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FLOOD MANAGEMENT IN THE GRAND RIVER WATERSHED

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The Grand River is located in southwestern Ontario; it stretches 280 km from its source in Wareham, Ontario to where it empties into the north shore of Lake Erie, see map in Appendix A [1]. The land use in the watershed is primarily agricultural but with some urban development, including the municipalities of Waterloo, Guelph, Cambridge and Brantford [2]. Flooding from the Grand River has a long standing history and continues to affect cities today. A reservoir network was built starting in 1942 to reduce issues from spring melt and high levels of precipitation which has been effective in reducing flood peaks by 50% or more [3]. However, due to the large and continuous changes to the landscape such as paving over extensive areas, cutting down trees and draining wetlands, flooding continues to be a problem [3]. One area that has had multiple floods and flood warnings is Water Street (Highway 24), located right next to the Grand River in Cambridge, Figure 1 [4]. Roads, walking trails and bridges in this area have been closed due to flooding as recently as April 2014. Dike systems were built to reduce the risk of flooding but there is always a need for improvement.

Gus Rungis, a Senior Water Resources Engineer at the Grand River Conservation Authority, suggested that an extension to the dikes near Water Street could provide a feasible solution to the flooding issues in Cambridge.[1]

Figure 1 – Flooded trail on Water Street, 2014. Photo by Amanda Grant for CBC News [4]

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[1] The authors of the case study would like to acknowledge Gus Rungis and James Etienne of the GRCA for their time and support on the development of this case study

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Cambridge Flooding

On May 17, 1974, following a month of heavy precipitation and a night with over 10 centimeters of rain, the Grand River flooded the City of Cambridge. There were no deaths resulting from the flood but some city streets were flooded to a depth of 4 meters and the flood resulted in property damages worth $6.7 million dollars, the equivalent of $33 million dollars in 2014 [5]. This event necessitated channelization and diking for the major flood damage areas of Cambridge which was completed in 1995 [6]. Flooding in Cambridge is still a regular problem today since it is a high risk flood damage center (the portion of a community located in a floodplain).

Flood Management in Cambridge

The Grand River Conservation Authority (GRCA), the agency responsible for the management of the Grand River watershed, has setup extensive flood management programs within Cambridge and the Region of Waterloo. GRCA's flood control programs include operating reservoirs, pumping systems, owning and maintaining dikes, as well as controlling development in flood-prone areas [7]. The large multi-purpose reservoir solution started in 1942 with the construction of the Shand Dam near Fergus and finished in 1976 with the completion of the Guelph Reservoir [8].

The GRCA currently manages a total of nine dikes in communities near the Grand River. The Cambridge dike, located near Dickson Street, has an average height of from 2 to 3 meters and provides full protection for regulatory floods [8]. The GRCA also has a weather monitoring program along with an extensive flood warning system. They provide resources in order to educate and prepare property owners for the possibility of floods.

Water Street

Water Street (Highway 24) is a road located in the center of Cambridge; it intersects with Main Street in the north end and Concession Street in the south end. Water Street is a two-lane highway and is populated by both businesses and homes. It runs parallel to the Grand River and the distance between the road and the river ranges between 20 to 300 meters. A map of Water Street is provided in Appendix A as well as an elevation map that outlines river stations.

The proximity to the river makes Water Street a high risk area for flooding. Flood warnings are often issued for areas surrounding Water Street with a recent minor flooding in April 2014 [9]; this resulted in water rising up over barriers along the Grand River near the Cambridge Mill in Galt. There was also water creeping up to the edge of Water Street near Concession Street [9].

Appendix B provides topographic data on the Grand River's water surface elevation and river bed elevation. The water surface elevation changes depending on storm events. The normal summer low flow is about 15 m^3/s and the current dike in Cambridge has a capacity of 2352 m^3/s [10].

As can be seen in Figure 2, a cement flood wall already exists along Water Street as a current flood preventative measure. This is in addition to the Dickson Street dike (which is part of the diking system for the surrounding area). The view of Figure 2 is from Concession Bridge and this flood wall only extends along Water Street up to the intersection of Water Street and Ainslee Street South. After this, there are no businesses or residential buildings near the river, only Highway 24 and some greenery.

This specific section is recommended for an earthen dike, as an extension to the pre-existing flood wall, specifically where Highway 24 is in close proximity to the Grand River. Appendix C provides a proposed location for an earthen dike along Water Street. Appendix D provides a cross sectional figure of an earthen dike. This additional earthen dike would be an extension to the current diking system and is one feasible solution to flooding in Cambridge; other alternatives exist and should also be explored.

