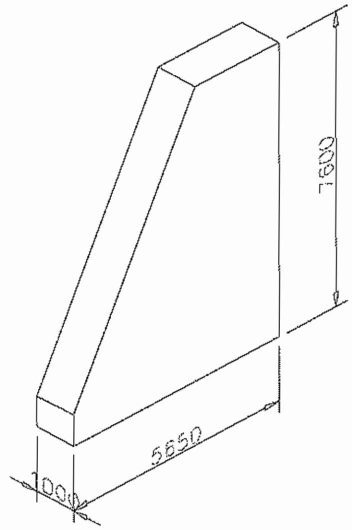
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	741.43	741.43	741.43	741.43	741.43	741.43	741.43	741.43	kN	Weight of Section
V_{water}	0.02	0.02	0.02	0.02	0.38	0.02	0.02	8.57	m^3	Volume of Water Over Section
M_2	0.22	0.22	0.22	0.22	3.71	0.22	0.22	84.07	kN	Weight of Water Over Section
x	0.05	0.05	0.05	0.05	0.27	0.05	0.05	2.21	m	Location of Water Force Along X-Axis
ICE	-	73.00	-	73.00	-	-	73.00	-	kN	Total Ice Force
y	-	3.03	-	3.03	-	-	3.03	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	4.70	1.32	-	kN	Westergaards Force
y	-	-	-	-	-	1.87	1.37	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	4.33	2.27	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	2.89	1.51	-	%g	Vertical Seismic Coefficient
w_1	101.55	54.39	101.55	54.39	205.33	101.55	54.39	445.10	kN	Hydrostatic Pressure From Headwater
y	1.52	1.11	1.52	1.11	2.16	1.52	1.11	2.99	m	Location of Headwater Force Along Y-Axis
w_2	5.94	5.94	5.94	5.94	15.02	5.94	5.94	95.83	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	156.58				122.77			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.182				3.008			
Stress at Heel	kPa	-142.81				-130.80			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-64.29				-88.27			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		3.69				3.69			
F.S. Sliding ϕ= 25		2.60				2.21			
F.S. Sliding ϕ= 30		3.22				2.73			
F.S. Sliding ϕ= 35		**3.91**				**3.32**			
F.S. Sliding ϕ= 40		4.68				3.97			
F.S. Sliding ϕ= 45		5.58				4.74			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	156.58				122.77			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.964				2.907			
Stress at Heel	kPa	-114.46				-116.93			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-85.06				-98.18			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		2.90				3.24			
F.S. Sliding ϕ= 25		1.86				1.90			
F.S. Sliding ϕ= 30		2.30				2.36			
F.S. Sliding ϕ= 35		**2.79**				**2.86**			
F.S. Sliding ϕ= 40		3.34				3.43			
F.S. Sliding ϕ= 45		3.98				4.08			
Accepted F.S. Sliding		1.00				1.00			

Buttress



Geometrical Definitions

Base Elevation	211.730 m
Log Top Elevation (Summer)	219.330 m
H.W.L. (Summer)	218.240 m
T.W.L. (Summer)	212.830 m
Log Top Elevation (Winter)	219.330 m
H.W.L. (Winter)	218.240 m
T.W.L. (Winter)	212.830 m
Log Top Elevation (Flood I, 1:100yr)	219.330 m
H.W.L. (Flood I. 1:100yr)	218.200 m
T.W.L. (Flood I, 1:100yr)	213.480 m
Log Top Elevation (Flood II, Hazel)	219.330 m
H.W.L. (Flood II, Hazel)	221.500 m
T.W.L. (Flood II, Hazel)	216.150 m
Deck Top Elevation	219.330 m
Thickness of Deck	0.000 m
Ice Elevation	217.940 m
Volume of Section	31.55 m^3
Centre of Gravity X	3.442 m
Centre of Gravity Y	3.246 m
Length of Pier Section	5.650 m
Width of Pier Section	1.000 m
Length of Sluiceway #1 Section	0.000 m
Width of Sluiceway #1 Section	0.000 m
Distance to Edge of Sluiceway #1 Section	0.000 m
Length of Sluiceway #2 Section	0.000 m
Width of Sluiceway #2 Section	0.000 m
Distance to Edge of Sluiceway #2 Section	0.000 m

Material Properties

f_c'	20.00 MPa	Concrete Compressive Strength
f_{b1}	4.00 MPa	Rock Bearing Strength
f_{b2}	4.00 MPa	Till Bearing Strength
ϕ_1	25.0 °	Angle of Friction #1
ϕ_2	30.0 °	Angle of Friction #2
ϕ_3	35.0 °	Specified Angle of Sliding Friction
ϕ_4	40.0 °	Angle of Friction #4
ϕ_5	45.0 °	Angle of Friction #5
τ_n	0.00 MPa	Cohesion
τ_1	0.38 MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76 MPa	$(0.17\sqrt{fc'})$
τ_3	1.00 MPa	(0.05fc')
γ_{conc}	23.50 kN/m^3	Unit Weight of Concrete
γ_{water}	9.81 kN/m^3	Unit Weight of Water
ϕ_β	35.0 °	Basic Friction Angle

