Nottawasaga Valley Conservation Authority

NVCA Natural Hazards Technical Guide

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This document has been prepared by the Nottawasaga Valley Conservation Authority, in consultation with our 18 member municipalities, engineering consultant stakeholders and representative community groups. This document relies heavily on the work previously undertaken by the Ministry of Natural Resources, Credit Valley Conservation and Environmental Water Resources Group Ltd., and we are thankful for their efforts.

This document may be updated as a result of additional NVCA technical guide chapters or changes in municipal and/or technical guidance. Please contact the NVCA Engineering Department prior to applying the information contained within this guide.

Publication Information

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1 Introduction

1.1 Purpose of Guidelines

The purpose of these guidelines is to provide assistance to consulting firms and our municipal partners in the development and review of technical reports in support of new development. These guidelines are intended to work in conjunction with the NVCA Planning and Regulation Guidelines, the Ministry of the Environment Stormwater Management and Design Manual, and the Ministry of Natural Resources Natural Technical Guides.

These guidelines present procedures, computation methods, and input parameters that are commonly used and accepted by NVCA staff, however it is still the designer's responsibility to recommend and justify the most appropriate methods. If the designer determines that alternative procedures, computation methods, or parameters are required to best describe the development site, an explanation of the rationale must be provided to assist the Conservation Authority in their review.

Municipal guidelines should also be consulted as they may exceed the recommendations of the guidelines, policy and design documents referenced here.

1.2 Overview

Natural hazards are defined by the Ministry of Natural Resources as "natural, physical environmental processes that occur near or at the surface of the earth [that] can produce unexpected events of unusual magnitude or severity."

The Nottawasaga Valley Conservation Authority (NVCA) is mandated through the *Conservation Authority Act* to regulate lands that are subject to five types of natural hazards:

- flood;
- erosion;
- hazardous soils;
- karst; and
- dynamic beach.

References for evaluating and addressing natural hazards are as follows:

- Natural Channel Systems: Adaptive Management of Stream Corridors in Ontario, including Natural Hazards Technical Guides for River and Stream Systems: Flooding Hazard Limit, Erosion Hazard Limit and Hazardous Sites Technical Guides (MNR 2002);
- Great Lakes – St. Lawrence River System and Large Inland Lakes Technical Guides for Flooding, Erosion and Dynamic Beaches in support of Natural Hazards Policies 3.1 of the Provincial Policy Statement (MNR 2002).

These natural hazard references should be read in conjunction with the NVCA Planning and Regulations Guidelines. The guidelines provide background information and direction in meeting the Authority's goal, objectives and targets for both the Plan Input and Review and Permitting programs. A copy of the NVCA Planning and Regulations Guidelines can be found on the NVCA website.

The information provided below is intended to provide technical assistance for determining the location and extent of the natural hazards. As such, additional technical information related to defining the natural hazards may be required by the NVCA, and applicants are encouraged to preconsult with appropriate NVCA staff prior to undertaking natural hazard studies.

2 Erosion Hazard Assessment

Erosion hazard assessments are requested for applications that are located within the estimated erosion hazard based on NVCA regulation mapping. Erosion hazard assessments may be one of two types: 'apparent' (confined) or 'not apparent' (unconfined).

For further information related to defining erosion hazards, please refer to section 4.3.3.2 *Defining River or Stream Valleys* of the NVCA Planning and Regulation Guidelines.

2.1 Toe Erosion Allowance

Toe erosion allowance is an estimation of the distance the toe of a slope would move over the next 100 years.

Through aerial photography interpretations undertaken by the NVCA, the Authority has determined that the maximum toe erosion allowance of 15 metres (as noted in Table 3 of the Erosion Hazard Limit Technical Guide) is insufficient in certain portions of our jurisdiction. Applicants are requested to pre-consult with NVCA engineering staff to determine which assessment methods are applicable for determining the toe erosion component of the erosion hazard limit.

Where toe erosion may exceed 15 meters, the selection of the toe erosion allowance should be based on one of two methods: the average annual recession rate based on 25 years of data, or a study using accepted geotechnical and engineering principles and based on a minimum 25 years of data.

A site specific study, also may determine that erosion allowance of less then 15 metres could apply.

2.2 Stable Slope Allowance

When undertaking a site-specific stable slope analysis, the toe and top-of-bank should be determined through a site-specific topographic survey rather than using aerial photography generated topographic information. The information available within the NVCA jurisdiction from aerial photography has an accuracy of +/- 1 meter both vertically and horizontally, which could lead to erroneous determinations.

The factor of safety required for a proposed development should be as per Table 4.3 of the MNR Technical Guide. NVCA notes that for active, infrastructure and public use a value of 1.5 meters is required.

2.3 Meander Belt Width Determinations

For large development applications, such as those requiring planning approvals related to plans of subdivisions, condominiums or site plans, the undertaking of a fluvial geomorphologic assessment will be required to delineate the hazards associated with an unconfined system.

Meander belt width determinations can be undertaken in one of two ways:

- An allowance based on the bankfull width applied on the axis of the watercourse as per the MNR Technical Guide; **or**
- As per the methodology outlined in the 2004 Parish Geomorphic Report entitled "Belt Width Delineation Procedures."

The selection of the methodology should take into account factors such as the size of the watercourse, soils, drainage area and the existing meander pattern of the watercourse. The engineer/consultant should make a recommendation of the appropriate method with the rationale for the selection. This recommendation should be submitted to the NVCA for review and approval prior to undertaking the study.

2.4 Erosion Access Allowance

As per the MNR Technical Guide, this allowance is supported by three principles:

- providing for emergency access to erosion prone areas;
- providing for construction access for regular maintenance and access to the site in the event of an erosion event or failure of a structure;
- providing protection against unforeseen or predicted external conditions which could have an adverse effect on the natural conditions or processes acting on or within an erosion prone area of provincial interest.

As such, the NVCA requires a minimum erosion access allowance of 6 metres at the top of the bank as defined by the slope stability and toe erosion allowances. It is also recommended that there be 6 metre access from the municipal road to the top-of-bank access allowance for construction equipment. The NVCA may reduce the access allowance between the road and the top-of-bank on a site-specific basis but only if absolutely necessary.

3 Flood Hazard Limits

For further information related to defining floodplain and floodplain policies, please refer to section 4.3.3.2 *Defining River or Stream Valleys* of the NVCA Planning and Regulation Guidelines.

Flood hazard assessments are requested for applications that are determined to be at risk for flooding based on NVCA regulation mapping, where a site-specific study does not exist and/or where the site-specific study is not valid with respect to the development proposed.

3.1 NVCA Regulation Hydraulic Models

The NVCA released floodplain mapping for the entire watershed as required as part of the “NVCA Regulation Mapping.” This mapping was meant to be used to identify areas that are potentially impacted due to floodplain inundation. This mapping was based on HEC-RAS computer modelling undertaken for the entire NVCA watershed on watercourses with drainage areas larger than 50 hectares, based on computer generated drainage areas.

These hydraulic models were based on aerial topographic information and a number of conservative assumptions such as:

- flow rates taken from McLaren (1988) when the drainage area is larger than 75 km^2 or the rational method;
- left and right channel banks are taken as the starting and ending points in the cross-section;
- 0.08 used as a Manning’s n value regardless of land use type; and
- modelling culverts with more than 1 meter depth over top-of-road at culvert.

NVCA continues to maintain and improve the regulation floodplain modelling by incorporating additional culvert crossings, reviewing the location and orientation of cross-sections such that they were perpendicular to the regulatory flows and checking the flows for accuracy.

