Evaluating the Impact of Erosion on Our Natural Riverbanks

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Acknowledgments

- Don Kingerski, P.Eng.
  Waterways Engineer, City of Winnipeg
- Riverbank Management Committee
  City of Winnipeg
- Leanne Fernando, M.Sc., P.Eng.
  Dam Safety Engineer, Manitoba Hydro

What's the Problem?

- There are 240 km of waterfront property inside the City of Winnipeg.
- 45% is owned by the City of the Winnipeg, much of which is in designated parks.
- The City is losing on average over a million dollars (2000$) worth of riverbank property on an annual basis.
- The estimated total cost to stabilize the 49 city owned riverbanks identified in the 2000 Riverbank Characterization study report is in the range of $80 million (2000$)

What Does this Mean to Us?

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PERSPECTIVE

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Brian Turnbull looks out over his property, which is rapidly crumbling into the river.

High river levels have caused unprecedented damage and loss of land to private property and parks along the Red

THE RIVER'S TOLL

By Patti Edgar

BERYL and Brian Turnbull recall summer nights when they would eat dinner in a glassed-in gazebo in their riverfront backyard, reluctantly walking back to their home at midnight.

This month, six metres of their yard tumbled into the Red River, on top of the seven metres they lost in the 1997 flood. Now buried in the silt below their home are a bird bath, a flagpole, an elm, a spruce and a rock garden.

The gazebo survived thanks to a taut rope and pilings, but it's now dangling precariously over the newly created cliff. The Turnbulls plan to take it apart and rebuild it closer to the house.

"It's just devastating. We lost quite a lot of property in '97 but it didn't really affect our lifestyle," said Beryl. "I've accepted it now, but I was too upset to go down there for awhile."

Four months of higher-than-normal river levels this spring and summer caused riverbank damage within the city limits as bad — if not worse — than the 1997 flood, says the city's expert on the topic.

edge.

Parkland slumped into the rivers, taking along trees and leaving benches precariously close to steep cliffs.

An untold number of riverbank trees have vanished, while others are threatening to tumble because fast water has carved their roots out of the soil.

Tree experts fear the unusually long flood could be felt for years to come on the elms left standing. Submerged roots don't get the oxygen they need during the summer, putting stress on the trees that could eventually kill them.

Some of the worst damage to private property is through Fort Garry and St. Vital, where the river narrows and bends, undercutting the soft riverbanks. North of The Forks, the damage is less severe, but if it hadn't been for last winter's $1.2 million of work along the shoreline of the Elmwood Cemetery, Kingerski said gravestones could have washed away.

Too much water, too long

Like a heavy, wet sponge, the banks of Winnipeg's rivers were saturated by rain this spring.

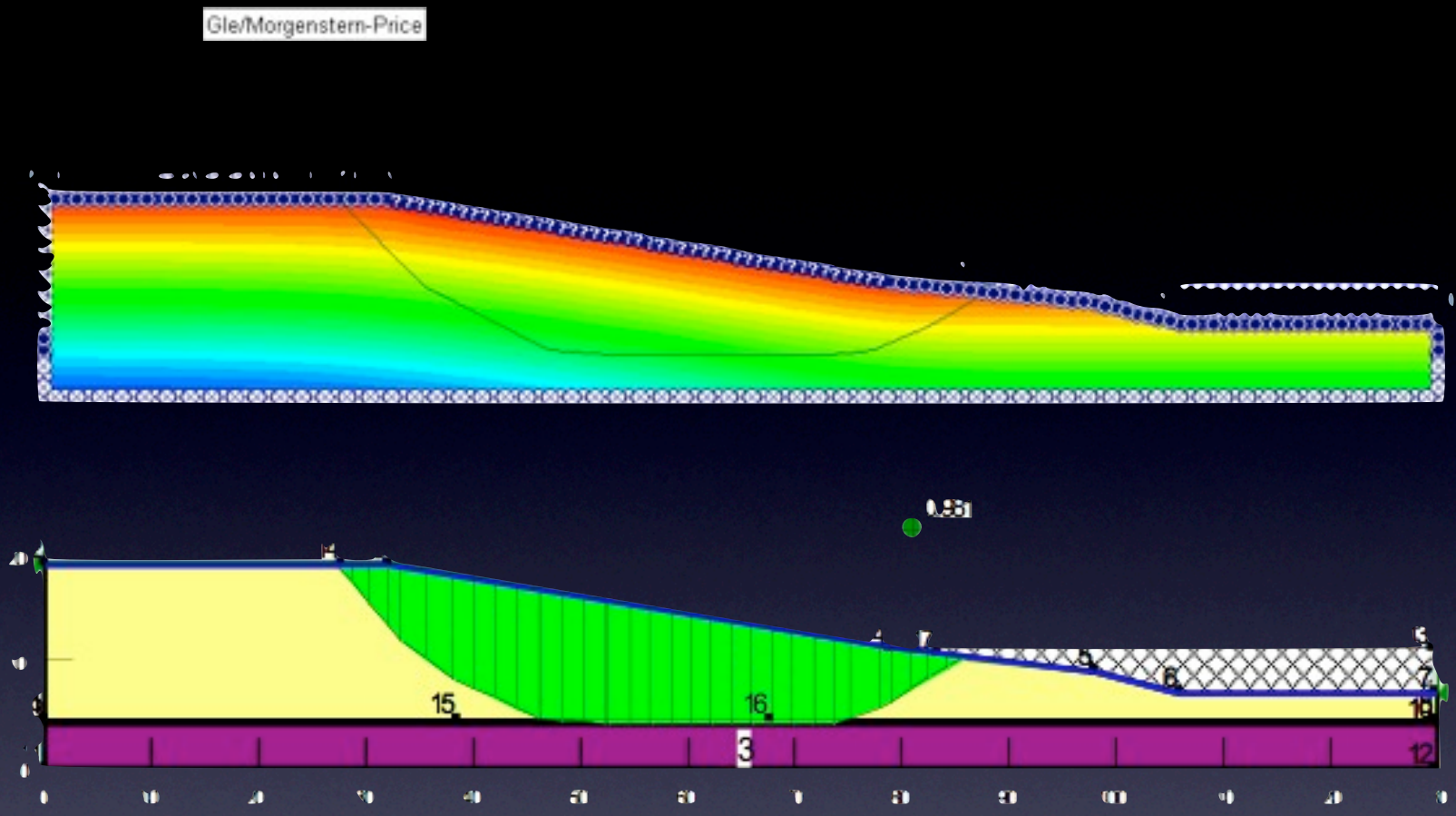
High, fast-running water scraped away at soft, unsupported banks like those in Crescent Park. When the river levels dropped, the support on those heavy wet banks disappeared, sending soil tumbling.

Homeowners are responsible for tackling their own riverbank problems, ranging in cost from $500 per metre of waterfront to $5,000.

St. Norbert Coun. Justin Swandel,

What Do We Do?

- Engineering study to examine how to best remediate specific sections of riverbank.
- Often examine combinations of ground reinforcement and erosion protection.
- Analysis is based on existing and proposed remediated geometry.
- We ignore erosion quantitatively



Analysis Gives Static F.S.

What About Erosion?

- Erosion is very difficult to characterize quantitatively either theoretically or empirically.
- This study is directed to quantify erosion and how it dictates river morphology.
- If we can quantify erosion and its effect on the morphology of the riverbank, we can examine the transient Factor of Safety.

Key Questions

1. What is the annual reduction in Factor of Safety for typical inside, outside and transition riverbanks?
2. We know floods impact erosion rates but by how much?
3. Is the magnitude or duration of the flood more important?
4. How effective are remediation alternatives in comparison to natural conditions?

‘This is something that was unprecedented’

— Riverbank engineer Don Kingerski.

Bunn’s Creek
Noticeable riverbank erosion is occurring to the north of the creek.

Shooters Family Golf Centre
From the river, golfers at Shooters Family Golf Centre appear to be swinging out of a sand trap, but owner Guido Cersani laid the sand on four riverside holes that had been submerged in the flood to cover the mud. For a month, the back nine was closed and the water caused $150,000 in damage not covered by insurance. The entire course is open now and Cersani bills it as more challenging thanks to the sand.

Crescent Drive home
The flood waters sliced under a modest rental home on Crescent Drive, buckling a massive balcony this month. “This house is in danger of going in. This isn’t a gradual drop, it’s like a cliff,” said Eric Matthies, a longtime next-door neighbour. His home isn’t threatened by the slump - yet. “I’m concerned the cliff will do a right turn.”

Scotia Street
A homeowner takes a break as more and more of the property disappears.

Scotia Street
Hopefully, no one was in the dog-house when it tumbled toward the river.

Mager Drive
Riverbank erosion threatens a home just south of St. Mary’s and St. Anne’s roads.

North of St. John’s Park
While St. John’s Park is on the priority list for shoreline stabilization, a nearby homeowner says properties further north rarely experience erosion. But this summer a swirling undercurrent collapsed at least a metre of yard.

Kildonan Park
If you’ve ever wondered what a tree’s roots look like exposed, now you know.

Kildonan Drive
A faded wood fence dangles over the Red River at the south end of Kildonan Drive, revealing how much land has slipped into the Red River.

Kildonan Park
The park is a little bit smaller now, thanks to riverbank erosion.

St. Mary’s Road
An apartment block near the intersection with St. Anne’s Road edges closer to the river.

Crescent Drive Park
This tree appears to be sliding toward the river, roots and all.

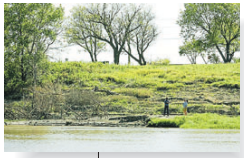
University of Manitoba
Erosion is visible around the first bend on the south side of the university.

McNulty Crescent
Contractor Walter Goshulak prepares to make repairs from unusually high river levels that tore away a deck and stairs, tossed over a picnic table and swamped a garden.

Crescent Drive Park
There’s not much room left for visitors to sit and enjoy the view on this wooden bench along the river.

St. Norbert Heritage Park
Signs in the park are now dangerously close to the banks.

Off a private road in St. Norbert
A curve in the Red River creeps closer each year to this rural rental home. The water is now just a few steps away from the sunroom. The bulk of the damage happened in 1997, but this summer two more trees were swept away.



St. Mary’s Road
People check out the damage along the riverbank that collapsed near the south perimeter.

Norwood Bridge
A large log-jam gathers on the southwest side of the bridge.

Jubilee Avenue
This gazebo, at home near the Bridge Drive-In, is holding on.

Riverside Drive
Jim Flood’s backyard suffered massive erosion.

Jubilee Avenue
Six metres of Beryl and Brian Turnbull’s yard tumbled into the Red River this summer, on top of the seven metres they lost in 1997. A bird bath, a flagpole, an elm, a spruce and a rock garden are buried in the silt below. The gazebo survived thanks to a taut rope and pilings, but it’s now dangling precariously over a cliff. The Turnbulls plan to take it apart and rebuild it closer to the house.

Riverside Drive
A ladder is propped up against a slumped riverbank so Barry McMillan can reach his boat. McMillan and neighbour Jim Flood spent $14,000 two years ago shoring up the bank in front of both homes with limestone. This August, four metres of their backyards tumbled into the Red River, burying the project and yanking out trees and lawn along four properties. A heartbroken Flood points to ominous cracks along the soil that show where the grass will slump next, taking along at least one more tree. He estimates repairs could cost $50,000 for both properties. “My story isn’t unique. Perhaps the money we put in reduced the amount of land we lost.”

St. Vital Park
Free Press reporter Patti Edgar surveys the massive loss of riverbank.

