P.O. Box 1749
Halifax, Nova Scotia
B3J 3A5 Canada

Item No. 14.2
Halifax Regional Council
May 3, 2022
May 17, 2022

TO: Mayor Savage and Members of Halifax Regional Council

SUBMITTED BY: Original Signed

Denise Schofield, Acting Chief Administrative Officer

DATE: December 10, 2021

SUBJECT: **Flood Mitigation Near John Stewart and Arklow Drive, Cole Harbour**

INFORMATION REPORT

ORIGIN

February 26, 2019 Halifax Regional Council motion 18.1:

MOVED by Councillor Nicoll, seconded by Councillor Karsten

THAT Halifax Regional Council request a staff report on the options and costs of flood mitigation in response to a petition submitted by Councillor Nicoll January 29, 2019 from residents concerning flooding, property damage, loss of property and child safety caused by excess runoff from the waterway located between John Stewart Drive and Arklow Drive, Cole Harbour."

MOTION PUT AND PASSED UNANIMOUSLY

LEGISLATIVE AUTHORITY

Halifax Regional Municipality Charter, SNS 2008, c 39, s 79:

> 79A (1) Subject to subsections (2) to (4), the Municipality may only spend money for municipal purposes if
>
> (a) the expenditure is included in the Municipality's operating budget or capital budget or is otherwise authorized by the Municipality;
>
> (b) the expenditure is in respect of an emergency under the *Emergency Management Act*; or
>
> (c) the expenditure is legally required to be paid..

BACKGROUND

During a storm event on July 9, 1995, approximately 120 flooded basements were reported to have occurred in the Cole Harbour area of the former Halifax County. In response to this event and previous flooding, the former Halifax County Municipality and the Province of Nova Scotia retained the services of WSP Limited (formerly Wallace Macdonald and Lively Ltd.) to investigate the cause of the flooding and to recommend remedial actions.

In 1998, Halifax Regional Municipality retained the services of Whitman Benn to provide a technical review of the remedial measures recommended by WSP, and to provide cost estimates for the recommended suite of improvements. From 1998 to 2006, approximately $1 million worth of construction work of infrastructure improvements were completed to address storm drainage issues.

Notwithstanding the improvements referenced above, critical storm drainage infrastructure downstream of Bissett Run has never been upgraded. This drainage infrastructure upstream of Cole Harbour Road was built by the Nova Scotia Department of Housing. The former Halifax County did not accept it because it failed to meet their standards. The system is still owned by the Province.

On several occasions, Halifax Water has advised the Province about its concerns regarding the performance and the maintenance required to this system. One of the concerns was the removal of debris collecting on the inlet grates. In 2012, Halifax Water was advised that the Province was cleaning the grates annually.

In 2014-2015, Dillon Consulting Limited (Dillon) completed a report utilizing conceptual hydrological and hydraulic modelling, that identified infrastructure limitations potentially contributing to the flooding issues along upper Bissett Run.

In 2018, HRM retained WSP to carry out a risk assessment study. The National Disaster Mitigation Program (NDMP) Study was presented to Regional Council on October 30, 2018. The area surrounding Bissett Run in Cole Harbour was identified as one of the Top-10 priority sites.

At the February 26, 2019 Regional Council meeting, a staff report was requested on the options and costs of flood mitigation in response to a petition submitted on January 29, 2019. The petition was signed by 41 residents with flooding concerns along John Stewart Drive and Arklow Drive.

Pursuant to Council's request along with the NDMP Study findings, Dillion Consulting was retained to carry out a detailed analysis of the Bisset Run Watershed and mitigation study.

The discussion which follows provides an overview of the study findings. It also provides a response to the request for a staff report on the options and costs of flood mitigation in the area near John Stewart Drive and Arklow Drive in Cole Harbour.

DISCUSSION

Study Overview

A detailed hydrological and hydraulic study was carried out for the Bissett Run watersheds. Bissett Run is referred to by the following sections:

- Upper Bissett Run is the section between Cole Harbour Commons and Cole Harbour Road; and
- Lower Bissett Run is the section between Cole Harbour Road and Bissett Lake.

Upper Bissett Run flows through a narrow corridor of green space immediately between John Stewart Drive and Arklow Drive. This popular recreation green space is a mix of public and private areas where historical

flooding has been reported. Lower Bissett Run consists of a relatively flat marsh area downstream of Cole Harbour Road. A site location map is provided in Attachment A.

Runoff flows from Upper Bissett Run to Lower Bissett Run via an inlet structure near Civic 1241 (Fong's Restaurant) Cole Harbour Road. It then flows through an engineered system under Cole Harbour Road where it finally discharges into Lower Bissett Run. Once discharged, the stormwater flow is combined with additional runoff from the adjacent sub-watersheds. It then travels approximately 1 km where it ultimately discharges into Bissett Lake.

The hydrologic model included a detailed watershed delineation and surveyed cross sections. The survey targeted hydraulic structures, representative channel cross-sections, finished floor elevations of flood susceptible infrastructure, and existing storm sewers within the study area. This allowed the consultant to simulate tailwater conditions downstream of Cole Harbour Road and Bissett Lake. Hydraulic modelling was carried out to estimate flood levels under existing and proposed conditions.

The hydrologic model also included allowances for climate change. The method utilized to accommodate this was to increase the current 24-hour storm rainfall amount within the study area by 16%. This is consistent with the methodology used by Halifax Water. It was observed that incremental flow rate increases in Lower Bissett Run do not result in significant increases to the extent of flooding. This is attributed to the relatively wide and flat floodplain along Lower Bissett Run.

The following upgraded scenarios were tested:

- Scenario #1: Diversion of stormwater runoff from Arklow Drive to Silistria Drive;
- Scenario #2: Outlet improvement near intersection of Arklow and John Stewart Drive;
- Scenario #3: Storm sewer upgrade across Cole Harbour Road to Lower Bissett Run; and
- Scenario #4: Detention pond with a trunk sewer located in the recreational area near Cole Harbour Place.

When applying the 16% climate change factor uniformly across the area for the 100-year rainfall event, the water elevations along Bissett Run do exhibit an increase. Based on the sensitivity analysis, it is anticipated that climate change impacts will be minimal as the water elevations changes range from 0.02 m to 0.10 m under existing conditions, and 0.02 m to 0.20 m under the proposed mitigation measures in scenarios 1, 2 and 3.

Of the four scenarios tested, the storm sewer upgrades across Cole Harbour Road showed the most promise. Hydraulic modelling with twin 3.6 x 1.5m box culverts showed a decrease in the flood level of 0.52 meters immediately downstream of Structure 7 (near 38 John Stewart Drive). Modelling also shows the structure can convey the increased flows resulting from climate change. The Dillon report notes that residences just south of Structure 7 are at risk of basement flooding during extreme precipitation events. This upgrade would have an immediate benefit by reducing the flooding that occurs between Arklow Drive and John Stewart Drive as well as reducing the flooding near 1241 Cole Harbour Road.

Staff Analysis

Based on the results of the Dillon Study, further work was carried out by staff to determine the cost and feasibility of the twin box culvert option. There are several constraints with the twin box culvert option. They include:

- the elevation difference between Upper and Lower Bissett Run;
- the cross section and profile of Cole Harbour Road; and
- the proximity of sanitary sewer and watermains.

Three options were developed. The preferred option involves purchasing the Civic 1241 Cole Harbour Road property, daylighting Bissett Run, realigning the sanitary sewer and watermains, and installing a pre-cast bridge structure instead of twin box culverts across Cole Harbour Road. This option is illustrated in Attachment B. The estimated cost including land acquisition is approximately $3.6 million. Staff are currently inquiring on potential funding from other orders of government.

Ownership of the existing storm system is complicated. The system upstream of Cole Harbour Road (1241 Cole Harbour Road) is owned by the Province. The culvert that crosses Cole Harbour Road is owned by Halifax Water. If the culvert is upgraded to a bridge, ownership will be transferred to the Municipality as HRM is responsible for bridge structures. The transfer of ownership would still occur with the twin box culverts option instead of a bridge, as the culverts would be classified as a bridge.

Several constraints with the bridge option have been identified. They include property acquisition, building demolition, relocation of utilities, downstream impacts, and temporary traffic control. In addition, any mitigation option must consider alleviating the flooding that occurs near the intersection of Perron Drive and Cole Harbour Road. This intersection is considered the low point on the street.

Next Steps

This project will be included in the implementation plan that staff are currently developing for the flood prone areas identified in the National Disaster Mitigation Program: Flood Risk Assessment Study. It is expected that, given the amount of work that has been completed thus far for the area, the next steps will be to carry out a detailed design of the preferred solution to confirm the design solution and budget.

In the meantime, staff will consult with Halifax Water to determine if it has the capability to improve the level of maintenance to clear both the debris grate located near 1241 Cole Harbour Road and the cross culvert. Staff will also further investigate the down-stream impacts of the proposed storm system upgrade. It is anticipated that a small-scale study on this item could be funded from the operating budget.

FINANCIAL IMPLICATIONS

There are no financial implications associated with this report.

COMMUNITY ENGAGEMENT

A key component of this report was the petition signed by 41 residents in the area. The completed study (Attachment C) presented as part of this Council report addresses the concerns presented in the signed petition.