In certain circumstances, the NVCA will make these models available to consultants as an initial basis for floodplain assessments for development applications through a data sharing agreement. It should be noted that the NVCA models would not meet the requirements of the province for providing a site-specific floodplain limit and, as such, NVCA requires that all inputs, such as flow rates, Manning’s n values and overbank locations, into the models be adjusted by a qualified professional in order to meet the provincial requirements.

As the accuracy that the topographic data for the NVCA hydraulic models is +/- 1 meter, all cross-sections within a given development site must be based on site-specific geodetic topographic survey completed by a professional engineer or an Ontario Land Surveyor. Based on this survey a correction factor for the datum related to the NVCA hydraulic model can be determined by comparing points on the survey with the appropriate Triangular Irregular Network (TIN) and determining the average error for a site.

The location of the points selected should be based on a variety of land uses, as the TIN is more accurate with respect to hard surfaces such as roads than to vegetated areas. The corrected TIN can then be used to generate cross-sections adjacent to the proposed development as required. All bridges and culverts that influence flood elevations at the development site must be inserted into the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model based on site-specific geodetic survey using the same datum. If a datum adjustment is required, then the methodology and specific points used to determine the correction factor will be required in the hydraulic report.

See Appendix A for a discussion on the technical differences between the TIN and the DEM.

3.2 Site-specific Hydraulic Models

The intent of the information in the following sections is to provide the modeler with guidance to help them through the modeling exercise. It is the responsibility of the modeler to determine the most suitable approach and parameters to best simulate the physical conditions on the site. The purpose of the hydraulic guidelines is to provide the modeler with a detailed list of the information required by the NVCA for technical review and to outline standard hydraulic parameters that are commonly used in the watershed for hydraulic modeling.

If the modeler determines that non standard parameters are required in the model, then an explanation of the rationale should be provided to assist in the NVCA's review, as well as any references required.

3.2.1 General

The technical reports for hydraulics are to be prepared in such a manner that the entire work can be recreated by a qualified person without the need to refer to any other material. All reports are required to be standalone documents with any previously completed and reviewed sections of previous reports included as an appendix.

Further, qualified persons are to be able to recognize and understand all the methods, approaches, basic data, assumptions and rationale used for these methods.

The floodplain within the NVCA jurisdiction is defined by the MNR Technical Guide as the "flood produced by the Timmins Storm or the 100-year Flood, whichever is greater." The 100-year flood is determined by the greater runoff generated by either the 1:100-year 24 hour SCS Type II storm or the 1:100-year 4 hour Chicago Storm.

The NVCA will only approve a floodplain limit for development if it has been surveyed and sealed by a licensed professional (i.e. an Ontario Land Surveyor or a Professional Engineer) and tied to a geodetic elevation.

The NVCA only supports the use of the latest version of the HEC-RAS software for the completion of hydraulic modeling for setting the location of the floodplain.

HEC-RAS analysis submitted to the NVCA should be clearly identified using the program's plan files to organize digital runs. Plans should be clearly labeled with specific identifiers such as pre-development conditions, pre-development conditions with flows reduced to X, etc. For submissions that are not clearly organized into plans, a separate section of the report or separate readme file must be included describing which combination of geometry and flow files represent the pre-development and proposed conditions.

NVCA Standard Hydraulic Parameters, Section 3.3, should be used in the hydraulic computations.

As well, discussion on the assumptions made and methods used with respect to parameter estimation and effective flow areas at various stages of hydraulic analysis shall be included in the Hydraulics Report.

3.2.2 Channel Cross-sections

Cross-sections are required at all locations where changes occur in longitudinal slope, cross-sectional area, channel roughness, bridges and other channel constriction. Several cross-sections maybe required to describe abrupt changes.

All cross-sections should be coded from left to right looking downstream. Cross-section data points shall only be abstracted from topographic mapping, geodetic field surveys or measured low flow sections. Overbank and channel distances between cross-sections shall be reflective of actual water course bends. Left and right bank channel stations shall be representative of actual channel low flow banks.

Maximum spacing between successive cross-sections shall be dictated by the analytical requirements of the model and in no case shall result in more than one-half metre difference in successive water surface elevations, unless approved by the Authority. The length between cross-sections should be based on river geometry and the assumption that gradually varied flow within a reach is valid.

Cross-sections shall be extended across the entire floodplain, should be perpendicular to the anticipated flow lines (approximately perpendicular to contour lines) and only positive chainages are to be utilized. At high flows, cross-sections are expected to follow the valley feature and not the low flow channel. Computer generated vertically extended or interpolated cross-sections are not acceptable unless determined acceptable through pre-consultation with Authority engineering staff.

Where possible, cross-sections of the channel above and below the waterline must be taken by field survey at all representative locations throughout the channel reach. Cross-sections must include the entire floodplain of the main channel and any tributaries. Cross-sections must be tied in vertically to established geodetic benchmarks and horizontally to permanent structures or GIS co-ordinates.

The same numbering system for the cross-sections must be used in the HEC-RAS model, as on the floodline maps and field survey notes and plots.

3.2.3 Crossing Analysis

The top-of-road profile must be obtained by field survey and extend across the entire width of the floodplain.

Left and right bank stations should be located at the edge of the bridge opening. Road crossing barriers/parapets should be coded in the road profile section.

Equivalent culverts may be required where culverts are composed of two or more segments with different shapes and constructed of different materials.

3.2.4 Boundary Conditions

Where a control starting elevation (such as a weir) is not possible, the starting section shall be located sufficiently downstream that the reach under consideration is not significantly affected by the starting elevations, typically at least three cross-sections downstream of any significant change in channel form. Using the computed water surface elevation from a downstream model is acceptable but the value must be verified with the Conservation Authority. Otherwise, the model should use normal water surface elevation unless it is known that critical flow occurs at the starting cross-section.

For channels flowing into Georgian Bay, the starting water surface elevation shall be based on the long-term mean lake level, 176.44 m for all events as taken from *The Canadian Hydrographic Service Central and Arctic Region - Historical Water Level Data*. Once analysis is complete for the regional and 100-year events, the 1:100-year lake levels for Georgian Bay are to be superimposed on the resultant water surface profile to establish the regulatory level.

In the case where the backwater computations are to begin at another river, the starting water level should be selected according to the respective travel times of both watercourses.

Discussion on the method used and assumptions made in the determination of the starting water surface elevations for backwater computations shall be included in the Hydraulic Report.

3.2.5 Calibration

The hydraulic model should be calibrated where data such as high water marks are available and where model is near a gauge location.

Discussion on the data used in calibration work including the reasons for the choice of data used in the work shall be included in the Hydraulic Report.

3.2.6 Sensitivity Analysis

An assessment of the sensitivity of culvert blockages on upstream flood levels must also be carried out. Proposed development designs must provide sufficient overland flow capacity to allow safe passage of the Regulatory storm event and dry floodproofing of all lots, with 50% of the culvert opening blocked.

Table 3.1: Sensitivity analysis

Sensitivity Runs	Minimum Variance
peak flood discharge	+/- 20%
channel and floodplain roughness	+/- 20%
expansion and contraction	+/- 100%
starting water levels	+0.5m
debris blockage (*bridge & culvert locations)	-50% of opening

MNR lists the following as typical sensitivity runs:

- peak flood discharge;
- channel and floodplain roughness;
- expansion and contraction coefficients;
- starting water levels, tidal conditions or control gate operations;
- channel configuration, including the spacing, location and definition of cross-sections;
- ice-jamming and debris blockage;
- sedimentation and sand bars.