Figure 2 - Google Streetview image of Grand River along Water Street (street is located on left in image) and cement flood wall

Problem Statement

A flood management control is needed to reduce the risk of flooding along Water Street. An extension to the diking system has been considered as one potential option therefore a design and cost analysis of an earthen dam are required in order to determine if this is an appropriate solution.

References

[1] Grand River Conservation Authority, “Facts About the Grand River Watershed”. Internet. http://www.grandriver.ca/index/document.cfm?Sec=74&Sub1=4. [Accessed November 7, 2014].

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[10] Grand River Conservation Authority, “GRCA monitoring network - Central & Lower Grand River”. Internet. http://www.grandriver.ca/index/document.cfm?Sec=2&Sub1=6&sub2=4. [Accessed November 7, 2014].

[11] Friends of the Grand River, “Grand River Map”. Internet. http://www.friendsofthegrandriver.com/map.htm. [Accessed December 15, 2014].

[12] Gus Rungis, Grand River Conservation Authority. Private Communication. [November 17, 2014].

[13] James Etienne, Grand River Conservation Authority. Private Communication. [November 26, 2014].

[14] Mark Knight, University of Waterloo. Private Communication. [December 8, 2014].

Appendix A – Maps of the Grand River

Figure 3 - Location of the Grand River, map of Ontario [11]

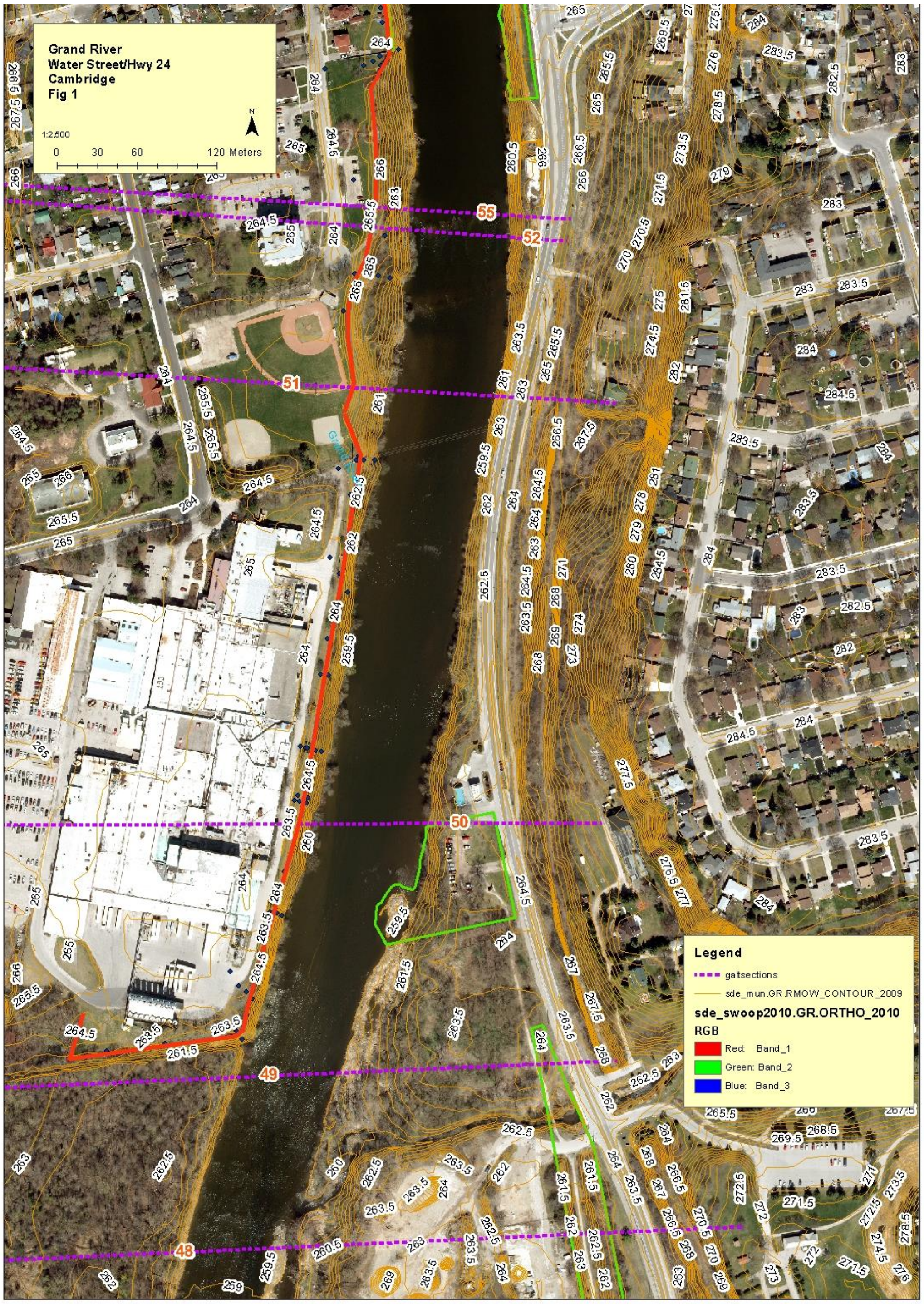

Figure 4 – Topographic map of Water Street along the Grand River and locations of river stations [12] (cross-sections from HECRAS model, see Appendix B for data)