Kilkenny Drive
Trees along the encroaching banks have fallen into the river.

Lord Avenue
Homes are protected from erosion.

Lord Avenue
This $1.5-million wall was completed in 2003 to protect a handful of homes along Lord Avenue. The flood-reduction project was one of about two dozen in the city paid for out of a $12-million pot from all three levels of government. Residents will pay 10 per cent of the costs back through fees added to their city tax bills.

St. Cross Street
A glassed-in gazebo belonging to a house near St. John’s Park is dangerously close to the banks.

Lyndale Drive
The banks along here have fallen in the river.

Crescent Drive Park, St. Vital Park, Kildonan Park, Bunn’s Creek, Lyndale Drive Park
All five parks are on the list of 11 slumping city parks each needing about $1 million worth of stabilization work. City-owned riverbank collectively needs $80 million worth of stabilization.
In these parks this summer, high water swept off with tress and scraped away at soft banks, some of which collapsed when the river level dropped. At Churchill Park, part of a pathway was swept down the river.

TOP 11 RIVERBANK STABILIZATION PROJECTS ON CITY LAND:

- St. Vital Park
- Lyndale Drive Park
- St. John’s Park
- King’s Park
- Churchill Park
- Red River at Bunn’s Creek
- Fort Rouge Park
- Crescent Drive Park
- King’s Park
- Evans Avenue at Cusson Street
- Granite Curling Club/Mostyn Park

The Research Plan

Establish the Theoretical Basis for Erosion of Cohesive Soil

Determine Necessary Material Parameters with Laboratory Testing

Predict Erosion and therefore Change in Riverbank Stability Using Analysis

Verify Predictions with Field Evidence

Calculating Soil Erosion

- To calculate erosion, three primary parameters are required:
    - Fluid shear stress (Pa)
    - Critical shear stress (Pa)
    - Erosion rate (mm/hr)

Calculating Shear Stress

$$WS = \tau \cdot P \cdot dx$$

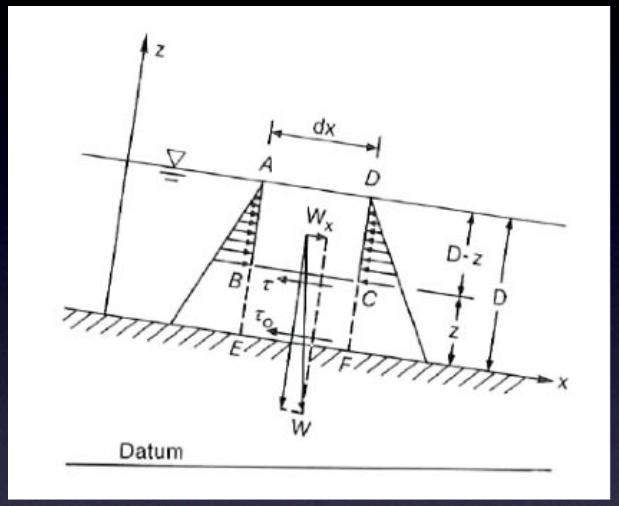
$$\Upsilon \forall S = \tau \cdot P \cdot dx$$

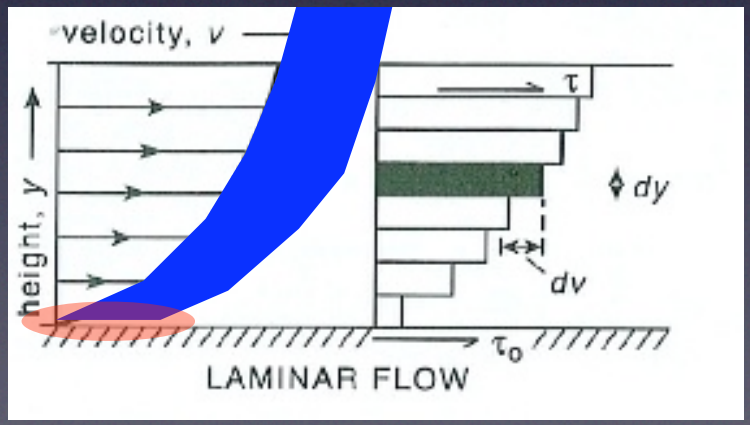
$$\Upsilon \cdot A \cdot dx \cdot S = \tau \cdot P \cdot dx$$

$$R = A/P$$

$$\tau = \Upsilon \cdot RS$$

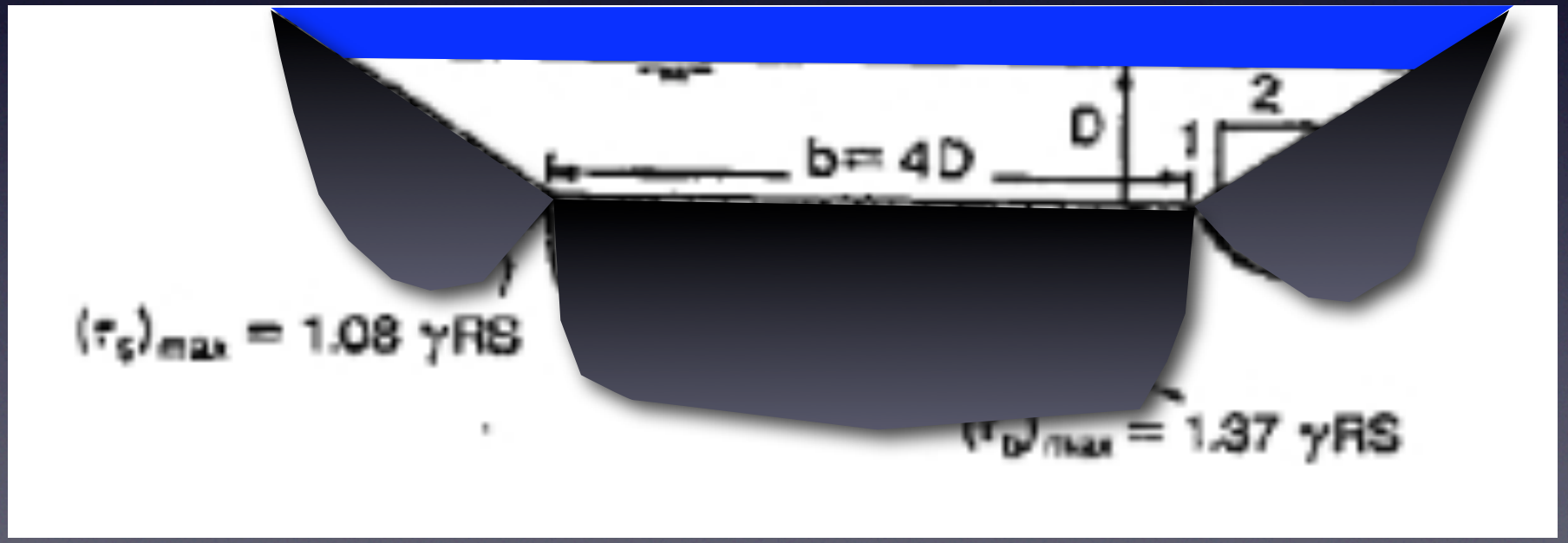
$$\tau = \nu \cdot (dv/dy)$$





Shear Stress Distribution

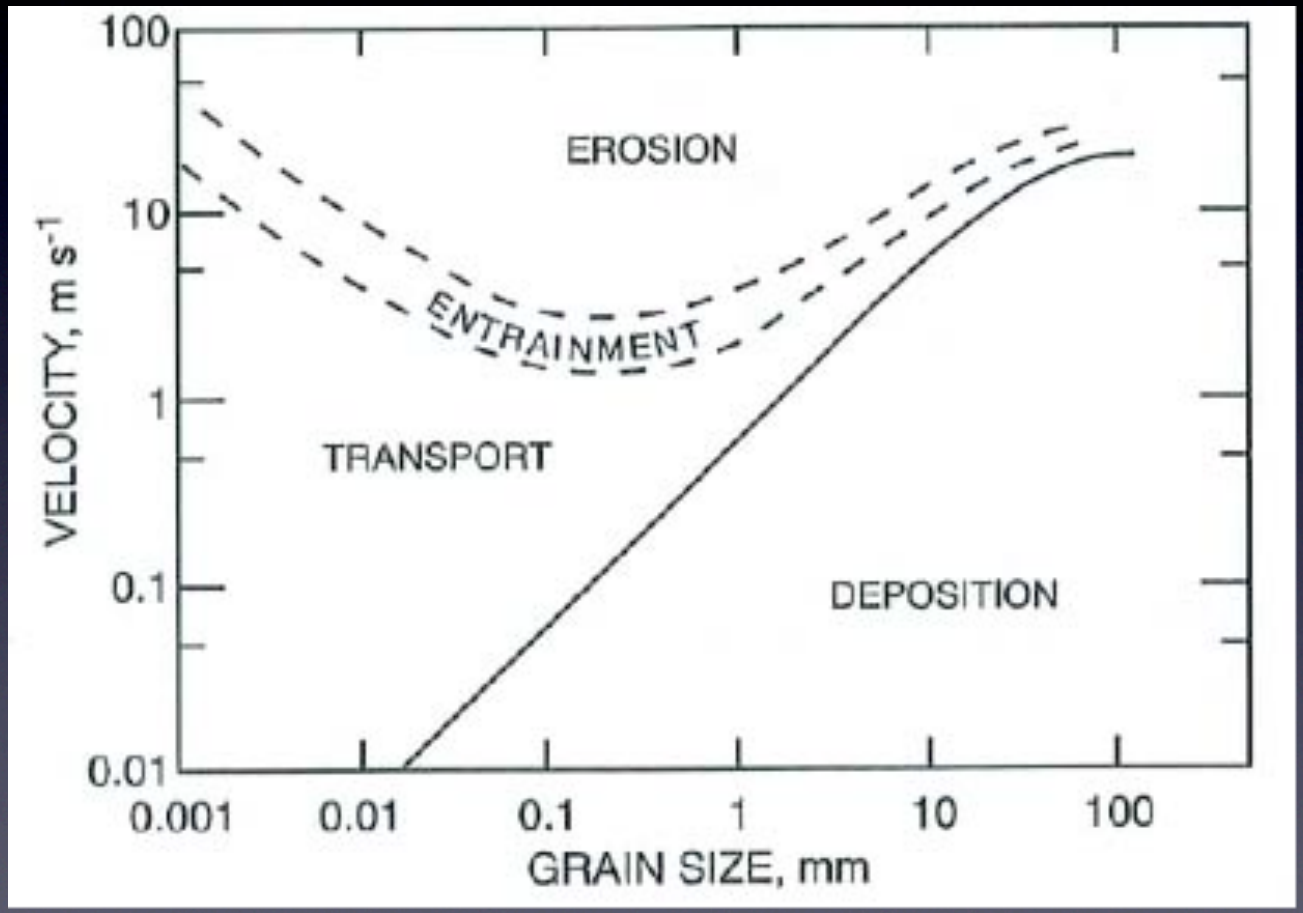
- Shear stress exerted by flow on riverbank (Olsen and Florey 1952)