3.2.7 Spill Analysis

Spills are defined within section 4.13 of the MNR's 2002 "Technical Guide – River & Stream Systems: Flooding Hazard Limit" as water that moves into an adjacent watercourse or re-joins the same watercourse at a distance downstream.

Consultants must determine the extent and depth of flooding due to the spill, the volume of spill flow going out of the floodplain and its impact on downstream peak flows and flood levels. Consultants should consult section 4.13 of the MNR's 2002 "Technical Guide – River & Stream Systems: Flooding Hazard Limit" when dealing with floodplain analysis that include spills to adjacent watercourses for further guidance.

The consultant must investigate whether the spill is natural or as a result of manmade structures and discuss this with the Authority. If the spill is due to manmade structures, downstream flood levels are to be determined for total flows. In the case of a significant natural spill, downstream flood levels may be based upon reduced peak flows if the natural condition is protected from future changes.

Discussion on the methods used and assumptions made in the determination of spill flows, effects on downstream flows and regulatory flood limits, and areas affected due to the spill shall be included in the Hydraulic Report.

Within areas defined as spills, all new development should be floodproofed as per Section 5.5 and safe access/egress should be provided to the new development as per Section 5.1. As fill will be required as part of floodproofing, the development will need to be designed to provide safe passage of the spill flows through the proposed development without impacting adjacent properties.

3.2.8 Flow Rate Validation

Modeled pre-development flows should be substantiated through a comparison to design flows generated using the design flow and headwater drainage area equations as per Appendix G and Section 3.3.4.1 respectively of:

MacLarenPlansearch, 1988. "Watershed Hydrology Study for Nottawasaga, Pretty and Batteaux Rivers, Black Ash, Silver and Sturgeon Creeks", Volume 1-Technial Report", Canada-Ontario Flood Damage Reduction Program.

Linear Regression Analysis of Peak Flow vs. Drainage Area Headwater Drainage Areas Formula:

$$Q=CA^n$$

Where: Q = Peak discharge in m^3/s
A = Drainage area in km^2

Table 3.2: Linear regression analysis parameters for headwater drainage areas

WATERCOURSES	5 Year		10 Year		20 Year		50 Year		100 Year	
	C	**n**	**C**	**n**	**C**	**n**	**C**	**n**	**C**	**n**
Innisfil/Beeton/ Bailey	0.556	0.751	0.683	0.753	0.826	0.750	0.993	0.753	1.12	0.757
Upper Nottawasaga	0.639	0.652	0.820	0.643	0.957	0.647	1.19	0.644	1.35	0.646
Boyne River	0.767	0.894	1.05	0.883	1.47	0.851	1.79	0.869	2.31	0.842
Pine River	0.228	1.00	0.289	0.999	0.332	0.999	0.396	0.998	0.443	0.999
Mad River	2.43	0.489	2.99	0.489	3.51	0.489	4.24	0.489	4.81	0.489
Willow Creek	0.553	0.880	0.624	0.880	0.698	0.878	0.789	0.878	0.879	0.872
Georgian Bay Inflows	1.58	0.817	2.02	0.808	2.51	0.790	3.37	0.749	3.99	0.729

For sites where there are MacLaren basins upstream and downstream of the proposed location, a linear interpolation of the basin flows should be used.

3.3 Hydraulic Parameters

The selection of an appropriate Manning's n value is one of most crucial and most difficult parts of a hydrologic model. HEC-RAS and Manning's calculations are extremely sensitive. There are many sources of Manning's n and selecting a value can be difficult. A few values have been presented in Table 3.3 and

Table 3.4 to help as a guide. Manning's n values selected should be well documented in the report.

NVCA staff note that in some cases it is appropriate to select a Manning's n value that is outside of the ranges provided in the Tables below. One important consideration for Manning's n is to consider what will happen to the channel over the next 100 years. Consultants should explain/justify their selected value.

Additional values for parameters used in hydraulic modelling can be found in the HEC-RAS Reference Manual.

Table 3.3: Manning's Roughness Coefficients – overland sheet flow

Cover	***n***
Impervious areas	0.013
Woods	
with light underbrush	0.4
with dense underbrush	0.8
Lawns	
short grass	0.15
dense grass	0.24
Agriculture land	0.050-0.170

Ref: Adapted from Soil Conservation Service, Urban Hydrology for Small Watersheds, U.S. Dept. of Agriculture, Soil Conservation Service, Engineering Division, Technical Release 55, June 1986

Table 3.4: Manning's Roughness Coefficients - for routing

Location	***Cover***	***n***
Overbank	Woods	0.080-0.120
	Meadows	0.055-0.070
	Lawns	0.035-0.050
Channel	Natural	0.030-0.080
	Grass	0.030-0.050
	Natural rock	0.03
	Armour stone	0.025
	Concrete	0.013
	Articulated block i.e. Terrafix	0.02
	Gabions	0.025
	Wood	0.015
	Corrugated steel pipe - 3"x1"	0.024
	Structural plate corrugated steel pipe - 6"x2"	0.032

Ref: Adapted from Design Chart 2.01, Ontario Ministry of Transportation, "MTO Drainage Management Manual," MTO. (1997)

4 Shoreline Hazards

Application of the information in this section is limited to development that is adjacent to the Georgian Bay Shoreline as well as part of the adjoining channel of the Nottawasaga River.

4.1 Coastal Engineer Certification

NVCA staff do not have specific expertise in coastal engineering. As such and as permitted by Professional Engineers Ontario, the NVCA requires all individuals submitting coastal engineering reports to submit a Curriculum Vitae (CV) with respect to their qualifications in coastal engineering. Upon receipt of the submitted CV, the experience will be reviewed by NVCA staff.

4.2 Shoreline Flood and Erosion Hazards

The shoreline floodproofing that the NVCA associates with Georgian Bay is the 100-year monthly mean lake level plus the 100-year storm surge plus an allowance for wave action. The 100-year monthly mean lake level plus the 100-year storm surge together have an elevation of 178.0 metres within the jurisdiction of the NVCA.

The allowance for wave action is taken as 15 metres or to a wave uprush elevation as determined by a qualified professional, as defined above, using the policies and guidelines established under the Provincial Policy Statement and the Ontario Ministry of Natural Resources' "Great Lakes – St. Lawrence River System and Large Inland Lakes – Technical Guides" (Queens Printer May 2001).

In general, the shoreline along Georgian Bay in the Nottawasaga River Watershed is not composed of bluffs and as such does not meet the requirements to apply the erosion hazard guidelines as set for in the MNR's "Great Lakes – St. Lawrence River System and Large Inland Lakes – Technical Guides." However, a determination of the appropriate setback related to the shoreline erosion hazard should be included in all coastal engineering reports.

4.3 Dynamic Beach

Dynamic beach is defined in the MNR's "Great Lakes – St. Lawrence River System and Large Inland Lakes – Technical Guides" as a term used to emphasize and describe beach profiles that "undergo changes on a broad range of time scales, from hours or days to years and decades, in response to changing wave, wind and water level conditions and to changes in the rate of sediment supply to a particular section of shoreline." Within the NVCA jurisdiction this will apply to portions of the Collingwood shoreline and all of the shoreline within Wasaga Beach.

The extent of the dynamic beach process is determined by the calculation of the cumulative impact of the shoreline flooding hazard, the average annual recession rate and a dynamic beach allowance:

- The landward limit of the flooding hazard (100-year flood level plus a flood allowance for wave uprush and other water related hazards) plus a 30 metre dynamic beach allowance
- The landward limit of the flooding hazard (100-year flood level plus a flood allowance for wave uprush and other water related hazards) plus a dynamic beach allowance based on a study using accepted scientific and engineering principles by a qualified professional.

