6.0 SURFACE WATER MANAGEMENT STRATEGY

The Surface Water Management Strategy comprises three main parts: Carp River Floodplain management; overland flow/cross drainage features; and, Shirley's Brook Realignment. The management strategies for each part have been developed to satisfy the study goals and objectives and mitigate potential impacts identified by the performance targets set in Section 1.3. The strategy recommends drainage structures, drainage features, and floodplain compensation. Each feature has been designed to meet or exceed performance targets.

Overland ditch design, and location and sizing of cross culverts are based on the maintenance of existing major (overland) flow routes. These design features address the need to maintain macroscopic drainage patterns for the various drainage areas associated with Terry Fox Drive. Required overland drainage cross culverts are necessary if the construction of Terry Fox Drive progresses independently of adjacent development. Associated issues pertaining to development, lot grading, stream realignment, and interceptor ditch configuration may dictate the need to update crossing locations as the detailed design progresses. The following subsections describe the surface water management strategy for the two main watercourses found in the Study Area, as well as the management of smaller natural drainage features and overland flow.

6.1 Carp River Floodplain Impacts

6.1.1 Summary of Carp River Floodplain Analysis from 2007 Preliminary Design

During the Preliminary Design stage completed in July 2007, the encroachment on the floodplain by the Terry Fox Drive project was calculated to be approximately 45,000 m^3. The volume calculation was based on modelled flood water elevations provided by MVCA. Based on HEC-RAS modelling the encroachment raised water levels very marginally (i.e. by 1 cm) at only two of the modeled cross-sections. Despite this minimal impact on flood-levels, it was recognized that a displacement of flood storage can adversely affect design flow rates in downstream reaches of a system due to a reduction in flow attenuation capacity. Therefore, a compensation plan was developed at a conceptual level to compensate for lost storage volumes at corresponding elevations. The compensation plan proposed in the 2007 PDR consisted of a large cut just north of the project area. **Figure 14** shows the conceptual compensation plan included in the 2007 Draft Stormwater Management Plan.