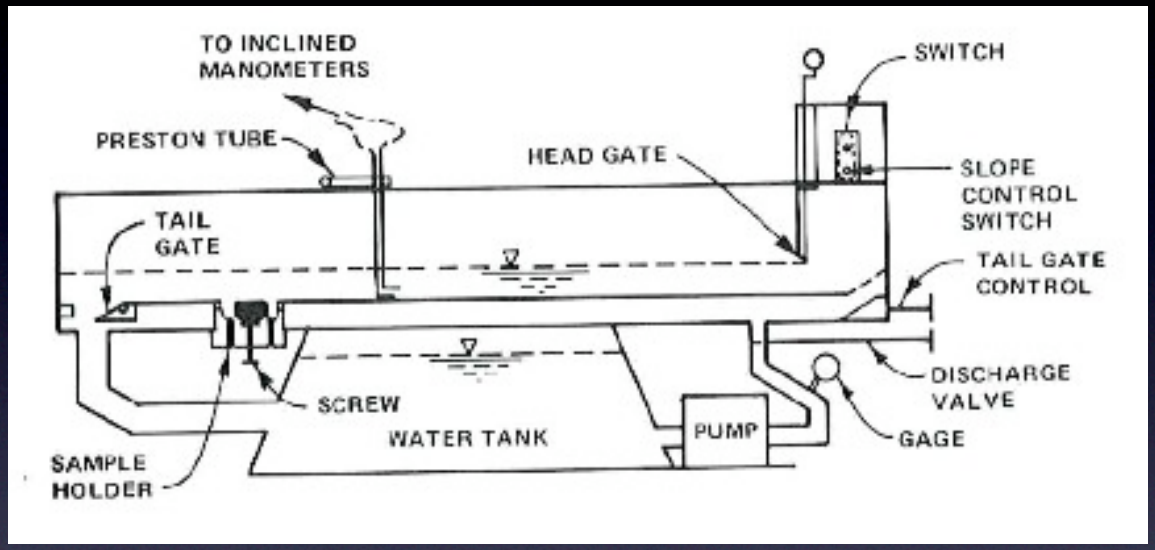
Critical Shear Stress

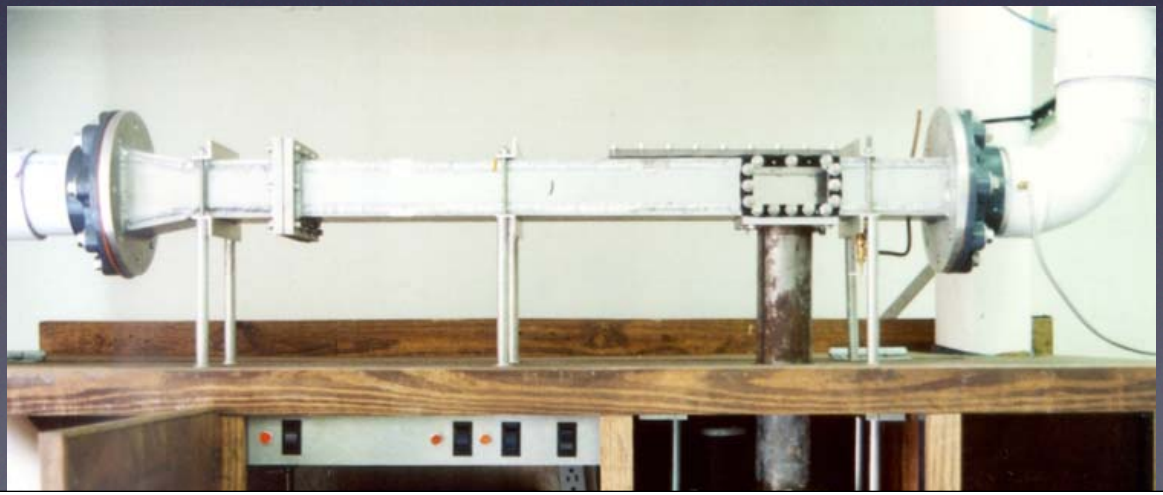
- Represents the minimum shear stress required in order for erosion to take place
- Theoretical and experimental methods available
- Method selected was proposed by Briaud *et al*. (2001) Erosion Function Apparatus (EFA)

Critical Shear Stress

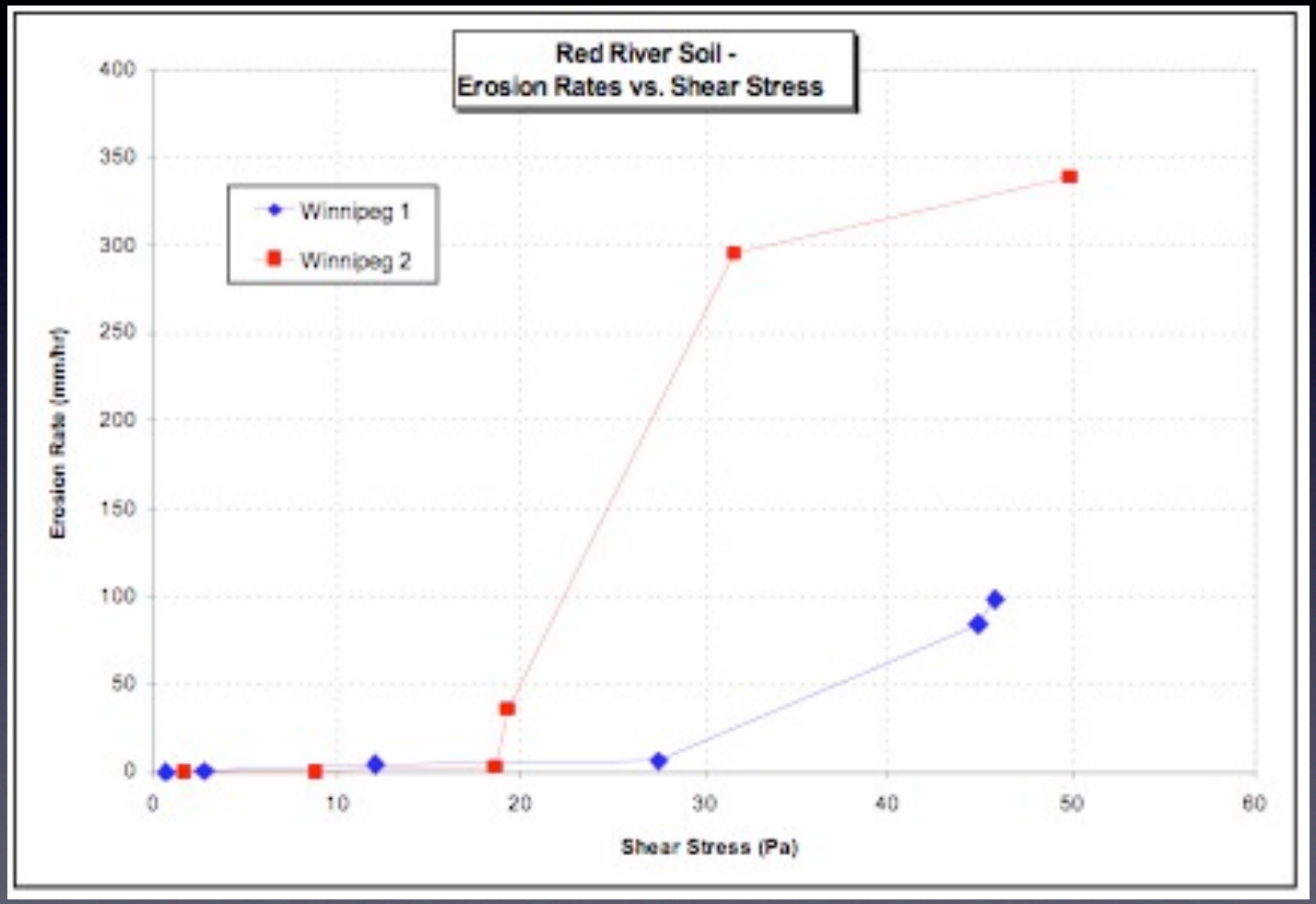


Critical Shear Stress





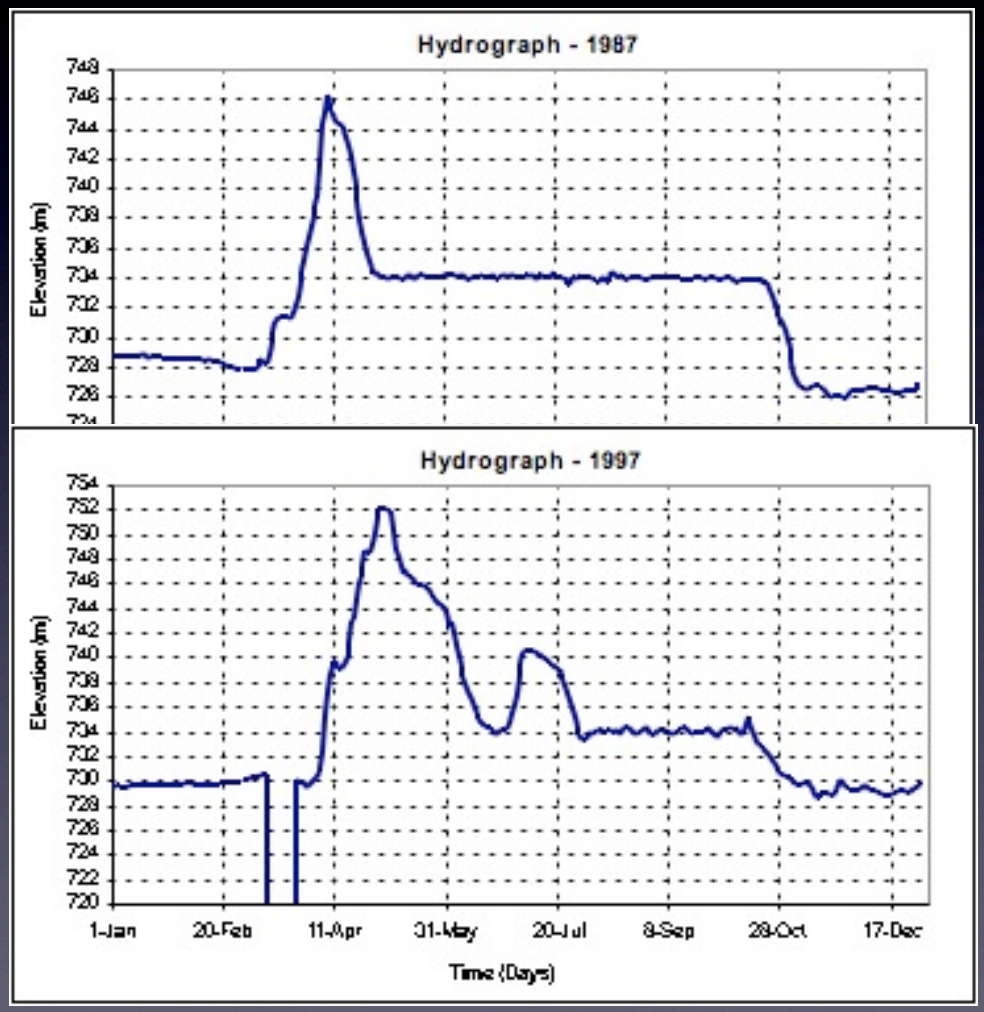
Critical Shear Stress

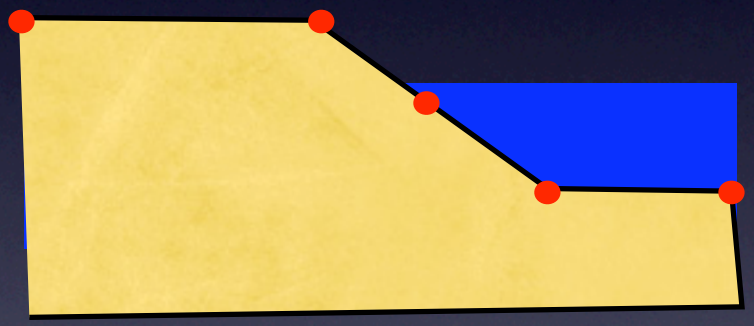


Erosion Rate

- Represents the amount of soil eroded in a unit of time (e.g. mm/hr)
- Erosion Rate is multiplied by the amount of time over which the fluid shear stress is above the critical shear stress to determine the quantity of erosion in a time increment
- Sum up the quantity as a function of position and time and we can determine the change in riverbank profile.

