KGS GROUP
CONSULTING ENGINEERS

Brantford 2018 Ice Jam Study

November 1, 2018

Study Phases

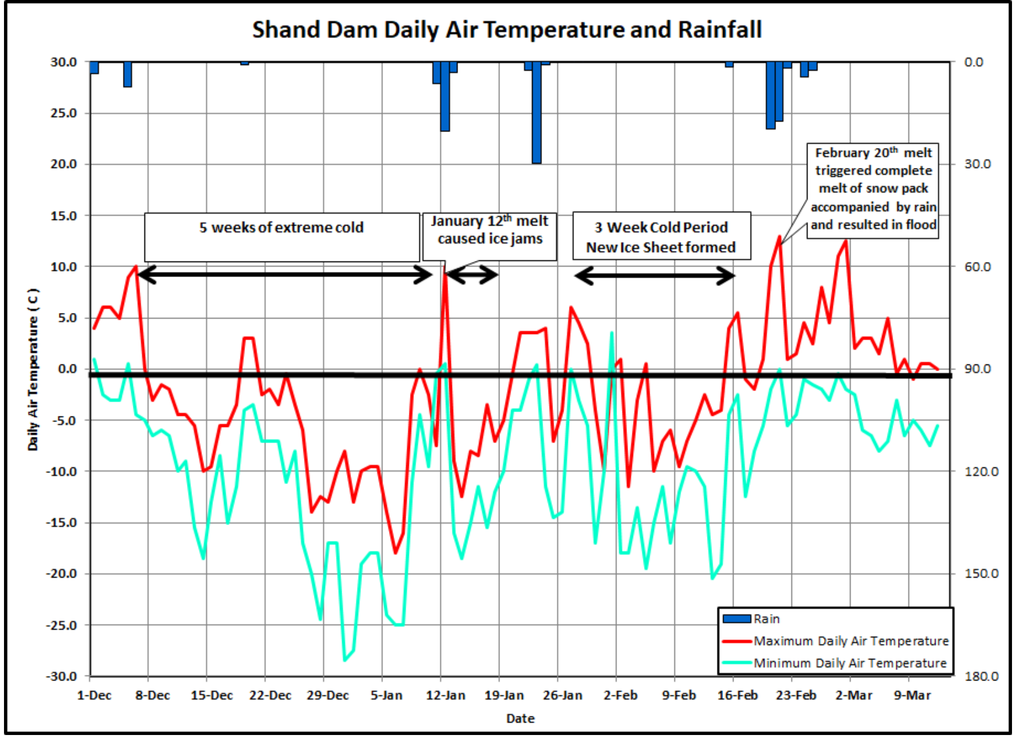
- **Phase 1**: Review available data and documentation from the February 2018 ice jam event that occurred in Brantford
- **Phase 2**: Develop a quantitative description of that ice jam
- **Phase 3**: Analyze the conditions and mechanisms that contribute to ice jam formation in Brantford with the assistance of river ice models
- **Phase 4**: Develop and evaluate alternative measures to prevent and/or mitigate future similar ice jam events in Brantford

Data Available (Phase 1)

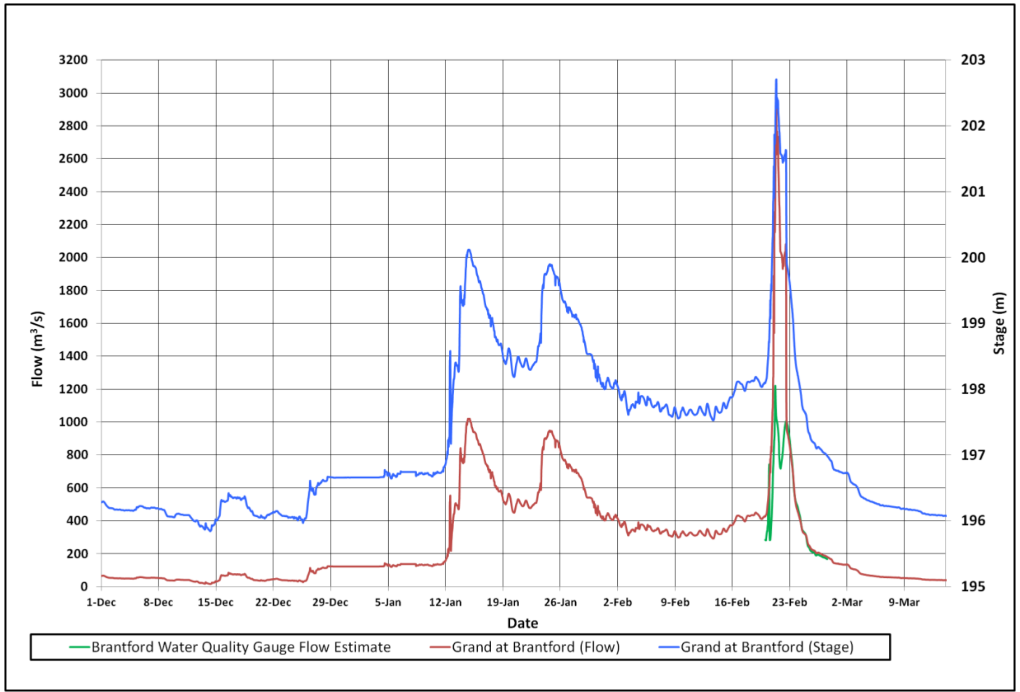
- **Gauge Data**
  - WSC Gauge 02GB001
  - Brantford Water Quality and Level Gauge
  - WSC Gauge 02GA003
- **Reference Elevations of Bridges and Dike Floodwall**
- **Video and Photos**
  - “My Little Hobby” and “Police Drone Video”
  - Key features and associated times of each video can be seen in Table 2 of the Memorandum

File Type	Before Event	Feb-21	Feb-22	After Event
Aerial Drone Video	0	5	2	0
Ground Video	1	0	3	0
Image	0	15	0	720
WSC Gauge Image	336	168	168	0

- **GRCA Analyses of Meteorological and Flow Conditions**



Shand Dam Daily Air Temperature and Rainfall
Daily Air Temperature (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
0.0
30.0
60.0
90.0
120.0
150.0
180.0
5 weeks of extreme cold
January 12th melt caused ice jams
3 Week Cold Period New Ice Sheet formed
February 20th melt triggered complete melt of snow pack accompanied by rain and resulted in flood
Rain
Maximum Daily Air Temperature
Minimum Daily Air Temperature
1-Dec
8-Dec
15-Dec
22-Dec
29-Dec
5-Jan
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
16-Feb
23-Feb
2-Mar
9-Mar
Date



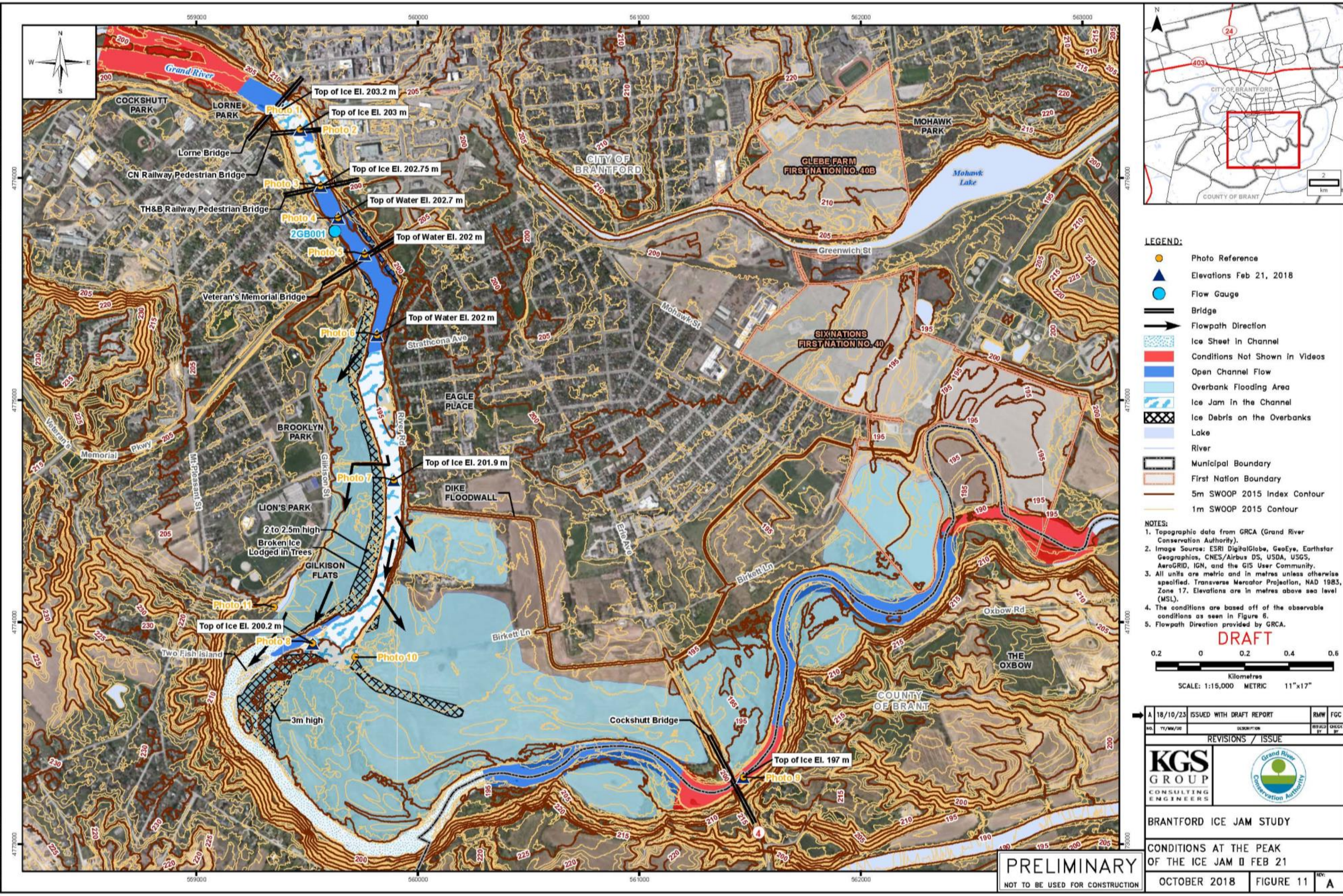
Flow (m3/s)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Stage (m)
203
202
201
200
199
198
197
196
195
1-Dec
8-Dec
15-Dec
22-Dec
29-Dec
5-Jan
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
16-Feb
23-Feb
2-Mar
9-Mar
Date
Brantford Water Quality Gauge Flow Estimate
Grand at Brantford (Flow)
Grand at Brantford (Stage)