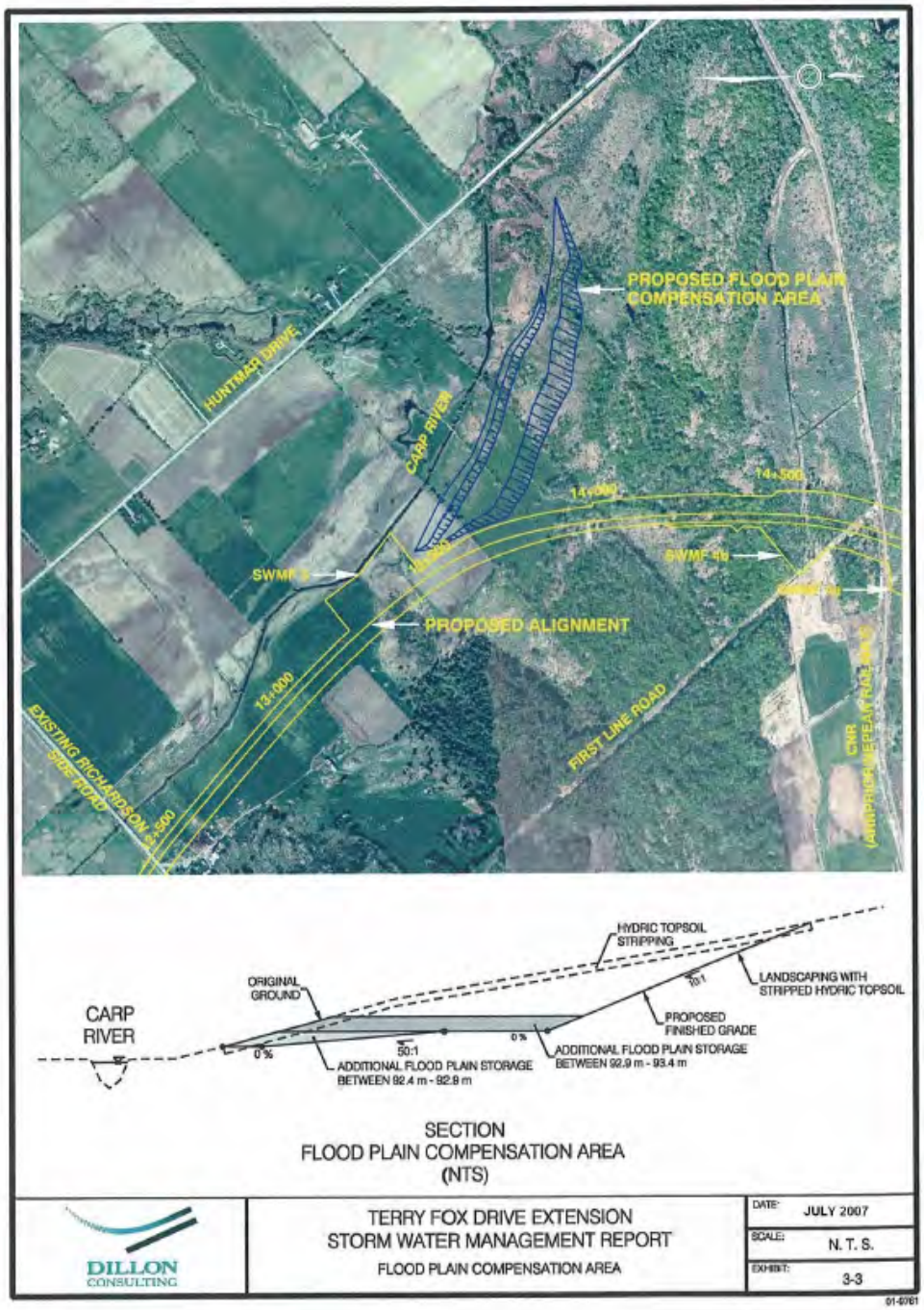


Figure 14: Floodplain Compensation Conceptual Plan Provided in 2007 Preliminary Design Report

6.1.2 Summary of Planning and Development Issues in Carp River Floodplain

A number of suburban developments have been planned in the Carp River watershed, upstream of the Terry Fox Drive Study Area. These developments will result in a re-definition of the Regulatory floodplain. The rationale for allowing development to proceed was based in part on the Carp River Restoration Plan (CRRP), developed to rehabilitate the Carp River from the impacts of development and agriculture. The CRRP was a component of the Carp River Watershed/Subwatershed Study prepared by Robinson Consultants in 2004. Since the Subwatershed Study area included the Carp River watershed upstream of Richardson Side Road, it did not extend into the Terry Fox Drive Study Area.

The Carp River Restoration Plan includes a plan to construct a low flow channel with meander bends and other naturalized features designed to improve the degraded channel and habitat. The Carp River is surrounded by farm land and is located in silty clay plain. The high sediment load and low gradient channel has resulted in artificial and natural widening and straightening of the river over time. The plan to re-establish a low-flow channel in the river includes the addition of a fish habitat pond in the floodplain area. The Carp River Restoration Plan overlaps with the Terry Fox Drive project area for approximately 700 m near Richardson Side Road.

In 2007 and 2008, a number of issues were raised with respect to the Carp River Restoration Plan, including the validity of the two-zone floodplain policy as it applies to the Carp River floodplain, the hydrologic and hydraulic models used to support the plan and other planning decisions and environmental assessment rulings in the watershed. The models and policy were reviewed by Greenland Consulting Engineers who were retained by the City of Ottawa. The exercise reviewed a number of hydrologic models and hydraulic models including:

- CHM2Hill HEC-RAS Carp River existing conditions 2005 and revised 2008; and
- Totten Sims Hubicki (TSH) HEC-RAS Carp River restoration project 2006.