5 Floodproofing

5.1 NVCA Access/Egress Criteria

The term 'safe access/egress' refers to the ability of both pedestrians and vehicles to enter and exit a property safely during flood events. The maximum depth, velocity and depth/velocity product guideline for the NVCA jurisdiction is based on the information provided for in Appendix 6 of the MNR's 2002 "Technical Guide – River & Stream Systems: Flooding Hazard Limit".

Where safe access and egress is required for new development, the NVCA assumes that both pedestrian and vehicular access/egress is required. Residents and emergency personnel must be able to have pedestrian access between vehicles and the development. Both residents' vehicles and emergency vehicles must be able to safely pass between the development and the municipal roadways outside of the floodplain. The NVCA applies the following criteria to determine safe access/egress:

- Maximum depth of flooding of 0.3 m for vehicular access;
- Maximum depth of flooding of 0.8 m for pedestrian access;

- Maximum velocity of flooding of 1.7 m/s;
- Combined depth velocity product of 0.4 m^2/s.

A depth velocity product of 0.4 m^2/s is selected as it indicates an area of low risk to individuals and cars being overcome by flood waters.

The above criteria will apply both on the proposed development property and to the municipal right-of-way that is adjacent to the property to an area located outside of the floodplain. Where the depth criteria for safe access cannot be achieved for a site due to the municipal right-of-way being subject to unsafe conditions, the NVCA may undertake consultation with municipal emergency services to obtain confirmation that alternative provisions for safe access will be used for the subject site; as such, the NVCA may consider development on the property.

In the case where a driveway will need to be constructed such that it is elevated to meet the 'above safe access/egress' criteria, the NVCA will require the submission to show:

- Provision for safe access/egress to the location of the dwelling/development on the property.
- The depth of flooding over the road as based on a 50% blockage scenario of the culvert/bridge crossing proposed;
- The duration of flooding over the driveway and on the municipal right-of-way.
- A driveway design that includes permanent markers to the show the location of the road that will be visible during a flood event;
- That the side slopes of the fill placed to facilitate the driveway are appropriately protected from erosion from the floodwaters such that access will not be affected.

In some cases, safe pedestrian access/egress is required. The following minimum criteria must be met for safe pedestrian access/egress:

- Maximum depth of flooding of 0.8 m;
- Maximum velocity of flooding of 1.7 m/s;
- Maximum combined depth velocity product of 0.4 m^2/s.

5.2 Flooding Risk Criteria

The following sections define the different risk levels for development in lots of record with appropriate zoning in the floodplain as defined by the Planning Regulation Guidelines.

5.2.1 Acceptable Risk

The NVCA defines areas of acceptable risk as any portion of the lot for new development that meets the following:

- Flood depths less than or equal to 0.8 metres;
- Velocities less than or equal to 1.7 m/s;

- A depth-velocity product less than or equal to 0.4 m^2/s;
- That safe access/egress as defined in Section 5.1is provided on the municipal right-of-way.

Developments within this area will need to provide:
- Floodproofing of the development as per Section 5.5;
- Access and egress to the municipal road; above the Regulatory storm flood elevation if possible, and as a minimum meet the safe access and egress criteria;
- If the access/egress route is subject to flooding, provide permanent markings showing the location of the driveway.

5.2.2 Unacceptable Risk

Areas of high risk in the floodplain are defined as:
- Flood depths greater than 0.8 metres;
- Velocities greater than 1.7 m/s;
- A depth velocity product greater than 0.4 m^2/s.

These areas are considered to be areas of unacceptable risk due to the extreme risk to life if a pedestrian or a vehicle were to enter into these flood waters. The amounts of fill that would be required to floodproof such structures would have significant cumulative impacts to the storage volumes within the floodplain.

5.3 Cut/Fill Balance

The NVCA may allow in certain cases a cut/fill balance of the floodplain to be completed at the discretion of the Authority engineer. These cases require that pre-consultation is done with the NVCA prior to the first submission and is normally used to regularize the boundaries of a development to provide a better development layout.

Cut/fill balances, approved in principle by the NVCA, must be completed on a 0.3 m increment such that the cut and fill are balanced for each 0.3 meter increment. In special circumstances other criteria may be applied as approved by NVCA engineering staff.

5.4 Flood Fringe

Where a two zone policy exists as defined by the NVCA Planning and Regulation Guidelines and within municipal planning documents, the flood fringe has been defined in one of two ways: 100 year floodline versus Regional floodplain or based on a critical depth and velocity value. The former will be applied only where current planning policy identifies this as the criteria. Where planning documents within the municipality do not reference specific flood fringe criteria, NVCA will define flood fringe based on the criteria outlined in the MNR Natural Hazards Technical Guides for River and Stream Systems (MNR 2002).

5.5 Appropriate Methods for Floodproofing

The NVCA in general applies the floodproofing criteria outlined in the MNR Natural Hazards Guidelines. The following sections clarify how the NVCA applies floodproofing measures for development within the watershed.

In general, all new development should be floodproofed to the following standards:

- Active floodproofing is not permitted (any floodproofing that requires human action such as sandbagging or temporary barriers)
- NVCA does not permit the use of floodproofing based on columns, piles and piers;
- NVCA does not permit berms (or levees) and floodwalls to be used for floodproofing;
- For dry floodproofing (habitable, commercial, industrial and institutional):
  - The minimum opening elevation into the development will be 0.3 m higher than the Regulatory storm flood elevation;
  - For buildings where the foundation or basement is below the regulatory flood elevation the structure may be subject to hydrostatic pressure during a flood. The structure could be protected by a fill pad around the building, structural engineering of the basement or a combination there-of. A qualified engineer could be required to design the site specific solution. Where a fill pad is recommended the fill pad should not be extended beyond the recommended width around the building.
- For wet floodproofing (non-habitable):
  - All mechanical and electrical systems should be designed and installed so that the heating, lighting, ventilation, air conditioning and other systems are not vulnerable to flood damage during the flood standard and are located at a minimum 0.3 metres above the regulatory floodplain elevation where possible;
  - The interior space – from 0.3 metres above the flood standard and below – should remain unfinished, be non-habitable and be free of service units and panels, thereby ensuring minimal damage;
  - New development must not be used for storage of immovable or hazardous materials that are buoyant, flammable, explosive or toxic;
  - Access-ways into and out of a wet-floodproofed building should allow for safe pedestrian movement if possible;
  - Additions allowed under the Planning and Regulation Guidelines that are subject to more than 0.8 m of flooding are required to have the structure designed to withstand the hydrostatic and hydrodynamic pressures that the flood waters will impart onto the structure. Designs must be signed and stamped by a Professional Engineer who is licensed in structural design.

In general, all minor additions to existing development must be floodproofed to the following standards:

- The minor addition will be considered as new development and subject to the same restrictions as above;

- Modifications should be made to the existing structure to bring the existing structure to the highest level of floodproofing possible.

5.5.1 Septic Beds

For lots where development is permitted as per Section 5.2, NVCA engineering staff will require as a minimum that the septic system be designed such that the septic tank is located at the floodplain elevation to minimize buoyancy forces, and that the bed is designed such that it minimizes the amount of fill placed within the floodplain. The septic bed should also be located such that it does not aggravate existing hazards on adjacent properties.

5.6 Structural Engineering

Development applications that are deemed allowable based on the August 2009 "NVCA Planning and Regulation Guidelines", that are located within the regulatory floodplain and that are subject to more than 0.8 metres of flooding are required to have the structure designed to withstand the hydrostatic and hydrodynamic pressures that the flood waters will impart onto the structure. Designs must be signed and stamped by a Professional Engineer who is licensed in structural design.