Summary of Conditions (Phase 2)

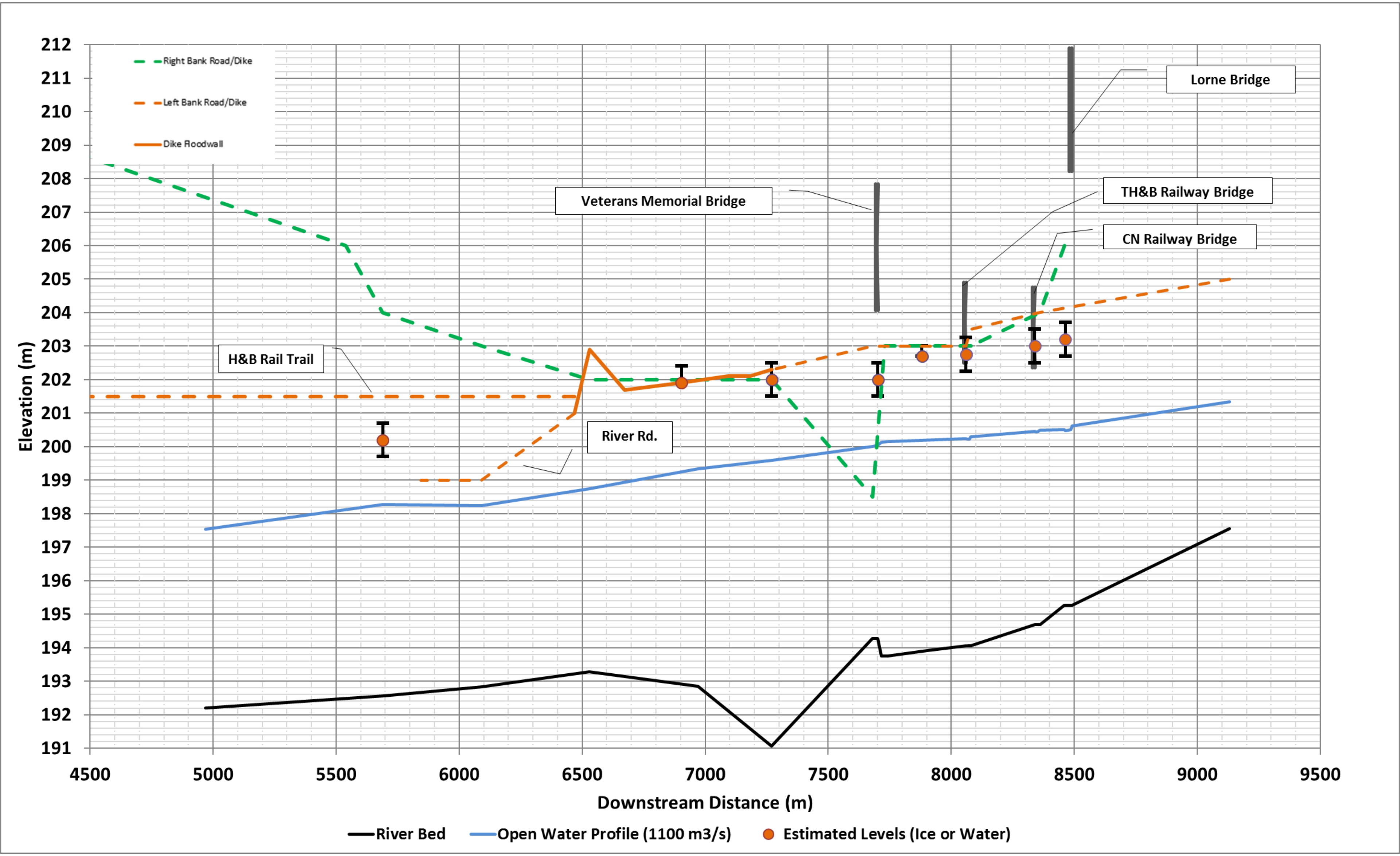
Ice Jam Extents

- Approximately 1.2 km long, From upstream of Two Fish Island to 400 m downstream of Veterans Memorial Bridge
- Approximately 3 m thick
- Channel width approximately 70 m
- Volume of Ice Jam including voids would be approximately 600,000 m^3 or more

- Downstream Smooth Ice Cover
  - Smooth ice cover beginning at the toe of the ice jam and extending 2 km downstream
- Open Channel Conditions
  - Open channel flow occurs after the 2 km ice sheet cover and extends downstream for an unknown length