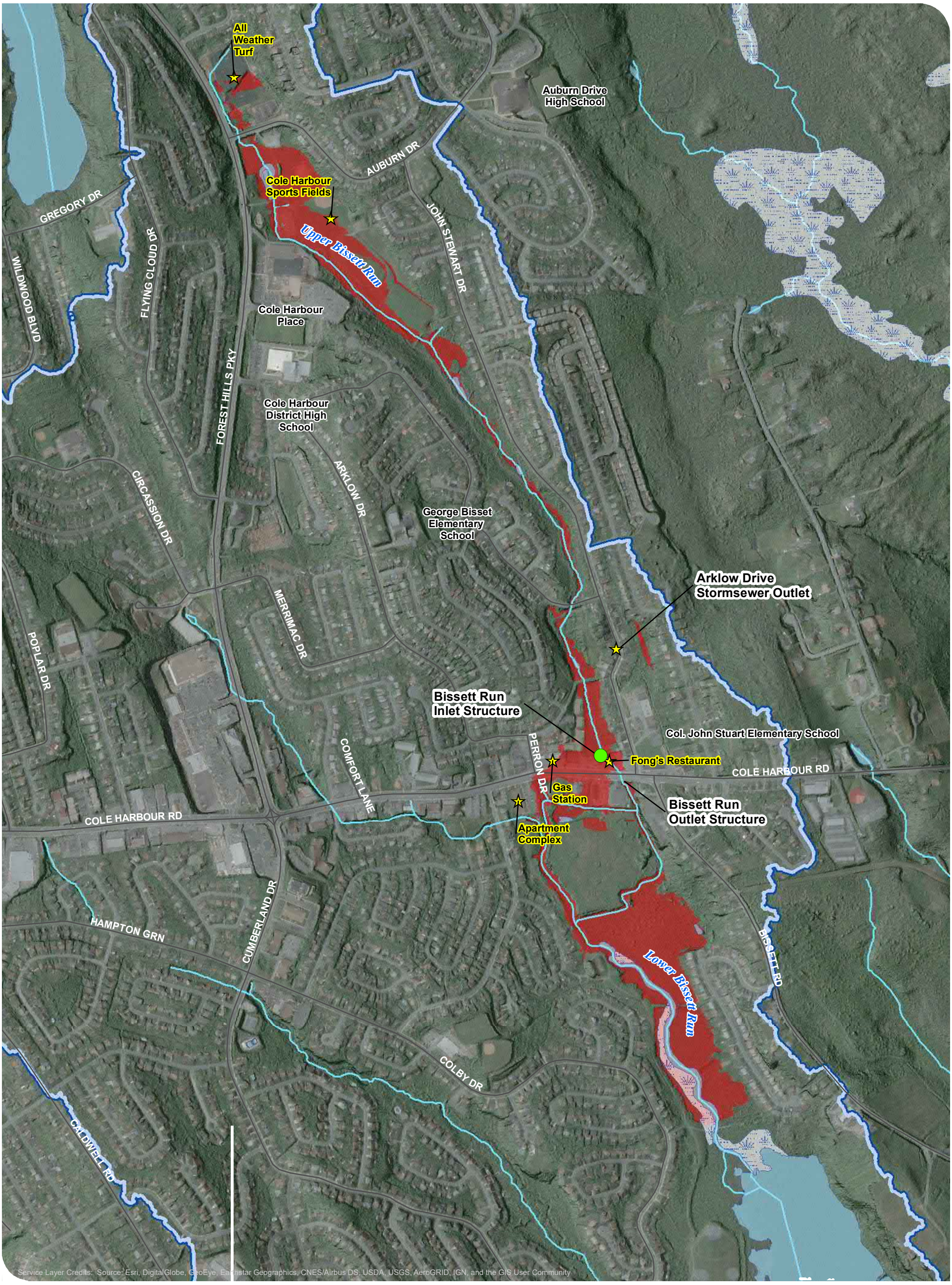
ATTACHMENTS

Attachment A: Site Location Map
Attachment B: Preferred Option
Attachment C: Cole Harbour NDMP Follow-up
Attachment D: Resident Petition

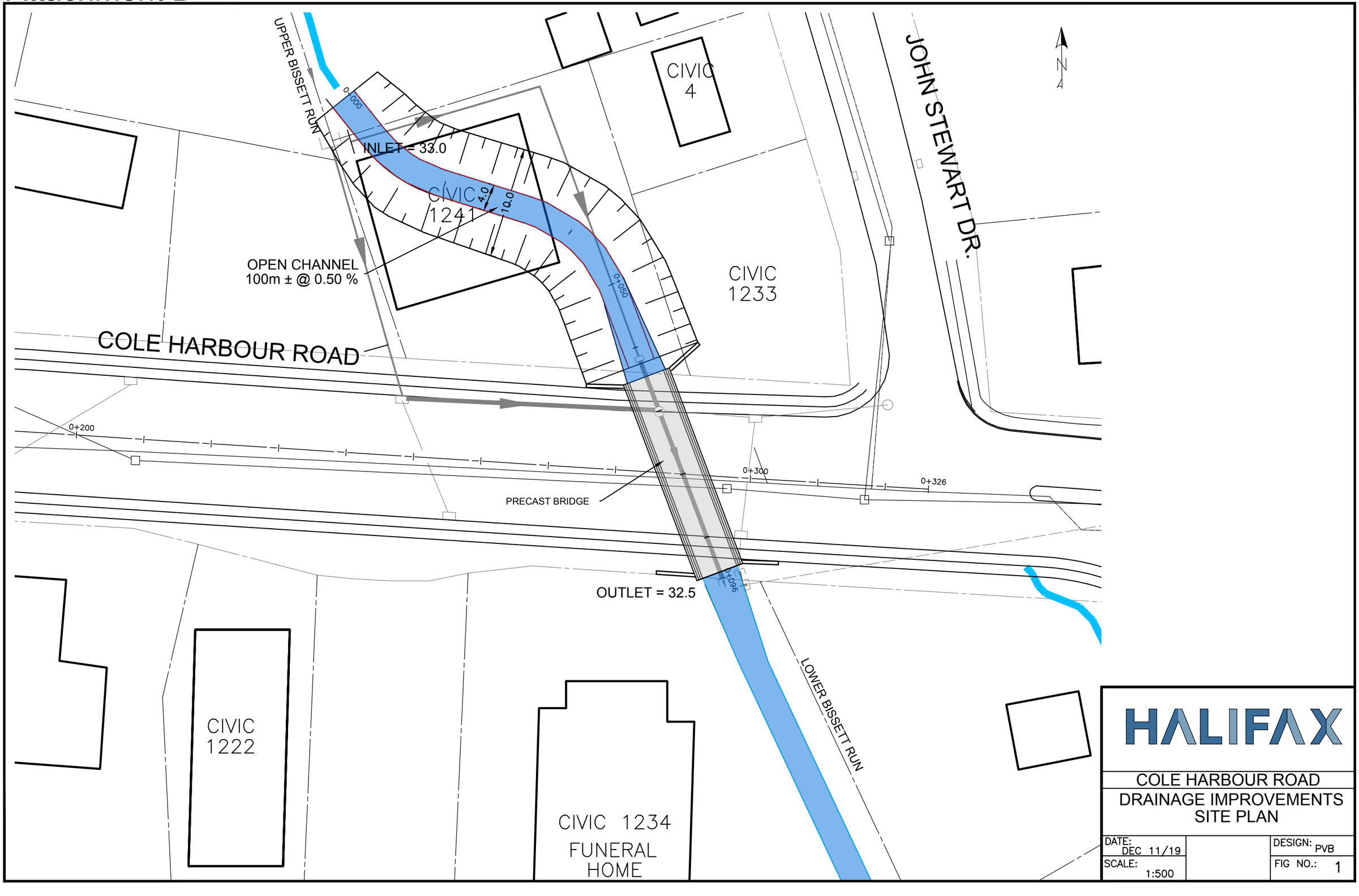
A copy of this report can be obtained online at halifax.ca or by contacting the Office of the Municipal Clerk at 902.490.4210.

Report Prepared by: Youssef Habboush, Program Engineer, 902.292.1490

Attachment A



Attachment B



HALIFAX

COLE HARBOUR ROAD
DRAINAGE IMPROVEMENTS
SITE PLAN

DATE: DEC 11/19		DESIGN: PVB
SCALE: 1:500		FIG NO.: 1

Attachment C

DILLON CONSULTING

HALIFAX REGIONAL MUNICIPALITY

Cole Harbour: National Disaster Mitigation Program Follow-Up Study

Final Report

November 2019 - 19-1220

November 26, 2019

Halifax Regional Municipality
P. O. Box 1749
Halifax, Nova Scotia
B3J 3A5

Attention: Paul Burgess
Program Manager

Cole Harbour National Disaster Mitigation Program Follow-Up Study
Final Report

Dillon Consulting Limited (Dillon) is pleased to provide the Halifax Regional Municipality (HRM) with the attached report outlining the findings of our hydrologic/ hydraulic assessment of the Bissett Run system, floodplain, and tributary watershed to Bissett Lake.

The attached report provides the methodology and the hydrologic/hydraulic simulation results for the existing study area drainage conditions, and for a proposed future condition as outlined in HRM's scope of work. Recommendations are also provided to mitigate the incremental impact on flood risk within the study area.

Please feel free to contact the undersigned should you have any questions or comments regarding the contents of this report.

Yours sincerely,

DILLON CONSULTING LIMITED
Original Signed

Sarah Devereaux, M.Eng., P.Eng., FEC, FCSSE
Project Manager

SLD:lni

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Figures

Tables

Appendices

1.0 Introduction

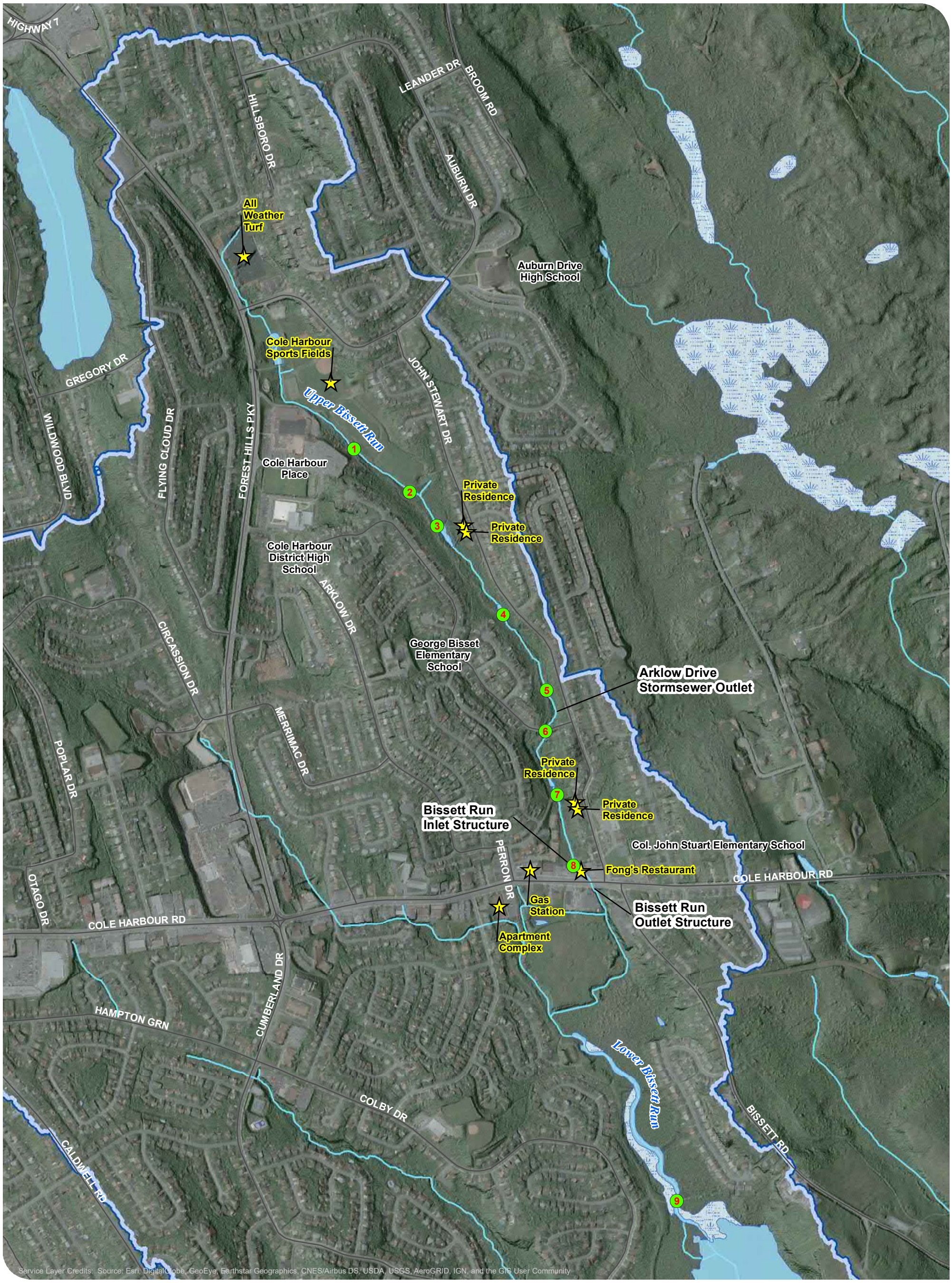
Dillon Consulting Limited (Dillon) has been retained by the Halifax Regional Municipality (HRM) to conduct a watershed scale hydrologic/hydraulic analysis of the Bissett Run system, floodplain, and tributary watershed to Bissett Lake located in Cole Harbour, Nova Scotia. Our initial report, in September 2014 identified potential limitations in the infrastructure that may have been contributing to on-going flooding issues along upper Bissett Run. Dillon was additionally retained to complete conceptual level hydrologic and hydraulic modelling to further investigate flood mechanisms in the study area, the results of which are presented in our March 2015 report. The intent of this study is to provide more detailed hydrologic and hydraulic modelling to:

- Determine the effects on Bissett Run's hydraulic grade line (HGL) using detailed hydrologic and hydraulic models considering the following:
  - Proposed detention pond upgrades;
  - Diversion of stormwater runoff from Arklow Drive to Bissett Run;
  - Outlet improvements near Arklow Drive and John Stewart Drive; and
  - Storm sewer upgrades across Cole Harbour Road to lower Bissett Run;
- Provide a phased upgrade approach to mitigate the impacts on downstream infrastructure;
- Provide flood limit mapping for existing and the fully upgraded scenario along Upper and Lower Bissett Run and Bissett Lake; and
- Determine the hydraulic conveyance capacity of lower Bissett Run.

In completing the above analysis, primary consideration will be given to the key assets identified in the National Disaster Mitigation Program (NDMP) study which was provided by HRM. The methodology and findings of this assessment are presented in the following sections of this report.

2.0 Background

The study area is located in Cole Harbour, Nova Scotia and includes the Bissett Run watershed, however, the hydraulic assessment includes only those areas adjacent to the watercourse known as Bissett Run. The reach of Bissett Run between Cole Harbour Commons and Cole Harbour Road is referred to as Upper Bissett Run, and the lower reaches between Cole Harbour Road and Bissett Lake is known as Lower Bissett Run. A plan view of the watercourse is presented in Figure 2-1. Notably the figure illustrates that Upper Bissett Run flows through a narrow corridor of green space immediately west of John Stewart Drive. The green space is a popular area for public recreation and contains a network of walking paths. Historical flooding has been noted at two locations (private residences) along the alignment of Upper Bissett Run (particularly in 2012); the approximate locations of the reported flooding are shown in Figure 2-1.



HALIFAX REGIONAL MUNICIPALITY
COLE HARBOUR MITIGATION STUDY

STUDY AREA LOCATION MAP
FIGURE 2-1

Key Asset
Structure
Waterbody
Wetland
Bisset Lake Watershed

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY HRM

MAP CREATED BY: JAB
MAP CHECKED BY: NO
MAP PROJECTION: NAD 1983 UTM Zone 20N

FILE LOCATION: X:\PROJECTS\DRAFT\GIS\Projects\191220_Cole_Harbour_Mitigation\data_maps\mxds\191220-Figure-2-1-SiteLocation.mxd

0 50 100 200 Metres SCALE 1:10000

N W E S

PROJECT: 19-1220 STATUS: DRAFT DATE: 2019/09/23

An inlet structure collects runoff from Upper Bissett Run, near Civic 1241 Cole Harbour Road (Fong's Restaurant), and conveys flow from Upper Bissett Run under Cole Harbour Road into Lower Bissett Run. In early February 2008, Atlantic Industrial Cleaners (AIC) completed a CCTV survey of the piped system conveying runoff from Upper to Lower Bissett Run. The survey report noted significant blockage in the 1200 mm pipe between the inlet and downstream manhole structure. A second survey undertaken in late February 2008, after maintenance operations had removed the blockage, showed that the pipe was clear. The 1200 mm pipe flows through a chamber structure prior to discharging into Lower Bissett Run. A second outlet structure discharges into Lower Bissett Run and collects primarily local road runoff from John Stewart Drive. The 2008 AIC survey report notes that this piped system consists of 600 mm diameter concrete pipe. A 375 mm diameter overflow connection between the two outlet lines exists immediately upstream of Cole Harbour Road. The general arrangement of this stormwater network can be seen in the AIC 2008 Survey Report presented in Appendix A.

The alignment of Lower Bissett Run consists of a relatively flat marsh area downstream of Cole Harbour Road. Flow entering the marsh area combines with runoff from adjacent Bissett Lake subwatersheds and flows approximately 1 km in a southerly direction, ultimately discharging into Bissett Lake. A second outlet into Bissett Run exists approximately 200 m west of the Upper Bissett Run outlet structures. Flow from this outlet is generated from watersheds located west of the Cole Harbour Commons and green space.

Concerns have been raised by local residents regarding flooding along Upper Bissett Run at the private residences noted in Figure 2-1. As part of the initial Dillon study (completed in September 2014), Dillon contacted residents in the vicinity of the Cole Harbour floodplain. These interviews suggested that extensive flooding near John Stewart Drive occurs frequently during moderate/heavy rainfall events. Frequent flooding of the green space located immediately west of John Stewart Drive was also described during the interviews. Dillon carried out a site survey of hydraulic structures along the alignment of Bissett Run and identified nine structures, which are described in Table 2-1. Structures 2, 3, 4, 7, and 8 are expected to be undersized to adequately accommodate existing and anticipated discharges from the watercourse during low-frequency rainfall events. While it is desirable to increase the flow capacity of these structures to reduce the potential for flooding along Bissett Run, it is recognized that doing so will increase the peak flows expected in the downstream reaches, thus a phased approach to upgrading will be provided. As part of the background review, Alicia McEachern of Halifax Water's Engineering Information Department provided the updated stormwater infrastructure GIS data.

Table 2-1: Summary of Infrastructure along Upper and Lower Bissett Run and Associated Capacity

Structure/Stormwater Infrastructure	Capacity/Description	
#1: Walking bridge (Adjacent to the upper field of Cole Harbour Commons)	Up to 100-year return period event	
#2: Walking bridge with concrete sliding gates (Below lower soccer field of Cole Harbour Commons)	Up to 2-year return period event	
#3: Walking bridge over the watercourse (Near the northern intersection of John Stewart Drive and Inglewood Crescent)	Less than 2-year return period event (Walking bridge could be at possible risk to wash out during a 5-year return period event and higher)	

Structure/Stormwater Infrastructure	Capacity/Description	
#4: Walking bridge (Near the southern intersection of John Stewart Drive and Inglewood Crescent)	The walking bridge is adequately sized to convey up to and including the 10-year return period event	
#5: Walking bridge (Near the intersection of John Stewart Drive and Halo Lane)	The walking bridge is adequately sized to convey up to and including the 100-year return period event	
#6: Bridge crossing (Intersection of Arklow Drive and John Stewart Drive)	The bridge crossing is adequately sized to convey up to and including the 100-year return period event	

Structure/Stormwater Infrastructure	Capacity/Description	
#7: Concrete chamber culvert (End of the pond adjacent to the walking path that connects Amaranth Crescent and John Stewart Drive)	The weir structure and culvert are not being engaged in rainfall event due to pond elevations spilling over the pedestrian walkway before reaching the weir elevation. The pedestrian walkway it at a lower elevation than the top of the weir. Therefore, peak rainfall events spill over the pedestrian walkway and downstream thus not engaging the culvert. The spillway is engaged in less than the 2-year return period event.	
#8: Dual culvert (Located behind Fong's restaurant)	Less than 2-year return period event	
#9: Walking bridge (Near the inlet from Bissett Run to Bissett Lake)	Up to and including the 100-year return period event	

3.0 Methodology

3.1 Review of Background Information

Three previous reports investigating flooding issues within the study area were reviewed to support this study. A summary of the findings of these reports as they relate to this study are discussed below.

Cole Harbour Storm Drainage Study (Wallace Macdonald and Lively 1996)

A detailed review of the Wallace Macdonald and Lively (1996) report entitled Cole Harbour Storm Drainage Study was undertaken. The report was prepared in response to a significant rainfall event which occurred on July 9, 1995. The rainfall event was estimated to have a return period in between 2 and 5 years. The report considered a considerably larger study area than this study. However, the report contains substantial discussion relating to flooding issues observed in the Bissett Run Watershed.

The Wallace Macdonald Lively (1996) report notes that considerable storage capacity is provided in the Cole Harbour Commons area. However, the report also notes that after a significant rainfall event, the parks and fields in the area can take days or even weeks to drain and be returned to the pre-storm condition. During this time these recreational facilities are not available for use which is undesirable.

The report also notes that surcharging of stormwater infrastructure throughout the study area was likely the primary cause of flooding during the July 1995 flooding event. It is suspected that the capacities of both major and minor drainage infrastructure within the study area were exceeded during the storm causing stormwater laterals and other drainage infrastructure to surcharge. The report recommends the use of check valves, diversion of flows, inlet control, lot grading improvements, and pipe replacement/twinning as potential solutions to the localized flooding issues in the area. The report also recommends that reaches of Lower Bissett Run should be graded to lower the tailwater elevation downstream of the Bissett Run outlet structures.

Typical water levels in Bissett Lake were also observed to vary between 32.3 and 32.7 metres above sea level, which when converted to CVGD2013 correspond to between 31.7 and 32.1 meters. The report also notes an estimated maximum lake level, resulting from the passage of the 100-year event, of 33.5 masl (32.9 m in CVGD2013).

Cole Harbour Floodplain Consulting Services for High Level Issue Delineation and Vulnerability Assessment (Dillon 2014)

As noted earlier, a detailed review of the Dillon 2014 study was undertaken to understand the initial review of flooding issues in the study area. That report outlined a high-level Rational Method based approach to estimating the flow capacity of five hydraulic structures located along the alignment of Upper Bissett Run.