The following phenomena occur during flooding:

- hydrostatic pressure
- velocity – hydrodynamic load
- velocity – shear stress
- frequency of flooding
- duration of flooding
- ice jamming effects

5.6.1 Hydrostatic Pressure

Hydrostatic pressure is the single most important consideration in floodproofing design. Hydrostatic pressure is directly correlated with flood depth and saturated soil depth in contact with a structure. Hydrostatic pressure is equal in all directions and acts perpendicular to a given surface. It can be further defined into vertical or down, horizontal or lateral and uplift or buoyant pressures. The imposition of an enclosed structure in flood waters (including basements below saturated grade) unbalances localized hydrostatic pressures. The tendency of lateral pressure is to overturn, shear or displace an enclosed structure or vertical elements thereof. The tendency of buoyant pressure is to differentially heave, rupture or float an enclosed structure or horizontal elements thereof.

For conservative design purposes a fully saturated soil profile, irrespective of soil type, should be assumed to exist at the time of flooding. Hydrostatic pressures should as a result be considered both above and below grade. Below-grade hydrostatic pressure is determined by isolating the volume of available water from the volume of soil. In addition, standard foundation design considers lateral earth pressures. For floodproofing, lateral earth pressure should be considered using the submerged unit weight of soil. Total pressure below grade will be a combination of the above considerations.

Saturated sub-grade and the bearing capacity (compressive strength) and settlement failure potential in various soil types must also be clearly considered. Note that bearing and settlement design must also respect the extra load induced by the monolithic nature of reinforced foundation walls and floor slabs, which are a design response to the hydrostatic pressures.

5.6.2 Hydrodynamic Load

Hydrodynamic load is a manifestation of the pressure moment induced on an object by the depth of flood waters in ‘motion’. This can also apply below grade if significant piping of water exists. It is assumed, however, that under fully saturated soil conditions subsurface movement is nominal. The dynamic effect of water in motion can be converted into a correspondent hydrostatic pressure, but within the allowable velocity range defined by policy, the additional pressure due to hydrodynamic load is minor and further consideration is unwarranted.

5.6.3 Shear Stress

Shear stress is a manifestation of the tractive or constant force required to move an object and keep it in motion. It is a commonly analyzed variable in watercourse erosion study and applies to floodproofing consideration from the perspective of potential scour damage around a structure triggering structural failure. It is a function of water depth, slope and resultant velocity. It is sufficient to say that fill pads, berms and floodwalls must be designed to be erosion resistant under identified velocities.

Appendix A: Elevation Data Products and Modelling - Product Descriptions and Derivation

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1 Introduction

The NVCA possesses a number of elevation products. Each product has distinct characteristics that makes it more or less suited to various applications. Such characteristics include but are not limited to geometry type (e.g. points, lines or grids), level of detail and memory storage requirements. Regardless of what format the elevation product comes in, it is important to note that all of them are generated from the same original source data. What follows is a description of the Digital Terrain Model (DTM) source data and the various elevation products derived from this by the NVCA.

1.1 Source Data

The source data used in the creation of all NVCA products are the DTM mass points and breaklines supplied by First Base Solutions. These were collected photogrammetrically from flights in the spring of 2002 and some areas of notable change were updated in the spring of 2008. The majority of the mass points and breaklines present in the dataset were collected during the 2002 flight. The updates made in 2008 were mostly collected in areas where new subdivisions and other developments were observed.

During the collection process by First Base Solutions, mass points were gathered in a staggered 20 metre grid spacing as seen in Figure 1:

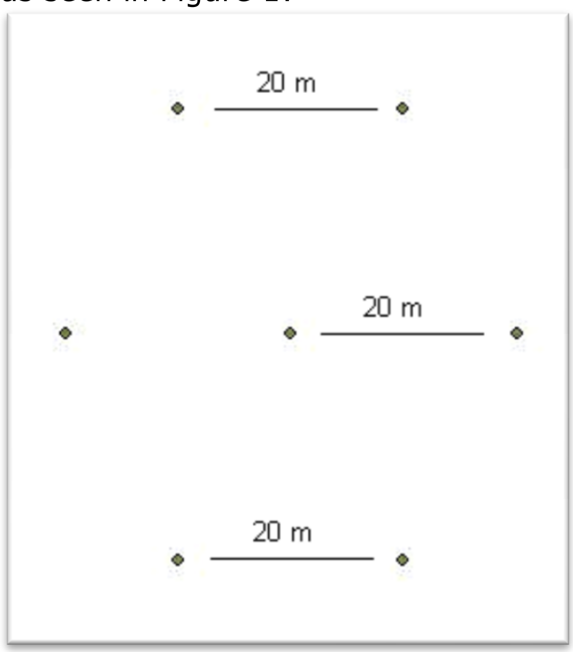

Figure 1 – Mass point collection

In addition to mass points, breaklines – linear features that influence elevation – were also collected. Like mass points, breaklines store 3D elevation information. Within every breakline, every point, or vertex, has an associated elevation (Z-value). Hard breaklines were used to define stark changes in elevation. Notable locations where hard breaklines were used are roadside ditches, cliffs, stream beds, culvert headwalls and bridges. Soft breaklines, in contrast, ensure that known elevations collected along linear features were included in the modelled surface. They do not define a stark change in elevation. Examples in this dataset include small gravel roads that are continuous with surrounding terrain, or minor creek beds that are not deeply cut into the landscape. Other uses for soft breaklines include known contour lines of equal elevation, survey transect lines and road centre lines.

Figure 2, below, shows the elevation (Z-value) stored within each mass point. Although not visible in the figure below, similar Z-values are stored within each breakline vertex.