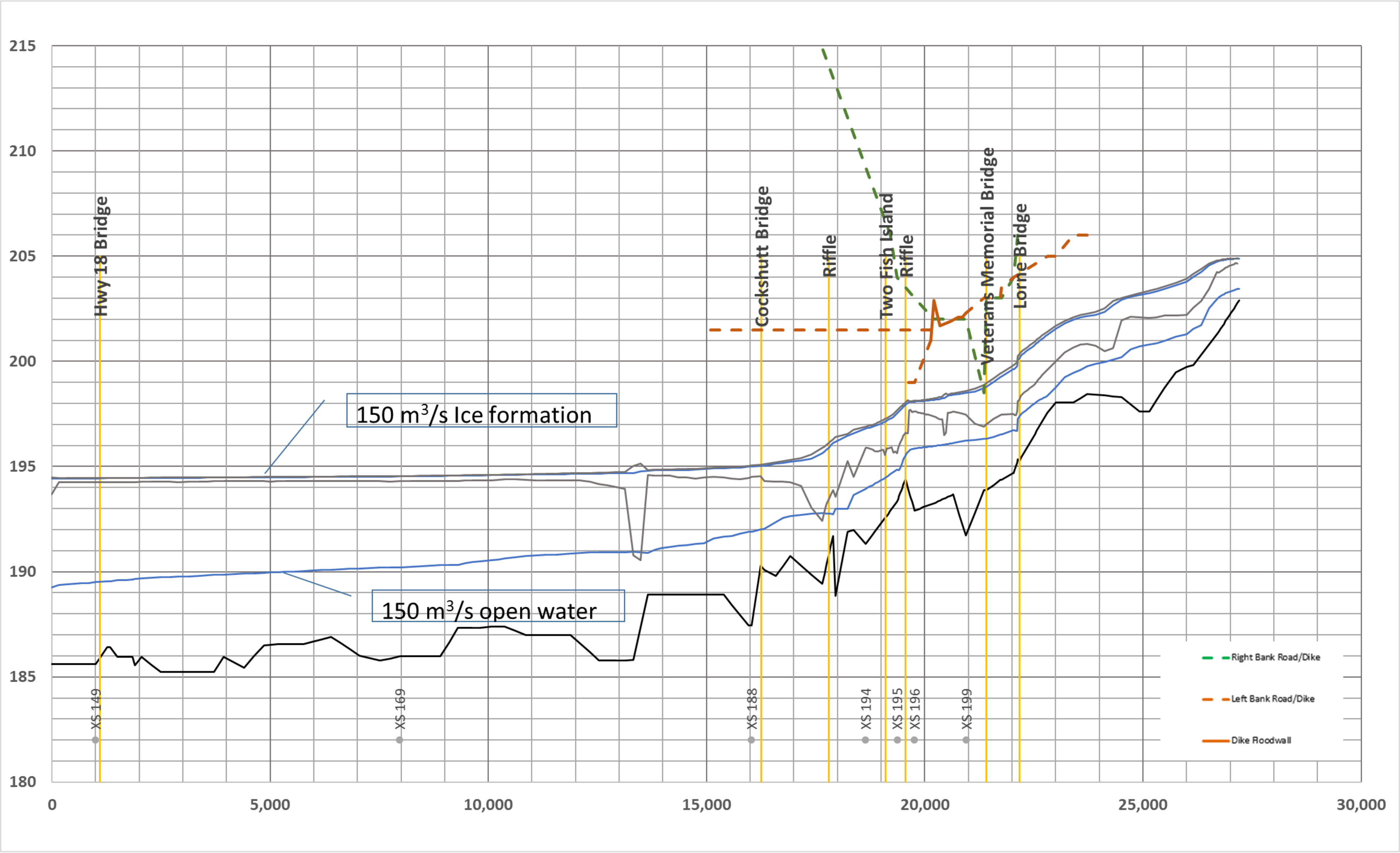


Grand River
COCKSHUTT PARK
LORNE PARK
Top of Ice El. 203.2 m
Top of Ice El. 203 m
Photo 1
Photo 2
Lorne Bridge
CN Railway Pedestrian Bridge
Top of Ice El. 202.75 m
Photo 3
TH&B Railway Pedestrian Bridge
Top of Water El. 202.7 m
Photo 4
2GB001
Top of Water El. 202 m
Photo 5
Veteran's Memorial Bridge
Top of Water El. 202 m
Photo 6
Strathcona Ave
EAGLE PLACE
BROOKLYN PARK
Veteran's Memorial Pkwy
Mt Pleasant St
Gilkison St
River Rd
Top of Ice El. 201.9 m
Photo 7
DIKE FLOODWALL
LION'S PARK
2 to 2.5m high
Broken Ice Lodged in Trees
GILKISON FLATS
Photo 11
Top of Ice El. 200.2 m
Photo 8
Two Fish Island
Photo 10
3m high
Birkett Ln
Cockshutt Bridge
Top of Ice El. 197 m
Photo 9
CITY OF BRANTFORD
GLEBE FARM FIRST NATION NO. 40B
MOHAWK PARK
Mohawk Lake
Greenwich St
Mohawk St
SIX NATIONS FIRST NATION NO. 40
Erie Ave
Oxbow Rd
THE OXBOW
COUNTY OF BRANT
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION
CITY OF BRANTFORD
COUNTY OF BRANT
LEGEND:
Photo Reference
Elevations Feb 21, 2018
Flow Gauge
Bridge
Flowpath Direction
Ice Sheet in Channel
Conditions Not Shown in Videos
Open Channel Flow
Overbank Flooding Area
Ice Jam in the Channel
Ice Debris on the Overbanks
Lake
River
Municipal Boundary
First Nation Boundary
5m SWOOP 2015 Index Contour
1m SWOOP 2015 Contour
NOTES:
1. Topographic data from GRCA (Grand River Conservation Authority).
2. Image Source: ESRI DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 17. Elevations are in metres above sea level (MSL).
4. The conditions are based off of the observable conditions as seen in Figure 6.
5. Flowpath Direction provided by GRCA.
DRAFT
Kilometres
SCALE: 1:15,000 METRIC 11"x17"
A 18/10/23 ISSUED WITH DRAFT REPORT RMW FGC
REVISIONS / ISSUE
KGS GROUP CONSULTING ENGINEERS
Grand River Conservation Authority
BRANTFORD ICE JAM STUDY
CONDITIONS AT THE PEAK OF THE ICE JAM 0 FEB 21
OCTOBER 2018
FIGURE 11
REV: A

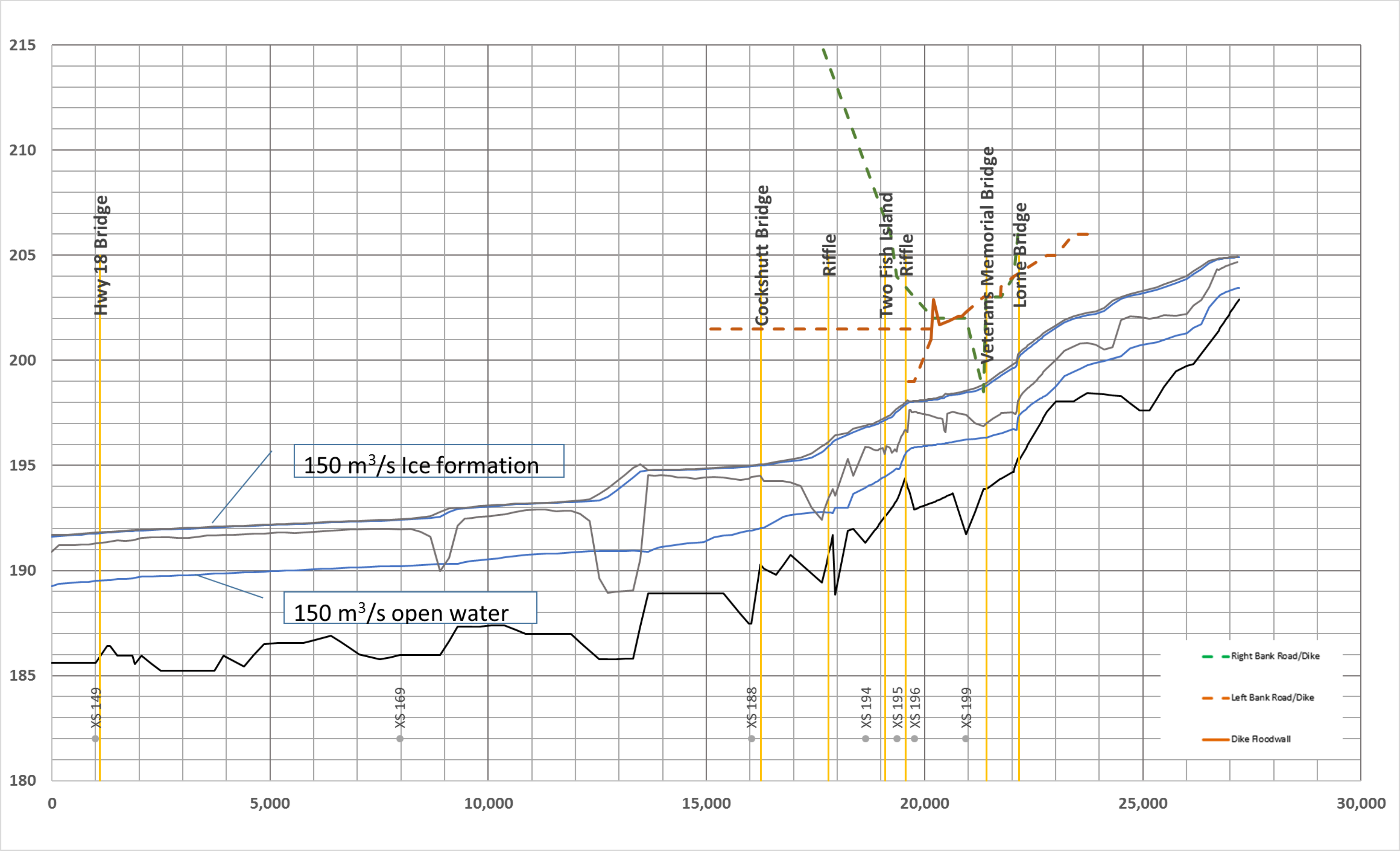


Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall
Lorne Bridge
Veterans Memorial Bridge
TH&B Railway Bridge
CN Railway Bridge
H&B Rail Trail
River Rd.
Elevation (m)
Downstream Distance (m)
212
211
210
209
208
207
206
205
204
203
202
201
200
199
198
197
196
195
194
193
192
191
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
River Bed
Open Water Profile (1100 m3/s)
Estimated Levels (Ice or Water)