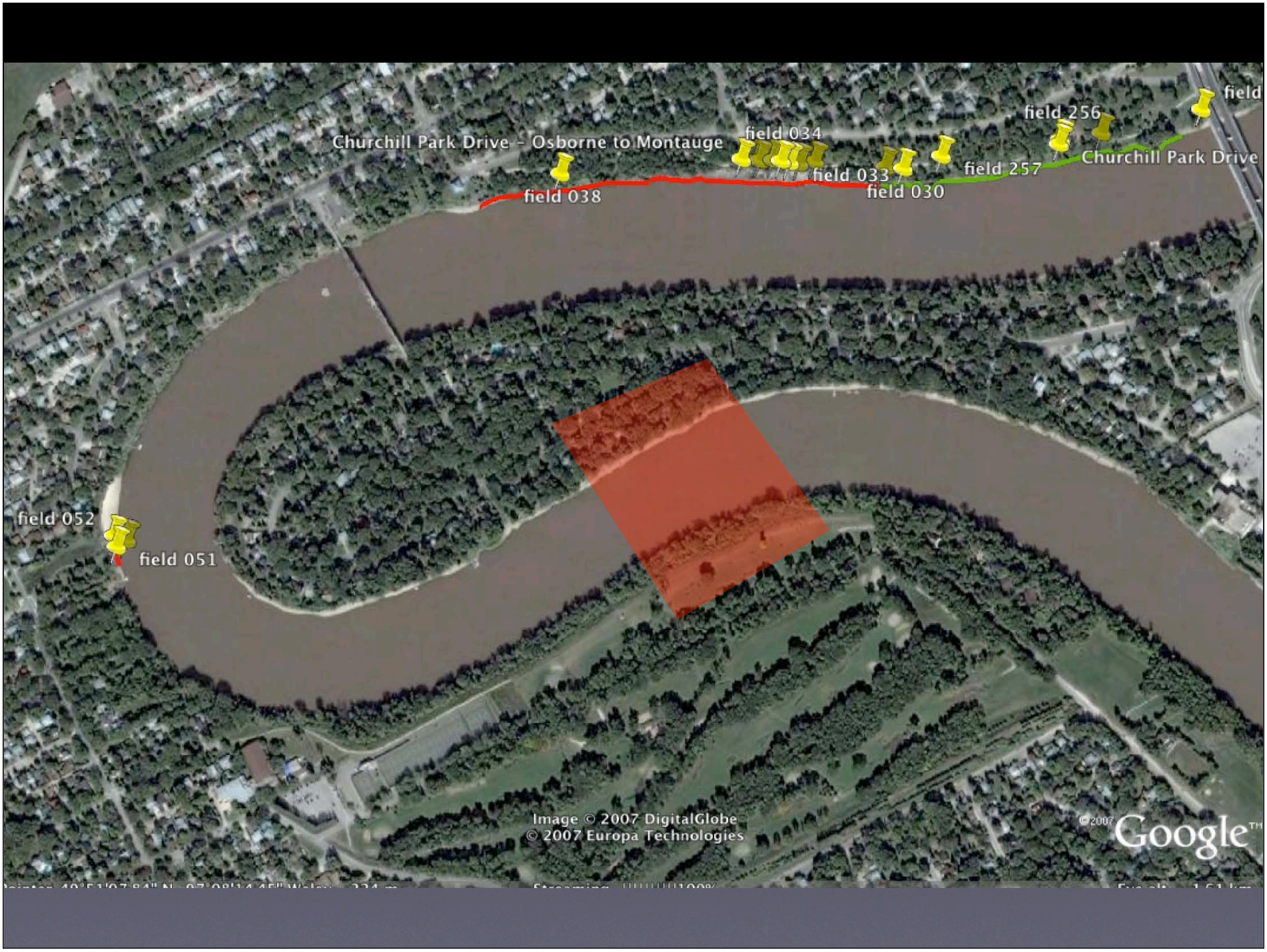
River Hydrographs





How do we Verify?

- Obtain historical cross-sections at a given location along the Red River
- Distance between the toe (for a given reference water surface elevation) represents the erosion between those two consecutive cross-sections
- Limitation: few historically surveyed cross-sections and air photos for interpretation


Churchill Park Drive - Osborne to Montauge
field 038
field 034
field 033
field 030
field 257
field 256
Churchill Park Drive
field
field 052
field 051
Image © 2007 DigitalGlobe
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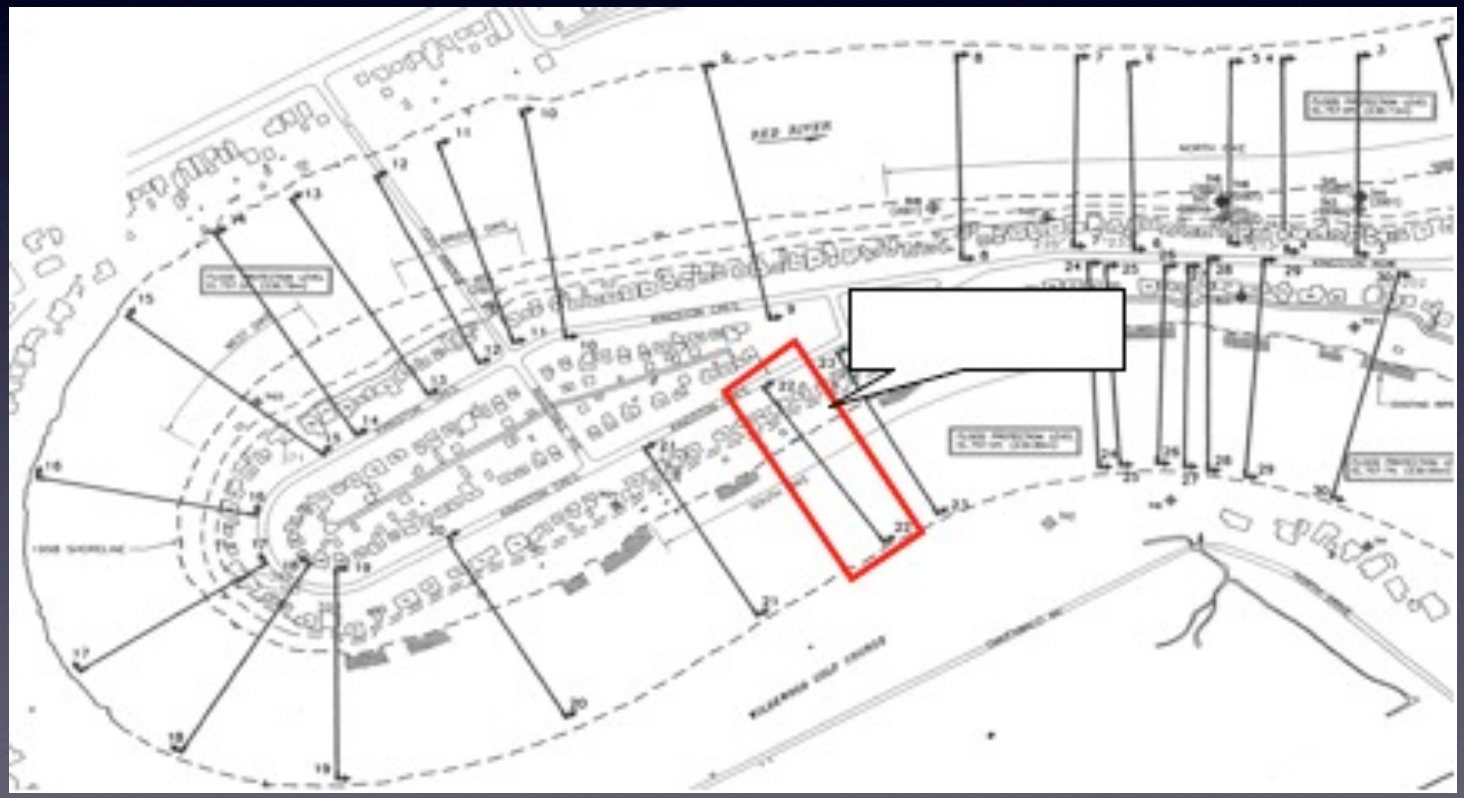
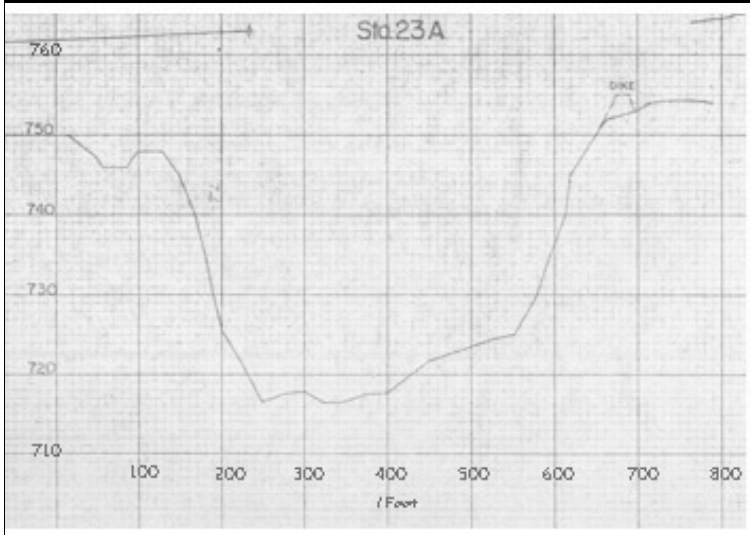
Kingston Row Section

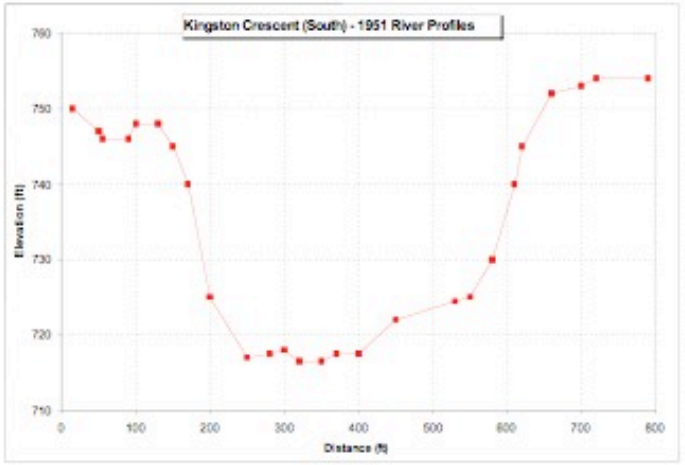
- Historical surveys limited to 1912, 1951 and 2001