The Dillon study also notes that the presence of beaver activity along the southern reaches of Upper Bissett Run may have contributed to the flooding issues observed in the area. It is understood that these beavers were relocated, however, may continue to be a concern if they return in the future. Other "pinch points" (areas where the movement of water was identified to be partially restricted) were also noted in the study. Examples of these pinch points include undersized hydraulic structures, and the presence of large rocks intentionally placed along the watercourse to provide pedestrian crossing of the stream.

The Dillon 2014 study recommended the removal of the pinch points noted along Upper Bissett Run, as well as a review of the suspected undersized hydraulic structures identified in the study area. A review of options for creating additional water retention infrastructure upstream of the affected areas within the watershed was also suggested as part of the study.

Cole Harbour Floodplain Assessment (Dillon 2015)
Hydraulic and hydrologic modelling was undertaken along Upper and Lower Bissett Run. That study found that upstream storage in the existing recreational area near Cole Harbour Place provided significant benefit to the lower reaches. If this storage were to be eliminated, downstream flooding would be expected to worsen. A significant challenge to upgrading conveyance in the area is the mild channel slope along Lower Bissett Run. Recommendations included completing a detailed hydraulic/hydrologic assessment to identify improved storage options upstream, and to evaluate options to improve downstream conveyance.

This study is expected to progress with the recommendations included in the Dillon (2015) study.

National Disaster Mitigation Program (NDMP): Site No. 5 – Cole Harbour (2018)
WSP carried out a Flood Risk Assessment Project as part of the NDMP for Cole Harbour (Site no. 5). The report focused on Bissett Run, including Cole Harbour Road near the intersection of John Stewart Drive and Perron Drive. This report outlined surface flooding risks along Bissett Run and adjacent properties, including the Cole Harbour Place sports fields, Cole Harbour Road, and properties along Cole Harbour Road (i.e., a restaurant, gas station, and apartment complex). The report provides recommended mitigation strategies, which include a detailed Bissett Run watershed drainage study and mitigation concept development, ongoing monitoring and maintenance, stormwater master plan/ land-use planning and development policies, design/construction of Cole Harbour Road crossing upgrades, and design/construction of upgrades to Bisset Run.

3.2 Site Reconnaissance and Survey

To complete a detailed review of hydraulic performance along the existing reaches of lower and upper Bissett Run, a topographic and bathymetric survey was completed. This survey targeted hydraulic structures, representative channel cross-sections, finished floor elevations of flood susceptible infrastructure, and existing storm sewers within the study area. The surveys were completed on August

19 and August 21, 2019, and completed collaboratively by Dillon field staff and Servant Dunbrack, McKenzie and MacDonald Land Surveyors. These survey data were used to support subsequent hydrologic and hydraulic modelling discussed in following sections.

3.3 Meteorological Data

Meteorological data for this study was derived from the latest intensity duration frequency (IDF) statistics from the Shearwater RCS (Station # 8205092) Environment and Climate Change Canada station. Rainfall observations for this site span approximately 61 years (1955 – 2016). The total rainfall depths associated with this station are presented in Table 3-1 for the 24-hour duration design storms.

Table 3-1: Summary of Simulated Rainfall Depths for Shearwater RCS

Return Period (years)	Historical Rainfall Depth (mm)	Rainfall Depth with 16% Increase for Climate Change (mm)
2	67.42	78.21
5	87.00	100.92
10	100.37	116.43
25	117.73	136.57
50	130.97	151.93
100	144.41	167.52

Table 3-1 also includes estimates of future climate conditions based on the 16% increase in rainfall depth as requested in the project requirements provided by HRM. These rainfall depths have been used to generate 24-hour rainfall events using the Chicago Storm Distribution. The 16% increase for climate change has been applied uniformly across the entire rainfall event. These rainfall events were input into the HEC-HMS hydrology model to estimate runoff hydrographs within the study watershed.

3.4 Hydrologic/Hydraulic Modelling

Hydrologic Modelling

Hydrologic modelling was completed for all watersheds contributing to Bissett Run. This area included the watersheds considered in the Dillon 2015 study, as well as watersheds located further to the west. The watershed delineation used to develop the hydrologic model is presented in Figure 3-1. The delineation of these subwatersheds was completed using the available 1 m digital elevation model (DEM) data provided by HRM.

The United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's Hydrologic Modelling System version 4.3 (HEC-HMS) was used to complete the hydrologic modelling exercise. The U.S. Soil Conservation Service (SCS) runoff curve number method was used to estimate the runoff potential from each subwatershed. A review of the Surficial Geology Map for the Province of Nova Scotia (Stea, Conley, and Brown, 1992) indicates that soils in the Cole Harbour area are comprised

predominately of silty till. It is believed that this till is high in fines and has a considerably high runoff potential, and corresponds to a Group C soil as described by the SCS guidelines (Ponce, 1989). The percent impervious area has also been estimated for each subwatershed and included in the model (parking lots, commercial roofs, etc.). The schematic is presented in Figure 3-2.

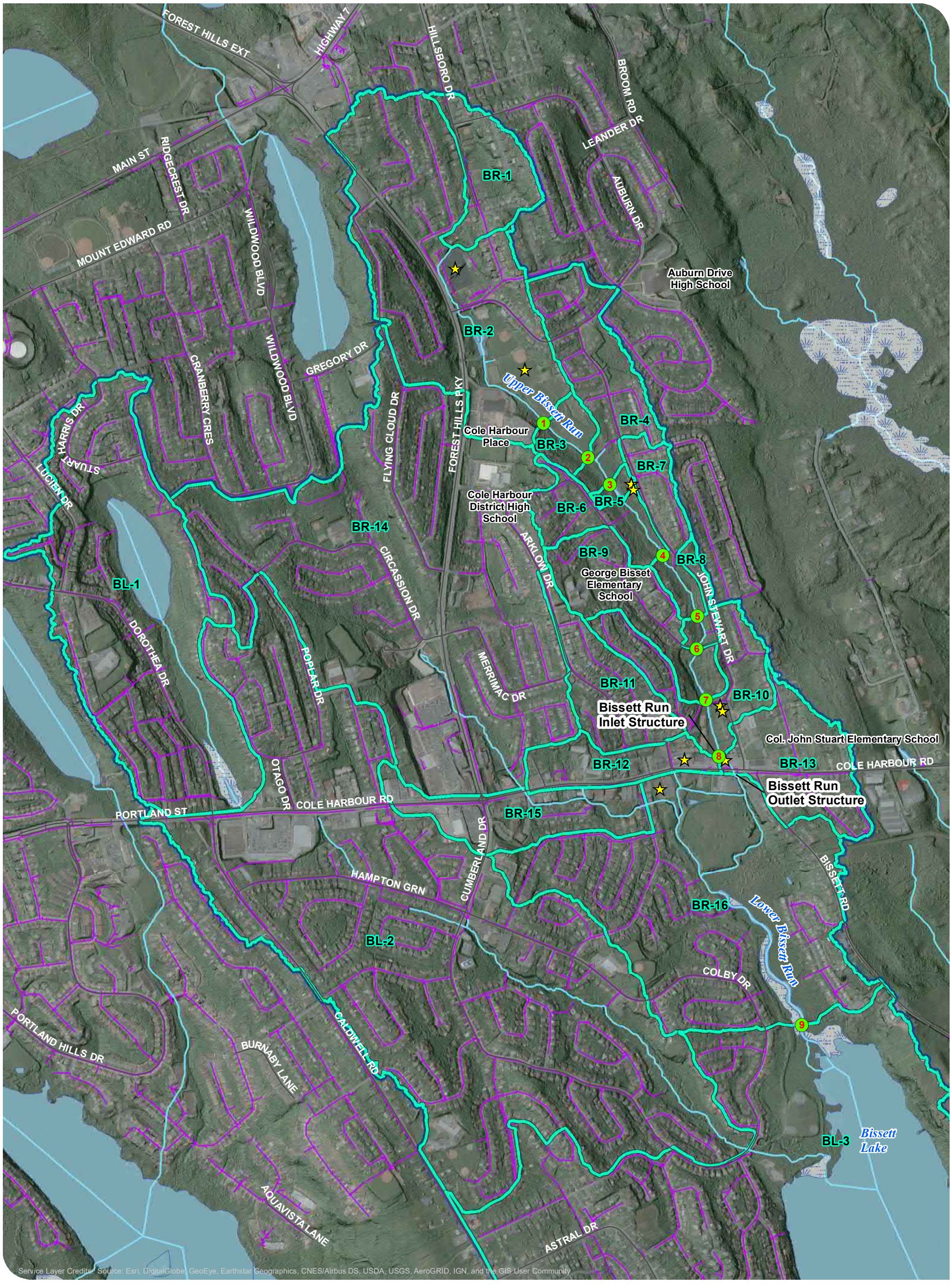
This model represents a refinement from the hydrologic modeling completed for the 2015 study. Stormwater infrastructure GIS data were obtained from Halifax Water and used for watershed/sewershed delineation. The current model includes a more detailed watershed/sewershed delineation, including significant sources of runoff from western watersheds draining to Lower Bissett Run. This was required to more accurately simulate tail water conditions downstream of Cole Harbour Road and in Bissett Lake.

Surveyed cross-sections of the brook were incorporated into the HEC-HMS model. Data from individual cross-sections were compiled into tabular format for input into the hydrologic model. Information extending past the limits of the surveyed cross-sections was gathered from the DEM and the two datasets were combined for finalized model inputs.

Hydraulic Modelling

To evaluate hydraulic performance in Upper and Lower Bissett Run, steady-state hydraulic modelling of the reaches in this area was completed. The USACE HEC River Analysis System (RAS) version 5.0.7 has been used to complete the hydraulic simulation. The reach cross sections were developed from the available LiDAR data for the study area and the survey data collected for this study.

The HEC-RAS model also included reaches between Cole Harbour Road and the inlet to Bissett Lake. The purpose of hydraulic modelling along Lower Bissett Run is to estimate flood levels under baseline (existing) and proposed upgraded conditions. The Wallace Macdonald & Lively (1996) report notes that typical water levels in Bissett Lake can vary between 31.7 and 32.1 metres above sea level (CGVD 2013). The report also notes an estimated maximum lake level resulting from a 100-year storm of 32.9 masl (CGVD 2013). For the hydraulic modelling undertaken in this study a lake level of 32.1 m was applied for all scenarios as a conservative measure. Our field survey indicated that the lake level was 31.58 m downstream of Structure 9; therefore, there is evidence of variability in the lake level. The lower level captured during our field survey may have been the result of the relatively dry 2019 summer, resulting in increased evaporative losses from the lake surface.