The review was completed in the spring of 2009 and identified necessary revisions to the models. Dillon obtained a copy of the revised model incorporating revisions from the Third Party Review in April 2009. The revised model predicted higher floodplain elevations in the vicinity of the Terry Fox Drive Study Area.

The results of the Third Party Review highlighted the uncertainty in the modeling of the most upstream reaches of the Carp River watershed. The uncertainty was related to the modeling of bedrock in the headwaters, which could either have a high infiltration capacity due to weathering and fractures, or a very low infiltration capacity based on the traditional understanding of runoff from bedrock. The Third Party ran the model at the two limits of the uncertainty, the best and worst case scenarios. The results indicate that under high infiltration conditions, the Carp River floodplain will have sufficient capacity to accommodate flows from the development as planned now. Under high runoff/low infiltration conditions, the floodplain will require another 85 000 m^3 of storage. Until the model can be refined with monitored data, the City has required development in Kanata West, upstream of the Terry Fox Drive Study Area, to provide an extra 125 m^3/ha of storage to account for the potential shortage of storage. Once the models are calibrated and development in Kanata West is complete, the updated regulatory floodplain of the Carp River will be modeled and

mapped. The current regulatory flood-line based on previous modeling and design flood levels date back to 1985.

The Auditor General concluded that the two-zone flood plain management approach, as applied to the Carp River upstream of Richardson Side Road, is not in keeping with the intent of the Provincial Policy Statement. However, the Third Party Review concluded the opposite. Currently, the City's Official Plan includes a policy allowing the City to request MVCA or MNR to consider defining the flood plain as two distinct zones. According to the policy, where the two-zone approach is applied, development may be considered in the flood fringe, subject to review by the City and MVCA.

6.1.3 Floodplain Compensation Approach

Flow through a natural watercourse system can be characterized based on the watercourse's ability to convey and store flood flows. The conveyance capacity of a watercourse is characterized by the size and configuration of its channel and floodplain and may be limited by the size and type of hydraulic structures (bridges and culverts) throughout the system. The storage capacity of a watercourse system is characterized by the size and configuration of its floodplain, as well as the relative depth or stage at which flood waters can access it.

Floodplain plays an important role in both the conveyance capacity and storage capacity of a natural watercourse system. As floodwaters rise in the watercourse system, the size and shape of its floodplain allows the system to convey much greater flow based on a larger cross-sectional area. In instances where other restrictions exist, such as limited floodplain width or restrictive hydraulic structures, floodplain provides storage of runoff and attenuates peak flows, therefore limiting potential downstream adverse effects on public and private property and public safety.

The construction of the Terry Fox Drive road embankment from south of Richardson Side Road, north to the 'saddle' area, directly impacts the Carp River floodplain. During Preliminary Design (completed July 2007), the Carp River floodplain encroachment was assessed both in terms of its impact on conveyance capacity and resultant floodwater depths and the physical displacement of floodplain storage. Based on model and floodwater elevation information provided by MVCA, the proposed encroachment raised water levels by approximately 1.0cm, resulting in the displacement of approximately 45,000 m^3 of floodplain storage. Despite this minimal impact on flood levels, it was recognized that a displacement of flood storage, even at the edges of the floodplain area, can adversely affect the peak flow due to a reduction in flow attenuation capacity.

Floodplain management guidance was provided by the MVCA during Preliminary Design phase. MVCA identified the following general requirements for Terry Fox Drive within the Carp River Floodplain:

- The road surface must be above the 100-year floodplain elevation to ensure appropriate flood proofing;
- The loss of floodplain storage due to the roadway footprint will be compared to additional floodplain storage created from the construction of any stormwater management and required fish habitat compensation works. Local grading that creates additional storage can be used to compensate for any residual loss of flood plain storage; and

- The cross culvert near Sta 13+400 must remain to allow the existing backwater floodplain storage to remain upstream of the road.