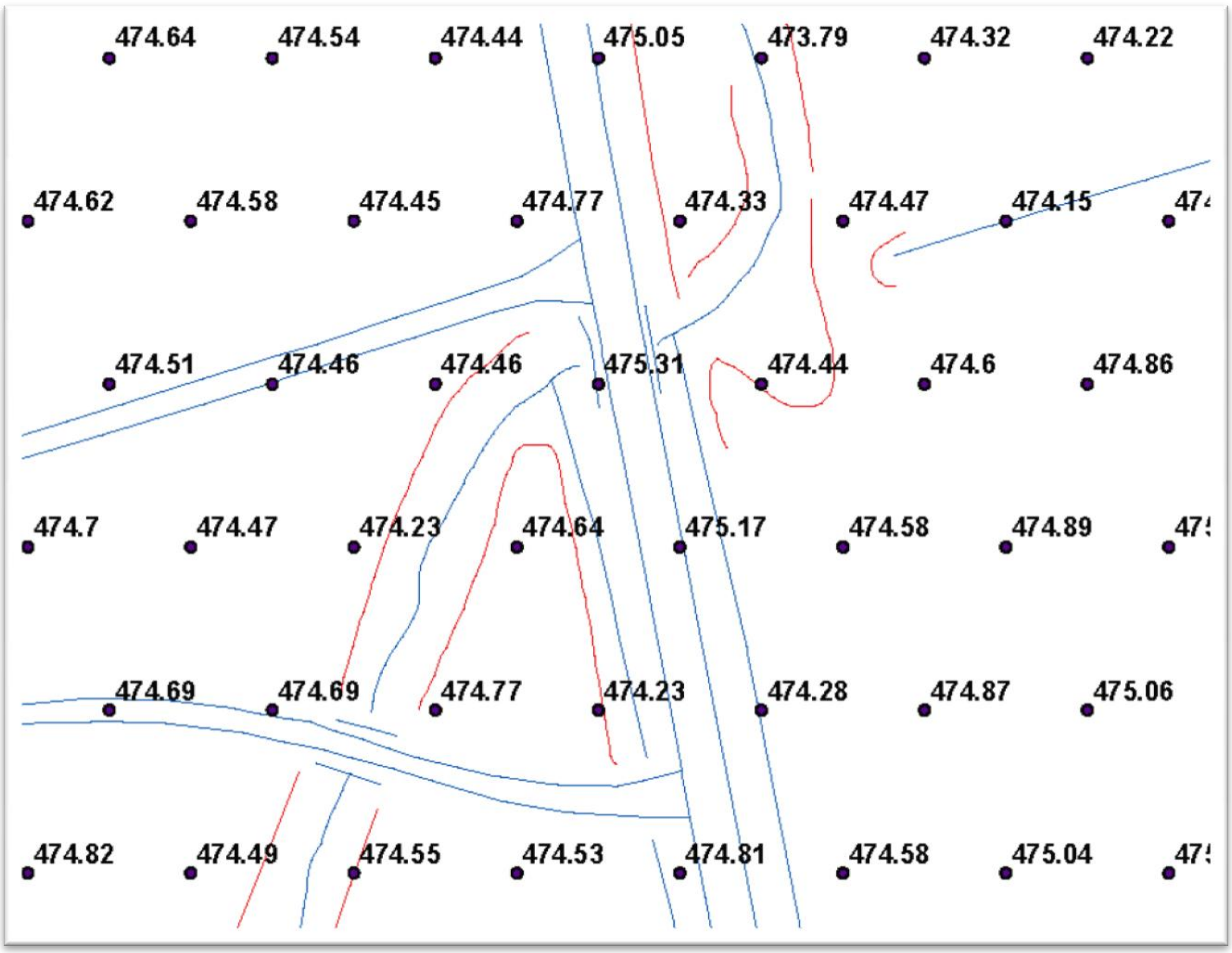

Figure 2 – Mass point Z-Values

Below, in Figure 3, a collection of mass points and breaklines can be seen in a forest setting. The grid-like, evenly spread white dots are mass points. They provide a distributed source of elevation information. Blue hard breaklines are included to show stark changes in surface elevation – in this case the breaklines were collected to capture the topography of stream beds contained in the image. Finally, the beige soft breaklines illustrate where subtle changes in the forest floor slope are observable, but which are not dramatic enough to warrant a hard breakline.

Figure 3 – DTM mass points and breaklines

The accuracy of mass points and breaklines in the First Base Solutions dataset are accurate to ±1m, both horizontally (X & Y) and vertically (Z).

It should be noted, however, that vertical accuracy is influenced by the "hardness" of underlying terrain; for example, breaklines and mass points located over top of road surfaces will be more accurate relative to similar features located under the forest canopy. Since coniferous forests maintain their canopy cover year-round, they are the most difficult terrain from which to gather elevation data. This stems from the difficulty in attaining a clear view of the forest floor. Features in vegetated fields with grasses rather than trees would therefore be relatively more accurate than forest, but not quite as accurate as mass points gathered over top of pavement, for example. An exact measure of how much vertical accuracy is affected by underlying surface type is not available.

1.2 Derived Elevation Products

Many different elevation products can be modelled from the source data described above. In addition to the DTM mass points and breaklines – which are sometimes distributed by the NVCA in their original form – Triangular Irregular Networks (TINs), contour lines and Digital Elevation Models (DEMs) are also frequently distributed. A description of how these various formats are constructed follows.

1.2.1 Triangular Irregular Network Datasets

TINs are direct linear interpolations of the DTM data they are derived from. They are the most accurate source of elevation information for anywhere not directly captured by a breakline or mass point. An excerpt from the ArcGIS Desktop Help File follows:

- TINs are a form of vector based digital geographic data and are constructed by triangulating a set of vertices (points). The vertices are connected with a series of edges to form a network of triangles. There are different methods of interpolation to form these triangles, such as Delaunay triangulation or distance ordering. ArcGIS supports the Delaunay triangulation method.
- The edges of TINs form contiguous, nonoverlapping triangular facets and can be used to capture the position of linear features that play an important role in a surface, such as ridgelines or stream courses.

In Figure 4, below, all of the mass point and breakline nodes store an elevation or Z-value. Every node is joined to neighbouring nodes with edges. The start- and end-points of each edge are assigned Z-values corresponding to the nodes that they connect. The edge also stores the slope between the two nodes so that Z-values can be derived at various points along the edge.

In Figure 5, below, the final TIN is shown with hillshading to emphasize topographical relief. Using the nodes and edges as a foundation, an irregular network of triangles has been created. The elevation information stored in each node allows the software displaying the TIN to calculate the slope, aspect, surface area and surface length of each triangle, with this data also accessible to the end-user. Figure 5 also gives a 3D visual of how the nodes and edges are combined to generate a continuous surface of irregular triangles.