HALIFAX REGIONAL MUNICIPALITY
COLE HARBOUR MITIGATION STUDY

SUBWATERSHEDS/ SEWERSHEDS
FIGURE 3-1

Key Asset | Structure | Waterbody | Wetland | Subwatershed/Sewershed | Bisset Lake Watershed | Stormwater Pipe

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY HRM

MAP CREATED BY: JAB
MAP CHECKED BY: NO
MAP PROJECTION: NAD 1983 UTM Zone 20N

FILE LOCATION: X:\PROJECTS\DRAFT\GIS\Projects\191220_Cole_Harbour_Mitigation\data_maps\mxds\191220-Figure-2-1-SiteLocation.mxd

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SCALE 1:12500

PROJECT: 19-1220 STATUS: DRAFT DATE: 2019/09/23

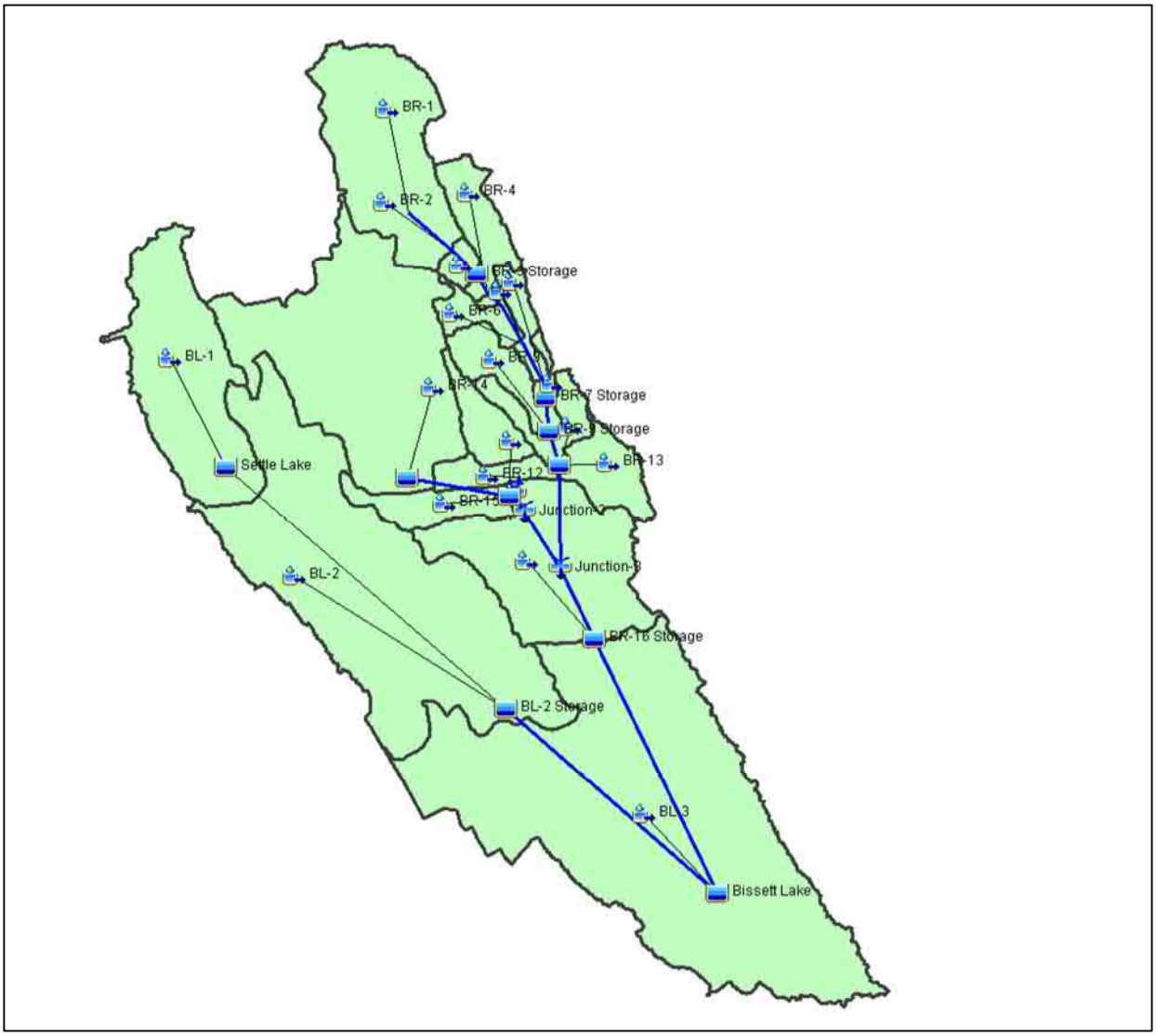


Figure 3-2: HEC-HMS Hydrologic Model Schematic showing subcatchments, storage, and reaches within the Bissett Lake Watershed

4.0 Results

The hydrologic and hydraulic modeling exercises discussed in the previous sections were completed for both upper and lower reaches of Bissett Run. The simulation was completed under base (existing) conditions and for several upgraded scenarios. The upgraded scenarios included consideration of the following upgrades, as requested by HRM:

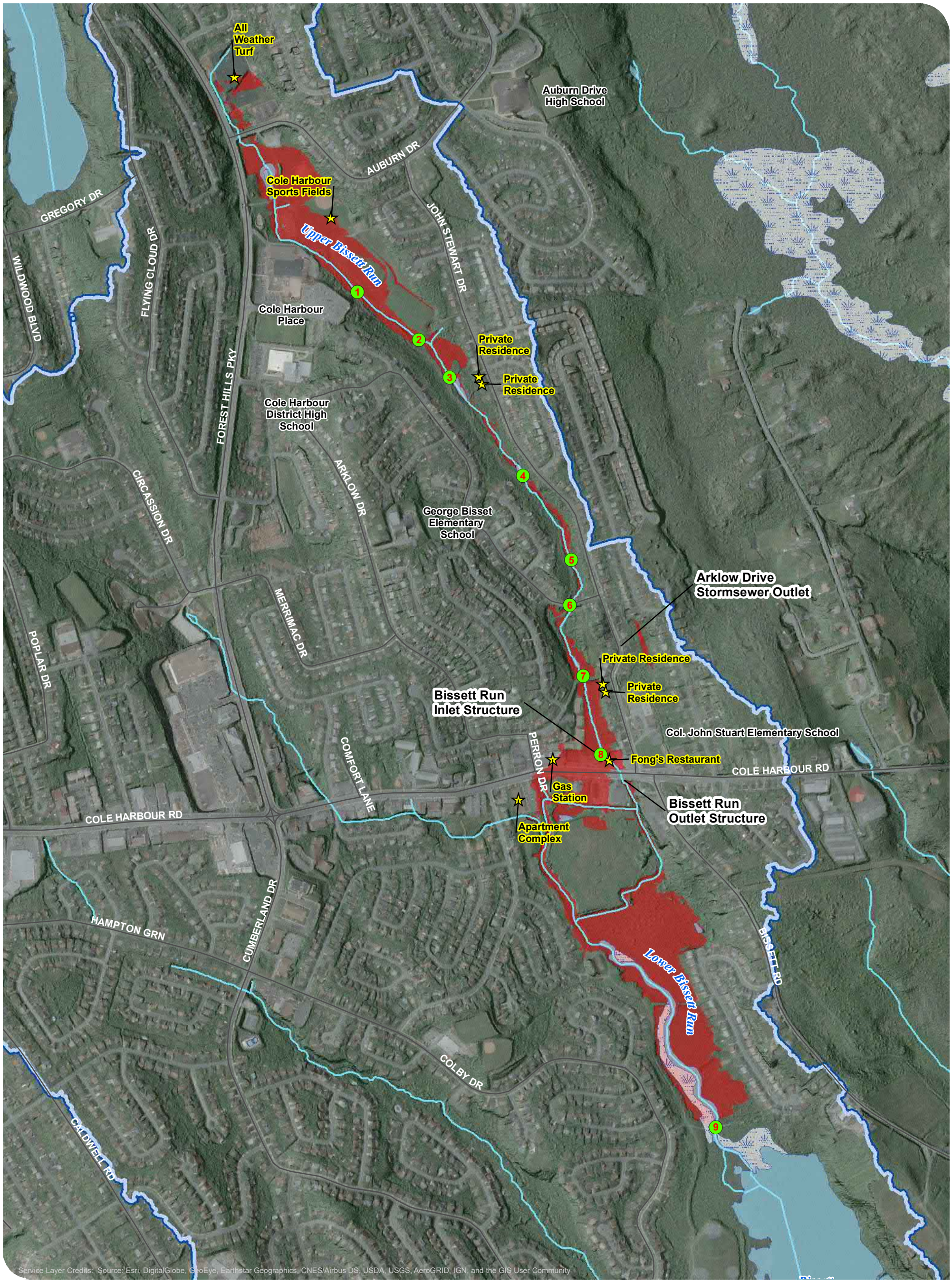
- Scenario #1: Diversion of stormwater runoff from Arklow Drive to Silistria Drive;
- Scenario #2: Outlet improvement near intersection of Arklow and John Stewart Drive;
- Scenario #3: Storm sewer upgrade across Cole Harbour Road to Lower Bissett Run; and
- Scenario #4: Detention pond with a trunk sewer located in the recreational area near Cole Harbour Place.

The scenarios and corresponding model results are discussed in the following sections. The simulations have been completed to evaluate the effectiveness of the above upgrades, and the incremental flood risk impact to reaches downstream of Cole Harbour Road as a result of these upgrades.

4.1 Existing Conditions

An existing conditions simulation has been completed to estimate hydraulic grade line (HGL) elevations along the study reaches. The following sections present HGL elevations for Upper and Lower Bissett Run which were selected based on the key assets inventory in the NDMP report and other significant locations. These simulation results, particularly along Lower Bissett Run, will form baseline conditions to evaluate the hydraulic impact of upstream conveyance and storage upgrades.

Figure 4-1 below and Table 4-1 presents the simulated maximum HGL elevations along Upper and Lower Bissett Run.



