June 2, 2022

Kettle Creek Conservation Authority
44015 Ferguson Line
St. Thomas, ON, N5P 3T3

Attn: Joe Gordon,

Dear Joe:

RE: Port Stanley Floodproofing Elevations and Development Guides

Introduction

Thank you for the opportunity to provide engineering services on this interesting project. The objective of this work is to provide Kettle Creek Conservation Authority (KCCA) with i) updated floodproofing elevations for lands exposed to lake flooding, and ii) devise a set of development guides that will aid those undertaking development activities in areas subject to coastal flood hazards in Port Stanley.

The study area is shown in Figure 1, and includes Port Stanley's west beach (areas west of the river outlet) and harbour lands downstream of the lift bridge (along Carlow Road on the west, and Main Street on the east). The project focuses on coastal flood hazards, defined as those attributed from wave action arriving from Lake Erie. Recently completed floodplain mapping update project (TRUE, 2022) focused on developing updated floodplain mapping (and regulatory flood elevations) for riverine hazards of Kettle Creek at Port Stanley.

The second part of this work relates to producing guides to assist those considering or undertaking development activities along Port Stanley's main beach and harbour lands (such as building new homes, adding additions to existing homes, garages, decks, sheds, swimming pools, etc). The development guides are intended to provide a set of prescriptive rules and procedures to be followed as standard practice, without requiring site specific assessments by qualified specialist engineers or scientists.

This memo is organized as follows: First, a background review is carried out summarizing existing reports available for the study area. Existing studies provide a wealth of knowledge on coastal processes and associated hazards that need to be incorporated into the existing work as best management practice. Doing so ensures most appropriate and applicable development guidance is established for the Port Stanley community. Second, a characterization of water levels, waves propagation, and wave uprush according to current Provincial rules are developed and summarized (for existing and proposed conditions). Third, a set of development guides is presented that aims to assist those contemplating development activities located within known coastal flood hazards.

Vertical Datum and Associated Conversions
Several vertical datums are used in practice to describe land elevations and lake levels within the Great Lakes region. Most common are: Canadian Geodetic Vertical Datum 1982 (abbreviated as CGVD28), International Great Lakes Vertical Datum 1985 (IGLD85), and Canadian Geodetic Vertical Datum 2013 (CGVD2013). The CGVD28 and IGLD85 have been established many decades ago and have used manual leveling information to establish vertical control. More recent CGVD2013 vertical datum uses Global Navigation Satellite Systems (GNSS) to establish vertical control, and are considered most accurate by today's standards.

As references to elevations in past studies are made to vertical datums historically used, means to convert back and forth between them is necessary. For this work, a first order vertical benchmark ID 937006 established on a brass tablet on the West Pier by Natural Resources Canada is used for conversions. The published benchmark provides elevations for the above three referenced vertical datums.

The NRCAN benchmark ID 937006 is used as the basis for all vertical datum conversions in this work. For reference, the elevations of the brass tablet are:

CGVD2013	175.460 m
CGVD28	175.902 m
IGLD85	175.934 m

Background Review
In completing the background review staff from KCCA have provided key reports/studies relevant to the present undertaking. Background reports summarized below are presented chronologically.

First known assessment of coastal hazards for Port Stanley are summarized in the KCCA Shoreline Management Plan (Philpott, 1989). The Shoreline Management Plan report provides a high level description of the entire shoreline within KCCA watershed boundary and documents the coastal hazard assessment that was completed. Of most relevance to this work is the assessment of the wave uprush elevation for the main beach at Port Stanley that were historically used as a floodproofing elevation for development activities along the main beach.

The design wave uprush elevations were computed by Philpott (1989) by using a 100-yr nearshore wave conditions, and added to the 100-yr instantaneous lake level. Three beach profiles were surveyed, and used to determine the wave uprush height above the design water level (100-yr instantaneous water level) using several empirical relationships (the best available method at the time). The value of wave uprush height fronting the beach dunes was estimated at 1.5 m above the design water level. The authors recognized that much of the dune crest elevation lies below the calculated (empirical) wave uprush level, meaning that during design water level conditions, a wave will overtop the dunes and run as an overland bore instead of running up and down a beach face (as assumed in the empirical calculations). Philpott (1989) states that the exact uprush elevation would be difficult to determine as the land behind the crest of the dunes is relatively flat, and the empirical relationships used do not account for flat land inshore of dune crests. Recognizing the limitations of the wave uprush height estimates, Philpott (1989) reduced the wave uprush height to 1.3 m, and recommended it for use at Port Stanley's main beach.

The Philpott (1989) report identified that 100-yr instantaneous water level of 175.5 m CGVD28 and a 1.3 m wave uprush height should be used to establish an elevation of 175.5 m + 1.3 m = 176.8 m CGVD28. The same report recommended that elevation to be used as the floodproofing elevation.

Philpott's (1989) Shoreline Management Plan identified a need for a dune management plan at Port Stanley. The need was further reinforced by the enactment of the Provincial Planning Act, that designated the lands within the fillet beach as a dynamic beach zone, where development activities could be significantly restricted. KCCA commissioned Shoreplan (1996) to carry out the Port Stanley Beach Management Study. The purpose of the 1996 study was to more precisely define the landward extent of the dynamic beach standard for Port Stanley and to recommend standards to be met by future development proposals within the defined dynamic beach hazard lands. The Shoreplan (1996) report used base mapping provided in Federal Disaster Recovery Program from 1988 (which was best available at the time of their work).

The Port Stanley Beach Management Study (Shoreplan 1996) defines i) *Regulatory Dynamic Beach Standards*, ii) *Modified Regulatory Flood Standard*, and iii) *Regulatory Flood Standard* for Port Stanley. Each is described below:

The *Regulatory Dynamic Beach Standard* is defined as a 60 m offset from the position of the 100-yr instantaneous water level at Port Stanley. The defined Regulatory Dynamic Beach Standard consists of an active beach zone (40 m from the position of the 100-yr instantaneous water level) and a dune formation zone (20 m allowance inland of the active beach zone). The 1996 study states that the active beach zone is an area where substantial modification of the beach profile takes place during design storm conditions. The study also recommends that no development or structures be located within the active beach zone.

The *Modified Regulatory Flood Standard* is defined as the area north of the Regulatory Dynamic Beach Standard, up to the limit of wave uprush (which was delineated on a map in the Shoreplan, 1996 study). The 176.8 m CGVD28 elevation of the wave uprush limit was used, as determined previously by Philpott (1989). The Shoreplan (1996) study identified development guidelines that are to be used when evaluating future proposals within the zone covering the Modified Regulatory Flood Standard. Development in the Modified Regulatory Flood Standard zone recommends a site review by a qualified coastal engineer.

The *Regulatory Flood Standard* applies to the area in the close vicinity to the West Pier, where wave activity is considered negligible (Shoreplan, 1996) as the wave would have traveled across shallow flooded beach areas.

Upon release of the Great Lakes – St. Lawrence Technical Guide (MNR, 2001), came updated definitions of flood hazard limits and floodproofing elevations. According to the MNR (2001) Technical Guide, the flood hazard limit on the shores of the Great Lakes are to be defined as a sum of a 100-yr instantaneous water level and a flood allowance for wave uprush and other water related hazards (as completed in historic studies at Port Stanley). For the determination of the flood hazard limit, the wave uprush is to be calculated using a 10-yr to 20-yr return period wave heights in conjunction with the 100-yr instantaneous water level (MNR, 2001, Part 3, pg. 3-39).