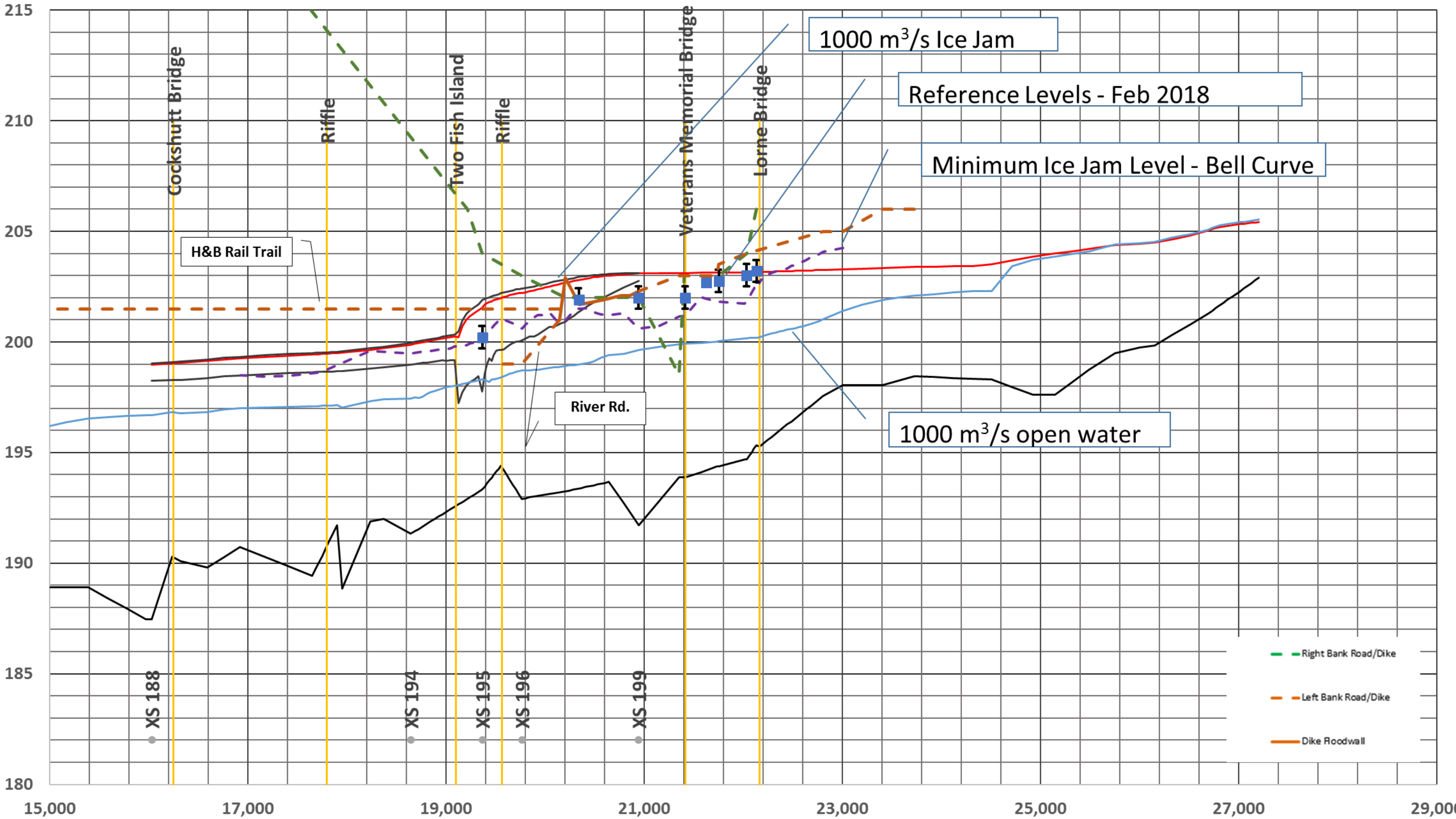
PHASE 3. ANALYSES AND MODELLING



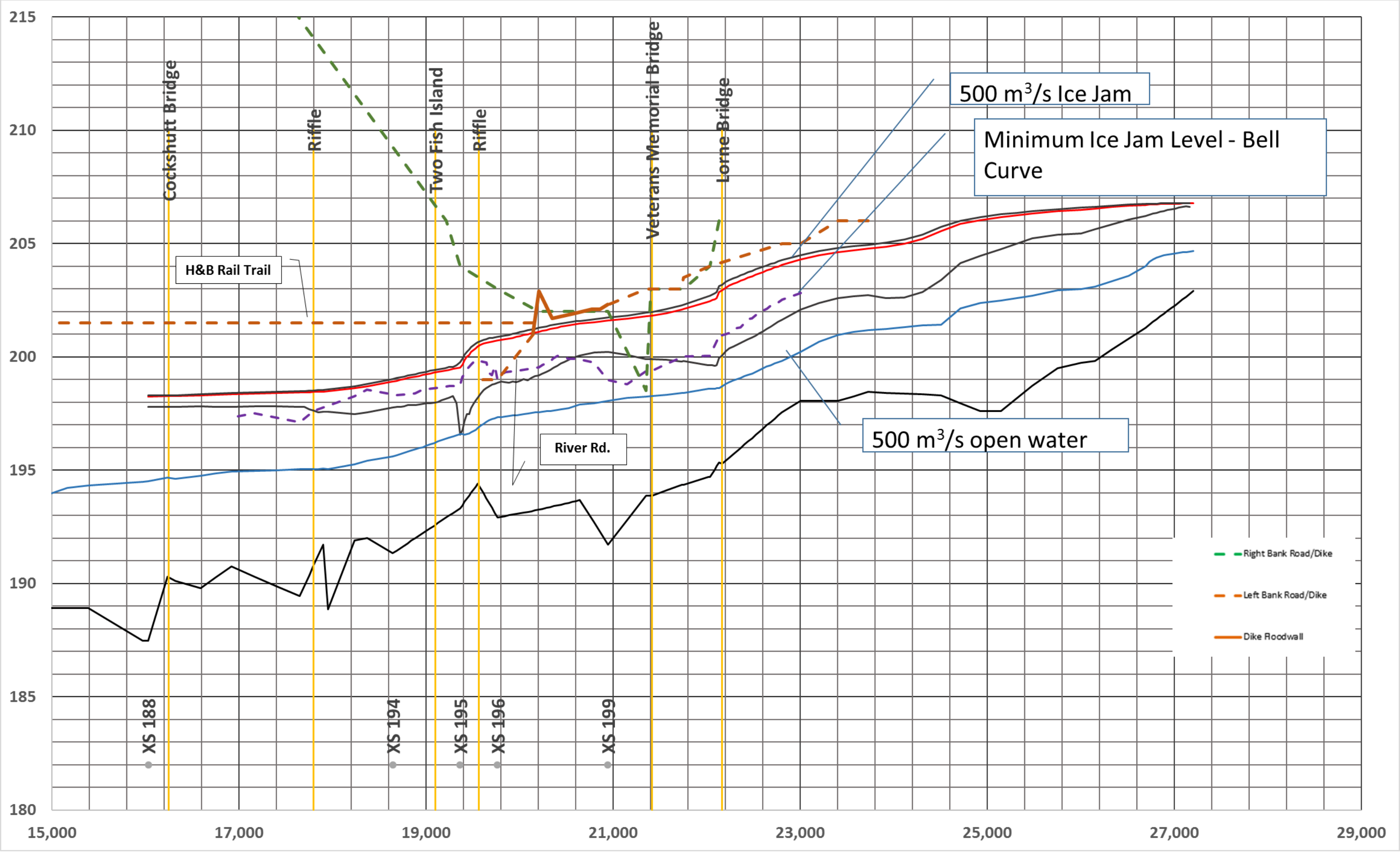
215
210
205
200
195
190
185
180
0
5,000
10,000
15,000
20,000
25,000
30,000
Hwy 18 Bridge
Cockshutt Bridge
Riffle
Two Fish Island
Riffle
Veterans Memorial Bridge
Lorne Bridge
150 m³/s Ice formation
150 m³/s open water
XS 149
XS 169
XS 188
XS 194
XS 195
XS 196
XS 199
Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall



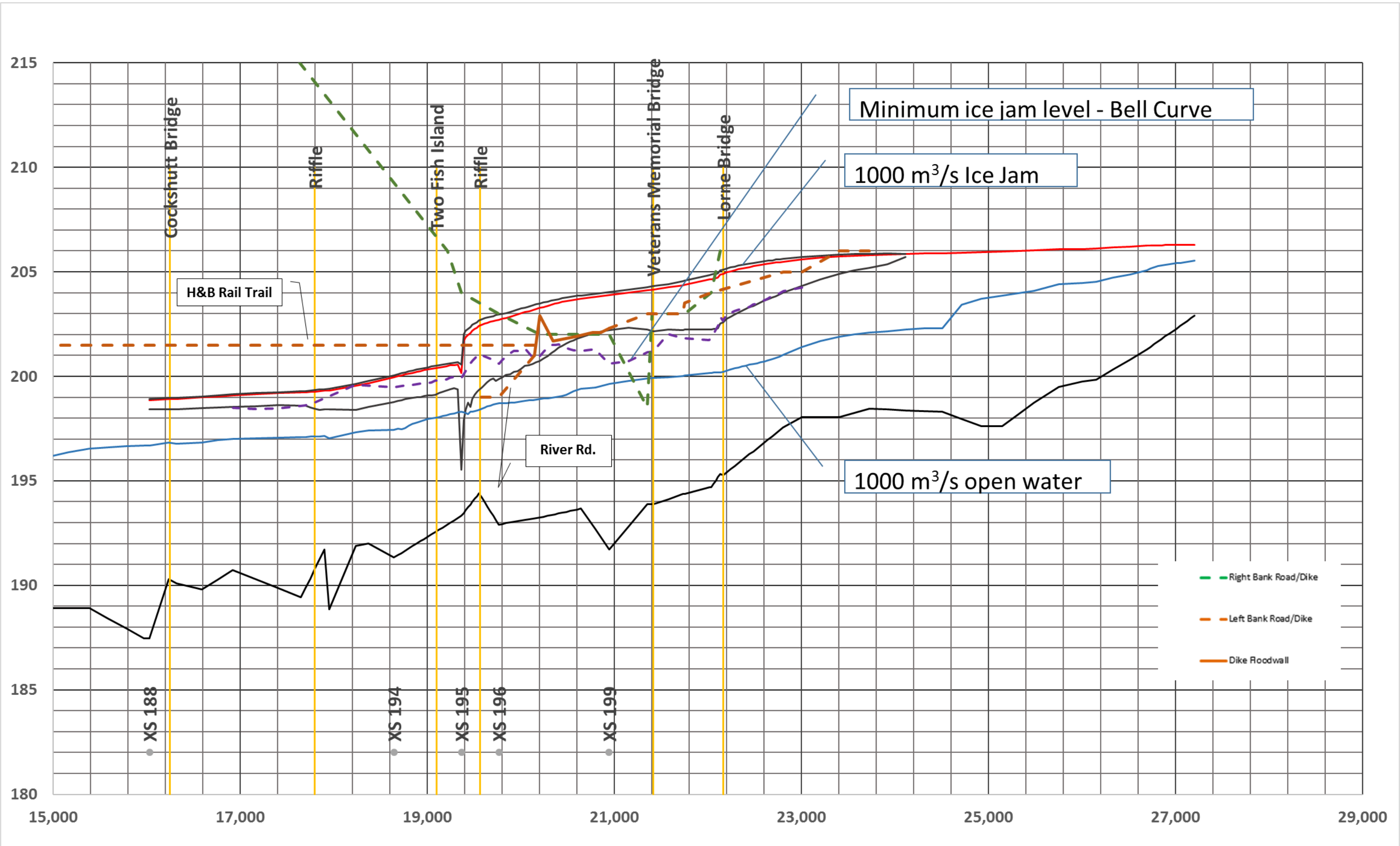
215
210
205
200
195
190
185
180
0
5,000
10,000
15,000
20,000
25,000
30,000
Hwy 18 Bridge
Cockshutt Bridge
Riffle
Two Fish Island
Riffle
Veterans Memorial Bridge
Lorne Bridge
150 m3/s Ice formation
150 m3/s open water
XS 149
XS 169
XS 188
XS 194
XS 195
XS 196
XS 199
Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall



215
210
205
200
195
190
185
180
15,000
17,000
19,000
21,000
23,000
25,000
27,000
29,000
Cockshutt Bridge
Riffle
Two Fish Island
Riffle
Veterans Memorial Bridge
Lorne Bridge
1000 m³/s Ice Jam
Reference Levels - Feb 2018
Minimum Ice Jam Level - Bell Curve
H&B Rail Trail
River Rd.
1000 m³/s open water
XS 188
XS 194
XS 195
XS 196
XS 199
Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall



500 m3/s Ice Jam
Minimum Ice Jam Level - Bell Curve
500 m3/s open water
H&B Rail Trail
River Rd.
Cockshutt Bridge
Riffle
Two Fish Island
Riffle
Veterans Memorial Bridge
Lorne Bridge
XS 188
XS 194
XS 195
XS 196
XS 199
Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall
215
210
205
200
195
190
185
180
15,000
17,000
19,000
21,000
23,000
25,000
27,000
29,000


Minimum ice jam level - Bell Curve
1000 m³/s Ice Jam
1000 m³/s open water
H&B Rail Trail
River Rd.
Cockshutt Bridge
Riffle
Two Fish Island
Riffle
Veterans Memorial Bridge
Lorne Bridge
XS 188
XS 194
XS 195
XS 196
XS 199
Right Bank Road/Dike
Left Bank Road/Dike
Dike Floodwall
215
210
205
200
195
190
185
180
15,000
17,000
19,000
21,000
23,000
25,000
27,000
29,000