HALIFAX REGIONAL MUNICIPALITY
COLE HARBOUR MITIGATION STUDY

EXISTING CONDITIONS 100-YEAR RETURN PERIOD HGLS OF BISSETT RUN
FIGURE 4-1

Key Asset | Waterbody | Flood Extent | Bisset Lake Watershed
Structure | Wetland

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY HRM

MAP CREATED BY: JAB
MAP CHECKED BY: NO
MAP PROJECTION: NAD 1983 UTM Zone 20N

FILE LOCATION: X:\PROJECTS\DRAFT\GIS\Projects\191220_Cole_Harbour_Mitigation\data_maps\mxds\191220-Figure-2-1-SiteLocation.mxd

0 50 100 200 Metres
SCALE 1:9000

PROJECT: 19-1220 STATUS: DRAFT DATE: 2019/11/19

Table 4-1: Summary of Baseline Conditions Simulation Results

Location[1]	Simulated HGL Elevation for 2-year Event (m)	Simulated HGL Elevation for 25-year Event (m)	Simulated HGL Elevation for 100-year Event (m)
Structure #2	54.93	55.12	55.23
Arklow Drive Upgrade	43.27	43.36	43.39
Structure #7	35.98	36.04	36.08
Cole Harbour Road	35.36	35.43	35.46
Apartment Complex	32.49	32.85	32.99
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.06	34.35	34.49
Confluence of Eastern and Western Branches of Lower Bissett Run	32.35	32.56	32.70
Lower Bissett Run Pedestrian Bridge	32.33	32.57	32.71
Bissett Lake	32.19	32.39	32.51

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

The hydraulic conveyance capacity of Lower Bissett Run, obtained from the HEC-RAS model is illustrated in Figure 4-2, from the confluence of the eastern and western branches of Lower Bisset Run (south of Cole Harbour Road) to the pedestrian bridge (Structure #9). It is evident in Figure 4-2 that incremental increases in flow rate do not correspond to significant increases in the water surface elevation. This can be attributed to the relatively wide floodplain along Lower Bissett Run.

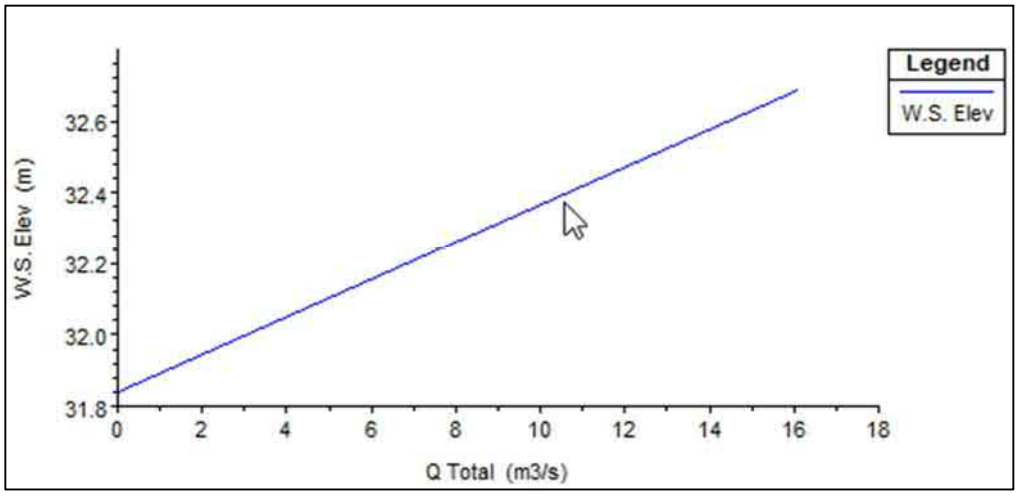


Figure 4-2: Rating Curve Illustrating the Hydraulic Conveyance Capacity of Lower Bissett Run

4.2 Scenario #1: Upper to Lower Bisset Run Diversion (Arklow Drive)

The proposed diversion from Arklow Drive to Silistria Drive includes diverting 0.019 km^2 (1.92 hectares) from subcatchment BR-11 to subcatchment BR-14 (shown in Figure 3-1), effectively diverting the runoff volume from Upper to Lower Bower Run. Due to the small scale of the diversion, there is no impact on Lower Bissett Run HGLs, which are presented in Table 4-2. This is in part due to the detention storage area located at the downstream end of BR-14, which is shown in Figure 4-3, however the reported storage elevation (49.5 m) and volume (13,600 m^3) is unchanged in the modified scenario during the 100-year return period event. Therefore, the diversion neither alleviates nor exacerbates HGLs elevations in Lower Bissett Run.

Table 4-2: Summary of Scenario #1 Simulation Results

Location[1]	Simulated HGL Elevation for 2-year Event (m)	Simulated HGL Elevation for 25-year Event (m)	Simulated HGL Elevation for 100-year Event (m)	100-year Difference from Baseline Conditions (m)
Structure #2	54.93	55.12	55.23	0.00
Arklow Drive Upgrade	43.27	43.36	43.39	0.00
Structure #7	35.98	36.04	36.08	0.00
Cole Harbour Road	35.36	35.43	35.46	0.00
Apartment Complex	32.49	32.85	32.99	0.00
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.06	34.35	34.49	0.00
Confluence of Eastern and Western Branches of Lower Bissett Run	32.35	32.56	32.69	-0.01
Lower Bissett Run Pedestrian Bridge	32.33	32.57	32.71	0.00
Bissett Lake	32.19	32.39	32.51	0.00

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

Figure 4-3: Detention Storage in Subcatchment BR-14 (Highlighted in Pink)

4.3 Scenario #2: Arklow Drive Storm Outfall Upgrade

The storm sewer outfall near the intersection of Arklow Drive and John Steward Drive was initially assessed for its capacity to convey the 10-year return period event as per the Halifax Water Design and Construction Specifications (Water, Wastewater, and Stormwater Systems). The outfall pipe was found to have the capacity to convey the design storm, the calculations for which are provided in Appendix B. The invert of the outfall pipe lies at an elevation of 42.74 m, whereas the existing 2-year HGL at that location is 43.27 m (provided in Table 4-2). Channel upgrades of Upper Bissett Run near the outfall location, which includes regrading the channel to a slope of 1.7%, having an elevation of 42.4 m near the outfall, and a minimum cross-sectional area of approximately 1.8 m^2 would address the inundated outfall. Downstream HGLs are unaffected by the channel regrading due to the hydraulic conveyance capacity of Structure #6, located just downstream of the outfall. Table 4-3 provides an overview of the study area for the channel upgrades scenario. Channel upgrades within Bissett Run would require regulatory permitting, which, at a minimum would include an application for a watercourse alteration permit through the Nova Scotia Department of Environment. If the area is deemed a wetland, habitat restoration efforts may be required. Additionally, if the channel is found to be fish bearing, a federal Fisheries Act Authorization application would be required. An analysis of the area indicates that species at risk are unlikely to be found, therefore, it is possible that the pertinent authorization may be obtained for channel modifications.

Table 4-3: Summary of Scenario #2 Simulation Results, Including Scenario #1

Location[1]	Simulated HGL Elevation for 2-year Event (m)	Simulated HGL Elevation for 25-year Event (m)	Simulated HGL Elevation for 100-year Event (m)	100-year Difference from Baseline Conditions (m)
Structure #2	54.93	55.12	55.23	0.00
Arklow Drive Upgrade	42.55	42.61	42.64	-0.75
Structure #7	35.98	36.04	36.08	0.00
Cole Harbour Road	35.36	35.43	35.46	0.00
Apartment Complex	32.49	32.86	32.99	0.00
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.06	34.35	34.49	0.00
Confluence of Eastern and Western Branches of Lower Bissett Run	32.35	32.57	32.69	-0.01
Lower Bissett Run Pedestrian Bridge	32.33	32.59	32.71	0.00
Bissett Lake	32.19	32.40	32.51	+0.01

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

4.4 Scenario #3: Cole Harbour Road Upgrades

The hydraulic model was used to simulate upgrades at the existing Cole Harbour Road Crossing near Fong's Restaurant. Two circular concrete culverts are the inlet of Upper Bisset Run which discharge under Cole Harbour Road (presented in Figure 4-4). The CCTV inspection report (Appendix A) confirms that one culvert is a 1200 mm. The culverts were inaccessible during the field visit due to fencing, therefore the second culvert was estimated to be 600 mm based on a visual inspection. These circular culverts discharge to a chamber under Cole Harbour Road, which ultimately discharge to a 1350 mm culvert to Lower Bissett Run. The Cole Harbour Road culverts were subsequently updated in the hydraulic model. The maximum culvert diameter given existing cover depth limitations is expected to be 1500 mm. The hydraulic simulation suggested that three 1500 mm diameter culverts was insufficient to reduce the upstream HGL to mitigate flooding in the area.

Given the hydraulic performance limitations of the circular pipe, a box culvert scenario was also considered. The existing crossing was upgraded to include twin 3.6 m x 1.5 m box culverts. With the twin box culverts the HGL elevation upstream of Cole Harbour Road is expected to be 34.6 m. This represents a decrease of 0.86 m below existing conditions. This significant reduction in HGL would benefit the residents immediately downstream from Structure 7 by providing a decrease of 0.52 m during the 100-year return period event. Based on the site survey, however, finished floor elevations of those residences are approximately 33.67 m, which puts those homes at risk of basement flooding during extreme precipitation events.

Figure 4-4: Culvert Inlets to Cole Harbour Road

Table 4-4: Summary of Scenario #3 Simulation Results

Location[1]	Simulated HGL Elevation for 2-year Event (m)	Simulated HGL Elevation for 25-year Event (m)	Simulated HGL Elevation for 100-year Event (m)	100-year Difference from Baseline Conditions (m)
Structure #2	54.93	55.12	55.23	0.00
Arklow Drive Upgrade	42.55	42.61	42.64	-0.75
Structure #7	35.98	36.04	36.08	0.00
Cole Harbour Road	35.36	35.45	34.60	-0.86
Apartment Complex	32.49	32.86	32.99	0.00
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.07	34.35	34.50	+0.01
Confluence of Eastern and Western Branches of Lower Bissett Run	32.35	32.57	32.70	0.00
Lower Bissett Run Pedestrian Bridge	32.33	32.59	32.72	+0.01
Bissett Lake	32.19	32.40	32.51	0.00

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

Survey data was additionally collected near the apartment complex identified in the NDMP report, through which the finished basement elevation was determined to be 32.7 m. During the 25-year return period event, there is a risk of basement flooding at the apartment complex. Flooding near John StewartDrive (near Structure #3) has additionally been reported in the past but was thought to be caused by beaver activity. Finished floor elevations in that area are estimated to be as low as 51.82 m, while the 100-year HGL is estimated to reach 53.45 m.

Figure 4-5 presents HGL elevations along Bissett Run with the combination of Scenarios #1, #2, and #3.

It is acknowledged that the existing pipe alignment is not ideal for a large box culvert installation. The box culvert installation along the existing alignment will be costly given the requirement of a large chamber to align the twin box culverts around Fong's Restaurant. The following options are recommended to establish a more suitable alignment:

- Explore the possibility of purchasing the properties at 13 and 6 John Stewart Drive to realign the existing stream, allowing for a straight run to Lower Bissett Run;
- Explore the possibility of purchasing the Fong's Restaurant property to avoid having to turn the new box culverts to align with Lower Bissett Run; and
- Establish a drainage Easement between Annapolis Pizza (1222 Cole Harbour Road) and the Cole Harbour Funeral Home (1234 Cole Harbor Road). The land between these two properties currently

consists of a gravel parking area; however, appears to be wide enough to accommodate the proposed twin box culverts. It is noted that re-alignment of Lower Bissett Run would be required to accommodate discharge from the box culverts.