The MNR (2001) Technical Guide made a distinction between the elevation of the flood hazard limit, and the elevation to be used in the floodproofing standard. For the calculation of the floodproofing standard, the Technical Guide (MNR, 2001, Chapter 3, pg. 3-40) recommends that 50-yr to 100-yr return period wave height be used in conjunction with the 100-yr monthly mean lake level and the 100-yr storm surge height to determine the floodproofing standard. The stricter definition of the floodproofing standard did not exist when 1989 or 1996 studies were completed.

A beach management plan for Port Stanley was initially recommended in the work of Philpott (1989), and was ultimately completed by Shoreplan (2010). The report identified a practical dune management plan (establishing dune grasses, maintaining existing dunes, installation of fences, etc), while recognizing on-going grading operations (which flatten dunes) and maintain an existing public beach areas for recreational purposes.

Shoreplan (2010) report notes that Port Stanley's beach has changed since the development of the original Shoreline Management Plan (Philpott, 1989), thus warranting updates to wave uprush and floodproofing characteristics. Shoreplan (2010) notes that width and height of the beach has changed (beach increased in width, with higher ground elevations) since the original mapping was produced that relied on 1989 topography. The width of the beach has increased between 1989 and 2010 (from predominantly lower water levels in that period). The beach has also increased in height from retention of some of the littoral sand bypassing the west breakwater, thus leading to the gradual increase in the volume of the fillet beach.

Zuzek's (2021) Port Stanley Coastal Risk Assessment study was tasked with collecting bathymetric sounding survey data, evaluating shoreline change, carrying out analysis of water levels using recent lake level observations, updating coastal hazard mapping, and offering comments on the potential development opportunities of the east headland.

A bathymetric field survey campaign was completed that gathered lake profiles approximately 4 km on either side of the harbour. Shoreline change analysis was completed by comparing historic aerial photographs of the main and little beach dating back to 1955. Zuzek (2021) reports an average annual rate of beach accretion of 1.15 m/yr since 1955, but also warns that short-term periods can exist (during higher lake levels) that can cause beaches to erode.

Statistical analysis of the observed lake levels at Port Stanley was carried out (Zuzek, 2021), ultimately concluding that 100-yr instantaneous water level has increased by 0.15 m, while the storm surge was identified as 0.15 m lower compared to previous analysis completed in 1989 (and reported in MNR, 2001).

Zuzek (2021) documents production of flood hazard mapping for Port Stanley. In their calculations a 100-yr instantaneous water level was used (calculated using most recent observations). For wave uprush analyses they conservatively used a 100-yr wave event (MNR, 2001 guideline allows using 10 to 20-yr wave for flood hazard delineations) along with empirical means to estimate wave uprush. Climate change effects were included in Zuzek's (2021) work by increasing the lake level by 0.35 m.

Our initial review found that nearshore wave transformation calculations documented in the Zuzek (2021) report use 1970's and 1980's empirical formulas instead of spectral wave modeling that are commonly in use today. The methods implemented in estimating beach runup calculations likewise use 1980's empirical equations, and do not include recent advances in coastal numerical wave modeling.

The 1970's and 1980's methods can not properly capture the overland wave bore behaviour that are known to exist in Port Stanley during design water level conditions (where dunes overtop and allow water to propagate inland). These limitations were initially identified by Philpott (1989), where computed wave uprush heights were intentionally reduced to account for the overland wave bore. No such reductions were reported in Zuzek's (2021) study, and values computed are thus considered conservative. Capturing the overland wave bore behaviour is extremely important when considering higher lakes levels from climate change or other natural causes.

It is important to recognize that mapping and elevations reported in Zuzek (2021) are those pertaining to the definition of flood hazard limit, and are used to identify areas subject to coastal flood hazards. Floodproofing elevations uses a stricter standard (100-yr mean monthly lake level plus 100-yr surge plus wave uprush from a 100-yr wave), were not documented in Zuzek's (2021) study. The floodproofing elevation are the subject of this work.

Floodproofing Elevation Updates

This section documents analyses carried out that establish the floodproofing standard for Port Stanley, including main beach and harbour lands. The analyses include assessment of water levels, offshore wind and wave characteristics, numerical modeling, interpretation, and professional judgment.

The floodproofing standard is defined in MNR (2001) as (pg. 7-54):

On lakes Superior, Huron, St. Clair, Erie or Ontario, development and site alteration is to be protected from flooding, as a minimum, to an elevation equal to the sum of the 100 year monthly mean lake level plus the 100 year wind setup plus a flood allowance for wave uprush and other water related hazards.

A schematic accompanying the floodproofing definition is shown in Figure 2 (taken directly from MNR, 2001).

For the purposes of this document, the floodproofing standard is defined as the top of the foundation. Using this definitions means that structural elements above the foundation (beams, trusses, connections) would be located outside of the wave related hazards.

Analysis of Water Levels

Hourly historic water levels at the Port Stanley gauge (ID 12400) were obtained from the Canadian Hydrographic Service database for years 1962-2021. Historic data was used to establish instantaneous water levels, storm surge, and monthly average lake level statistics for Port Stanley. Much of this work was completed as part of the recent Kettle Creek Floodplain Mapping Update at Port Stanley (TRUE, 2022).

For the instantaneous water level statistics, annual maximum water levels were extracted from the historic record and used to fit to several common statistical distributions. Comparing the answers among the distributions tested, results from the Generalized Extreme Value (GEV) statistical distribution with parameters estimated using the method of L-moments were selected for use in this work due to best fit, its general robustness and common acceptability in the literature.

Analyses of surge heights was completed by isolating the surge events from a weekly average base water levels. After developing a historic signal of surge heights, statistical analysis was carried out using the same distribution and method as above. Port Stanley, being located approximately mid lake, will tend to experience far lesser storm surges than locations at either ends of Lake Erie (such as at Bar Point on the west or Port Colborne on the east).

Lastly, statistical analyses were completed on monthly average data (required for the floodproofing calculations). Hourly data was averaged over each month for each year, and used in the analyses. Results from the statistical analyses are reported in Table 1, and generally agree to those reported by Zuzek (2021).

Table 1: Port Stanley water level statistics (from gauge ID 12400)

Return Period [yrs]	Instant. Water Level [m, IGLD85]	Storm Surge Height [m]	Mean Monthly Water Level [m, IGLD85]
2	174.75	0.35	174.53
5	175.03	0.45	174.79
10	175.17	0.52	174.93
20	175.28	0.59	175.03
50	175.39	0.68	175.14
100	175.46	0.76	175.20
200	175.52	0.84	175.25

For the purposes of this work (determining floodproofing elevations and completing foundation design), design still water level is established as 100-yr mean monthly lake level plus 100-yr storm surge, which is 175.20 m IGLD85 + 0.76 m = 175.96 m IGLD85 for Port Stanley. Wave uprush is to be applied on top of the deisgn still water level. The text that follows describes the steps undertaken to estimate wave uprush for Port Stanley.

Analysis of Wind Climate
For the analyses of wave uprush, a quantification of wave characteristics at Port Stanley is required. Observed data from Fisheries and Oceans wave buoy ID C45132, located offshore of Port Stanley, was downloaded from the Federal Government's directory. The time series of wind speed and direction was analyzed. Annual maximum wind speeds were extracted for each direction of a 16 point compass. The annual maximum data (for each compass direction) was then fit using statistical distributions, which facilitated computation of wind speed magnitudes associated with various return periods. 100-yr wind speed magnitudes are summarized in Table 2 for winds ranging from east to southwest (most relevant for Port Stanley).