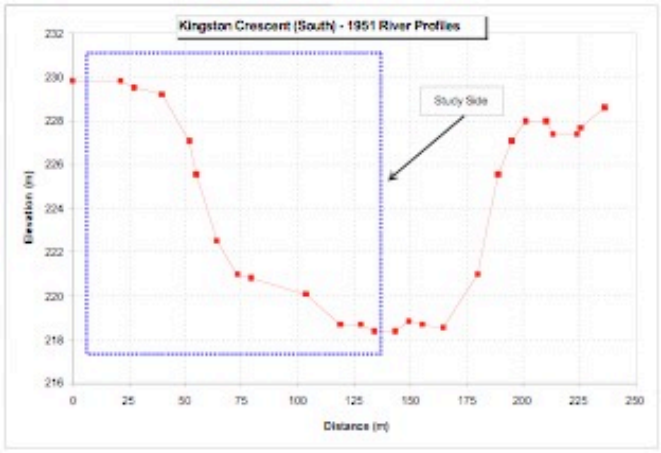
Kingston Row Section



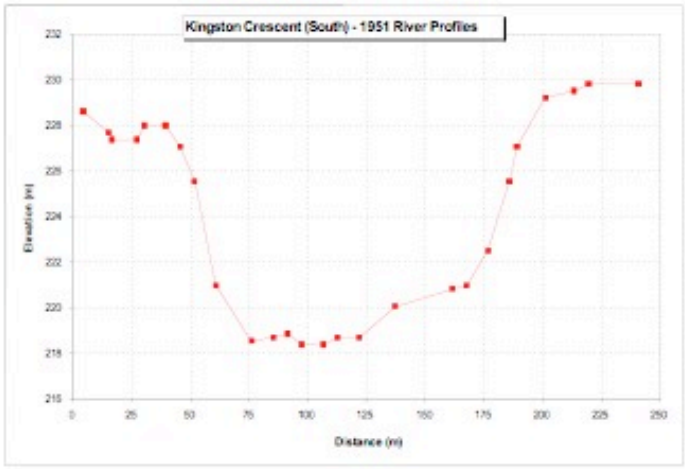
Original 1951 RRBI cross-section (left) is re-created in Microsoft Excel (right) by picking off the data points at all transitions on the original cross-section. View of the cross-section is looking downstream.



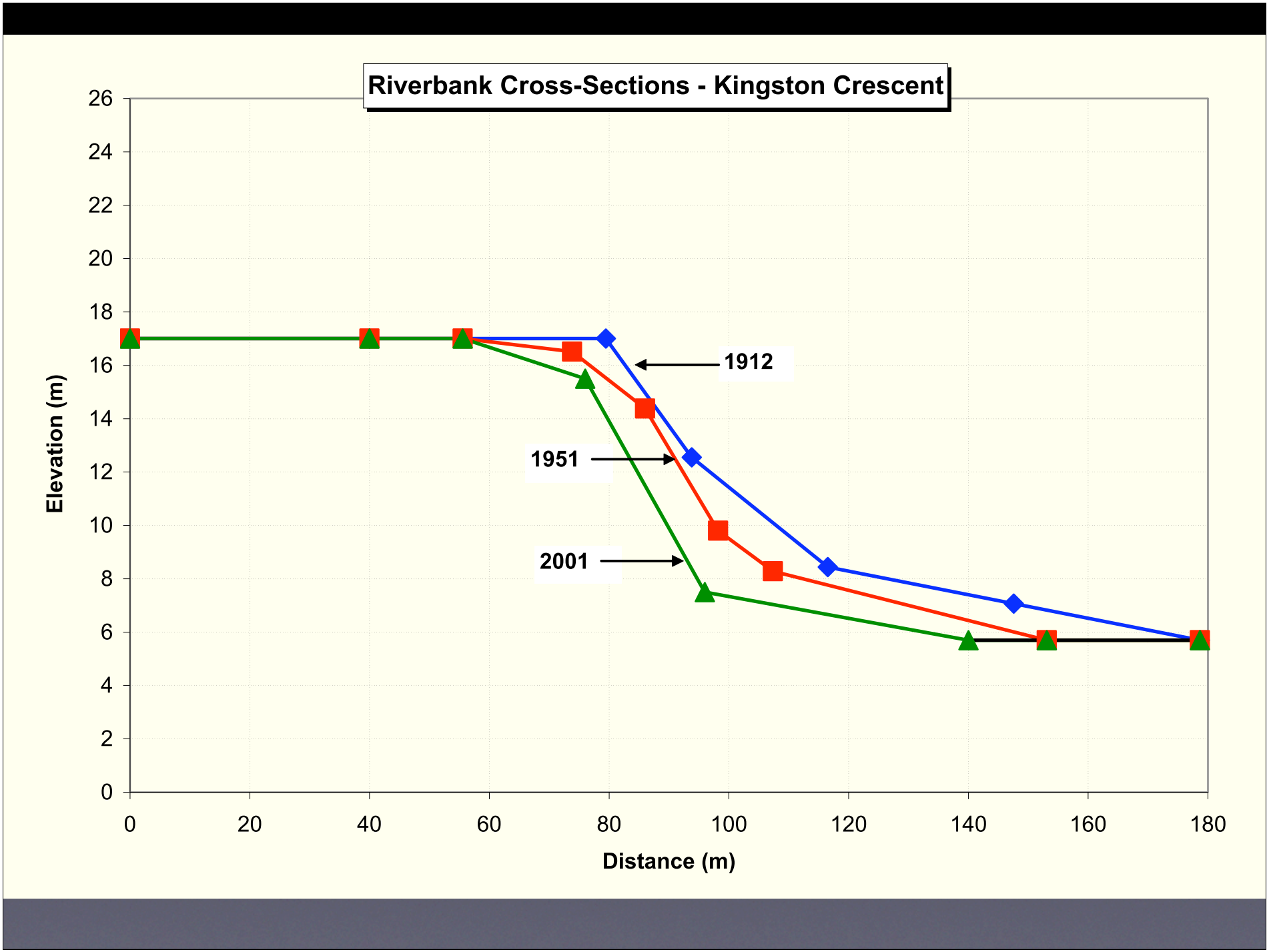
x (ft)	y (ft)
15	750
50	747
55	746
90	746
100	748
130	746
150	745
170	740
200	725
250	717
280	717.5
300	718
320	716.5
350	716.5
370	717.5
400	717.5
450	722
530	724.5
550	725
580	730
610	740
620	745
660	752
700	753
720	754
790	754



Cross-section is mirrored to have the same orientation (upstream view) as the 1912 and 2000 cross-sections



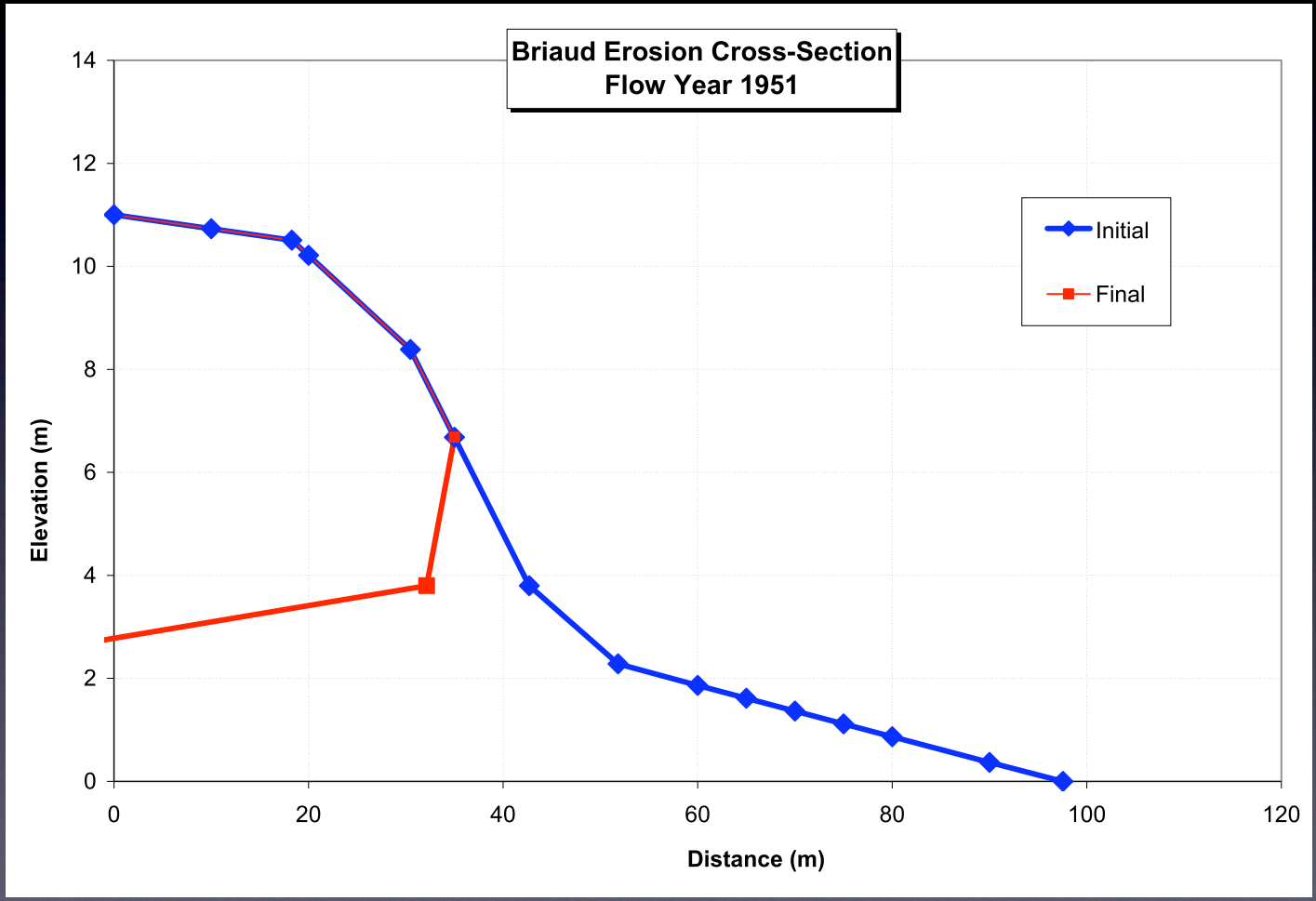
x (m)	y (m)
5	229
15	228
17	227
27	227
30	228
40	228
46	227
52	226
61	221
76	219
85	219
91	219
98	218
107	218
113	219
122	219
137	220
162	221
168	221
177	223
186	226
189	227
201	229
213	230
219	230
241	230


Riverbank Cross-Sections - Kingston Crescent
Elevation (m)
Distance (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
0
20
40
60
80
100
120
140
160
180
1912
1951
2001