Although the Preliminary Design Report (SWM Report) noted several options for floodplain compensation, the final determination of impacted floodplain volume and required compensation was left to Detailed Design. The following section summarizes the impact assessment and a number of potential options for floodplain compensation measures.

6.1.4 Floodplain Impact Assessment

Several minor revisions have been made to the design of the Terry Fox Drive roadway embankment through the floodplain area as a result of geotechnical and geometric design considerations during Detailed Design. To minimize preloading requirements for the consolidation of sensitive soils within the Carp River floodplain area, adjustments have been made to the profile of the road and the side-slopes of the roadway embankment. The final Detailed Design profile and typical sections were presented to stakeholders at the Terry Fox Drive Public Open House on June 22, 2009. The profile presents a saw-tooth configuration along the Carp River floodplain section that allows for the collection and discharge of stormwater along short sections of the road. The revised design allows the profile of the road to be lowered considerably, thereby reducing the height of fill placement on sensitive soils and overall floodplain impact.

Consistent with the Preliminary Design approach, the approach to the impact assessment and compensation planning has been to assess impact and corresponding compensation on a volumetric basis. This approach was previously approved by the MVCA and is consistent with the approach taken on other projects within the Carp River watershed.

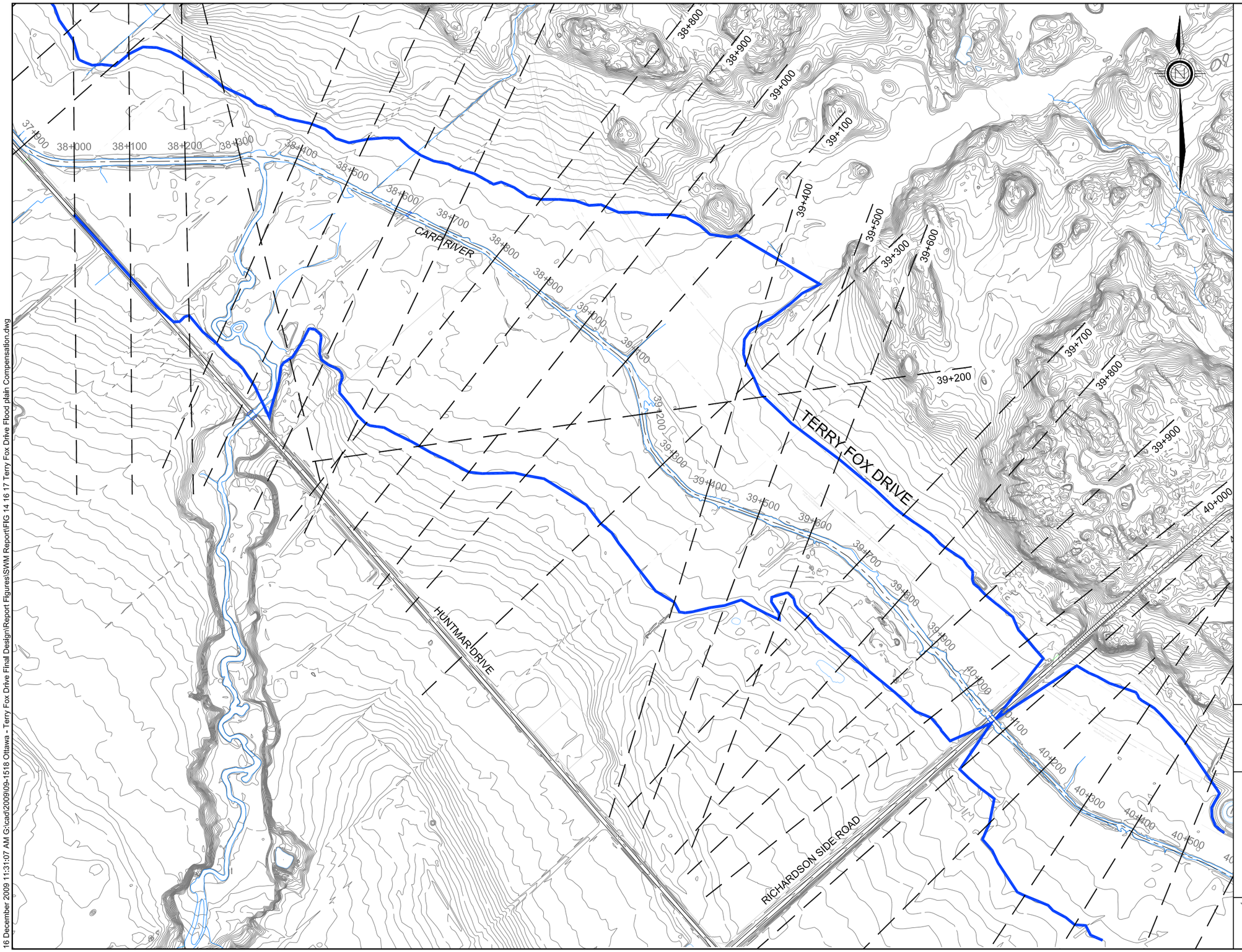
The general approach to mitigate the impact of floodplain displacement of the volume displaced within certain elevation bands is to compensate for the loss within the same elevation range. For example, 1,000 m^3 of volume displaced between 92.75 and 93.00 m.a.s.l. should be compensated for by excavation of 1,000 m^3 within the same 0.25 m elevation band. There are several different methods used in this approach. The most direct method to provide floodplain compensation is to achieve the compensation at the same cross-section of the river as the displacement occurs. The second method uses a similar approach, providing volumetric compensation at the appropriate elevation, not at the same cross-section but still within the same river reach as the displacement is caused. Both of these approaches have technical merit and were considered for the following options.