Loadings

1.16 %g	Vertical Ground Acceleration (Summer)
1.73 %g	Horizontal Ground Acceleration (Summer)
1.16 %g	Vertical Ground Acceleration (Winter, DEice)
1.73 %g	Horizontal Ground Acceleration (Winter, DEice)
73 kN/m	Ice Force on Concrete
73 kN/m	Ice Force on Logs/Gates

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	741.43	741.43	741.43	741.43	741.43	741.43	741.43	741.43	kN	Weight of Section
V_{water}	0.02	0.02	0.02	0.02	0.38	0.02	0.02	8.57	m^3	Volume of Water Over Section
M_2	0.22	0.22	0.22	0.22	3.71	0.22	0.22	84.07	kN	Weight of Water Over Section
x	0.05	0.05	0.05	0.05	0.27	0.05	0.05	2.21	m	Location of Water Force Along X-Axis
ICE	-	73.00	-	73.00	-	-	73.00	-	kN	Total Ice Force
y	-	6.21	-	6.21	-	-	6.21	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	3.85	3.85	-	kN	Westergaards Force
y	-	-	-	-	-	2.68	2.68	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	207.87	207.87	207.87	207.87	205.33	207.87	207.87	445.10	kN	Hydrostatic Pressure From Headwater
y	2.17	2.17	2.17	2.17	2.16	2.17	2.17	2.99	m	Location of Headwater Force Along Y-Axis
w_2	5.94	5.94	5.94	5.94	15.02	5.94	5.94	95.83	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.47	m	Location of Tailwater Force Along Y-Axis
H_1	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	m	Location of Other Horizontal Force Along Y-Axis
V_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kN	Other Vertical Force
x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	210.90				230.32			
Effective Base	%	100.0				87.0			
Length of Base in Compression	m	5.65				4.92			
Resultant	m	2.562				1.639			
Stress at Heel	kPa	-67.74				0.00			
Cracked		NO				YES			
Stress at Toe	kPa	-120.13				-207.94			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		2.14				1.49			
F.S. Sliding ϕ= 25		1.17				0.84			
F.S. Sliding ϕ= 30		1.45				1.04			
F.S. Sliding ϕ= 35		**1.76**				**1.26**			
F.S. Sliding ϕ= 40		2.11				1.51			
F.S. Sliding ϕ= 45		2.51				1.80			
Accepted F.S. Sliding		1.50				1.50			

Stability Parameters:

Seismic: Site is located near the Christie Dam

Christie Dam Seismic information from GSC data:

Probability of Exceedance Per Year	0.0100	0.0050	0.0021	0.0010	0.0001
Return Period (yrs)	100	200	476	1000	10000
Peak Horizontal Ground Acceleration (g)	0.026	0.034	0.048	0.065	0.162 (Estimated)

DE_{ice} = 2.60% MDE = 2.60%

Ice Loads:

Reservoir Shoreline Characteristics	Winter Air Temperature (January 1% Temperature* from NBC)		
	Mild 0° to -20°C	Average -21° to -29°C	Severe -30°C & Lower
Flat Shore (<20° slope)	58.4 kN/m (4 kips/ft)	80.2 kN/m (5.5 kips/ft)	102.1 kN/m (7 kips/ft)
Steeper Shore (20° to 45° slope)	73.0 kN/m (5 kips/ft)	87.5 kN/m (6 kips/ft)	116.7 kN/m (8 kips/ft)
Steep Rocky Shore (>45° slope)	87.5 kN/m (6 kips/ft**)	116.7 kN/m (8 kips/ft**)	145.9 kN/m (10 kips/ft**)

January 1% = -19 °C (OBC) Steeper Shore

Therefore,
Ice load on Concrete = 73.0 kN/m
Ice load on Steel Gates = 36.5 kN/m
Ice load on Stoplogs = 29.2 kN/m

Water Levels:

	HWL (m)	TWL (m)	
Summer (Usual)	216.28	212.83	Assume 1100mm above Base Elevation
Winter (Usual)	215.06	212.83	
Flood (1:100yr)	218.20	213.48	
Flood (Hazel)	221.50	216.15	

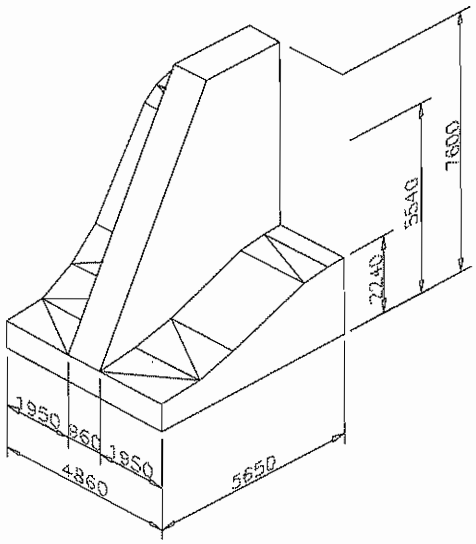
Assumed Base Elevation = 211.73 m

Frictional Resistance Angle: $\Phi = 31°$ (PetoMacCalluan Ltd. Stability Calculations)