Table 2: Port Stanley overlake 100-yr wind statistics (from buoy C45132)

Wind Direction	Wind Direction [Az, deg]	Wind Speed [m/s]
E	90	20.6
ESE	112.5	19.5
SE	135.0	18.1
SSE	157.5	17.2
S	180.0	18.9
SSW	202.5	21.1
SW	225.0	24.5

Wave propagation and transformation modeling
Offshore wave climate is typically established via wave hindcast modeling, and used in site specific studies (such as the present work). A wave hindcast study results for Lake Erie were not available during the preparation of this work. In the past, a wave hindcast study prepared by US Army Corps of Engineers was available for use in Canadian shores of the Great Lakes. As a result of not having a wave hindcast study, the following approach was used instead.

To establish the coastal climate for the study area a Lake Erie wide 2D spectral wave model SWAN model (at a 1 km grid size) was developed. Nested inside the Lake Erie model are two refinement regions (250 m regional grid, and 50 m local grid). Such refinements allow for localized calculation of wave characteristics with increased resolution appropriate for the present assignment. Publicly available lake contours were used from which a Triangulated Irregular Network (TIN) model of the underwater area of the lake was created and used to develop the SWAN model grids. The SWAN model solves the spectral action balance equation and captures the effects of spatial wave propagation, refraction, shoaling, generation, dissipation and nonlinear wave-wave interactions. Processes of wave breaking, bottom friction and (simplified) diffraction effects have been included in this work. The most important feature of SWAN relating to the current project is its ability to estimate the growth and propagation of wind generated waves.

Analysis of the wave generation and propagation simulations suggest that for Port Stanley waves from the dominant SW winds govern at the project site, and therefore are used in the calculation of the wave uprush. Given the orientation of the harbour entrance, south waves have the potential to create most damaging effects within the harbour. These were considered in the analyses, as were waves attacking directly from east.

SWAN wave modeling was carried out using wind forcing presented in Table 2, which was used to generate corresponding wave conditions in the offshore portions of the study area. Wave conditions at the 6 m depth contour (for transects used in beach wave uprush) and in front of the harbour entrance (for inner harbour modeling) were extracted from the 50 m local grid model. Results of the SWAN modeling are summarized in Table 3.

Table 3: Design wave conditions at Port Stanley (from 100-yr SW winds)

Location	**Sig. Wave Height Hm0 [m]**	**Peak Wave Period Tp [sec]**	**Wave Direction Dir [Az, deg]**
Main Beach (at 6 m depth contour)	3.4	8.14	202.2
Harbour Entrance (100 m offshore of the west breakwater)	2.87	8.14	192.2
Little Beach (at 3 m depth contour)	2.4	8.14	191.6

Beach and harbour wave uprush modeling

Having wave conditions summarized in Table 3, the next step is to carry out simulations and propagate the waves inland. For this assignment, one set of calculations are carried out for the main beach study area, and another for the harbour lands. Each set is described next.

From the 6 m depth contour in the lake to the toe of the bluff within the main beach, a 1D variant of SWASH numerical model is used. SWASH model is a sister program to SWAN, and captures nearshore processes (such as wave setup, wave transformation and breaking, wave uprush and overtopping) relevant to this work. The SWASH model is able to compute both wave uprush, and the inland propagation of the wave bore (which occurs in conditions when extreme high water level causes incoming waves to overtop the dunes, thus allowing waves to propagate inland as bores).

A total of 10 transects are used in the beach wave modeling, using 1 m resolution. Each transect is extracted using the 2021 surveyed bathymetry (for its below water portion) and MNRF 2017 LiDAR data (for its above water topography). Design still water level for use in floodproofing calculations was applied to the SWASH model, as per MNR (2001) definitions. Figure 3 shows the locations of the transects used in the SWASH model, which coincide with the bathymetry collected in 2021.

Since the main beach dunes are relatively low compared to the design water level some amount of wave energy propagates inland during design water level conditions. Classical tools can not accurately estimate characteristics of the inland propagation of a wave bore, nor estimate wave uprush characteristics that far inland. The SWASH numerical model overcomes these limitations. To quantify wave uprush at each transect a time series of water level (at several output nodes) were extracted, and analyzed to estimate the 2% wave uprush (R2%). R2% is defined as the average elevation of the highest 2% of waves during design conditions. Included in the SWASH analyses is wave setup, defined as the increase in water level at the shoreline due to wave breaking in the surf zone. It is unknown if previous analyses used wave setup in their calculations.

Several transects were extracted along beach areas where a natural dune has historically established, thus providing a level of protection for the residents upland. However, for many areas along the beach the dunes have been removed through beach grading operations to facilitate access to the lake. There are instances along the main beach where one property owner has a well established dune along the beach, while the next door neighbour has regraded the beach and eliminated the dune entirely. In such cases the owner who has the dune would not see its benefit realized during flooding conditions, as the flood water will simply travel along the lot that has the dune removed, and cause flooding regardless. For this reasons, the geometry in the transects has been adjusted to remove the natural dunes and represent conditions believed to be representative for the assessment of floodproofing elevations.

For the purposes of mapping the spatial extent of the wave uprush, several transects exhibited similar characteristics and were aggregated (or lumped) together. The final R2% wave uprush values for the main beach are shown in Table 4, and graphically in Figure 4. The floodproofing elevation is established by adding the wave uprush height to the design still water level identified previously.

Table 4: Port Stanley main beach wave uprush heights

Zone	Wave Uprush Height R2% [m]	Floodproofing Elevation FPE [m, IGLD85]
A	1.44	177.4
B	1.14	177.1
C	1.04	177.0

The overland wave bore mechanism governs for areas of the main beach. For the inner harbour downstream of the lift bridge (especially for the tablelands inland of the quay walls), another mechanism needs to be considered. This mechanism is the vertical wave uprush and overtopping resulting from the waves that propagate through the harbour entrance. To estimate the design wave climate in the inner harbour, a coastal numerical model is needed that considers effects of harbour structures on wave propagation through the entrance. In this work, a numerical wave model ARTEMIS is used.

ARTEMIS is an open source phase resolving wave model which solves the Elliptic Mild Slope equations using the finite element method using TELEMAC's open source libraries. Main applications of the ARTEMIS model deals with wave agitation in harbours and small bays where the following phenomena are captured: i) wave reflection by obstacles, ii) wave diffraction behind obstacles, iii) wave refraction by bottom variation, iv) regular, mono-directional or multi-directional random waves, v) bottom friction, vi) bathymetric breaking, and vii) dissipation by breaking and/or bottom friction.

A numerical model mesh consisting of triangles was developed for the Port Stanley inner harbour. Each of the perimeter structures in the harbour (vertical wall, rubble mound revetment, breakwater, etc) was assigned an appropriate reflection coefficient in the model. A sounding survey available from drawings provided by Riggs (2019, 2020) were digitized and used in the modeling to represent the most recent (and best available) harbour bathymetry. The domain was set up from approximately 100 m offshore of the west breakwater all the way to the lift bridge (see Figure 3 for the model extents).

The wave transformation analysis using ARTEMIS have been completed using waves conditions at the harbour entrance as an input forcing (see Table 3). Simulations using southwest (but also south and east) wave conditions were carried out, ultimately seeking conditions that produce maximum wave heights inside the harbour.

The ARTEMIS results suggests that waves that enter the harbour directly from the south (rare, but possible) produce the highest wave heights. Dominant southwest waves are not shown to propagate significantly inland. Due to the vertical reflection associated with vertical walls, direction of waves are oriented nearly perpendicular to the alignment of the existing quay walls.