6.1.4.1 Regulatory Flood-Line Mapping

The regulatory flood-line mapping for the Carp River has been the subject of much debate over the past several years. Recognizing the technical and political complexities surrounding the Carp River, the Carp River Restoration Plan, and the Third Party Review, the MVCA was again contacted to provide guidance on hydraulic modeling of the Carp River and appropriate floodwater elevations within this section of the Carp River. Based on personal correspondence with John Price (Watershed Management Coordinator), the MVCA has directed Dillon to use the regulatory flood mapping from 1985 and increase the flood levels to reflect the revisions made during the modeling revisions and Third Party Review of the Carp river hydraulic and hydrologic models. This results in

a floodplain with an elevation of 93.40 m through the reach impacted by Terry Fox Drive. To account for a potential increase in elevations as a result of future development, we have assumed a 100yr flood level of 93.5 m through this 1,500 m reach of the Carp River for the purposes of impact analysis. The magnitude of the likely increase to the floodplain elevation was deemed to be acceptable although refined modelling to reflect future impacts is not currently available (Greenland Consulting Ltd. and J. Price Personal Communication).

Figure 15 illustrates the location of Terry Fox Drive relative to the location of the Carp River and the 100yr flood-line. **Figure 15** also shows the Carp River river-station IDs through the Study Area.



LEGEND:

ESTIMATED CARP RIVER FLOODPLAIN (93.5m)

39+500 HEC-RAS CROSS SECTION ID

FIGURE 15

CARP RIVER FLOODPLAIN
HEC-RAC SECTIONS

TERRY FOX DRIVE EXTENSION

RICHARDSON SIDE ROAD
TO SECOND LINE ROAD
STORMWATER MANAGEMENT
REPORT

DILLON CONSULTING

DATE: DECEMBER 2009

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09-1518

16 December 2009 11:31:07 AM G:\cad\2009\09-1518 Ottawa - Terry Fox Drive Final Design\Report Figures\SWM Report\FIG 14 16 17 Terry Fox Drive Flood plain Compensation.dwg

6.1.4.2 Volumetric Impacts

The volume of encroachment was calculated by projecting the 100-year water elevation of 93.5 from the center-line of the existing Carp River Channel onto the adjacent topography of the east and west banks of the watercourse. The hydraulic gradient of the Carp River included in the existing conditions model provided by Greenland Consulting Engineers indicates a negligible lowering of the water surface elevation at the downstream end of the floodplain encroachment. For the Detailed Design of Terry Fox Drive, the road embankment was modeled in AutoDesk Civil3D utilizing the ultimate 4-lane road cross-section and 4:1 embankment side-slopes projected onto the original ground surface. The volume of storage lost was calculated using cross-sections spaced every 100m along the center-line of the existing Carp River channel through the area of encroachment.