Sediment Unit Weight: γ_{sat} = 14.4 kN/m^3 (Similar to Very soft organic clays)

Terzaghi, K, Peck, R, and Mersri, G. Soil Mechanics In Engineering Practice, "Table 6.3 - Porosity, Void Ratio, Density, and Unit Weight of Typical Soils in Nature State", p. 22. John Wiley & Sons Inc., 1996.

Spillway 2-3



Anchors required to Stabilize Dam at Original Water Levels:

3 - 32mm dia. Post-tensioned Anchors in each Pier. (3x500kN = 1500kN force applied to Pier)

Practical Number of Anchors that could be installed in the top of the Piers:

2 - 36mm dia. Post-tensioned Anchors in each Pier. (2x632.4kN = 1265kN force applied to Pier)

Note: The water levels for the summer condition will have to be lowered from the original water levels to make the dam stable with the practical number of anchors installed.

Summer Water Level = 218.10m

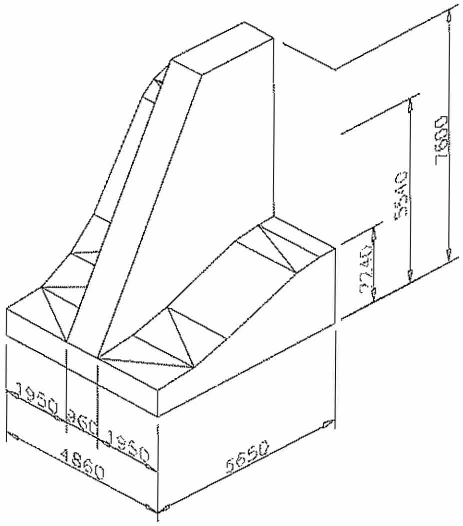
Summary

Load Combinations	Sliding		Base Stresses		Location of Resultant
	Acceptance Criteria in Sliding	Calculated Factor of Safety	At Heel (kPa)	At Toe (kPa)	
With Anchors required to Stabilize Dam at Original Water Levels					
Summer (Usual)	1.50	1.59	65.30	104.30	Within middle third of base.
Winter (Usual)	1.50	1.85	70.07	109.05	Within middle third of base.
Earthquake (Summer)	1.00	1.50	58.37	109.68	Within middle third of base.
Earthquake (Winter)	1.00	1.75	64.70	112.87	Within middle third of base.
Flood I (1:100yr)	1.30	2.35	113.06	80.22	Within middle third of base.
Flood II (Hazel)	1.30	1.49	45.64	141.54	Within middle third of base.
With Practical Number of Anchors that could be installed in the top of the Piers					
Summer (Usual)	1.50	1.50	95.23	58.61	Within middle third of base.
Winter (Usual)	1.50	1.53	77.33	84.66	Within middle third of base.
Earthquake (Summer)	1.00	1.42	88.42	63.87	Within middle third of base.
Earthquake (Winter)	1.00	1.45	71.96	88.48	Within middle third of base.
Flood I (1:100yr)	1.30	2.14	136.26	39.89	Within middle third of base.
Flood II (Hazel)	1.30	1.35	68.84	101.21	Within middle third of base.

Stresses: -ve = tension, +ve = compression
- Unacceptable Factor of Safety
Unstable - Unstable due to cracking of base

Calculations	By J. Neufeld	Date Sept. 13/05	Project No. 16681D0
	Checked B. MacTavish	Date Sept. 16/05	Calculation No.
Subject	Crook Hollow Dam - Condition Assessment - Max. # of Anchors Required	Page 31	of 36
	Geometry and Materials		

Spillway 2-3



Anchors required to Stabilize Dam at Original Water Levels:

3 - 32mm dia. Post-tensioned Anchors in each Pier. (3x500kN = 1500kN force applied to Pier)

Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	218.240	m
H.W.L. (Summer)	218.240	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	217.270	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I, 1:100yr)	213.970	m
H.W.L. (Flood I, 1:100yr)	218.200	m
T.W.L. (Flood I, 1:100yr)	213.480	m
Log Top Elevation (Flood II, Hazel)	213.970	m
H.W.L. (Flood II, Hazel)	221.500	m
T.W.L. (Flood II, Hazel)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	216.970	m
Volume of Section	78.29	m^3
Centre of Gravity X	3.592	m
Centre of Gravity Y	2.245	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_β	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	5.24	-	5.24	-	-	5.24	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	18.69	13.53	-	kN	Westergaards Force
y	-	-	-	-	-	2.68	2.28	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	1010.27	731.64	1010.27	731.64	655.61	1010.27	731.64	1168.60	kN	Hydrostatic Pressure From Headwater
y	2.17	1.85	2.17	1.85	1.38	2.17	1.85	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	207.50	44.60	44.60	415.80	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	2.92	0.67	0.67	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	kN	Other Vertical Force
x	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1024.96				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.608				2.620			
Stress at Heel	kPa	-65.30				-70.07			
Cracked		NO				NO			
Stress at Toe	kPa	-104.30				-109.05			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		2.05				2.19			
F.S. Sliding ϕ= 25		1.06				1.23			
F.S. Sliding ϕ= 30		1.31				1.52			
F.S. Sliding ϕ= 35		**1.59**				**1.85**			
F.S. Sliding ϕ= 40		1.90				2.22			
F.S. Sliding ϕ= 45		2.27				2.64			
Accepted F.S. Sliding		1.50				1.50			

		Load Case #4 - Flood I				Load Case #6 - Flood II			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1107.12				1911.20			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.985				2.343			
Stress at Heel	kPa	-113.06				-45.64			
Cracked		NO				NO			
Stress at Toe	kPa	-80.22				-141.54			
Allowable Stress at Toe	kPa	-3077				-3077			
F.S. Overturning		2.51				1.63			
F.S. Sliding ϕ= 25		1.57				0.99			
F.S. Sliding ϕ= 30		1.94				1.23			
F.S. Sliding ϕ= 35		**2.35**				**1.49**			
F.S. Sliding ϕ= 40		2.82				1.78			
F.S. Sliding ϕ= 45		3.36				2.12			
Accepted F.S. Sliding		1.30				1.30			

Input Summary

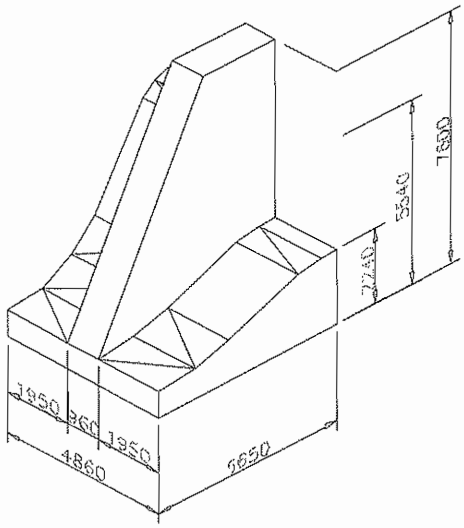
	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	5.24	-	5.24	-	-	5.24	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	18.69	13.53	-	kN	Westergaards Force
y	-	-	-	-	-	2.68	2.28	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	1010.27	731.64	1010.27	731.64	655.61	1010.27	731.64	1168.60	kN	Hydrostatic Pressure From Headwater
y	2.17	1.85	2.17	1.85	1.38	2.17	1.85	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	44.60	44.60	44.60	207.50	44.60	44.60	415.80	kN	Other Horizontal Force
y	0.67	0.67	0.67	0.67	2.92	0.67	0.67	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	kN	Other Vertical Force
x	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1024.96				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.608				2.620			
Stress at Heel	kPa	-65.30				-70.07			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-104.30				-109.05			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		2.05				2.19			
F.S. Sliding ϕ= 25		1.06				1.23			
F.S. Sliding ϕ= 30		1.31				1.52			
F.S. Sliding ϕ= 35		**1.59**				**1.85**			
F.S. Sliding ϕ= 40		1.90				2.22			
F.S. Sliding ϕ= 45		2.27				2.64			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1024.96				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.537				2.570			
Stress at Heel	kPa	-58.37				-64.70			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-109.68				-112.87			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		1.97				2.11			
F.S. Sliding ϕ= 25		1.00				1.16			
F.S. Sliding ϕ= 30		1.24				1.44			
F.S. Sliding ϕ= 35		**1.50**				**1.75**			
F.S. Sliding ϕ= 40		1.80				2.09			
F.S. Sliding ϕ= 45		2.14				2.50			
Accepted F.S. Sliding		1.00				1.00			

Spillway 2-3



Practical Number of Anchors that could be installed in the top of the Piers:

2 - 36mm dia. Post-tensioned Anchors in each Pier. (2x632.4kN = 1265kN force applied to Pier)

Note: The water levels for the summer condition will have to be lowered from the original water levels to make the dam stable with the practical number of anchors installed.