Design wave height inside the harbour is selected as 1.5 m from ARTEMIS simulations and professional judgment, and is used to identify wave uprush assuming vertical wall conditions.

Automated Coastal Engineering System (ACES) is used to establish vertical wave uprush assuming harbour depths ranging from 2 m to 4.5 m below chart datum (a range supported by the latest bathymetric surveys). Assuming head on wave attack (very conservative) against a vertical wall results in a wave uprush height of 1.9 m.

However, it is known (Atria, 1997) that waves attacking structures on oblique angles have their wave uprush effects dampened (in the limit, the maximum wave uprush for such highly oblique waves is the incident wave height itself, or 1.5 m).

For this work, it is recommended to use an average of the two wave uprush heights (i.e., by averaging 1.9 and 1.5 m), and thus allow for some conservatism. Therefore, for the inner harbour lands, the average uprush height is set at 1.7 m. The floodproofing elevation is shown in Table 5).

Table 5: Port Stanley harbour lands wave uprush heights and floodproofiing elevation

Zone	Wave Uprush Height R [m]	Floodproofing Elevation FPE [m, IGLD85]
D	1.7	177.66

The zones A-D are graphically mapped on an aerial photograph of Port Stanley, and are shown in Figure 4.

The floodproofing elevation in Table 5 assumes development to occur in close proximity to the harbour walls. Some amount of reduction of the floodproofing elevations can be anticipated if the proposed developments are to be located a distance inland of the quay walls. Such reductions are recommended to be subject to site specific studies, as they depend on geometry of proposed works.

Future (proposed) conditions, and their effects on floodproofing elevations
During the coarse of the project a question was posed to consider the effect of two mitigation measures that could potentially reduce adverse effects of coastal flooding in Port Stanley. These proposed conditions include joint efforts to i) establish a 480 m +/- long continuous dune along Port Stanley's main beach, and ii) extending of the west breakwater to create more of a tranquil inner harbour. The proposed mitigation efforts are shown on a schematic in Figure 5 and are assumed to be implemented jointly (both at the same time).

A dune across the main beach will limit the wave energy that can propagate inland, and acts to reduce the wave uprush height. Zuzek (2021) has commented that such a dune could have a crest elevation between 177.5 and 178.0 m IGLD85. In this work, a dune crest of 177.8 m IGLD85 is assumed under proposed conditions, with SWASH model transects in zone C modified to include the noted dune geometry. The simulations are repeated, which result in almost no wave overtopping under design still water conditions. Even though wave energy is not expected to propagate inland, a default uprush height of 0.6 m is still recommended to be applied to the design water level and ultimately define the floodproofing elevation. Zone C could consider reducing its floodproofing elevation to 175.96 m IGLD85 + 0.6 m = 176.56 m IGLD85 under this proposed scenario.

Detailed design work shall be necessary to provide drawings and specifications for such a flood protection dune, which will have to ensure that outflanking does not occur at either end (i.e., proper transitions will have to be detailed during final design). It must be cautioned that relying on a built structure for flood protection will require special policies and regulatory instruments to be devised, adopted, and enforced to ensure its ultimate upkeep and long-term maintenance. In other words, re-grading the dune or otherwise modifying it must not be permitted in the future, as doing so would put the entire community behind the dune at increased flood risk.

In addition to the dune option, extending the west breakwater will likewise cause a significantly less wave energy to propagate through the harbour entrance (compared to present conditions), and thus lead to a reduction in the wave uprush height. By partially blocking the harbour entrance through extension of the west breakwater, majority (and nearly all) of the wave energy would be eliminated. The effect of this option is that wave uprush within the harbour will be significantly reduced. Even though there will be only a nominal wave energy entering the harbour, a default wave uprush height of 0.6 m (as above) is recommended to be added above the design still water level for establishing the floodproofing elevation. Under the proposed conditions, the harbour lands would see a significant reduction in the floodproofing elevation, which would likewise be set at 176.56 m IGLD85 (a reduction of 1.1 m compared to existing conditions). Figure 6 shows the resulting floodproofing elevation assuming implementation of the measures outlined above (dune across the main beach with west breakwater extended).

Development of Port Stanley Development Guides
Given the above analysis, it is recommended that floodproofing elevation established under existing conditions (and summarized in Figure 4) be adopted in Port Stanley.

Appendix A of this document includes a set of development guidelines for Port Stanley. The development guides are consistent with the MNR (2001) Technical Guideline, and adopt a similar approach to neighbouring Conservation Authorities. The approach adopted recognizes existing development and provides strategies to eliminate the risk to human life and property damage over time from coastal hazards. The setbacks established in the original Port Stanley Beach Management Study (Shoreplan, 1996) are adopted here, and remain unchanged. By following the development guides KCCA can consider waving site specific development reviews by a coastal engineer for those considering developments in the Modified Regulatory Flood Standard Zone as recommended by the Port Stanley Beach Management Study (Shoreplan, 1996).

Should you have additional questions or require additional clarifications, please do not hesitate to contact the undersigned.

Yours truly,

TRUE CONSULTING

Pat Prodanovic, Ph.D., P.Eng.
Water Resources and Coastal Engineer

PP/jr

References:

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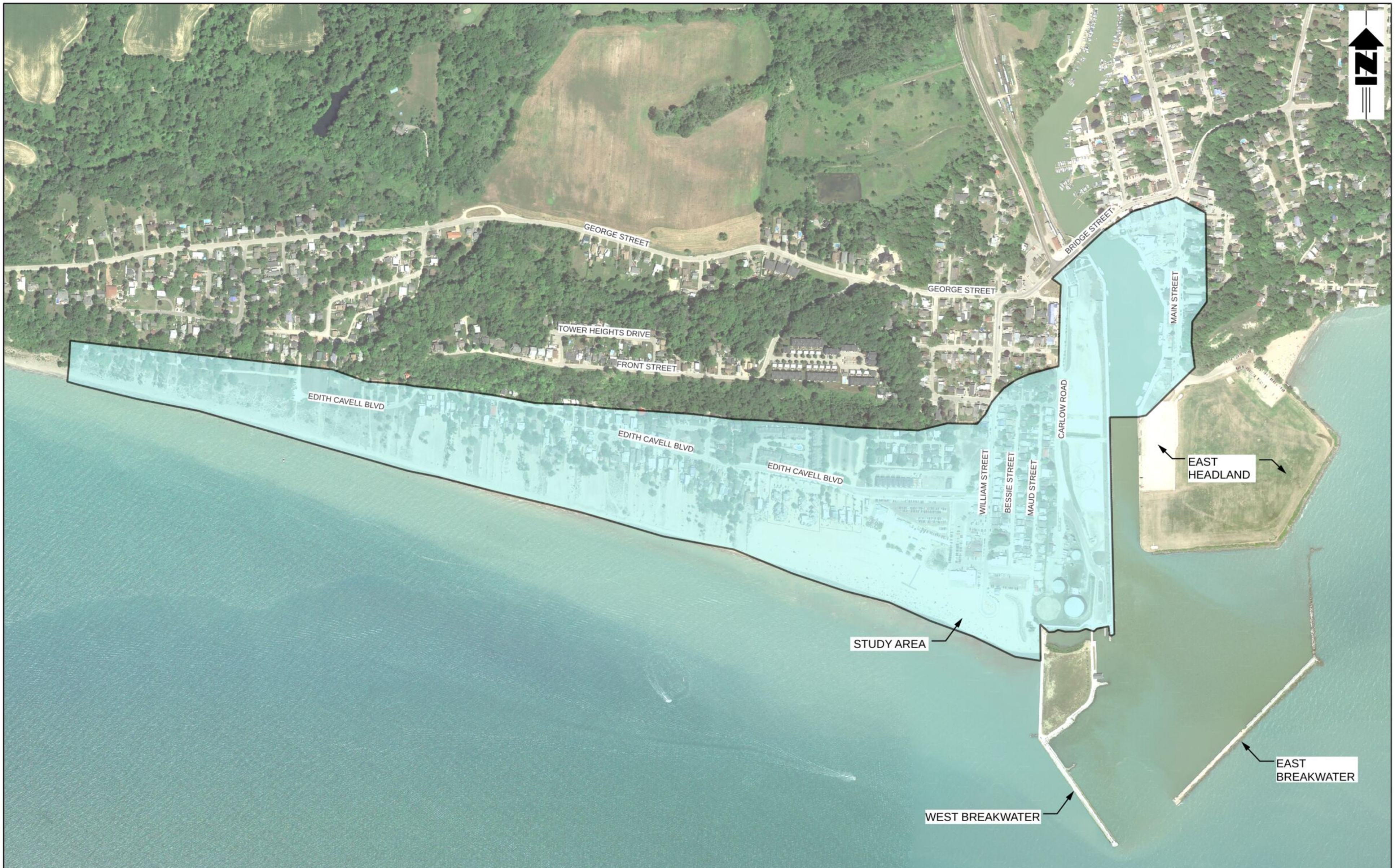
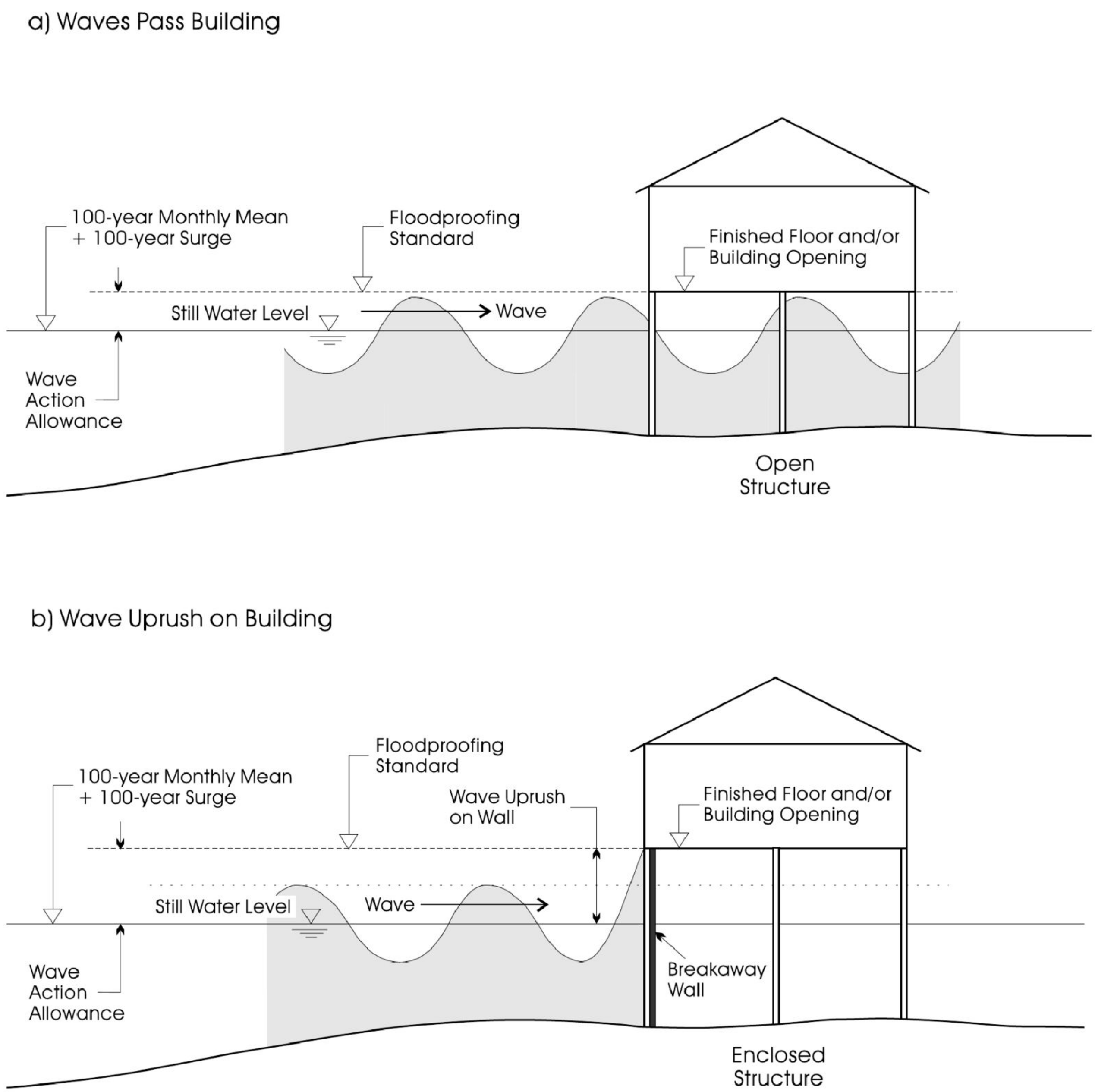


STUDY AREA

FLOODPROOFING AND COASTAL DEVELOPMENT GUIDES PROJECT, PORT STANLEY, ONTARIO

DRAWN BY: PP		
SCALE: 1:10,000		
PROJECT NO. 2389-031	FIG. NO.: 1	REV.: 0
DATE: APRIL 2022		



NOTE: ABOVE IS A REPRODUCTION OF FIGURE 7-30, TITLED FLOODPROOFING STANDARD, TAKEN FROM THE MNR (2001) TECHNICAL GUIDELINES, PART 7, PG. 7-55.