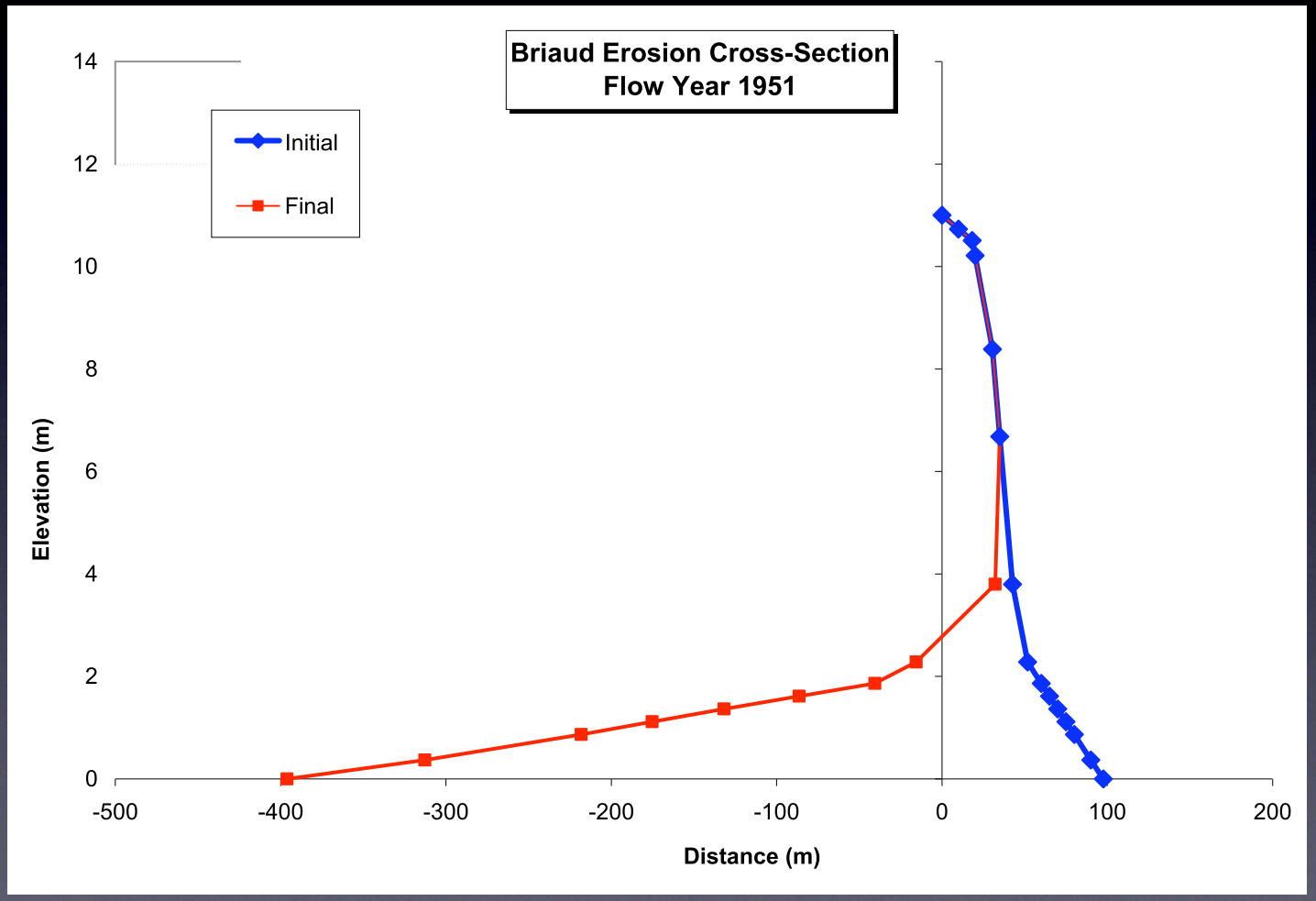
Compare Analysis with Field

- Compare field measurements based on historical surveys and aerial photographs with theoretical / laboratory based analysis.
- Of course theory matches practice and we now have a flawless method for assessing erosion rates!
- Not quite...

Comparison of Results



Comparison of Results

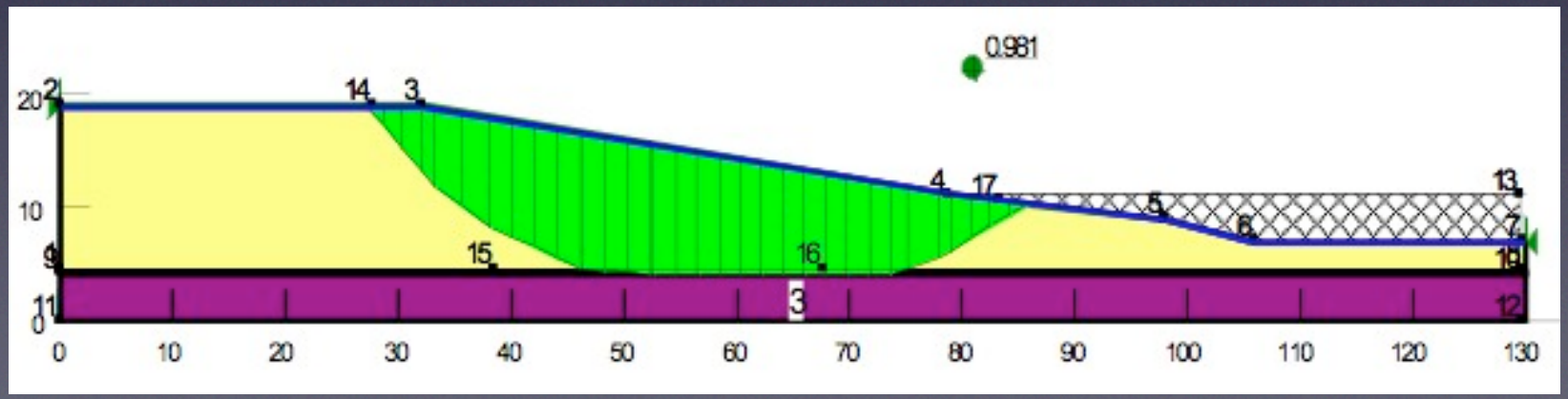


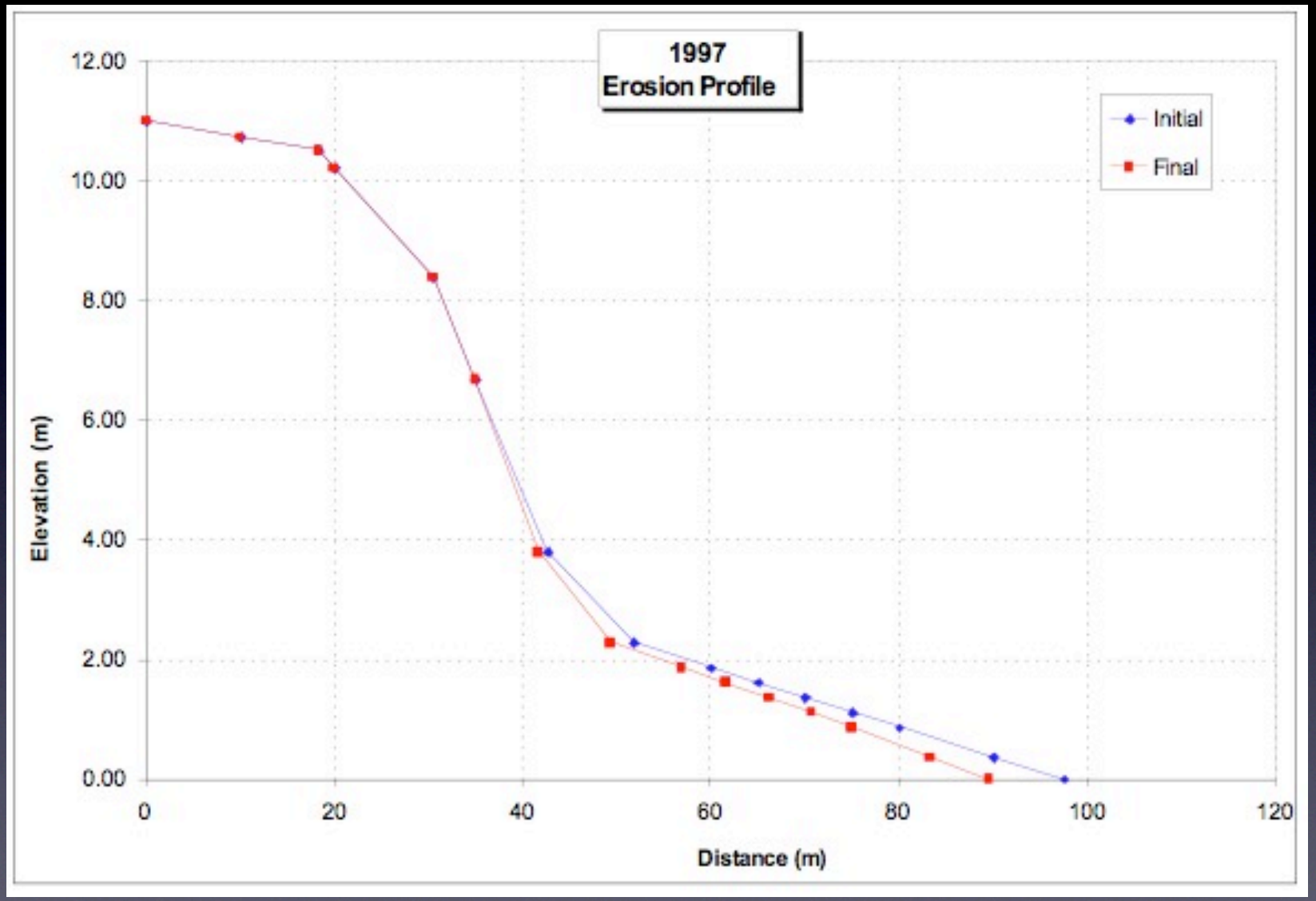
Common Sense

- There is no way riverbanks would erode at the rate shown or to the geometry shown.
- Calculated erosion rates are extremely sensitive to the critical shear stress measured in the EFA analysis.
- The precision of the measures and the eroding fluid are two major issues with the EFA measurements.
- Not all is lost. We can calibrate erodibility curves to field measurements.

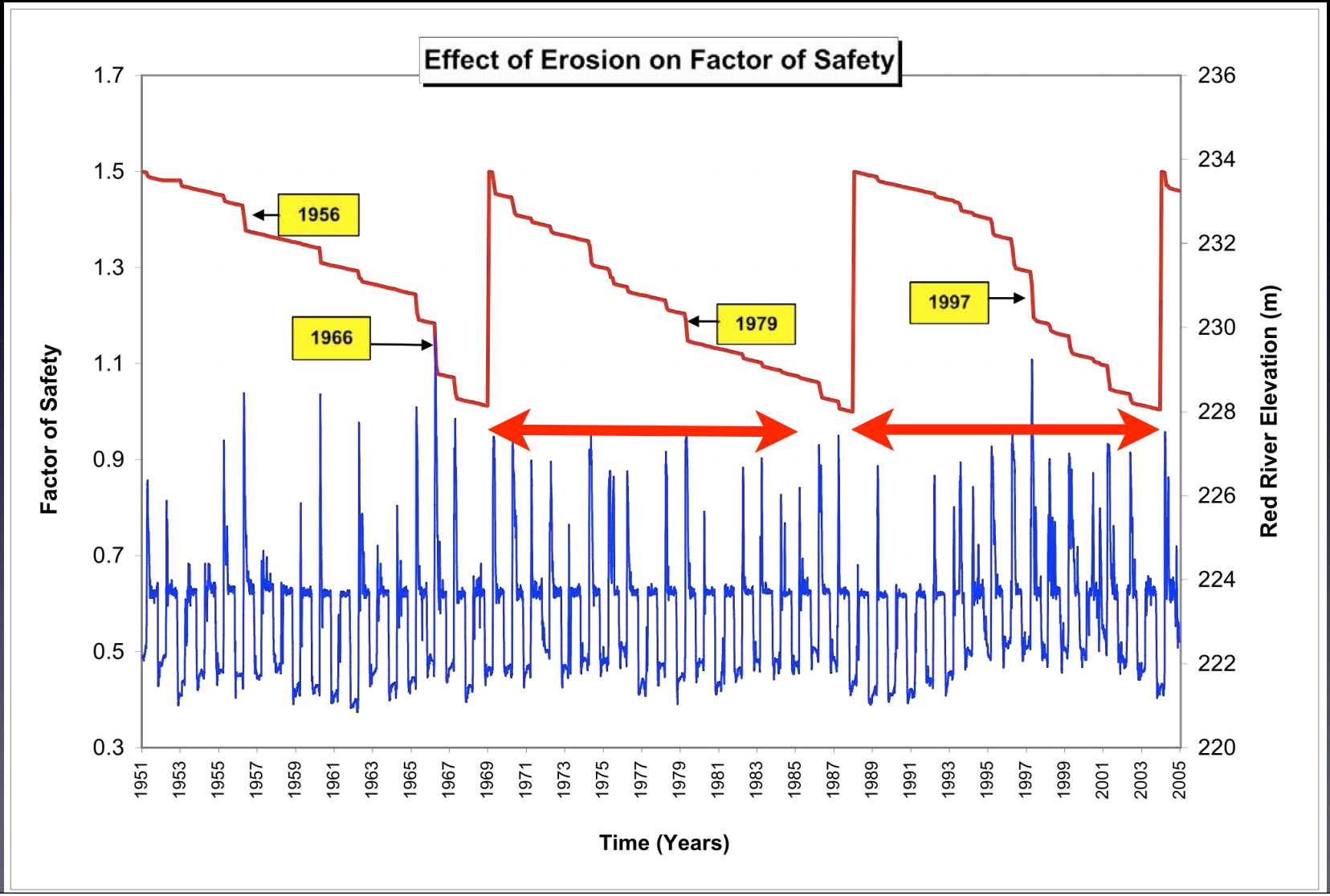
Calibration

- By shifting the erosion rate curves until the erosion rates match the difference between those measured at two different times, we can establish a more meaningful result.
- We can then apply the historic river hydrograph to see the impact of the varying past river conditions.