Figure 16 schematically illustrates a typical section from the proposed Terry Fox Drive roadway embankment located within the Carp River floodplain. The typical section shows the elevation bands used to define the displaced floodplain volume as it relates to the water surface elevation and the existing ground surface.

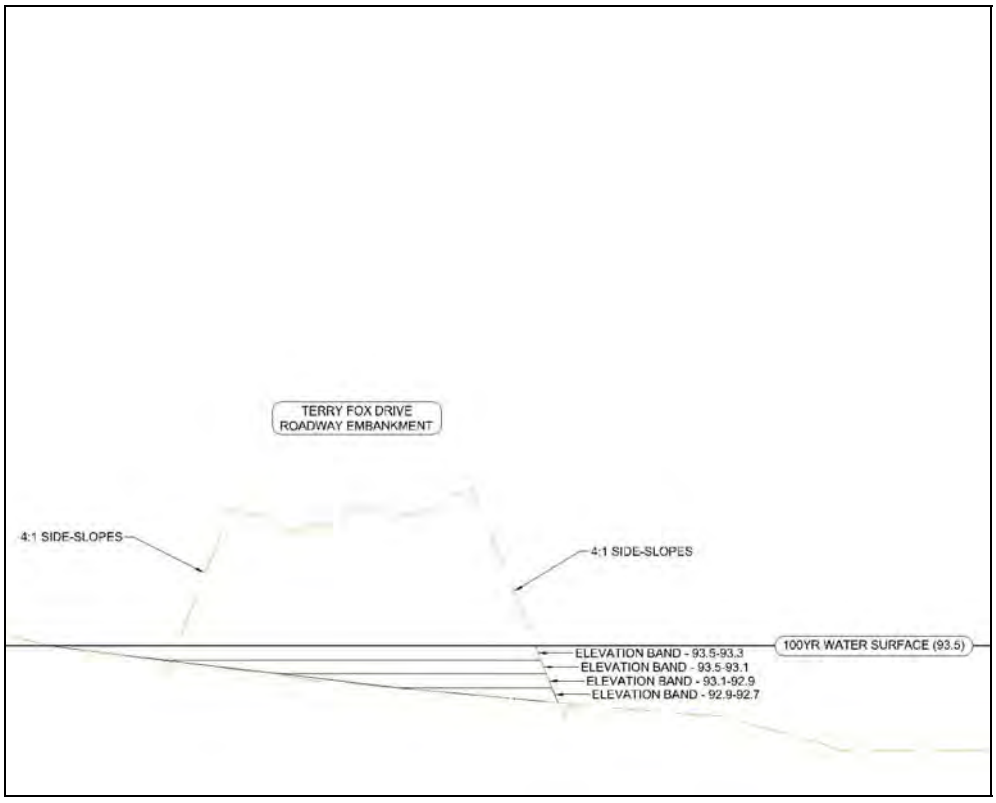
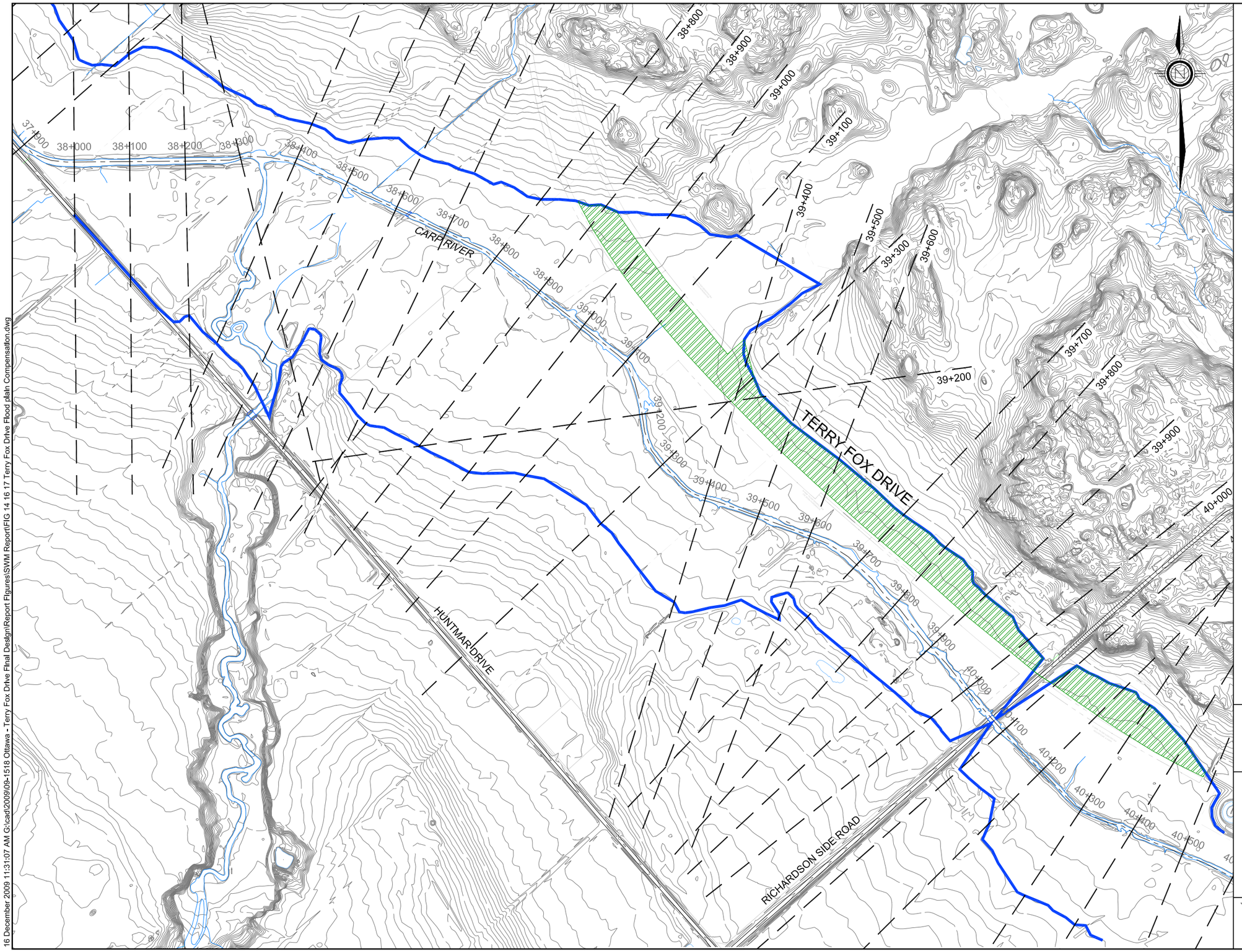


Figure 16: Terry Fox Drive Typical Section within Floodplain Area (includes vertical exaggeration)

Figure 17 illustrates the spatial extents of the floodplain displacement resulting from the construction of the Terry Fox Drive roadway embankment. The area of encroachment starts at approximately Sta 12+100 and extends to approximately Sta 13+600 (Terry Fox Drive). **Figure 17** also illustrates the area of maintained floodplain on the 'inside' of Terry Fox Drive. Access to this area by Carp River floodwaters will be maintained via backflow through a proposed culvert structure located near Sta 13+350 and therefore has not been included in the calculation of lost floodplain storage.