FLOODPROOFING STANDARD

FLOODPROOFING AND COASTAL DEVELOPMENT GUDES PROJECT

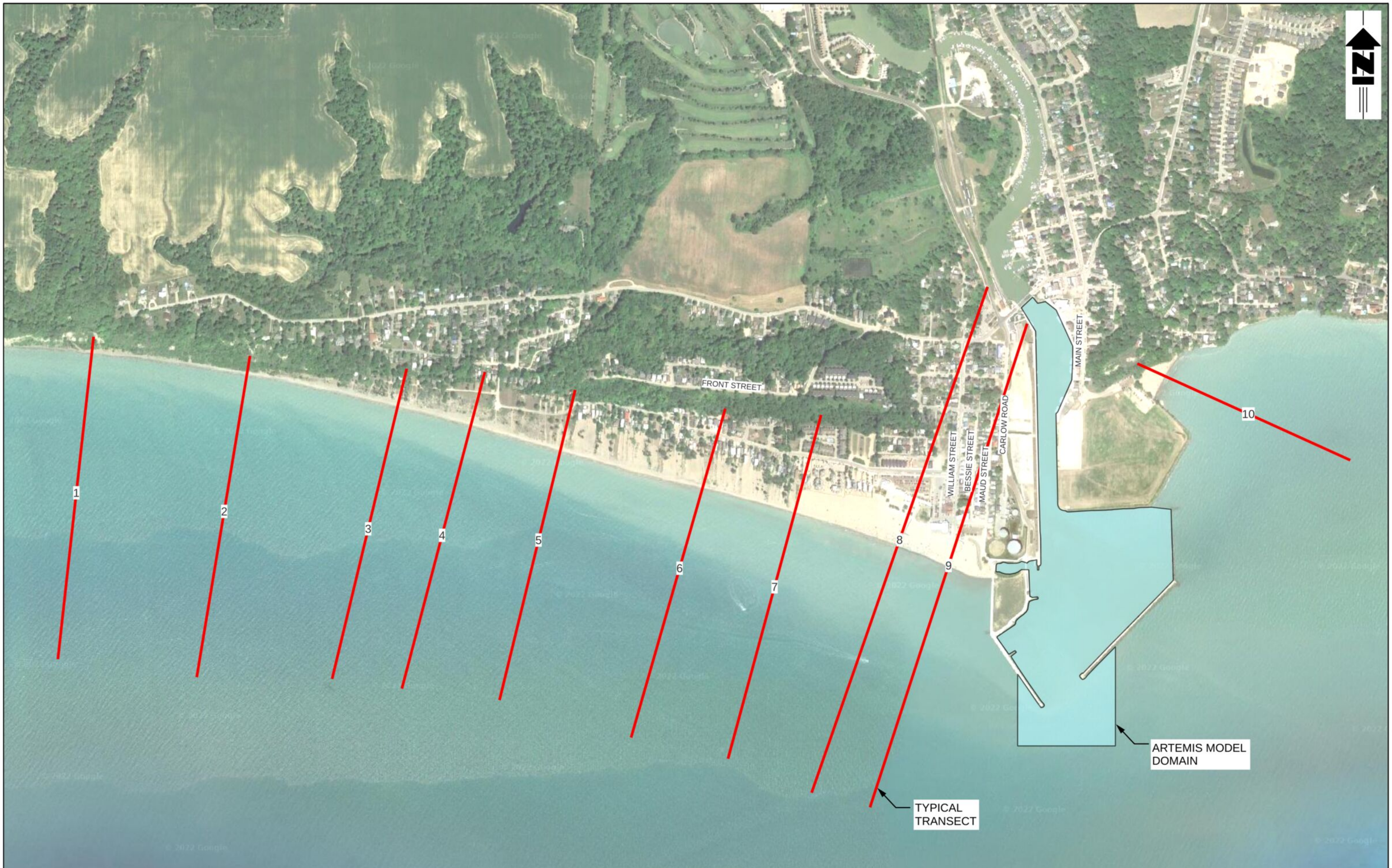
PROJECT NO: 2389-031

DATE: MARCH 2022

DRAWN BY: PP

SCALE: N/A

FIG. NO:	REV.:
2	0



MODEL TRANSECTS AND HARBOUR DOMAIN

FLOODPROOFING AND COASTAL DEVELOPMENT GUIDES PROJECT, PORT STANLEY, ONTARIO

TRUE

PROJECT NO. 2389-031

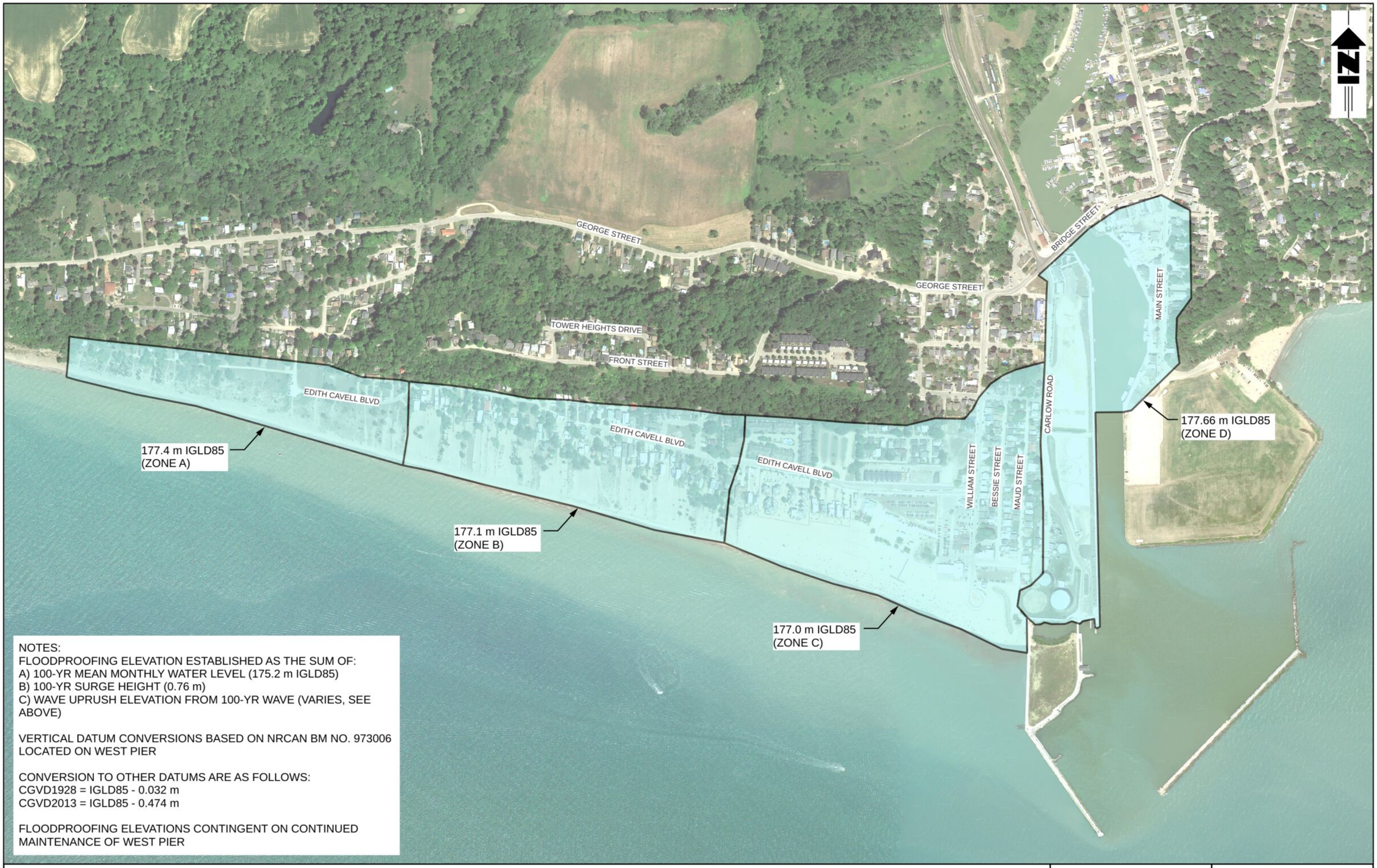
DATE: APRIL 2022

DRAWN BY: PP

SCALE: 1:15,000

FIG. NO: 3

REV.: 0



NOTES:
FLOODPROOFING ELEVATION ESTABLISHED AS THE SUM OF:
A) 100-YR MEAN MONTHLY WATER LEVEL (175.2 m IGLD85)
B) 100-YR SURGE HEIGHT (0.76 m)
C) WAVE UPRUSH ELEVATION FROM 100-YR WAVE (VARIES, SEE ABOVE)