For all options above the box culvert length exceeds 100 m. This length of culvert is expected to be extremely costly and efforts to shorten the required culvert run should be explored as part of detailed design once the preferred alignment has been selected.

4.5 Scenario #4: Cole Harbour Place Conveyance and Storage

Scenarios #1 to #3 have assumed that the existing level of available storage within the recreational areas is maintained. Based on the findings of Dillon (2015), elimination of this storage will require significant downstream conveyance upgrades to offset the increase in peak flow. HRM has expressed a desire to enclose the portion of Bissett Run from the existing enclosure behind Cole Harbour Place to Structure #2 (approximately 330 m).

The proposed drain enclosure is recommended to consist of a 1050 mm diameter pipe for the entire section. This is expected to provide an HGL within the top of pipe during the 100-year flood event. The existing drainage enclosure was verified in the field as 1050 mm in diameter, however, it is half full of standing water during dry conditions.

Under existing conditions, the outdoor recreational facilities (track, soccer and baseball fields) flood during intense rain. HRM would like to limit flooding in these areas by introducing stormwater detention within the area. The estimated storage volume currently provided in the sports fields during the 100-year event is estimated to be in the order of 16,000 m^3. The following low impact design (LID) options have been considered to offset this storage and mitigate flooding of the fields.

All Weather Turf
Auburn Drive High School
AUBURN DR
Cole Harbour Sports Fields
GREGORY DR
Upper Bissett Run
JOHN STEWART DR
WILDWOOD BLVD
FLYING CLOUD DR
FOREST HILLS PKY
Cole Harbour Place
Private Residence
Private Residence
Cole Harbour District High School
ARKLOW DR
CIRCASSION DR
George Bisset Elementary School
Arklow Drive Stormsewer Outlet
MERRIMAC DR
POPLAR DR
Private Residence
Private Residence
Bissett Run Inlet Structure
Col. John Stuart Elementary School
COMFORT LANE
PERRON DR
Fong's Restaurant
COLE HARBOUR RD
OTAGO DR
Gas Station
Bissett Run Outlet Structure
COLE HARBOUR RD
Apartment Complex
HAMPTON GRN
CUMBERLAND DR
BISSETT RD
Lower Bissett Run
COLBY DR
CALDWELL RD
1
2
3
4
5
6
7
8
9

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

HALIFAX REGIONAL MUNICIPALITY
COLE HARBOUR MITIGATION STUDY

PROPOSED CONDITIONS 100-YEAR RETURN PERIOD HGLS OF BISSETT RUN
FIGURE 4-5

Key Asset | Waterbody | Flood Extent | Bisset Lake Watershed
Structure | Wetland

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY HRM

MAP CREATED BY: JAB
MAP CHECKED BY: NO
MAP PROJECTION: NAD 1983 UTM Zone 20N

FILE LOCATION: X:\PROJECTS\DRAFT\GIS\Projects\191220_Cole_Harbour_Mitigation\data_maps\mxds\191220-Figure-2-1-SiteLocation.mxd

0 50 100 200 Metres
SCALE 1:9000
N W E S

PROJECT: 19-1220 STATUS: DRAFT DATE: 2019/11/19

Underground Detention Chambers

Underground HDPE chambers would be an effective means to offset storage in the sports fields, an example of which is provided in Figure 4-6. These chambers are installed over a bedding of clear stone and are typically opened bottom allowing for infiltration into underlying soils. Additional storage is also available in the pore spaces of the stone bedding beneath the chambers. While effective, these chambers are relatively costly compared to open storage/infiltration methods. However, they would allow continued use of the entire outdoor recreational area.

Figure 4-6: Example of HDPE Detention Chambers (https://www.conteches.com)

The existing soccer field is expected to be a suitable location for underground chambers. The existing field could be reinstated after installation of the chambers. The current footprint of the soccer field is estimated to be in the order of 8400 m^2. Based on experience on other sites, a maximum storage volume of approximately 10,000 m^3 is achievable. This volume may vary depending on the chamber type/manufacturer and bury depth of the chambers.

It is recommended that the proposed drain enclosure discharge directly to Structure #2 under typical flow conditions. However, during high flows will be routed through the underground storage chambers. This can be achieved using a staged outlet at the outfall of the drain enclosure. This option would reduce peak flows from the area by attenuating discharge from the upstream drainage area (i.e. maintain higher than average discharge rates for a longer period of time).

Infiltration Basin Upstream of Structure #2

Given that the underground storage network is expected to be costly, another alternative would be to construct an open infiltration pond/basin upstream of Structure #2. This option would likely require the elimination of the existing southern soccer field. While this is not desirable, there are no other suitable lands for a detention facility in the order of 16,000 m^3 (e.g. 90 m x 90 m with 2 m average depth). Other

configurations could be considered as part of detailed design of the storage facility. The wooded areas to the northeast and southwest of the field are not suitable due to the steep slopes.

Expansion of Existing Pond North of Cole Harbour Place

A small pond exists north of Cole Harbour Place. The wooded area surrounding the pond is bound by Forest Hills Parkway and Auburn Drive and has a total surface area in the order of 12,000 m^2. Provided these lands can be acquired, a storage facility in this location could provide storage in excess of 16,000 m^3. However, the proposed pond would be located approximately 500 m upstream and has roughly half the contributing drainage area compared to the sports fields immediately upstream of Structure #2. This severely limits the ability of this area to balance peak flows to the reaches downstream of Structure #2. Based on the modelling completed in this study, upgrades to this area would not be sufficient to offset the storage currently provided in the sports fields.

Based on the above options considered, the underground storage chambers are expected to meet HRMs objectives while mitigating flooding of the outdoor recreational areas. It is noteworthy that the underground storage may not be adequate to provide the full 16,000 m^3 required to offset existing storage; this should be considered further during detailed design.

A lower level of service may be acceptable for the sports fields based on a comparison with other location throughout Canada. For example, if the maximum underground storage available is in the order of 10,000 m^3, this would correspond to a return period of 10 years before flooding of the fields would be expected. In many municipalities, flooding of outdoor recreational spaces is acceptable during intense rainfall (e.g. > 10-25 year event). An example of this is the Ranchlands Boulevard multi-use outdoor recreational facility located in the City of Calgary which was designed specifically to provide temporary stormwater detention during intense rainfall.

A proposed schematic for the drain enclosure and storage footprint is presented in Figure 4-7.

HALIFAX REGIONAL MUNICIPALITY
COLE HARBOUR MITIGATION STUDY

PROPOSED SCHEMATIC FOR DRAIN ENCLOSURE AND STORAGE FOOTPRINT
FIGURE 4-7

Existing Piped Section
Potential Storage
Watercourse
Proposed Drainage Enclosure
Waterbody

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY HRM

MAP CREATED BY: JAB
MAP CHECKED BY: NO
MAP PROJECTION: NAD 1983 UTM Zone 20N

FILE LOCATION: \\54dillon\DATA\PROJECTS\DRAFT\GIS\Projects\191220_Cole_Harbour_Mitigation\data_maps\mxds\191220-Figure-4-4-ProposedDrainage.mxd

0 25 50 100 Metres
SCALE 1:4000

PROJECT: 19-1220
STATUS: DRAFT
DATE: 2019/09/26

5.0 Climate Change Sensitivity Analysis

As per HRM's request, climate change scenarios have been developed through a 16% increase for applied uniformly across the entire rainfall event. The 100-year return period event will be used to carry out a sensitivity analysis for the existing and proposed HGL elevations, which area summarized in Tables 5-1 and 5-2. Proposed conditions considered in this assessment include the implementation of all three of the scenarios #1 (Arklow Drive diversion), #2 (Arklow Drive outlet upgrade), and #3 (installation of dual 3.6 m by 1.5 m box culverts.

Table 5-1: Summary of Climate Change Impacts under Existing Conditions

Location[1]	Simulated HGL Elevation for Historical 100-year Event	Simulated HGL Elevation for 100-year Event Including Climate Change	Increase (m)
Structure #2	55.23	55.30	+0.07
Arklow Drive Upgrade	43.39	43.42	+0.03
Structure #7	36.08	36.10	+0.02
Cole Harbour Road	35.46	35.49	+0.03
Apartment Complex	32.99	33.08	+0.09
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.49	34.58	+0.09
Confluence of Eastern and Western Branches of Lower Bissett Run	32.70	32.74	+0.04
Lower Bissett Run Pedestrian Bridge	32.71	32.77	+0.06
Bissett Lake	32.51	32.61	+0.10

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

Table 5-2: Summary of Climate Change Impacts under Proposed Upgraded Conditions, Including Cole Harbour Road Upgrades

Location[1]	Simulated HGL Elevation for Historical 100-year Event	Simulated HGL Elevation for 100-year Event Including Climate Change	Increase (m)
Structure #2	55.23	55.30	+0.07
Arklow Drive Upgrade	42.64	42.66	+0.02
Structure #7	36.08	36.10	+0.02
Cole Harbour Road	34.60	34.80	+0.20
Apartment Complex	32.99	33.09	+0.10
Immediately Downstream of Cole Harbour Road Culvert Outlets	34.50	34.59	+0.09
Confluence of Eastern and Western Branches of Lower Bissett Run	32.70	32.76	+0.06
Lower Bissett Run Pedestrian Bridge	32.72	32.79	+0.07
Bissett Lake	32.51	32.61	+0.10

[1]HGL elevations are reported on the upstream side of each structure/roadway unless otherwise noted

Tables 5-1 and 5-2 indicate that the expected result of climate change is minimal and ranges from 0.02 m to 0.10 m for existing conditions and 0.02 m to 0.20 m under proposed conditions. The effects of climate change will not result in the overtopping of the proposed upgrades at Cole Harbour Road. The proposed twin box culverts are capable of conveying the anticipated increased discharge rates as a result of climate change.