Appendix B – Grand River Data

For different storm frequency events, the water surface elevation of the Grand River varies, Table 1 [12]. Table 2 provides water bed elevation of the Grand River [13].

Table 1 - Water surface elevation data for Grand River based on different storm events [11]

River station	Profile	Total Flow (m^3/s)	Water Surface Elevation (m)
48	2 year	434.0	261.1
48	5 year	647.0	261.5
48	10 year	797.0	261.8
48	20 year	947.0	262.1
48	25 year	996.0	262.2
48	50 year	1150.0	262.5
48	100 year	1310.0	262.7
48	May 1974	1550.0	263.2
49	2 year	434.0	261.4
49	5 year	647.0	261.9
49	10 year	797.0	262.2
49	20 year	947.0	262.5
49	25 year	996.0	262.6
49	50 year	1150.0	262.9
49	100 year	1310.0	263.1
49	May 1974	1550.0	263.5
50	2 year	434.0	261.7
50	5 year	647.0	262.3
50	10 year	797.0	262.6
50	20 year	947.0	262.9
50	25 year	996.0	263.0
50	50 year	1150.0	263.2
50	100 year	1310.0	263.5
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51	5 year	647.0	262.5
51	10 year	797.0	262.8
51	20 year	947.0	263.2
51	25 year	996.0	263.3
51	50 year	1150.0	263.6
51	100 year	1310.0	263.8
51	May 1974	1550.0	264.2

Table 2- Grand River water bed elevation data [13]

Location	Water Bed Elevation	Notes
Downstream of Concession St. Bridge	257.71 m	constant bed elevation for about 2.3 km (with the exception of several capped service crossings)

Appendix C – Proposed Diking System Extension

Figure 5 - Location along Water Street for proposed earthen dike as an extension to the existing diking system in Cambridge. An approximation of 350 m is assumed for the length of the earthen dike

Appendix D – Cross Section of an Earthen Dike

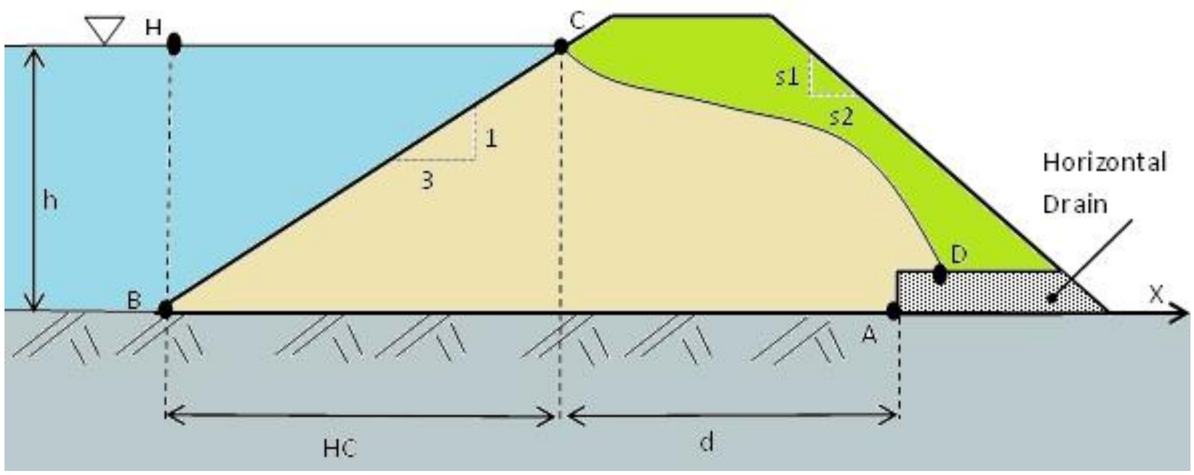

Figure 6 – Cross section of earthen dike [blue represents body of water, grey represents the foundation, green represents soil above the water table and beige represents the soil below the water table for the dike]