VERTICAL DATUM CONVERSIONS BASED ON NRCAN BM NO. 973006 LOCATED ON WEST PIER

CONVERSION TO OTHER DATUMS ARE AS FOLLOWS:
CGVD1928 = IGLD85 - 0.032 m
CGVD2013 = IGLD85 - 0.474 m

FLOODPROOFING ELEVATIONS CONTINGENT ON CONTINUED MAINTENANCE OF WEST PIER

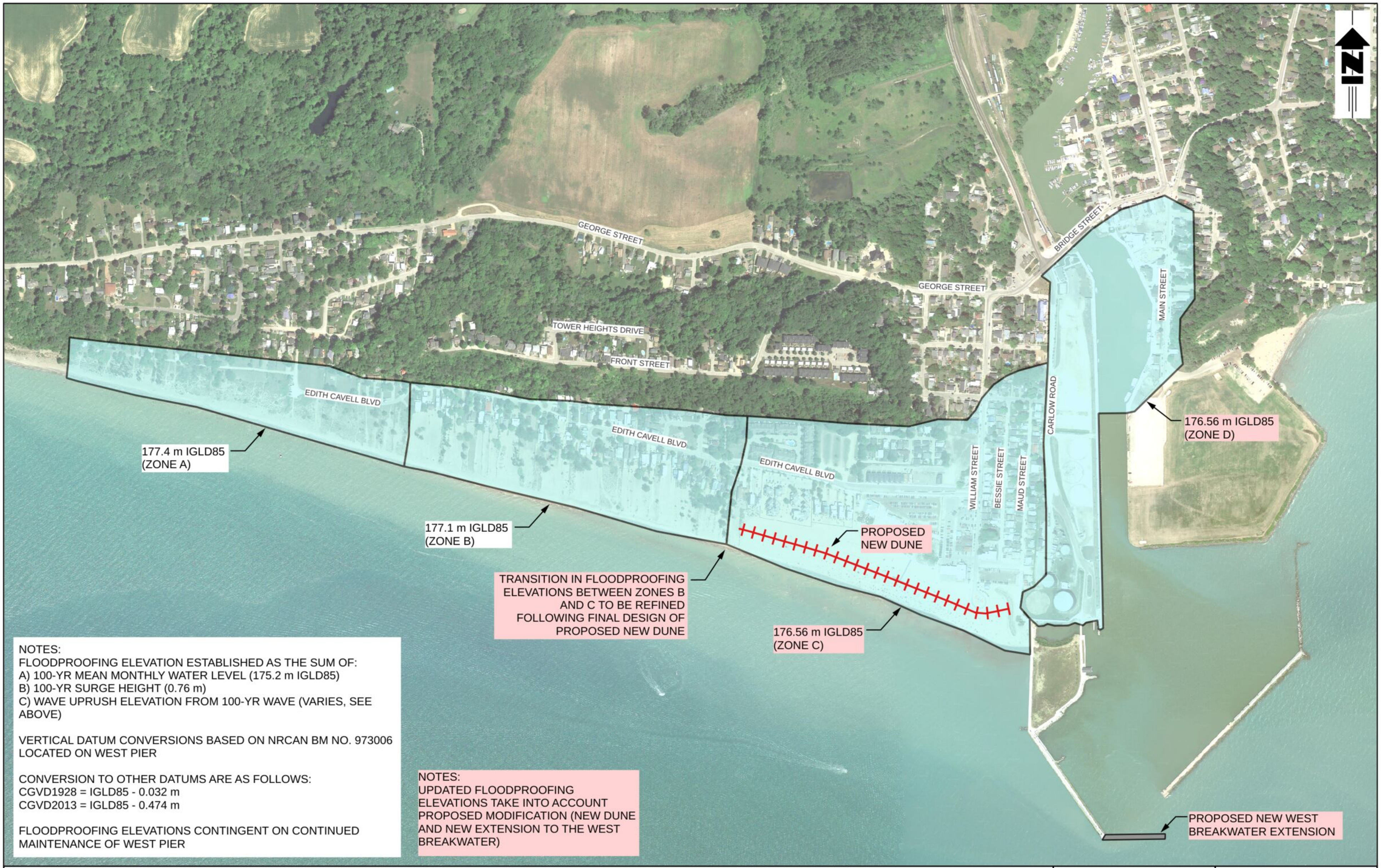
FLOODPROOFING ELEVATIONS, EXISTING CONDITIONS

FLOODPROOFING AND COASTAL DEVELOPMENT GUIDES PROJECT, PORT STANLEY, ONTARIO

TRUE

PROJECT NO. 2389-031	DRAWN BY: PP	
DATE: APRIL 2022	SCALE: 1:10,000	
	FIG. NO: 4	REV.: 0

PROPOSED MODIFICATIONS		DRAWN BY: PP
		SCALE: 1:10,000
FLOODPROOFING AND COASTAL DEVELOPMENT GUIDES PROJECT, PORT STANLEY, ONTARIO	PROJECT NO. 2389-031	FIG. NO: 5
	DATE: APRIL 2022	REV.: 0



NOTES:
FLOODPROOFING ELEVATION ESTABLISHED AS THE SUM OF:
A) 100-YR MEAN MONTHLY WATER LEVEL (175.2 m IGLD85)
B) 100-YR SURGE HEIGHT (0.76 m)
C) WAVE UPRUSH ELEVATION FROM 100-YR WAVE (VARIES, SEE ABOVE)

VERTICAL DATUM CONVERSIONS BASED ON NRCAN BM NO. 973006 LOCATED ON WEST PIER

CONVERSION TO OTHER DATUMS ARE AS FOLLOWS:
CGVD1928 = IGLD85 - 0.032 m
CGVD2013 = IGLD85 - 0.474 m

FLOODPROOFING ELEVATIONS CONTINGENT ON CONTINUED MAINTENANCE OF WEST PIER

NOTES:
UPDATED FLOODPROOFING ELEVATIONS TAKE INTO ACCOUNT PROPOSED MODIFICATION (NEW DUNE AND NEW EXTENSION TO THE WEST BREAKWATER)

FLOODPROOFING ELEVATIONS, PROPOSED CONDITIONS

FLOODPROOFING AND COASTAL DEVELOPMENT GUIDES PROJECT, PORT STANLEY, ONTARIO

TRUE

PROJECT NO. 2389-031
DATE: APRIL 2022
DRAWN BY: PP
SCALE: 1:10,000
FIG. NO: 6
REV.: 0

Appendix A – Port Stanley Coastal Development Guides

Port Stanley Beach Development Guides
June 2, 2022

DEVELOPMENT ACTIVITY[1]	DYNAMIC BEACH[2]	FLOOD HAZARD[3]
Repairs and/or Maintenance (no intensification of use)	N/A	Permitted without restrictions. Advise of flood risk and potential damage.
Interior Alterations (no intensification of use)	N/A	Permitted without restrictions. Advise of flood risk and potential damage.
Relocation of existing buildings and structures inland	Not Permitted.	Permitted, it meets Lot Redevelopment requirements.
Minor and Major Additions. Additions beyond 100% are considered a Lot Redevelopment.	Not Permitted	Permitted, with restrictions. Additions to be located on the least exposed portion of the lot, and no closer to the lake than the existing structure. Dry[6] passive[5] floodproofing standard applies. The floodproofing elevation are specified on Figure 4 (or Figure 5 if flood mitigation measures are incorporated). Top of foundation to be at, or above, the floodproofing elevation. All services and utilities to be above the floodproofing elevation. Structures encouraged to be supported on piles/piers when floodproofing elevation is 0.8 m or greater than existing grade, and structure is directly exposed to the lake. Perimeter foundations may be considered. However, foundations having floodproofing elevation 0.8 m or greater above existing grade, and directly exposed to the lake, to have i) top of foundation increased by 0.3 m (no opening below top of foundation), and ii) face of the foundation wall exposed to the lake protected with riprap and/or armour stone (top of rock to coincide with top of foundation).