Summer Water Level = 218.10m

Geometrical Definitions

Base Elevation	211.730	m
Log Top Elevation (Summer)	218.100	m
H.W.L. (Summer)	218.100	m
T.W.L. (Summer)	212.830	m
Log Top Elevation (Winter)	217.270	m
H.W.L. (Winter)	217.270	m
T.W.L. (Winter)	212.830	m
Log Top Elevation (Flood I, 1:100yr)	213.970	m
H.W.L. (Flood I. 1:100yr)	218.200	m
T.W.L. (Flood I, 1:100yr)	213.480	m
Log Top Elevation (Flood II, Hazel)	213.970	m
H.W.L. (Flood II, Hazel)	221.500	m
T.W.L. (Flood II, Hazel)	216.150	m
Deck Top Elevation	219.330	m
Thickness of Deck	0.000	m
Ice Elevation	216.970	m
Volume of Section	78.29	m^3
Centre of Gravity X	3.592	m
Centre of Gravity Y	2.245	m
Length of Pier Section	5.650	m
Width of Pier Section	0.960	m
Length of Sluiceway #1 Section	5.650	m
Width of Sluiceway #1 Section	1.950	m
Distance to Edge of Sluiceway #1 Section	0.000	m
Length of Sluiceway #2 Section	5.650	m
Width of Sluiceway #2 Section	1.950	m
Distance to Edge of Sluiceway #2 Section	0.000	m

Material Properties

f_c'	20.00	MPa	Concrete Compressive Strength
f_{b1}	4.00	MPa	Rock Bearing Strength
f_{b2}	4.00	MPa	Till Bearing Strength
ϕ_1	25.0	°	Angle of Friction #1
ϕ_2	30.0	°	Angle of Friction #2
ϕ_3	35.0	°	Specified Angle of Sliding Friction
ϕ_4	40.0	°	Angle of Friction #4
ϕ_5	45.0	°	Angle of Friction #5
τ_n	0.00	MPa	Cohesion
τ_1	0.38	MPa	$(0.17\sqrt{fc'})/2$
τ_2	0.76	MPa	$(0.17\sqrt{fc'})$
τ_3	1.00	MPa	(0.05fc')
γ_{conc}	23.50	kN/m^3	Unit Weight of Concrete
γ_{water}	9.81	kN/m^3	Unit Weight of Water
ϕ_B	35.0	°	Basic Friction Angle

Loadings

1.16	%g	Vertical Ground Acceleration (Summer)
1.73	%g	Horizontal Ground Acceleration (Summer)
1.16	%g	Vertical Ground Acceleration (Winter, DEice)
1.73	%g	Horizontal Ground Acceleration (Winter, DEice)
73	kN/m	Ice Force on Concrete
29.2	kN/m	Ice Force on Logs/Gates

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	5.24	-	5.24	-	-	5.24	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	17.89	13.53	-	kN	Westergaards Force
y	-	-	-	-	-	2.62	2.28	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	967.28	731.64	967.28	731.64	655.61	967.28	731.64	1168.60	kN	Hydrostatic Pressure From Headwater
y	2.12	1.85	2.12	1.85	1.38	2.12	1.85	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	130.00	44.60	130.00	207.50	44.60	130.00	415.80	kN	Other Horizontal Force
y	0.67	3.40	0.67	3.40	2.92	0.67	3.40	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	kN	Other Vertical Force
x	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #1 - Usual (Summer)				Load Case #2 - Usual (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1006.11				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.049				2.782			
Stress at Heel	kPa	-95.23				-77.33			
Cracked		NO				NO			
Stress at Toe	kPa	-58.61				-84.66			
Allowable Stress at Toe	kPa	-2667				-2667			
F.S. Overturning		2.15				2.06			
F.S. Sliding ϕ= 25		1.00				1.02			
F.S. Sliding ϕ= 30		1.24				1.26			
F.S. Sliding ϕ= 35		**1.50**				**1.53**			
F.S. Sliding ϕ= 40		1.80				1.84			
F.S. Sliding ϕ= 45		2.15				2.19			
Accepted F.S. Sliding		1.50				1.50			

		Load Case #4 - Flood I				Load Case #6 - Flood II			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1107.12				1911.20			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.340				2.646			
Stress at Heel	kPa	-136.26				-68.84			
Cracked		NO				NO			
Stress at Toe	kPa	-39.89				-101.21			
Allowable Stress at Toe	kPa	-3077				-3077			
F.S. Overturning		2.54				1.65			
F.S. Sliding ϕ= 25		1.43				0.90			
F.S. Sliding ϕ= 30		1.77				1.11			
F.S. Sliding ϕ= 35		**2.14**				**1.35**			
F.S. Sliding ϕ= 40		2.57				1.62			
F.S. Sliding ϕ= 45		3.06				1.93			
Accepted F.S. Sliding		1.30				1.30			