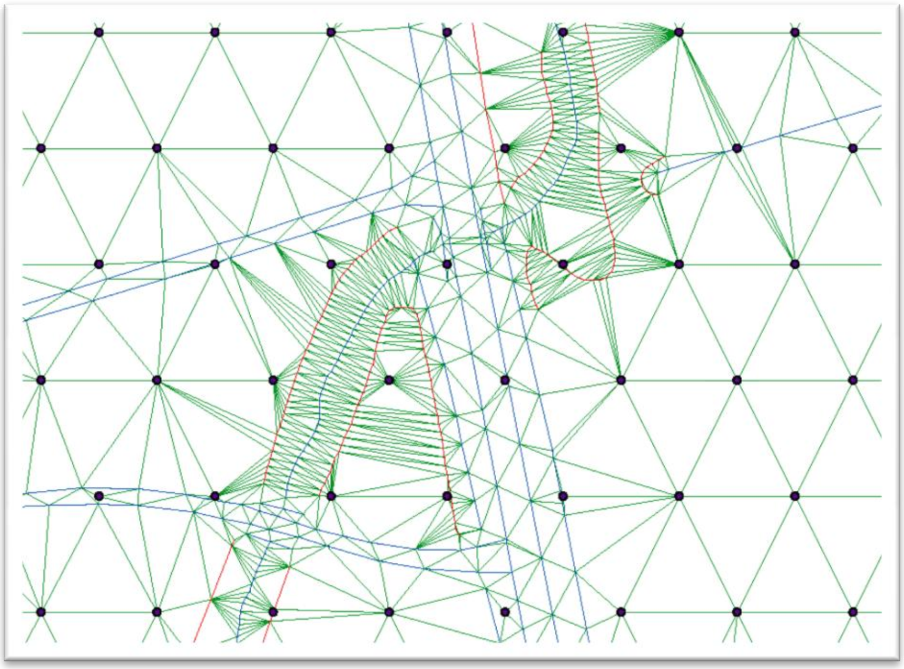

Figure 4 – TIN illustration showing nodes and edges

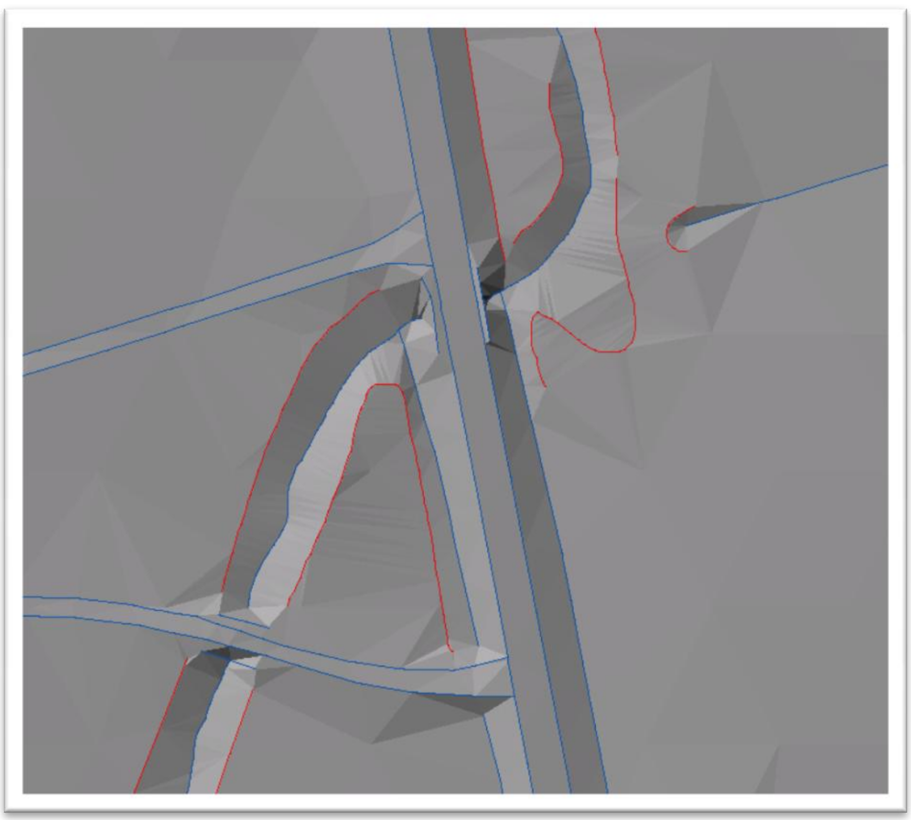

Figure 5 – TIN illustration with hillshading

1.2.2 Contour Line Datasets

Contour lines are perhaps the most familiar of all the elevation data formats. An obvious example would be the contour lines seen on Canadian National Topographic Map System (NTS) map sheets. By definition, each contour line joins all contiguous points of equal elevation. Contour line datasets typically have a defined contour interval where each successive contour line marks an equal change in elevation. The NVCA has generated contour lines with a 2 metre contour interval for the entire watershed. When data of this kind is distributed from the NVCA, it is most often using this contour interval.

There are many ways of generating contour lines. The method employed by the NVCA is to convert a TIN, as described above, into contour lines. The edges of a TIN interpolate the range of elevation values between nodes and contour lines intersect the edges where a particular value is modelled to occur. See Figure 6 for an example of how contour lines appear when draped over top of the TIN that was used to create them.

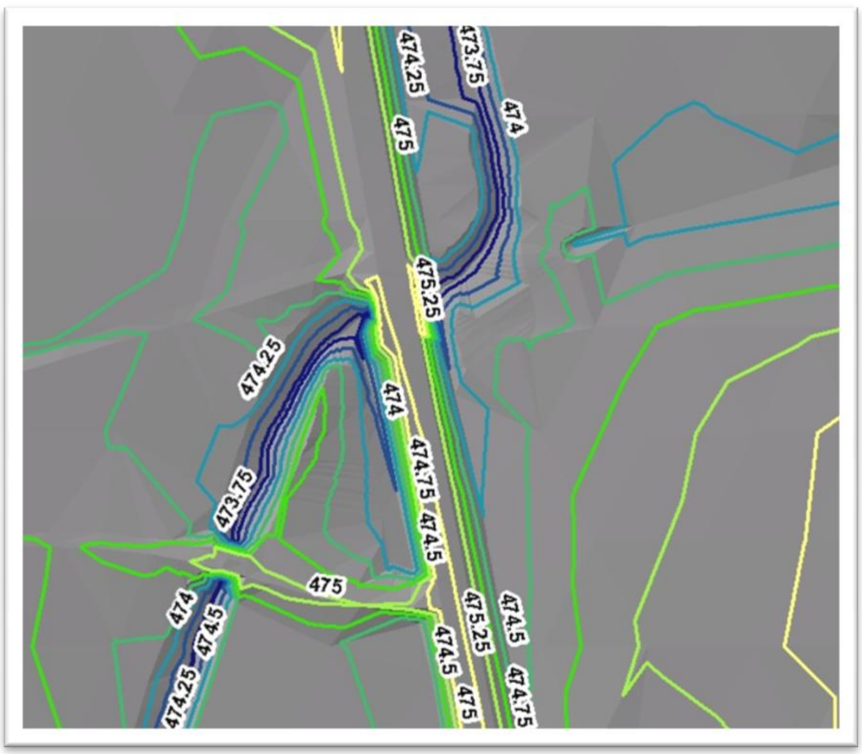

Figure 6 – Contour lines derived from TIN

1.2.3 Digital Elevation Model Datasets

The last elevation product typically produced and distributed by the NVCA is a Digital Elevation Model (DEM). DEMs consist of a rectangular grid of cells. This varies from a TIN in two very important ways, the first being that every cell is the same size and shape (regular), whereas a TIN is irregular – the tessellated triangles contained within the TIN dataset have different shapes and sizes. The second variation is that a DEM is stored in a raster format (a grid of values) rather than vector format (a collection of points, lines or polygons). A DEM is the only dataset described in this document that is raster-based.

As with contour lines, DEMs created at the NVCA are generated from a TIN. Each cell is assigned a Z-value based on the linearly-interpolated elevation of its centre point. The extent of each cell is determined by the areal resolution of the DEM. The DEM product most often distributed by the NVCA has a 10 metre resolution; at this scale, elevation information for the entire watershed can be effectively managed in a single dataset while still maintaining a reasonable level of spatial detail.

The following is an excerpt from the ArcGIS Desktop Help File describing the interpolation process from TIN to DEM:

- Because interpolation of the input TIN surface occurs at regular intervals, *some loss of information in the output raster should be expected. How well the raster represents the TIN is dependent on the resolution of the raster and the degree and interval of TIN surface variation.* Generally, as the resolution is increased, the output raster more closely represents the TIN surface. Because the raster is a cell structure, it cannot maintain the hard and soft breakline edges that may be present in the TIN.

Of important note in the above is the statement that accuracy is dependent the resolution of the output DEM and the degree of surface variation in the input TIN surface. Figure 7, below, provides a visual illustration of how important these considerations can be. The bridge, stream, roadside ditches, road deck and shoulders within the red circle create a complex topography to be captured within each grid cell. Despite there being a large degree of within-cell elevation variability, only one value can be chosen to represent the extent of each cell. There are varying methodologies regarding how to derive the “best” value to characterize the elevation but, regardless of method, the problem remains the same: one value has to be selected in order to represent all of the variation within each cell. Information is lost in this process. Additionally, an assortment of conversion artefacts can be introduced into the resulting DEM.