PHASE 4. ALTERNATIVES FOR PREVENTION OR MITIGATION

Overview of Options

1. Ice Cutting/Weakening/Breaking
2. Ice Control Structures Upstream of Brantford
3. Channel Modifications
4. Overbank Relief
5. Channel Relief/Ice Storage
6. Flow Regime Modification
7. Dike Floodwall Protection
8. Flood Forecasting/monitoring improvements

1. Breakup of Ice

Ice Cutting Equipment

Amphibex

1. Breakup of Ice

Name of Option	Pros	Cons
1.01 – Ice cutting	•Precedents exist; but mostly with predictable break up time •Could prevent the ice jam or move it downstream	**In General** •Conditions causing ice lodgement at bend could persist •Uncertainty on timing of operation **Other factors** •Limited access points •Specialized equipment/operators •Environmental/safety concerns •Limited effectiveness *
1.02 – Surface ice treatment		
1.03 – Ice blasting		

1. Breakup of Ice

Name of Option	Pros	Cons
1.04 – Ice breaking to release ice jam once formed	•Could reduce the time under flooding conditions	•Would not prevent the ice jam and associated flooding •Access limitation for standard equipment.
1.05 – Excavation of the ice upstream of bend before ice jam formation	•Could improve conveyance and promote movement of the ice •Could increase the rate of decay of ice at banks by reducing surface albedo	•Uncertainty in effectiveness. •Uncertainty regarding timing of operation. •Access limitation for equipment.

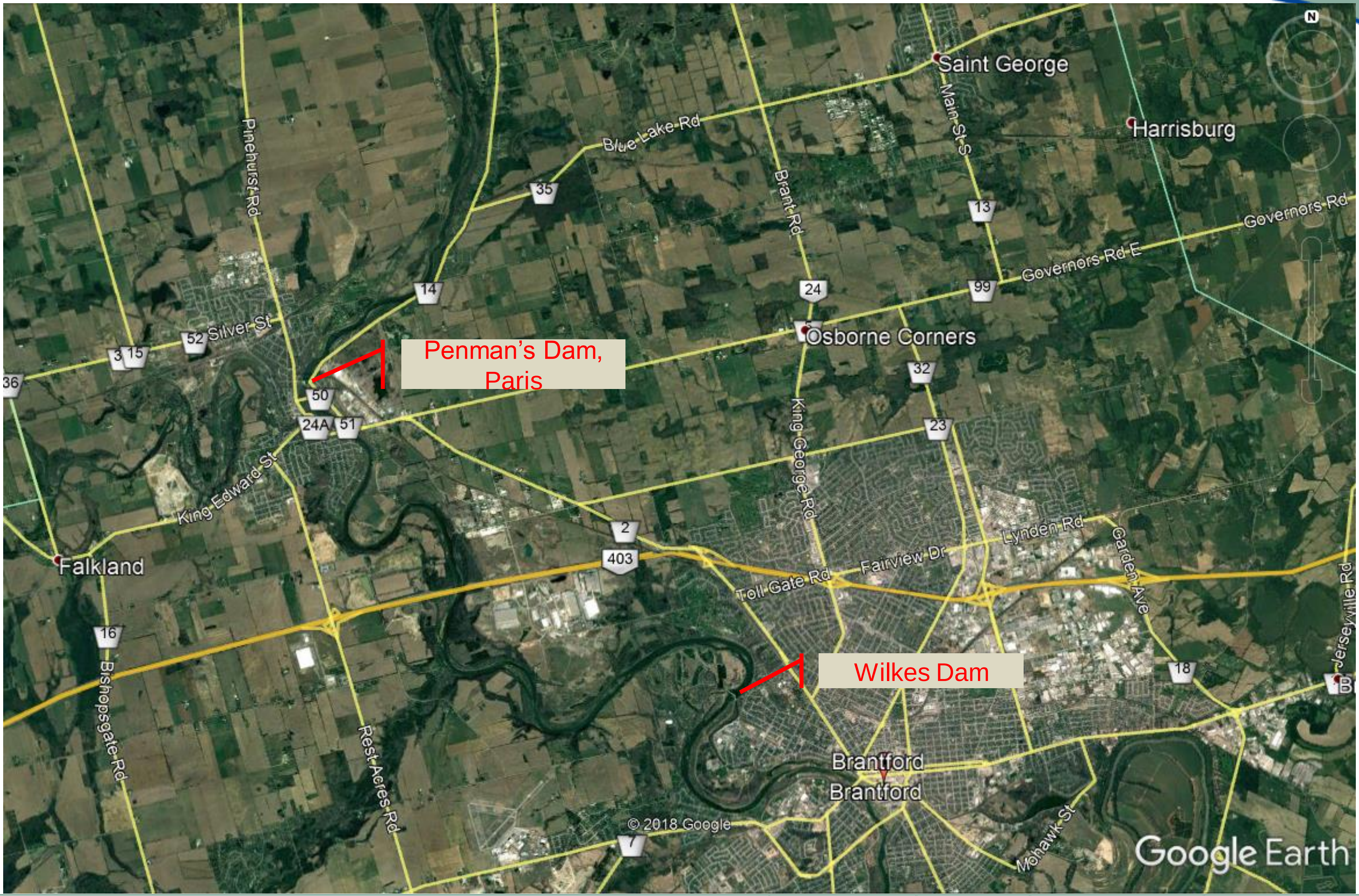
2. Ice Control Structures Upstream of Brantford

St Raymond (Quebec)

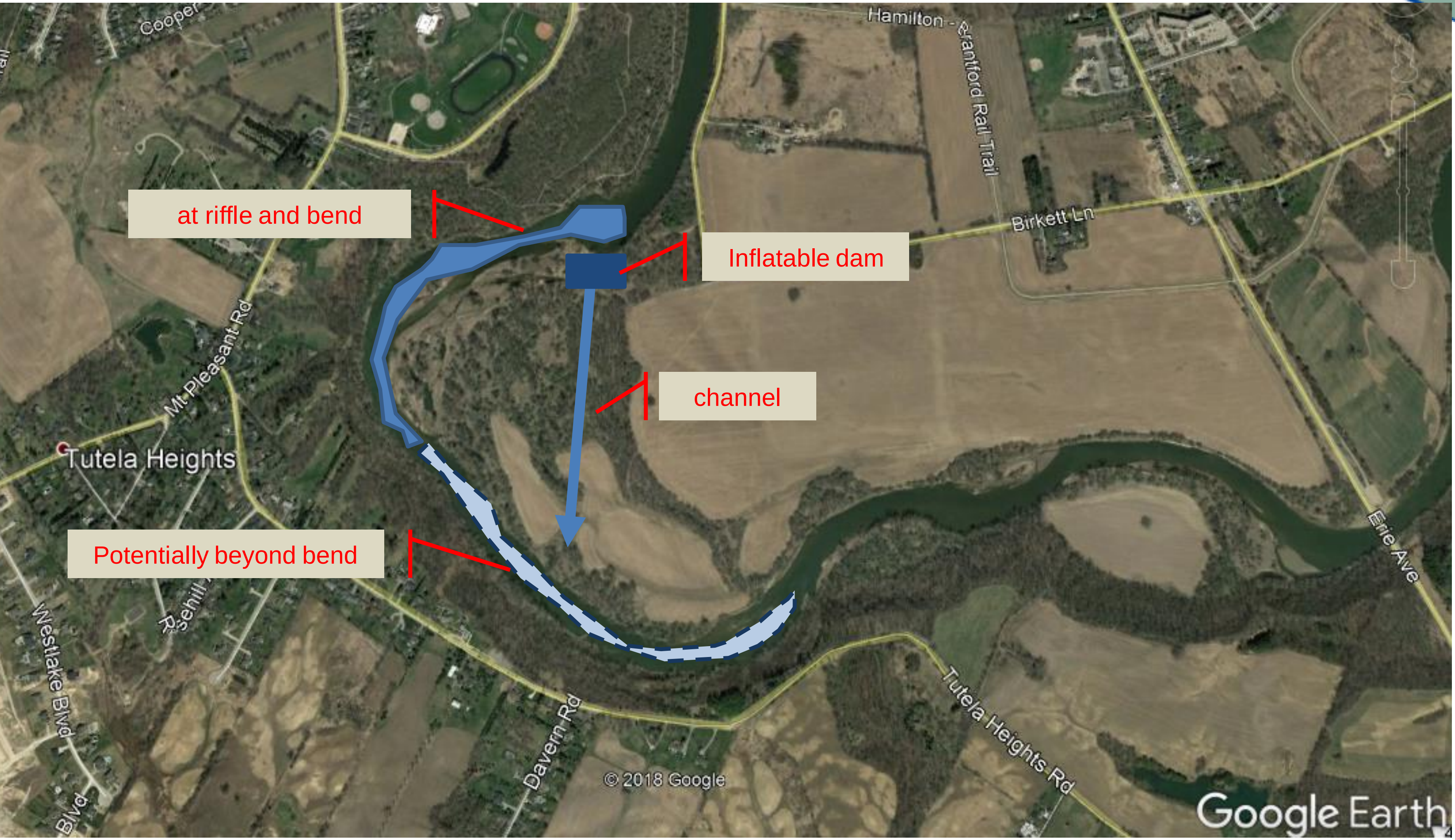
2. Ice Control Structures Upstream of Brantford

Name of Option	Pros	Cons
2.01 – Ice control structures upstream of Brantford	•Precedents exist •Would limit ice reaching Brantford •Does not require operation •Relatively effective.	•If at the Wilkes Dam, could cause flooding upstream potentially up to Paris (ON) •Could involve high cost