Input Summary

	Load Case									
	#1	#2	#3 (Sum)	#3 (Win)	#4	#5 (Sum)	#5 (Win)	#6		
M_1	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	1839.70	kN	Weight of Section
V_{water}	1.41	1.41	1.41	1.41	42.93	1.41	1.41	116.35	m^3	Volume of Water Over Section
M_2	13.81	13.81	13.81	13.81	421.10	13.81	13.81	1141.43	kN	Weight of Water Over Section
x	0.64	0.64	0.64	0.64	2.98	0.64	0.64	2.90	m	Location of Water Force Along X-Axis
ICE	-	183.96	-	183.96	-	-	183.96	-	kN	Total Ice Force
y	-	5.24	-	5.24	-	-	5.24	-	m	Location of Ice Force Along Y-Axis
W	-	-	-	-	-	17.89	13.53	-	kN	Westergaards Force
y	-	-	-	-	-	2.62	2.28	-	m	Location of Westergaards along Y-Axis
S_H	-	-	-	-	-	1.73	1.73	-	%g	Horizontal Seismic Coefficient
S_V	-	-	-	-	-	1.16	1.16	-	%g	Vertical Seismic Coefficient
w_1	967.28	731.64	967.28	731.64	655.61	967.28	731.64	1168.60	kN	Hydrostatic Pressure From Headwater
y	2.12	1.85	2.12	1.85	1.38	2.12	1.85	1.77	m	Location of Headwater Force Along Y-Axis
w_2	28.84	28.84	28.84	28.84	73.00	28.84	28.84	374.80	kN	Hydrostatic Pressure From Tailwater
y	0.37	0.37	0.37	0.37	0.58	0.37	0.37	1.11	m	Location of Tailwater Force Along Y-Axis
H_1	44.60	130.00	44.60	130.00	207.50	44.60	130.00	415.80	kN	Other Horizontal Force
y	0.67	3.40	0.67	3.40	2.92	0.67	3.40	3.41	m	Location of Other Horizontal Force Along Y-Axis
V_1	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	1264.80	kN	Other Vertical Force
x	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	m	Location of Other Vertical Force Along X-Axis

Results (ODSG)

		Load Case #3 - Post-Earthquake (Summer)				Load Case #3 - Post-Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1006.11				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	3.049				2.782			
Stress at Heel	kPa	-95.23				-77.33			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-58.61				-84.66			
Allowable Stress at Toe	kPa	-3636				-3636			
F.S. Overturning		2.15				2.06			
F.S. Sliding ϕ= 25		1.00				1.02			
F.S. Sliding ϕ= 30		1.24				1.26			
F.S. Sliding ϕ= 35		**1.50**				**1.53**			
F.S. Sliding ϕ= 40		1.80				1.84			
F.S. Sliding ϕ= 45		2.15				2.19			
Accepted F.S. Sliding		1.10				1.10			

		Load Case #5 - Earthquake (Summer)				Load Case #5 - Earthquake (Winter)			
Cohesion	MPa	0.00				0.00			
% Uplift at Upstream Face	%	100.0				100.0			
Total Uplift	kN	1006.11				894.32			
Effective Base	%	100.0				100.0			
Length of Base in Compression	m	5.65				5.65			
Resultant	m	2.977				2.728			
Stress at Heel	kPa	-88.42				-71.96			
Cracked		NO				NO			
Crack Propagated		NO				NO			
Stress at Toe	kPa	-63.87				-88.48			
Allowable Stress at Toe	kPa	-4000				-4000			
F.S. Overturning		2.07				1.99			
F.S. Sliding ϕ= 25		0.94				0.97			
F.S. Sliding ϕ= 30		1.17				1.20			
F.S. Sliding ϕ= 35		**1.42**				**1.45**			
F.S. Sliding ϕ= 40		1.70				1.74			
F.S. Sliding ϕ= 45		2.02				2.07			
Accepted F.S. Sliding		1.00				1.00			

Appendix E

Hatch Energy Technique for Establishing Shear Resistance Parameters

Appendix E

Hatch Energy Technique for Establishing Shear Resistance Parameters

Barton et al (1973, 1976, 1977, 1990) determined an empirical relationship for discontinuity shear strength that include a component accounting for the continuous shearing of the discontinuities as the normal stress increased.

$$\tau = \sigma_n * \tan\left[\phi_b + JRC_o * \log\left(\frac{JCS_o}{\sigma_n}\right)\right] \qquad (1)$$

where,

JRC_o = the joint roughness coefficient (100-mm long sample), which varies from 0 (smooth) to 20 (rough)
JCS_o = the joint wall compressive strength (100-mm long sample).

This criterion implies that the roughness component of strength of a discontinuity decreases with increasing normal load, falling to a value equivalent to the basic shear strength of the discontinuity surface when the normal stress is equivalent to the compressive strength of the rock. The Barton-Bandis criterion results in a curvilinear failure envelope that more closely represents the actual physical characteristics of shear resistance. Another major advantage of the Barton-Bandis approach is the relative ease at which the shear strength parameters can be established.

(a) Determination of the Joint Roughness Coefficient (JRC_o)
The JRC_o is determined by comparing the appearance of a given discontinuity surface with surface profiles originally published by Barton and Choubey (1977) as shown in Figure E1.