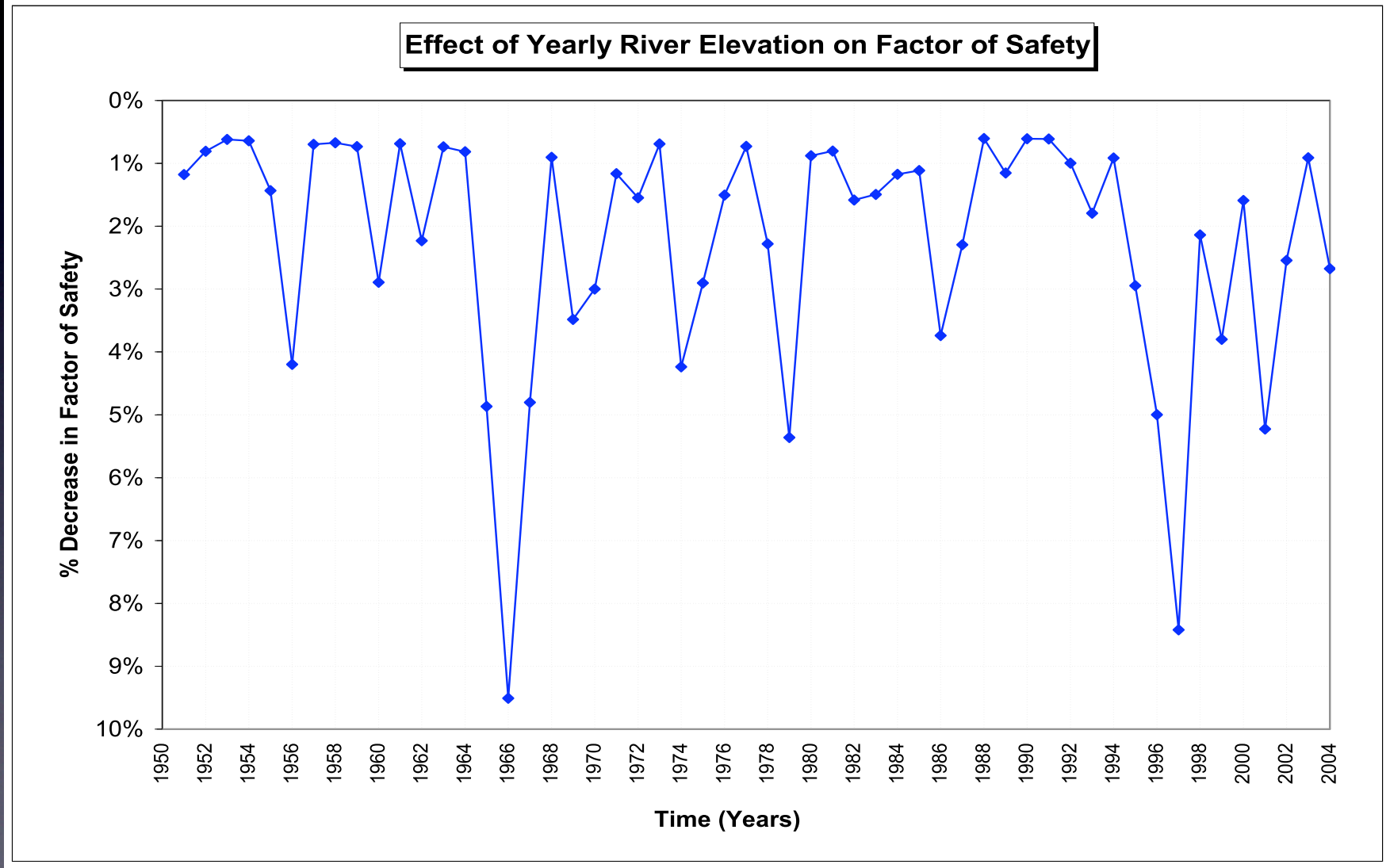


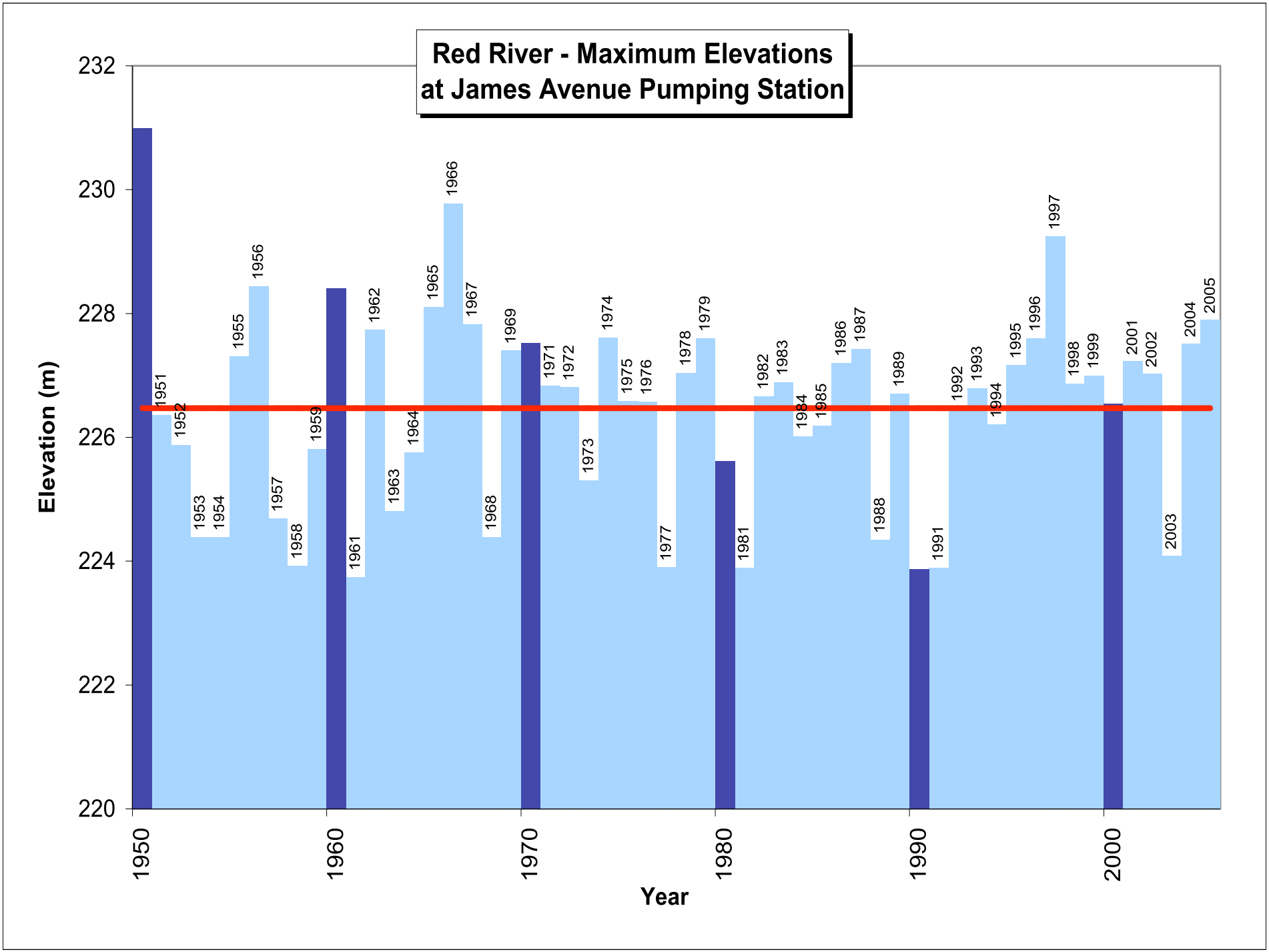

1997
Erosion Profile
Initial
Final
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Elevation (m)
0
20
40
60
80
100
120
Distance (m)