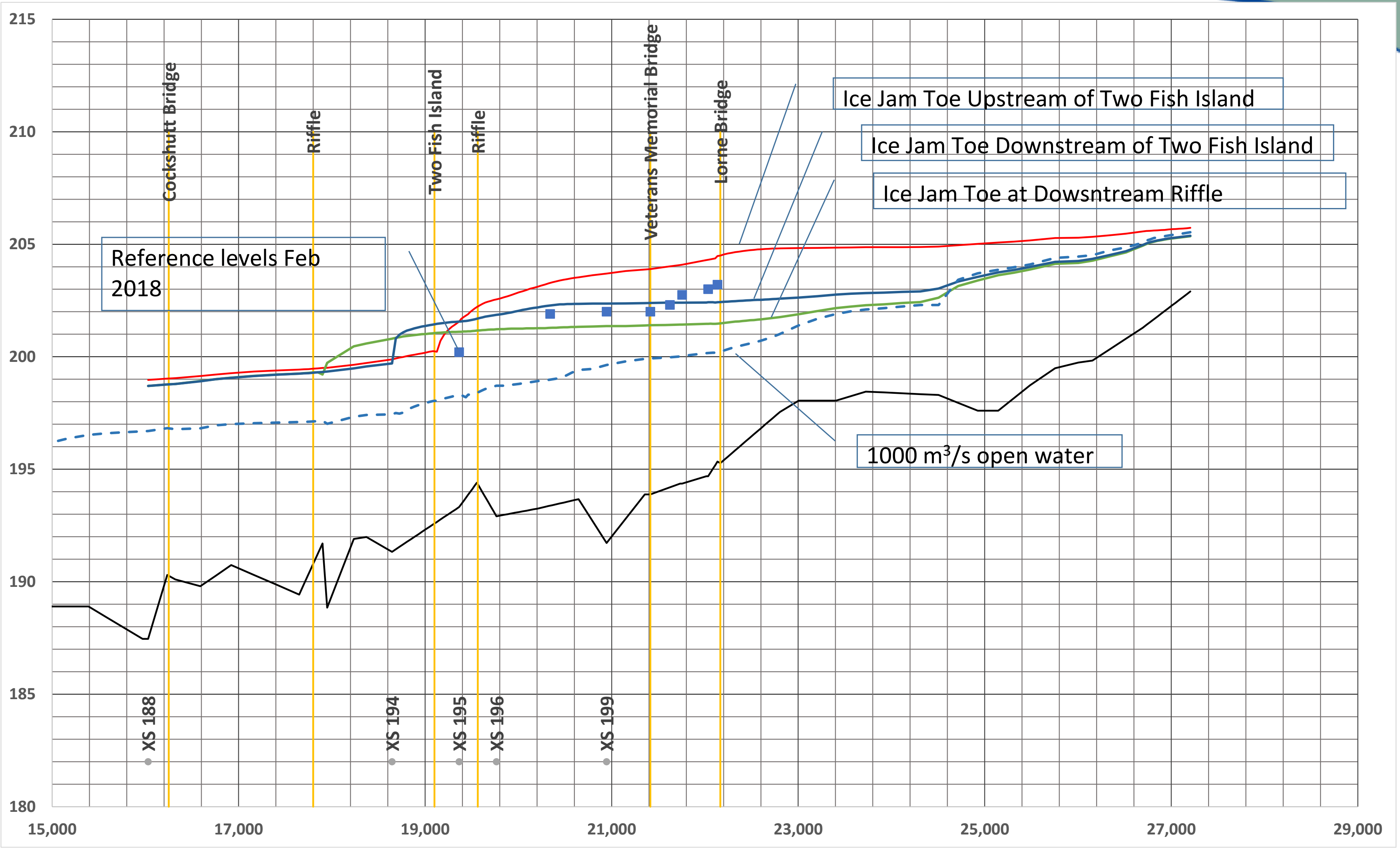
2. Ice Control Structures Upstream of Brantford



3. Channel Modifications

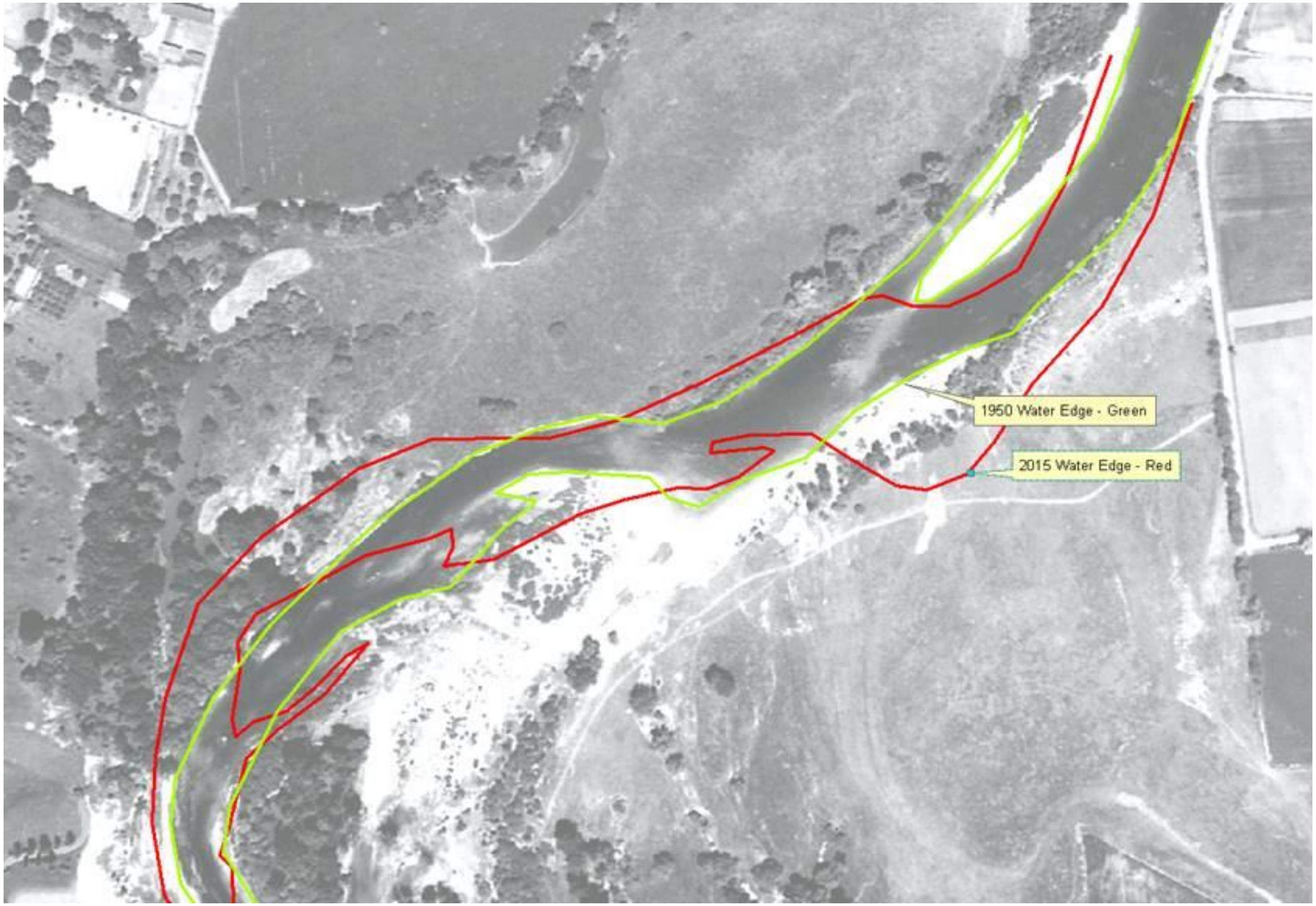


3. Channel Modifications



KGS GROUP CONSULTING ENGINEERS

3. Channel Modifications



3. Channel Modifications

<table>
<tr><th>Name of Option</th><th>Pros</th><th>Cons</th></tr>
<tr><td>3.01 – river channel modifications</td><td rowspan="3">•If effective could prevent or mitigate jamming or move it downstream

•Does not require operation (except 3.03)</td><td rowspan="3">•Effectiveness cannot be proven with analytical methods or state of the art models

•Need to ensure that it does not promote other problems if ice is formed at lower water levels