6.0 Conclusions and Recommendations

Based on the findings of the hydrological and hydraulic assessment of Bisset Run, the following conclusions can be made:

- The Arklow Drive diversion (Scenario #1) causes no downstream impacts in Lower Bissett Run and is therefore an option if the HRM chooses to move forward with this modification;
- The Arklow Drive storm sewer upgrade (Scenario #2) is unnecessary since the outlet is adequately sized to convey the minor system runoff amounts (i.e. 10-year return period event). High tailwater conditions in the area are resulting in the outlet being submerged for the 2- to 100-year events, and is expected to restrict the outlet capacity of the up-gradient sewer system. Channel upgrades would allow the outlet to discharge freely and limit backwater influences on the upstream sewer system. These channel upgrades should provide a minimum cross-sectional area of approximately 1.8 m^2;
- The dual culverts and chamber conveying stormwater under Cole Harbour Road are undersized and are resulting in high HGL elevations north of Cole Harbour Road. It is therefore recommended that

they be replaced with twin 3.6 m by 1.5 m concrete box culverts. This will reduce the upstream HGL by 0.86 m near Fong's restaurant;

- Residents downstream of Structure #7 along John Stewart Drive would benefit from the proposed twin culvert upgrade at Cole Harbour Road due to the reduction of 0.52 m in HGL during the 100-year event;
- The existing concrete chamber (Structure #7) upstream of Cole Harbour Road should be reconfigured to limit surcharging in the area and overtopping of the path. Associated reductions in floodplain storage will need to be accounted for in the design of the Cole Harbour Road crossing.
- Resident's located upstream of Cole Harbour Road and downstream of Structure #7 with finished floor elevations below 34.6 m may be at risk of flooding;
- The apartment complex (identified in the NDMP report) is at risk of flooding during the 25-year and higher events;
- Storage measures are required upstream of Structure #2 if the HRM would like to avoid the Cole Harbour Place fields from flooding. Expansion of the existing upstream storage is not a valid option as it will not be capable of capturing the require runoff volume to mitigate flooding. An infiltration basin upstream of Structure #2 can be installed; however, this will result in the loss on the lower soccer field due topographical restrictions to the west of the pedestrian crossing. Underground detention chambers under the lower soccer field would allow for the continued use of the field, although the level of service of this LID measure is estimated to be limited to a 10-year return period runoff and may be cost prohibitive;
- None of the presented upgrade scenarios significantly impact Lower Bissett Run at key locations, which is illustrated in Tables 4-1 to 4-4;
- Upgrade phasing should proceed from downstream to upstream. Therefore, the proposed twin box culvert upgrades under Cole Harbour Road should be initially carried out. The other upgrade scenarios were found to have no discernable effect on Lower Bissett Run and can be carried out after the Cole Harbour Road Upgrades at the HRM's discretion.

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Ponce, V.M., 1989. *Engineering Hydrology: Principles and Practices.*

Appendix A

Atlantic Industrial Cleaners Survey Report

C.C.T.V.
Inspection Report

For
H.R.M.

Of
Storm Systems

On
Cole Harbour Road @Fongs

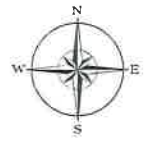
February 15th , 2008

Completed by:
Chris M. Longaphy

Atlantic Industrial Cleaners
Video Inspection Services

HALIFAX
REGIONAL MUNICIPALITY

1241 Cole Harbour Rd



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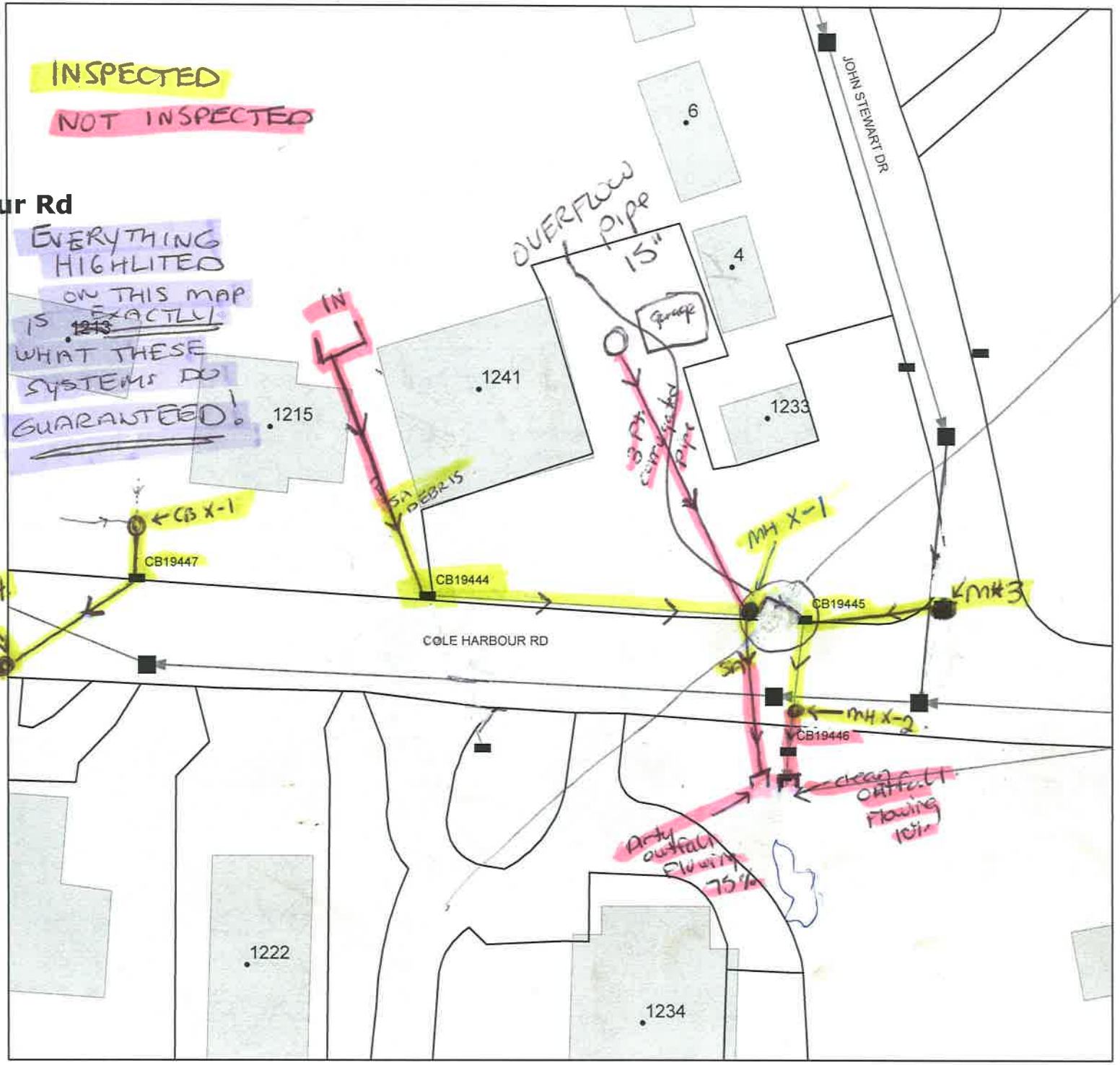
User: N. D. Belliveau

Print Date: Feb 1, 2008



Appendix B

Arklow Drive Outfall Capacity Calculations

Table 1: Time of Concentration (t_c) Calculation.

Section	Flow Length (m)	Upstream Elevation (m)	Downstream Elevation (m)	Slope (m/m)	Pipe Size (mm)	Material	n	Method	Hydraulic Radius (m)	Velocity (m/s)	t_c (min)
Overland	125	59.26	50.60	0.069							5.21
Pipe 1	69.0	47.16	45.86	0.019	375	Concrete	0.013	Manning's	0.094	2.18	0.53
Pipe 2	63.2	45.86	44.77	0.017	375	Concrete	0.013	Manning's	0.094	2.08	0.51
Pipe 3	71.9	44.77	43.90	0.012	375	Concrete	0.013	Manning's	0.094	1.75	0.69
Pipe 4	49.2	43.90	43.11	0.016	375	Concrete	0.013	Manning's	0.094	2.01	0.41
Total Time of Concentration (min)											**7.33**

Table 2: Calculation of 10-year flow using the Rational Method

Parameter	Value	Source
Runoff coefficient, C	0.5	Calculated based on land use
Intensity, i (mm/h)	86.67	IDF for Shearwater t_c = 7.33 minutes
Area, A (ha)	1.165	Calculated in ArcGIS
10-year design flow, Q (m^3/s)	0.140	

Table 3: Calculation of maximum pipe flow using Manning's equation for 375mm PVC pipe

Parameter	Value	Source
Flow area, A (m^2)	0.110	Calculated assuming full pipe
Wetted perimeter, P (m)	1.18	Calculated assuming full pipe
Hydraulic radius, R (m)	0.0937	Calculated from full pipe area and wetted perimeter assuming pipe full
Slope of pipe, S (m/m)	0.0111	Calculated using pipe specs from Halifax Water GIS data
Q (m^3/s)	0.239	

Attachment D

Item No: 12.2.2
Regional Council January 29, 2019

Petition Information

The following information outlines the purpose of the petition.

Title:	Flooding, property damage and loss of property John Stewart Dr and Arklow Dr Cole Harbour also a safety issue for children playing
Purpose:	To stop the excess runoff from the waterway between John Stewart Dr and Arklow Dr. that is running up onto peoples back yards causing erosion and property damage to building, fences and the fact that these residents cannot utilize the property they are paying taxes for. Water flows from Cole Harbour Place through to other side of Cole Harbour rd
Remedy Sought:	Conduct a study to see if the drains at Cole harbour road are sufficient for the water flow, review the water problems and solve this ongoing problem for the residents of John Stewart Dr and Arklow dr. Clean drains at Cole Harbour Road more frequently to help the water flow Clean debris and blockages in the waterway to improve water flow Review water damage done to residents by this ongoing problem
Start Date:	

Organizer Information

Information that uniquely identifies the petition organizer(s).

Full Name(s):	Sandra Mills
Civic Address(es):	16 John Stewart Dr Dartmouth NS B2W4J8
Phone or Email:	[redacted] or [redacted] email to [redacted]

41 signatures

A petition is deemed to be public information including the names and addresses of those signing.		
Name	Civic Address	Signature
Lynda Ledaire	5A Arklow Dr.	[redacted]
Allan Ledaire	5A ARKLOW Dr	
[illegible]	5C Arklow Dr	
[illegible]	5D Arklow Dr.	
[illegible]	7 Arklow	
[illegible]	5E Arklow	
FELIX FUNG	1D PERRON DR	
[illegible]	1A Perron Dr	
[illegible]	11H Arklow Dr.	
[illegible]	11H ARKLOW	
[illegible]	11 Arklow DR	
[illegible]	11E Arklow Dr	
Bryce Porter	9A Arklow Dr	
[illegible]	3D Arklow Dr.	
[illegible]	3B Arklow Dr	
[illegible]	1C Arklow Dr	
Corinne McLeod	1-B Arklow Dr	
KEN NICKERSON	1A ARKLOW DR.	
Marilee Duff Nickerson	1A Arklow Drive	
Marcia Olsen	5E Arklow Dr.	
Dawn Ripley	5B Arklow Dr.	
Danielle Budnicki	9B Arklow Dr.	
[illegible]	7C Arklow Dr.	
DONALD BAKER	1B PERRON DR	
Donnie Baker	1-B Perron Drive	