(b) Determination of the Joint Wall Compressive Strength (JCS_o)
The JCS_o is a measure of the compressive strength of the rock immediately adjacent to the sliding surface.

(c) Determination of the Basic Shear Resistance (φ_b)

Barton defined the value of the basic friction (φ_b) as the shear resistance offered between two saw-cut surfaces. Barton concluded that the value of the basic friction tends to be relatively constant (in the range of 25° to 40° for a wide range of rock types).

Rock Type	Basic Friction Angle (φ_b)
A – Sedimentary Rocks Sandstone, Shale, Siltstone, Conglomerate, Chalk, Limestone	26 to 37
B – Igneous Rocks Basalt, Fine-Grained Granite, Coarse-Grained Granite, Porphyry, Dolerite	29 to 38
C – Metamorphic Rocks Amphibolite, Gneiss, Slate	21 to 32

(After Barton and Choubey, 1977)

The two basic parameters that must be estimated for a rough, unbonded discontinuity are, therefore, the basic frictional resistance and the roughness (or dilational) component of shear resistance.

Basic Shear Resistance

For most assessments, reasonable estimates of basic shear strength can be established on the basis reasonable lower bound estimates for a particular rock type as suggested by Barton. In the case of this study, a standard value of 30º was used that would place the estimate at the lower end of the tested precedent.

Roughness values are then added to the basic shear strength. These were established in the field based on geological inspections, the type and size of structure and construction records.

Field Observations for the Assessment of Shear Strength

As at first step in the evaluation of shear resistance, the overall geometry of the potential failure mode was established. For example, the potential failure plane may not necessarily be along the rock/concrete interface, but could be along a weak layer below (but parallel to) the contact, or along a downstream sloping joint plane. In all cases, the angle of the potential failure plane is determined along with an evaluation of any 'release mechanism' that would allow downstream movement of the structure. Any geometry (such as a shear key, downstream outcrop or 3-dimensional effects) which would tend to preclude downstream movement is also assessed. On the basis of these data, a 'preferred' mode of failure is postulated, i.e., that which involves the most critical sliding surface as defined on the basis of the site engineers' observations and experience.

Once the 'preferred' mode of failure has been evaluated, the surface roughness characteristics of the assumed plane of failure are reviewed. As a first step in this process, it must be assessed whether the dam was founded on the natural bedrock surface, or on a single or a series of discontinuity surfaces produced by, for example, the excavations performed beneath a given structure. This information is used to determine the JRC for that particular surface. The nature of the rock surface (i.e., natural or blasted) is established on the basis of Ontario Power Generation (OPG) records which is used to define the available shear resistance. If this is not available, and if the rock/concrete contact is often not directly observable, estimation of the JRC on the basis of the appropriate profile match for surfaces of nearby bedrock outcrops similar to that under the dam.

On the basis of in-house experience, the methodology that Hatch Energy has developed for the selection of the Barton-Bandis roughness component under the circumstances of limited information involves the use of design charts that have been formulated that allow selection of the roughness component on the basis of the height of structure (i.e., normal load) and the general surface characteristics as can be ascertained from the field observation. This typical design chart is given in Figure E2.

$$\tau = \sigma_n \tan\left[\phi_b + JRC \log_{10}\left(\frac{JCS}{\sigma_n}\right)\right]$$

where *JRC* is the joint roughness coefficient and
JCS is the joint wall compressive strength.