•Environmental concerns and approval requirements

•Dynamic river morphology could change conditions

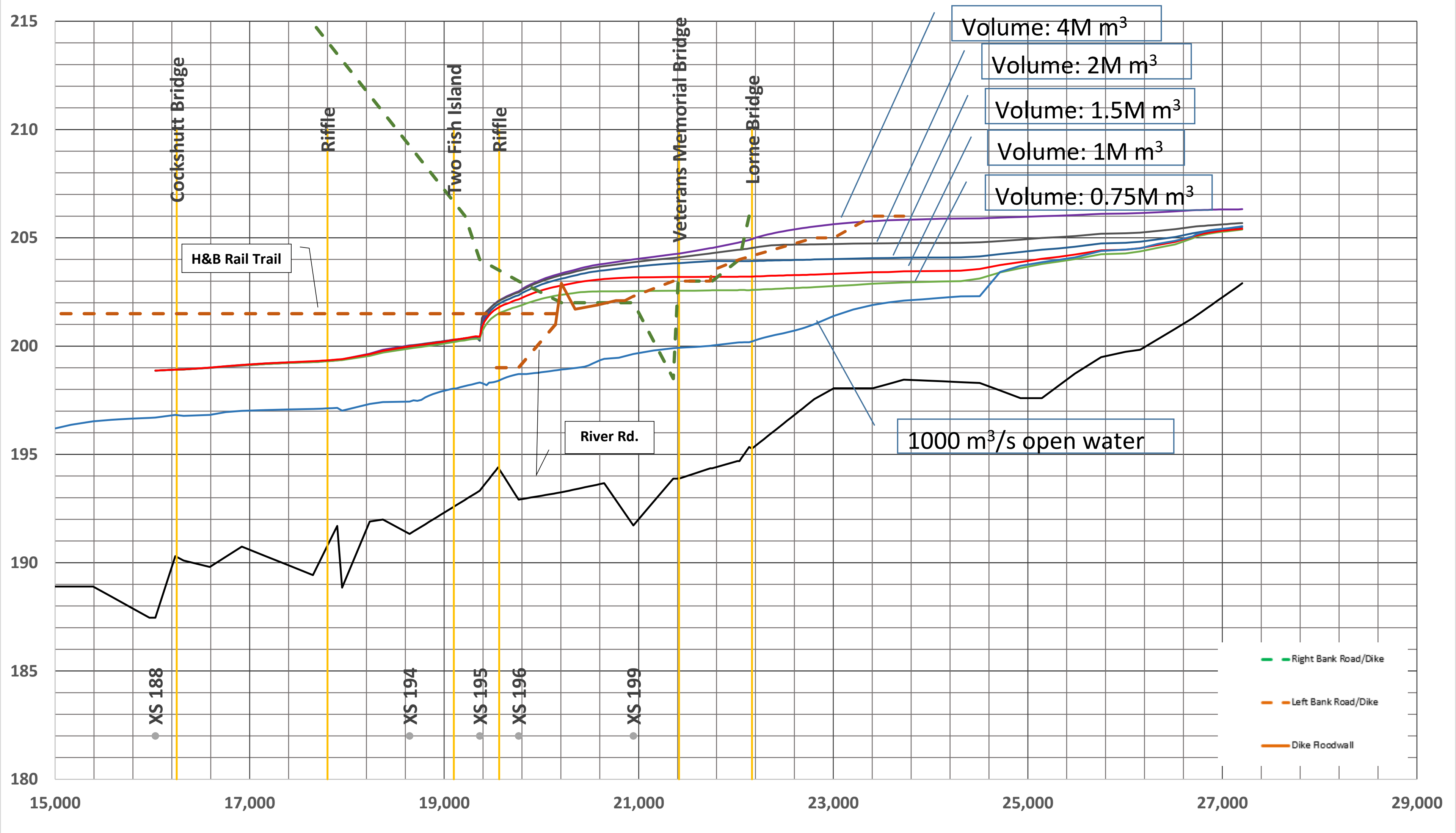
•Could require frequent maintenance
•Could require land easements

•Could involve high cost</td></tr>
<tr><td>3.02 – cutoff-channel</td></tr>
<tr><td>3.03 – inflatable dam</td></tr>
</table>

4. Overbank Relief

KGS GROUP CONSULTING

4. Overbank Relief



4. Overbank Relief

Name of Option	Pros	Cons
4.01 – Vegetation clearing and benching at bend (left bank)	•Low initial cost. •Could add conveyance for water and ice during high levels, across the bend.	•Effectiveness cannot be proven with analytical methods •Could require frequent maintenance •Limited effectiveness in moving ice •Could require land easement
4.02 – Vegetation clearing and benching upstream of bend (Gilkison Flats)	•Low initial cost. •Could help provide additional storage for ice	•Effectiveness cannot be proven with analytical methods •Larger volumes required for storage •Could require frequent maintenance

4. Overbank Relief

5. Channel Relief/Ice Storage

Name of Option	Pros	Cons
5.01 – Outlet channel on eat bank across River Rd into overland area	•Could help provide additional storage for ice (as 4.02)	•More complex and expensive than Options 4.01 or 4.02 and, therefore, less attractive •Operation and maintenance •Land easement.

KGS GROUP CONSULTING ENGINEERS

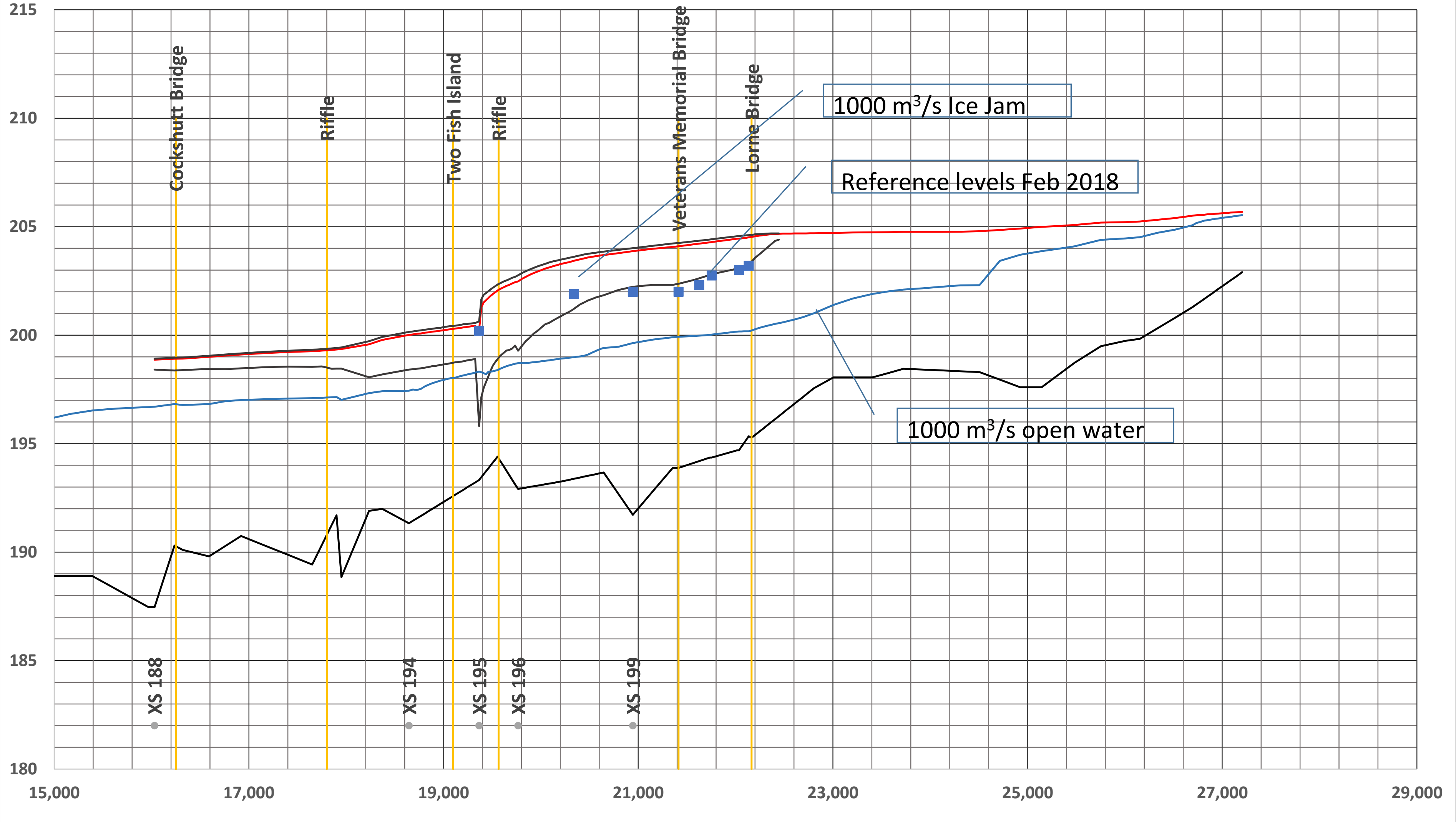
6. Flow Regime Modification

Name of Option	Pros	Cons
6.01 – Reservoir operation to modify river flows to cause the ice run	•If effective would cause the release of the ice jam before it reaches its potential maximum rates.	•Effectiveness cannot be proven with analytical methods or state of the art models •Risk of exacerbating or causing ice jam problems at that or other locations •Estimated required flow of 1,400 m^3/s using Bell Curve

7. Dike Floodwall Protection

Name of Option	Pros	Cons
7.01 – Raising the current level of dike and floodwall protection at River Rd		•Would not prevent ice jamming and related problems such as high groundwater levels •Aesthetics •Failure could result in large flooding. •Would not protect the west bank.
7.02 – Not raising the dike on River Rd	•Proven flood control strategy •Cost effective	•Limited infrastructure and property that could be affected.
7.03 – Other dike options		•Require large footprint area; but there is adequate space in Gilkison Flats •Maintenance

7. Dike Floodwall Protection



7. Dike Floodwall Protection

FIGURE 3
FREQUENCY ANALYSIS RESULTS
Brantford Ice Jam Level Frequency Analysis
Lognormal (Maximum Likelihood)

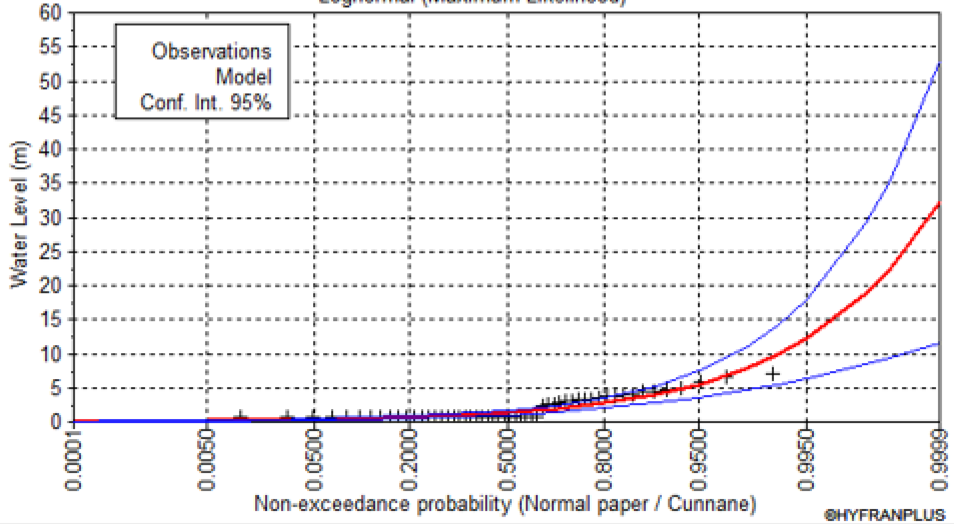


TABLE 2
FREQUENCY ANALYSIS OF ICE JAMS

Return Period (years)	Water Level (m)	Geodetic Water Level (m)
2	1.4	197.0
5	2.8	198.5
10	4.0	199.7
25	6.0	201.7
50	7.8	203.5
100	9.8	205.5

KGS GROUP
CONSULTING ENGINEERS

8. Flood Forecasting/monitoring Improvements

Name of Option	Pros	Cons
8.01 – Explore opportunities to increase monitoring and forecasting	•Cost effective. •Proven method. •Assists before, during, and after flood events.	•These options would not prevent ice jams but would help anticipate and monitor conditions as well as emergency response. •In some cases susceptible to vandalism.