DEVELOPMENT ACTIVITY[1]	DYNAMIC BEACH[2]	FLOOD HAZARD[3]
		All crawl spaces must be non-habitable, and used for non-permanent storage only. Openings below the floodproofing elevation are not permitted. All services and utilities to be above the floodproofing elevation. Water level to be used in foundation design is specified as 0.4 m above the design still water level. Foundation design and site grading details to be provided by a qualified civil/structural engineer.
Minor Structures (non-habitable accessory structures, tool-sheds, movable structures such gazebos and covered decks, pavilions, etc) without utilities and maximum size of 14 m^2	Not Permitted	Permitted, with restrictions. Advise of flood risks and potential damage. Safety concerns due to flooding hazards are to be addressed considering site conditions and nature and use of structure. Design must ensure there is no opportunity for conversion into habitable space in the future.
Major Structures (non-habitable accessory structures such as garages and car-ports) with utilities and maximum size of 50 m^2	Not Permitted	Permitted, with restrictions. To be located on the least exposed portion of the lot, and no closer to the lake than the existing habitable structure. Wet[7] passive[5] floodproofing standard applies. The floodproofing elevation are specified on Figure 4 (or Figure 5 if flood mitigation measures are incorporated). All services are required to be above the floodproofing elevation. The elevation for ingress and egress route to meet or exceed that of the existing habitable structure. Water level to be used in foundation design is specified as 0.4 m above the design still water level. Foundation design and site grading details to be provided by a qualified civil/structural engineer.

DEVELOPMENT ACTIVITY[1]	DYNAMIC BEACH[2]	FLOOD HAZARD[3]
Habitable Space above Major Structures (dwelling unit above garage/car port)	Not Permitted	Permitted, as long floodproofing requirements of Major Structures is met. Habitable space must be on the second level.
Lot Redevelopment (reconstruction of buildings or structures, other than those destroyed by flooding or erosion)	Not Permitted.	Permitted, with restrictions. Buildings and structures to be located on the least exposed portion of the lot. The number of dwelling units must remain unchanged if Provincial floodproofing standards for safe access/egress cannot be satisfied. The elevation for ingress and egress route to meet or exceed that of the existing structure on site prior to re-development. Dry passive floodproofing standard applies. The floodproofing elevation are specified on Figure 4 (or Figure 5 if flood mitigation measures are incorporated). Top of foundation to be at, or above, the floodproofing elevation. All services and utilities to be above the floodproofing elevation. Structures encouraged to be supported on piles/piers when floodproofing elevation is 0.8 m or greater than existing grade, and structure is directly exposed to the lake. Perimeter foundations may be considered. However, foundations having floodproofing elevation 0.8 m or greater above existing grade, and directly exposed to the lake, to have i) top of foundation increased by 0.3 m (no opening below top of foundation), and ii) face of the foundation wall exposed to the lake protected with riprap and/or armour stone (top of rock to coincide with top of foundation).

DEVELOPMENT ACTIVITY[1]	DYNAMIC BEACH[2]	FLOOD HAZARD[3]
		All crawl spaces must be non-habitable, and used for non-permanent storage only. Openings below the floodproofing elevation are not permitted. All services and utilities to be above the floodproofing elevation. Water level to be used in foundation design is specified as 0.4 m above the design still water level. Foundation design and site grading details to be provided by a qualified civil/structural engineer.
New Dwellings on existing vacant lots	Not Permitted.	Permitted, with restrictions. Buildings and structures to be located on the least exposed portion of the lot. The elevation for ingress and egress route to meet provincial standards. Dry[6] passive[5] floodproofing standard applies. The floodproofing elevations are specified on Figure 4 (or Figure 5 if flood mitigation measures are incorporated). Top of foundation to be at, or above, the floodproofing elevation. All services and utilities to be above the floodproofing elevation. Structures encouraged to be supported on piles/piers when floodproofing elevation is 0.8 m or greater than existing grade, and structure is directly exposed to the lake. Perimeter foundations may be considered. However, foundations having floodproofing elevation 0.8 m or greater above existing grade, and directly exposed to the lake, to have i) top of foundation increased by 0.3 m (no opening below top of foundation), and ii) face of the foundation wall exposed to the lake protected with riprap and/or armour stone (top of rock to coincide with top of foundation).

DEVELOPMENT ACTIVITY[1]	DYNAMIC BEACH[2]	FLOOD HAZARD[3]
		All crawl spaces must be non-habitable, and used for non-permanent storage only. Openings below the floodproofing elevation are not permitted. All services and utilities to be above the floodproofing elevation. Water level to be used in foundation design is specified as 0.4 m above the design still water level. Foundation design and site grading details to be provided by a qualified civil/structural engineer.
Swimming Pools (above or below ground)	Not Permitted.	Permitted (if not directly exposed to the lake), with restrictions. To be located on the least exposed portion of the lot. Lake level to be used in swimming pool design is specified as 0.4 m above the design still water level (specified in the main body of this document)). Swimming pool design details to be provided by a qualified civil/structural engineer. Servicing and utilities to be located above the floodproofing elevation.
Decks, Boardwalks, and Fixed Walkways	Permitted, provided design has no adverse impacts on ongoing coastal processes. May require a site specific assessment from a qualified coastal engineer or a coastal geomorphologist.	Permitted, provided safety concerns due to flood hazards are addressed considering site conditions and nature and use of development.
Site Alterations (re-grading of the existing beach)	Permitted, provided recommendations from Port Stanley Public Beach Management Plan (Shoreplan, 2010) are followed. May require a site specific assessment from a qualified coastal engineer or a coastal geomorphologist.	Permitted, provided recommendations from Port Stanley Public Beach Management Plan (Shoreplan, 2010) are followed. Provided safety concerns due to flood hazards are addressed considering site conditions and nature and use of development.

Notes:

1 Development Activity means the same as the definition of development under the Conservation Authorities Act.

2 Dynamic Beach limits are delineated in Port Stanley Beach Management Plan (Shoreplan, 1996).

3 Flood Hazard limits are delineated in Port Stanley Coastal Risk Assessment (Zuzek, 2021).

4 Floodproofing standard is defined as a combination of structural changes and/or adjustments incorporated into the basic design and/or construction or alteration of individual buildings, structures or properties subject to flooding hazards so as to reduce the risk of flood damages, including wave uprush and other water related hazards along the shorelines of the Great Lakes (MNR, 2001).

5 Passive floodproofing are techniques which are permanently in place and do not require advance warning and action in order to make the floodproofing and/or flood protection measure effective (MNR, 2001).

6 Dry floodproofing means the use of fill, columns, or design modifications to elevate openings in buildings or structures above the floodproofing standard (MNR, 2001).

7 Wet floodproofing is defined as protection to maintain structural integrity by avoiding external unbalanced forces from acting on buildings during and after a flood, to reduce flood damage to contents, and to reduce the cost of post flood clean up. As such, wet floodproofing requires that the space below the level of the flood standard remain unfinished, be non-habitable, and be free of service units and panels, thereby ensuring minimal damage. Also this space must not be used for storage of immovable or hazardous materials that are buoyant, flammable, explosive or toxic. Furthermore, access ways into and from a wet floodproofed building must allow for safe pedestrian movement (MNR, 2002).

8 Activities proposed other than those outlined in the above development guides may require services from a qualified coastal and/or civil/structural engineers. Such services may include site specific assessments, site reviews and/or designs. Scope of work for such services are to be established during consultations with KCCA staff.