Table 3 - Earth dike symbols and units

Symbol	Meaning	Units
A	Location at base of dike where horizontal drain starts	-
B	Location of base corner on the stream side of dike (level with datum)	-
C	Point where water surface elevation meets stream side of earth dike	-
D	Top streamline (phreatic surface) penetrates perpendicularly to drain at point D	-
X	Exit surface (A to X) and datum	-
h	Constant total head	m
H	Point on phreatic surface at water surface elevation	-
HC	Horizontal distance from bottom edge of dike to water surface elevation	m
d	Distance between water surface elevation and beginning of drain	m
s1 and s2	Rise over run (slope) based on φ from shear box test	-
Horizontal Drain	Earth dikes also have horizontal drains (or toe drains) that allow any water which does enter the structure to drain away	-

Appendix E – Flow Nets

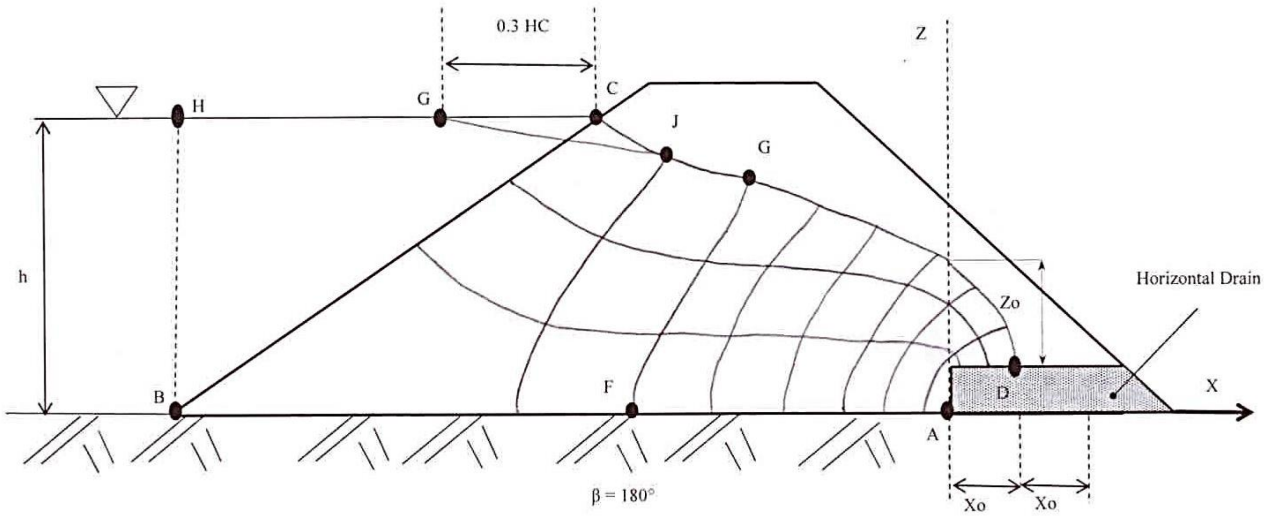

Figure 7 – Flow net for earth dike section

Appendix F – Unit Costs

Table 4 – Typical unit costs for dam and dike construction [14]

Item	Unit Cost	Unit
Material:		
Embankment fill	$3.00	m^3
Clean Sand	$6.00	m^3
Sand and gravel	$10.00	m^3
Soil Compaction:		
92% Modified Proctor	$1.50	m^3
95% Modified Proctor	$2.00	m^3
Material Hauling:		
Less than 1 km from site		
12 yard truck	$1.50	m^3/ km
40 tonne off road truck	$3.50	m^3/km
1 km to 2 km from site		
12 yard truck	$2.50	m^3/ km
40 tonne off road truck	$4.50	m^3/km
2 km to 5 km from site		
12 yard truck	$5.50	m^3/ km
40 tonne off road truck	$8.50	m^3/km
Excavation:		
Site grubbing	$1.00	m^3
Excavation & soil removal	$2.50	m^3
Borrow pit excavation	$2.50	m^3
Foundation Drainage:		
Sand drains 0-5m	$3.50	foot
Sand drains 5-10m	$6.00	foot
Sand drains 10-20m	$15.00	foot
Sand drains 20-30m	$30.00	foot
Wick drains 0-5m	$2.00	foot
Wick drains 5-10m	$4.00	foot
Wick drains 10-20m	$10.50	foot
Wick drains 20-30m	$20.50	foot
Geotextiles:		
Non-woven filter fabric	$1.50	m^2
Geogrid	$4.00	m^2
Woven Geotextile	$2.50	m^2
Dewatering	$0.50	m^3
Pump and Equipment Rental	$5000	Per day /10 linear meter
Mobilization and Demobilization	$20,000	Lump sum