Conclusions

1. The data available indicates that break up ice jams develop frequently at the site

2. Meteorological conditions contribute to this phenomenon. In particular the warm and cold spells in mid-winter

3. Frequency analyses of winter water levels were carried out to estimate frequency of events (30 to 40 years for the 2018 levels) and assist in definition of design criteria

4. Model results were consistent with engineering theory and past experience

5. Model analyses indicate that at formation ice progresses rapidly in the Oxbow area and without. Thermal processes would thicken the ice cover there

6. Mitigation options were evaluated. The most promising protective measure was the enhancement of floodwall and dike defenses

Conclusions

7. Relief options investigated would provide limited storage and benefits

8. Channel modifications can be effective if successfully move the ice lodgement downstream. Their effectiveness cannot be confirmed with available knowledge and tools. They are vulnerable to river changes and could cause environmental concerns

9. Weakening the ice cover might not be effective due to site conditions and difficulties on determining the time to act

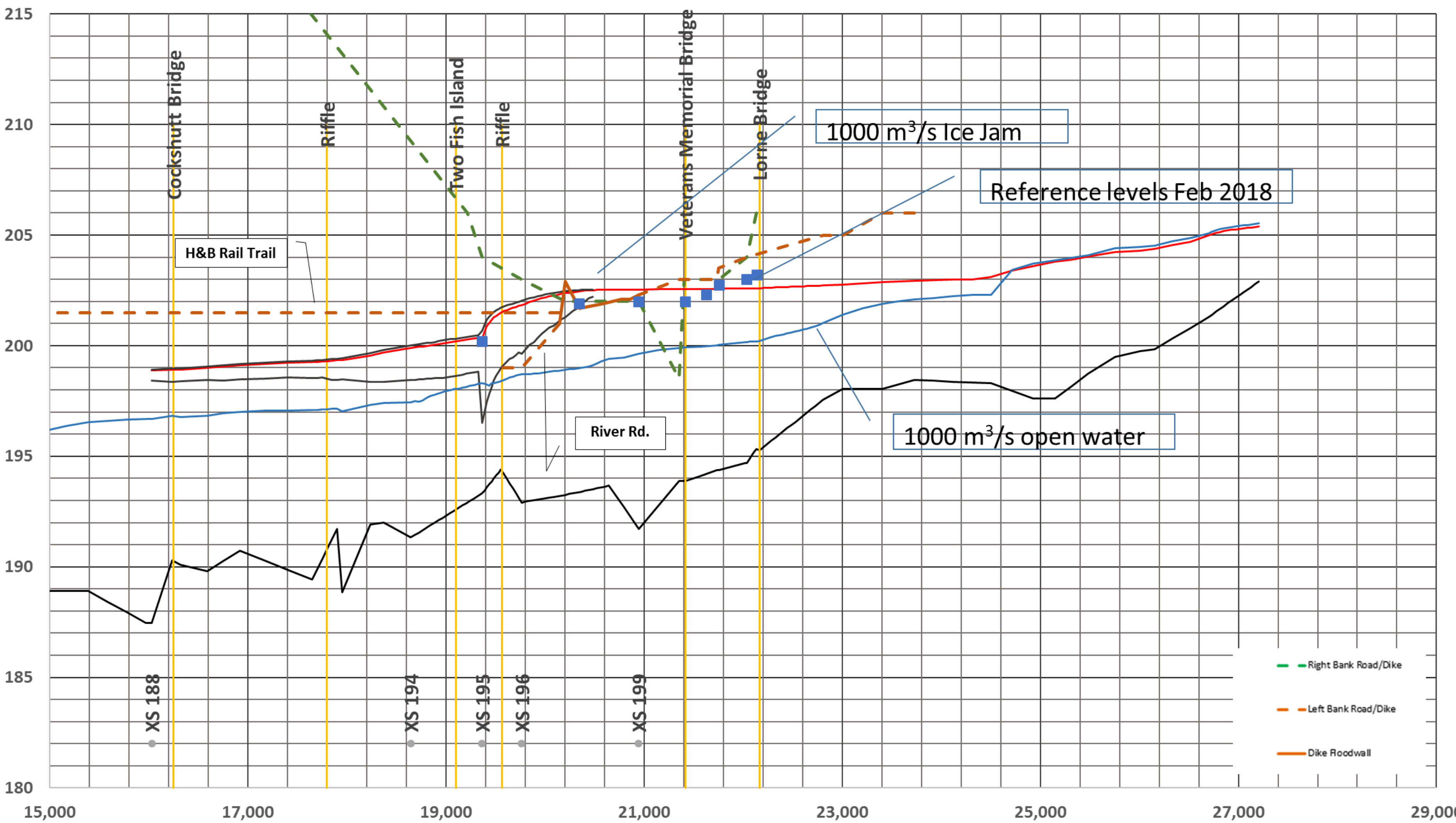
10. Ice control structures (ICS) are not considered attractive at the site due to concerns of causing upstream flooding (Wilkes Dam considered)

11. Flow regime modifications are applied to reduce runoff peaks. Increasing flows to promote early ice runs are considered not suitable

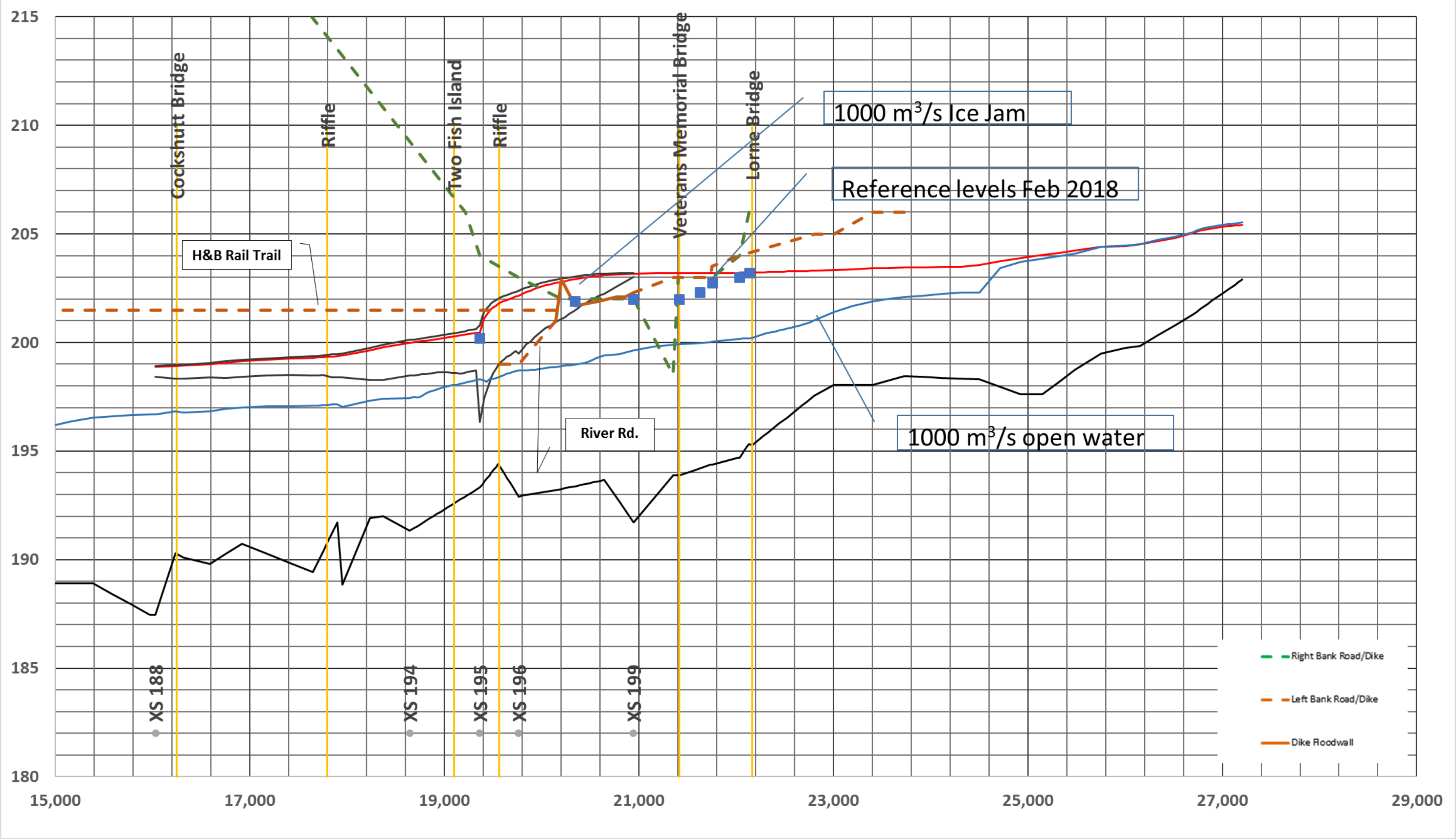
12. Ice removal could not be applicable due to short duration of jams

13. Explore opportunities for monitoring and forecasting improvements

Ice Jam Volume (including voids): 0.7 Million m^3



Ice Jam Volume (including voids): 1.0 Million m^3



Ice Jam Volume (including voids): 1.5 Million m³