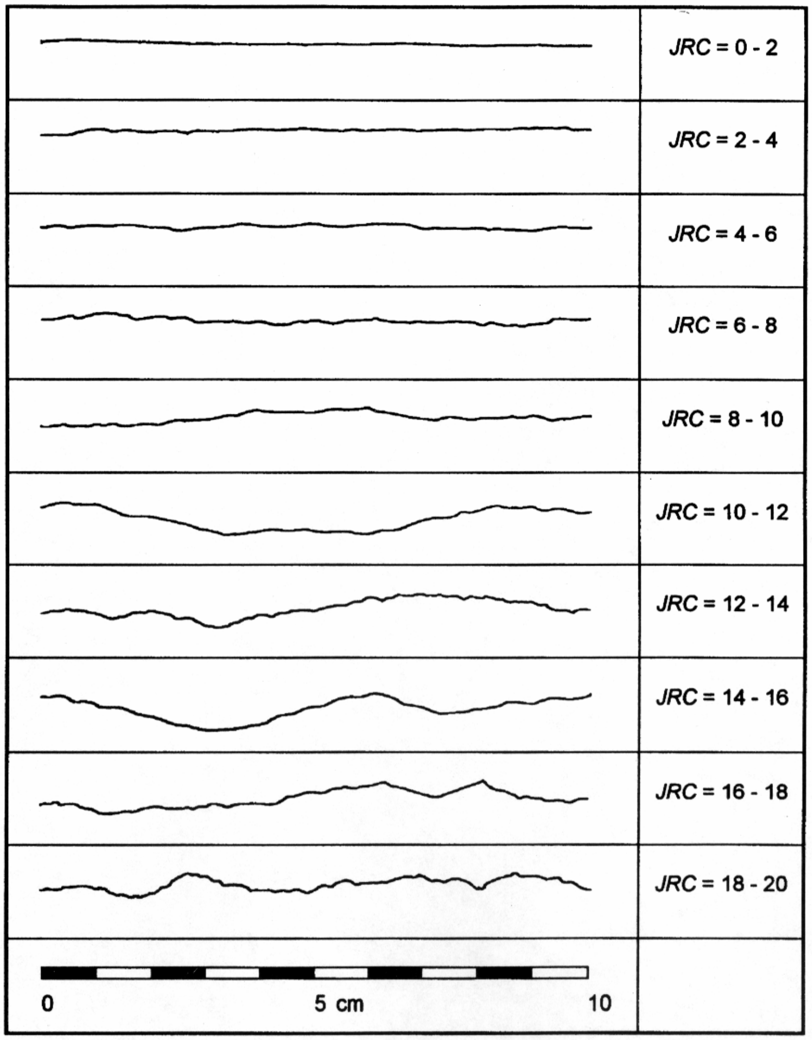


Figure 5.1: Roughness profiles and corresponding *JRC* values (After Barton and Choubey, 1977).

Figure E1
Roughness Profiles and Corresponding
JRC Values (from Hoek et al, 1995)

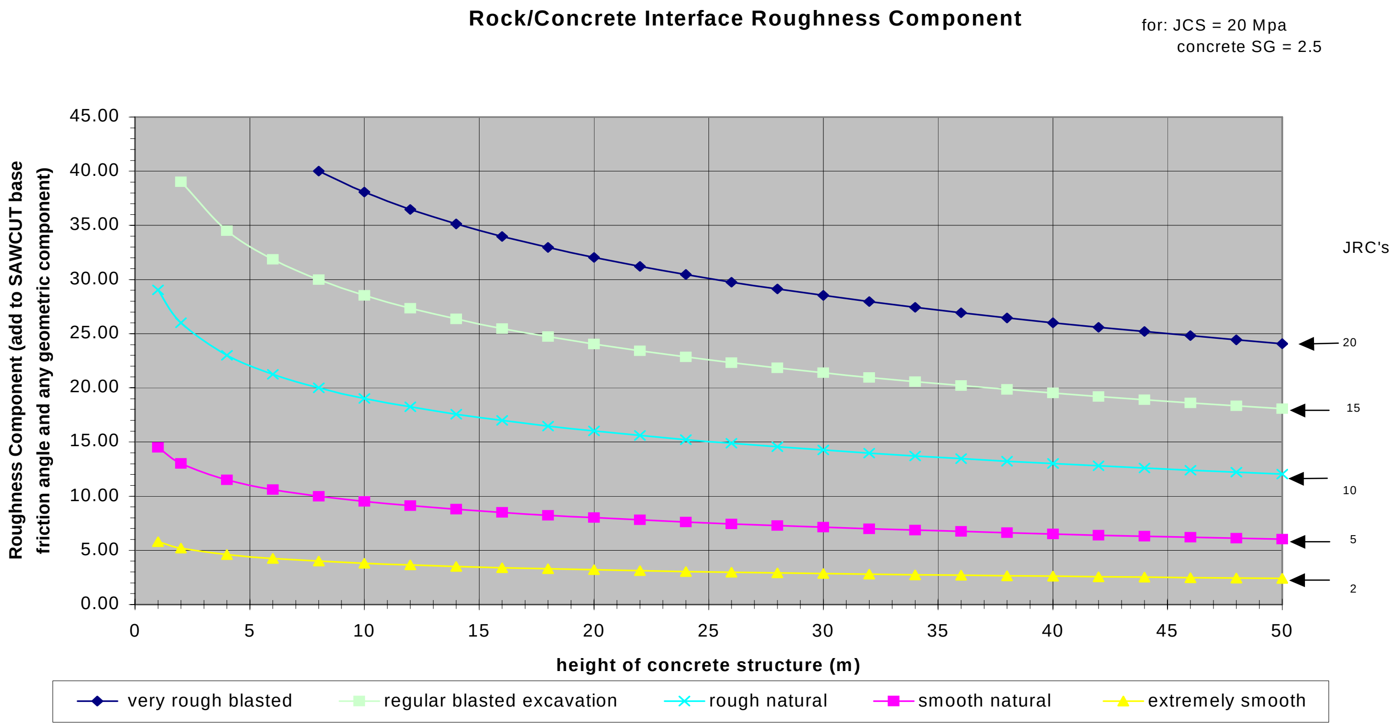


Figure E2
Design Chart for Roughness Component

4342 Queen Street P.O. Box 1001
Niagara Falls, Ontario, Canada L2E 6W1
Tel 905 374 5200 • Fax 905 374 1157