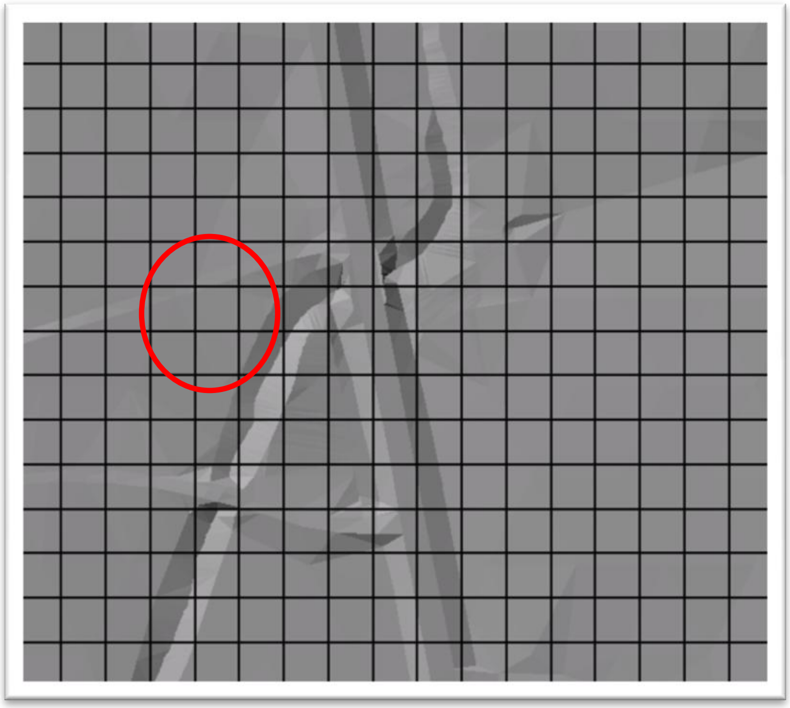

Figure 7 – 10-meter grid draped over TIN

One conversion artefact that can occur is the undulation of surface values on raised roads that stray from a strictly north-south or east-west alignment. See Figure 8 for a visual illustration of this effect. Due to the diagonal relationship between the road and the DEM grid, varying portions of high road-top are mixed in with portions of low-lying shoulder and ditch. Grid cells that contain a high portion of road-top will have a higher average value than the cells that contain a larger portion of ditch and shoulder. A 3D cross-section of the generally flat road-top (shown as a yellow arrow in Figure 8) still appears generally flat when deriving a 3D cross-section from the TIN. However, when the cross-section is derived from the corresponding DEM, elevations are falsely observed to be both undulating and significantly lower than the more accurate TIN-derived cross-section. Values of the DEM are lowered in varying amounts, by the varying amounts of low-lying ditch and shoulder that are captured within each cell. See a direct comparison in Figure 9.

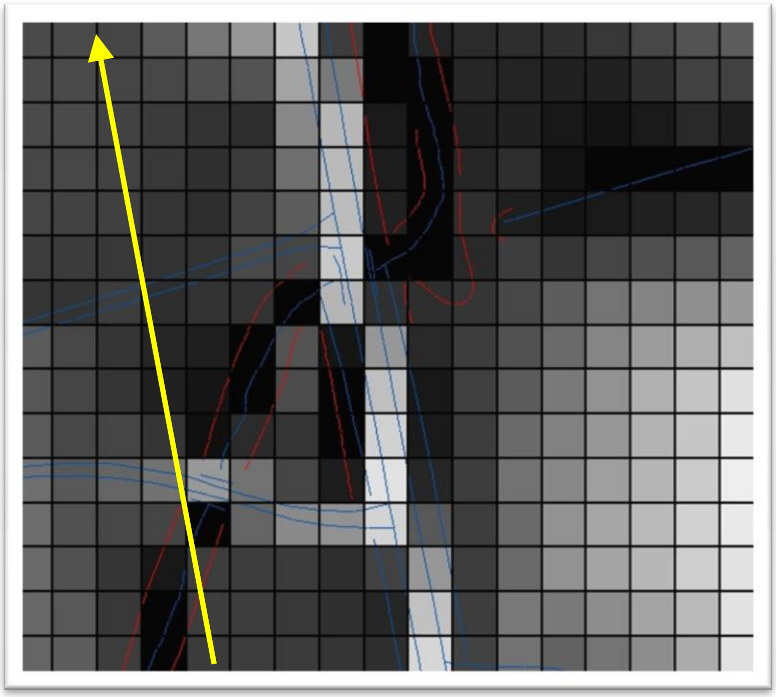

Figure 8 – DEM elevation values derived from TIN

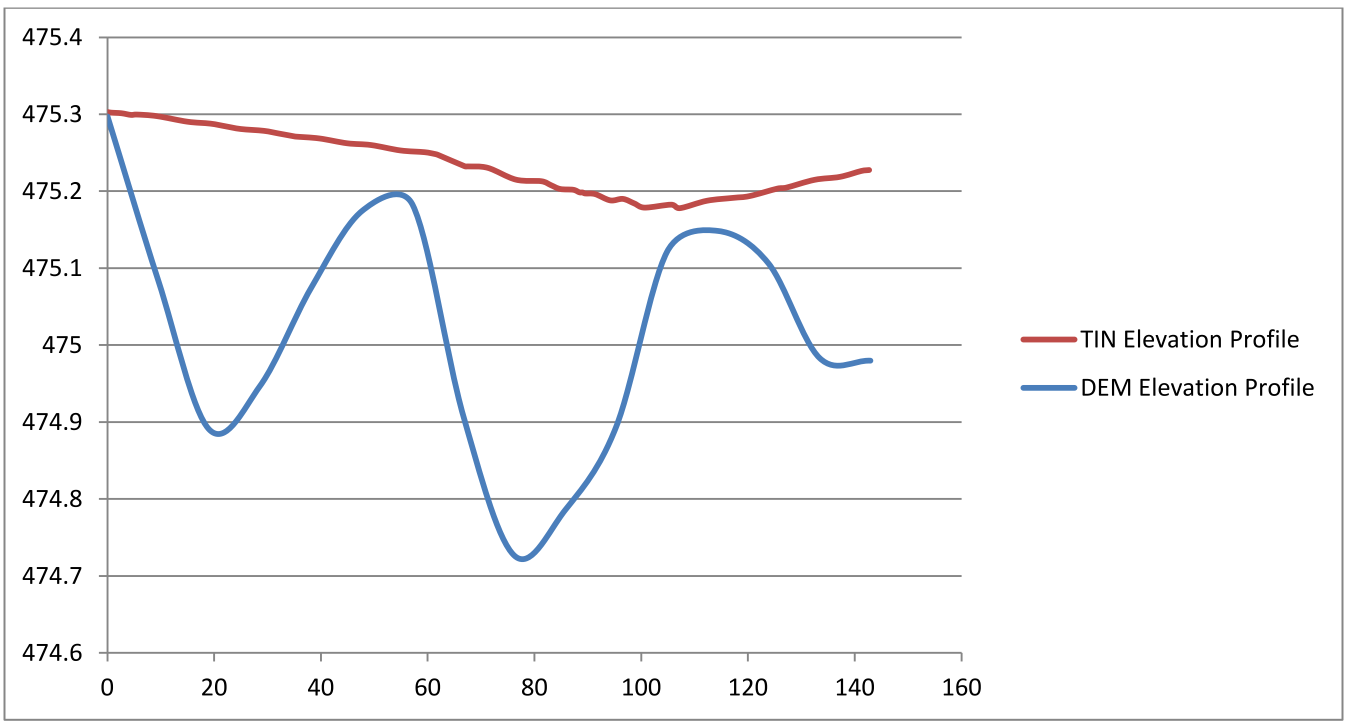

Figure 9 – Comparison of TIN and DEM cross-sectional profiles

1.3 Summary

There are many elevation products available, and commonly distributed, from the Nottawasaga Valley Conservation Authority. Each format has varying levels of accuracy, detail, accessibility, memory requirements and other distinguishing characteristics. It is hoped that this document will serve as a primer to help end-users select which elevation product is best for their needs. If further assistance is required, enquiries should be directed to Geographic Information Systems and Information Technology staff at the NVCA.