Results From 1951 – 2005



Percent Decrease in FS




Red River - Maximum Elevations
at James Avenue Pumping Station
Elevation (m)
232
230
228
226
224
222
220
1950
1960
1970
1980
1990
2000
Year
1951
1952
1953
1954
1955
1956
1957
1958
1959
1961
1962
1963
1964
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1966
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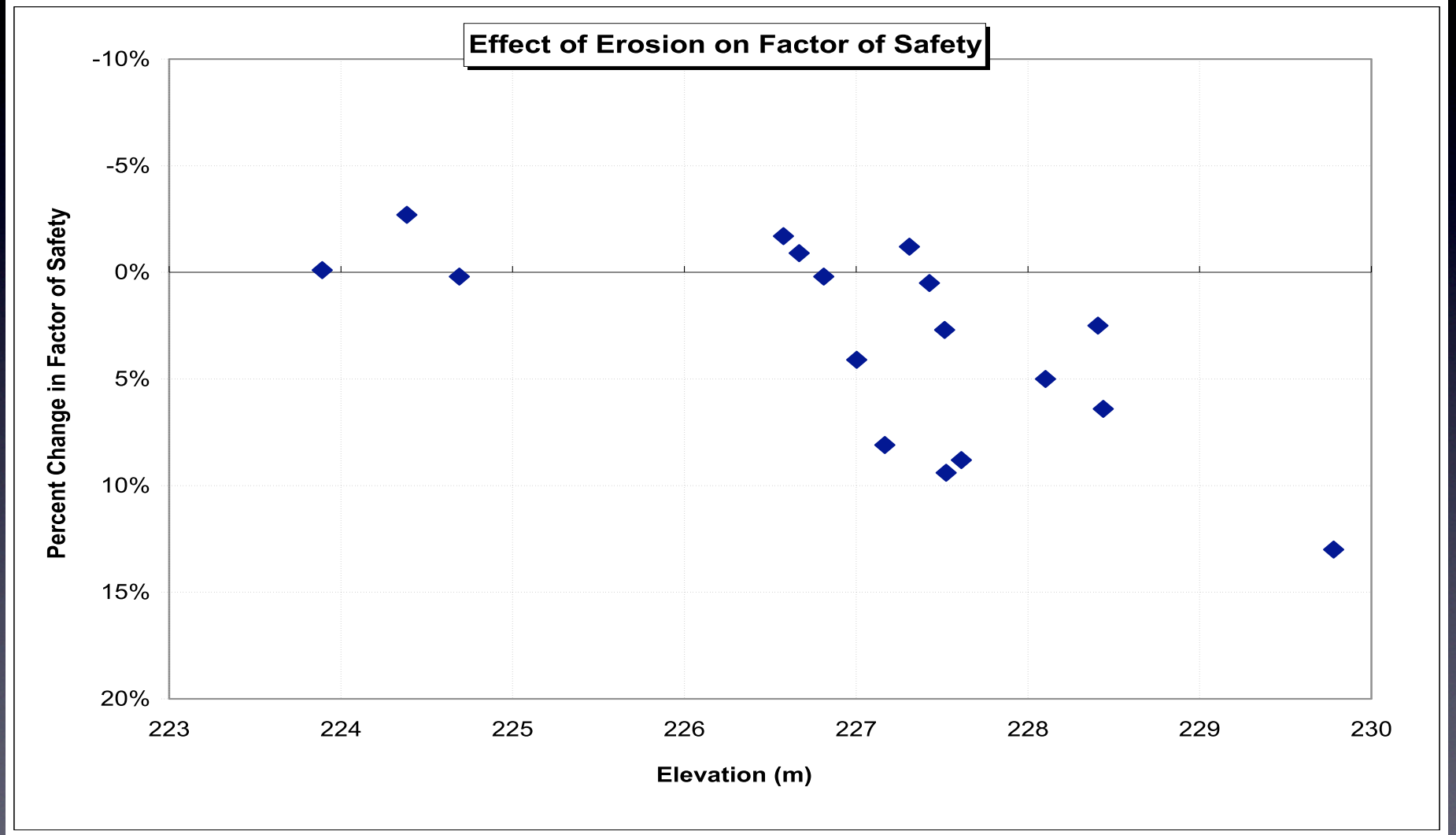
1997
1998
1999
2001
2002
2003
2004
2005

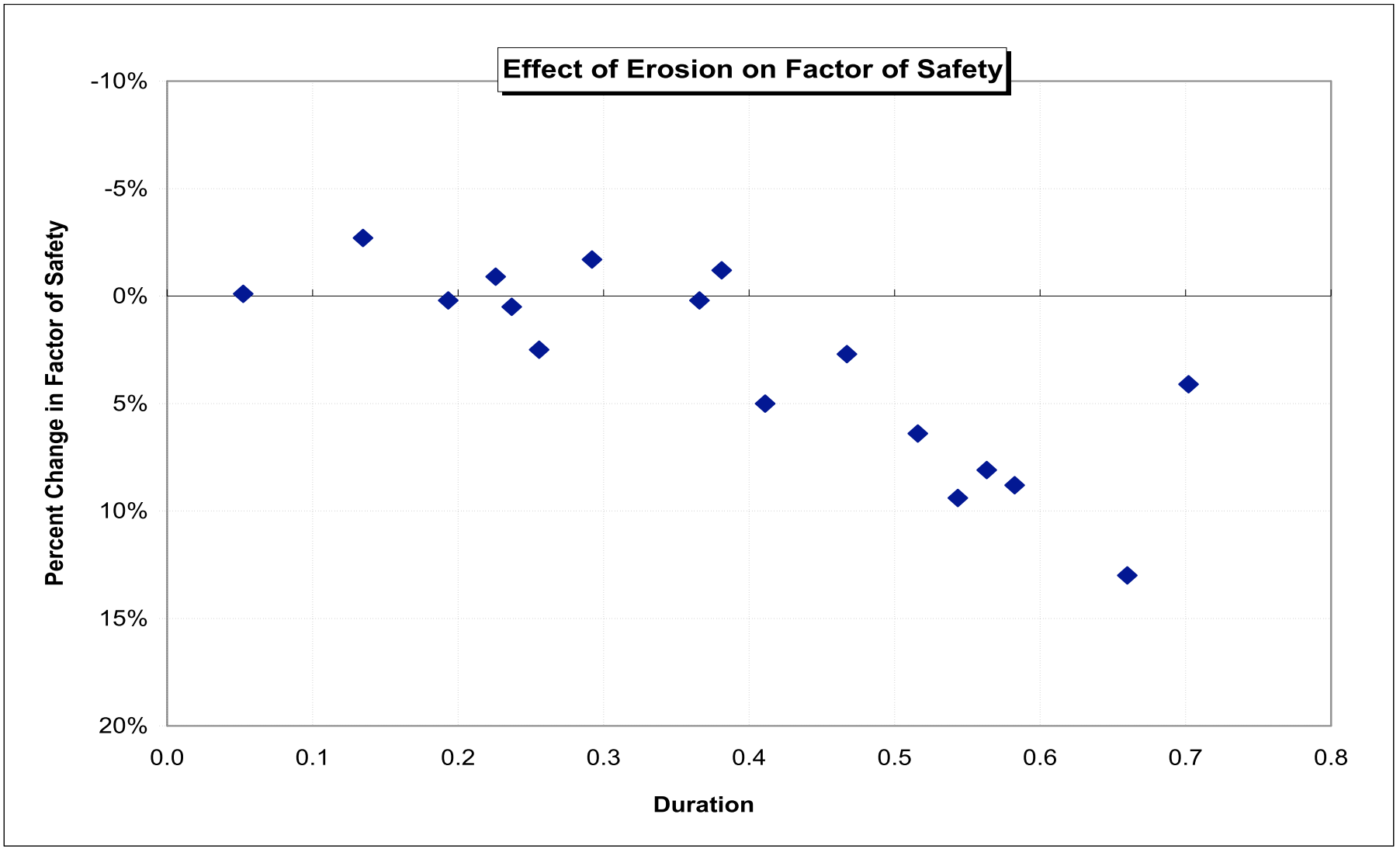
Results

- Appears to be a compelling linkage between flood magnitude and duration in terms of impacts on stability.
- Question as to which factor has more impact, duration or magnitude?

Sensitivity to Magnitude



Sensitivity to Duration



Results

- The link between flood events and increasing erosion is clear.
- Need better methods to measure erosion rates of specific materials to begin to examine the various bank conditions and materials.
- Need better data regarding the transient erosion from the field.
- Enter the GeoBlimp....

The GeoBlimp

From the Air – Single

From the Air – Group

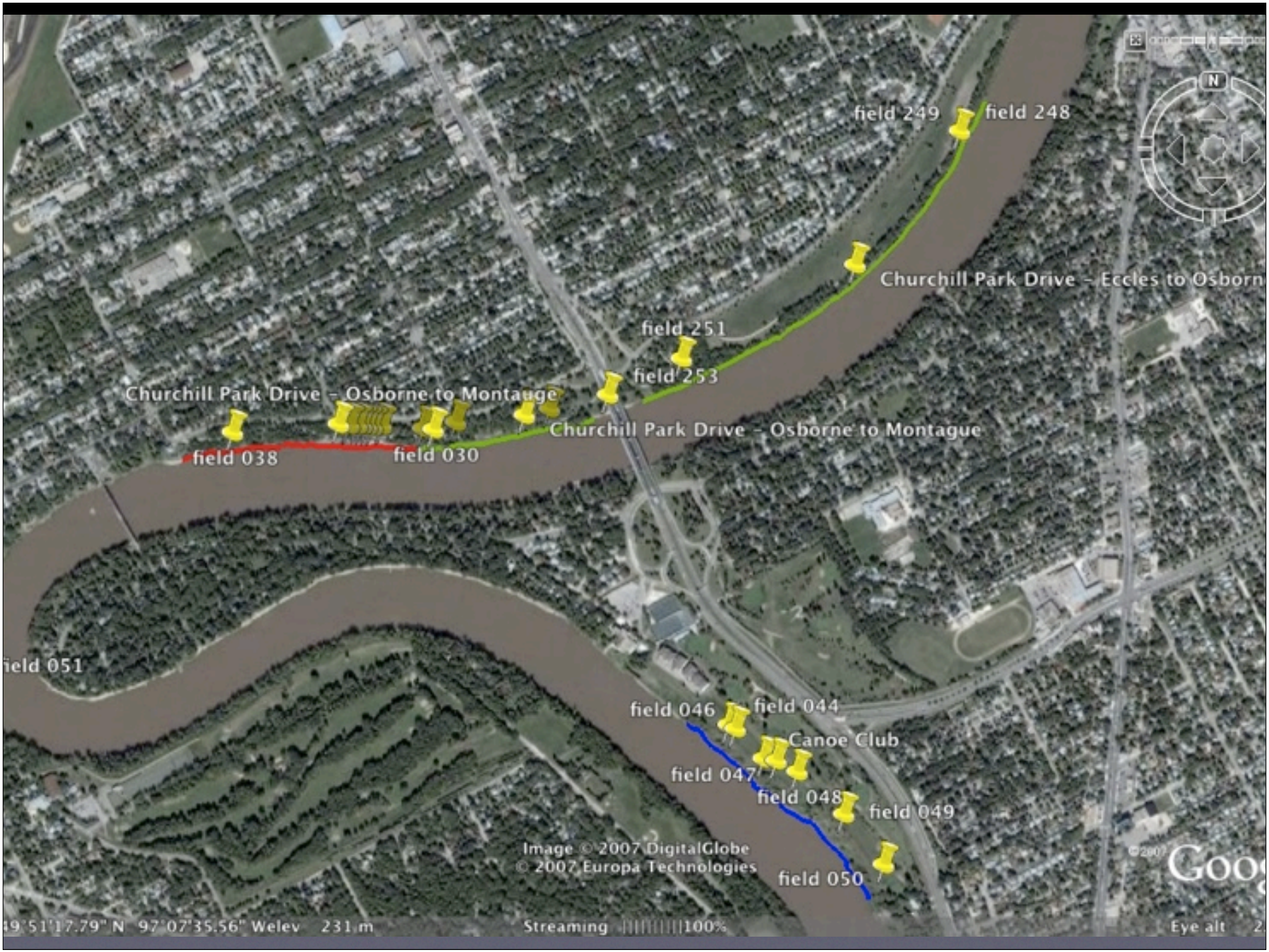
From the Air – Cropped

Discussion

- Blimp can be deployed in a matter of 1 hour and can get high resolution photos back within 2 hours.
- Photos are georeferenced to a measured datum.
- Provide the ability to photograph banks during optimal times with respect to river level and immediately following failures.

Path Forward

- Riverbank Asset Management System that will aid in priorization of remediation planning for the City of Winnipeg.
- Project is funded by the Riverbank Management Committee under the direction of the Waterways Engineer.
- Results will provide relative probability of failure measures along with consequence of failure measures to assess risk spatially along the river.


field 249
field 248
Churchill Park Drive - Eccles to Osborn
field 251
field 253
Churchill Park Drive - Osborne to Montague
Churchill Park Drive - Osborne to Montague
field 038
field 030
ield 051
field 046
field 044
Canoe Club
field 047
field 048
field 049
field 050
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49°51'17.79" N 97°07'35.56" W elev 231 m
Streaming 100%
Eye alt

Conclusion

- A study has been conducted that has quantitatively demonstrated potential impacts of flood events on erosion.
- Considerable challenges to physically measure erodibility of riverbank sediments still exist.
- Raises questions regarding public policy regarding river level control that may impact erosion and therefore riverbank failure

Thank you