LEGEND:

- FLOODPLAIN DISPLACEMENT
- ESTIMATED CARP RIVER FLOODPLAIN (93.5m)
- 39+500 HEC-RAS CROSS SECTION ID

FIGURE 17
TERRY FOX DRIVE FLOODPLAIN ENCROACHMENT AREA

TERRY FOX DRIVE EXTENSION
RICHARDSON SIDE ROAD
TO SECOND LINE ROAD
STORMWATER MANAGEMENT REPORT

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The following data (**Table 7** and **Table 8)** provide the volumetric displacement of floodplain volume, both in an incremental elevation basis and on a stream section basis.

Table 7: Summary of Displacement Volumes

Elevation Range (m)	Displacement volume (m3)	Percent of Total Displaced Volume
93.5-93.3	14,437.14	34%
93.3-93.1	11,748.05	28%
93.1-92.9	8,007	19%
92.9-92.7	4,132.94	10%
92.7-92.5	2,664.18	6%
92.5-92.3	1,418.28	3%
92.3-92.1	91.33	2%

Table 8: Summary of Displacement Volumes between Cross-sections

Cross-Section Station	Incremental Displacement Volume (m3)	Percent of Total Displaced Volume
38+800	0	0%
38+900	0	0%
39+000	1,099	3%
39+100	3,831	9%
39+300	11,674	27%
39+500	5,841	14%
39+600	2,857	7%
39+700	2,858	7%
39+800	2,894	7%
39+900	2,570	6%
40+000	1,832	4%
40+100	654	2%
40+200	1,639	4%
40+300	2,352	6%
40+400	1,957	5%
40+500	440	1%
40+600	0	0%

6.1.5 Floodplain Compensation Options

There are a variety of different sites in the general vicinity of the Terry Fox Drive extension project that have appropriate topographic relief suitable for providing volumetric floodplain compensation. Floodplain compensation should be provided as close to where the displacement of floodplain occurs. General practice dictates that compensation be located within the same river reach to replicate the hydrologic and hydraulic characteristics of the watercourse.

The section of Terry Fox Drive within the floodplain is within the river reach between Richardson Side Road and Huntmar Road. Throughout this reach, the Carp River is characterized as having similar low-flow channel and floodplain configurations, hydraulic gradient, hydraulic properties, and resultant floodwater elevations. In addition, the bridges located at Huntmar Road and Richardson Side Road further influence water levels at these two locations and act as hydraulic controls on the river along this reach. Based on the hydrologic and hydraulic uniformity of the subject reach, storage lost but compensated for within the reach should have little impact on the hydraulic dynamics of the watercourse upstream and downstream of the Study Area.

Three options for floodplain compensation have been developed to mitigate the impacts of lost floodplain storage caused by the construction of the Terry Fox Drive extension. The three compensation options are:

- **Option 1** - All displaced storage compensated for on an "elevation basis" in one large area located west of Terry Fox Drive and east of the Carp River between river-station 38+000 and 38+950.
- **Option 2** - High-level displaced storage compensated for on an "elevation basis" in one large area located west of Terry Fox Drive and east of the Carp River between river-station 38+000 and 38+950 and low-level displaced storage compensation on a cross-sectional basis along the westerly Terry Fox Drive toe-of-slope between river-station 38+950 and 40+075.
- **Option 3** - All displaced storage compensated for on a "cross-sectional basis" along the west side of the Carp River between river-station 38+800 and 40+450.

These options have been developed to a preliminary design level of detail to verify its ability to provide the appropriate level of compensation within the impacted elevation ranges noted in **Table** 7. **Table 9** outlines the design criteria and characteristics of the 3 compensation areas.

Table 9: Summary of Compensation Option Details

Design Detail	Option 1	Option 2	Option 3
Location - River-station Range	38+000 to 38+950 East Bank	38+000 to 38+950 East Bank 38+950 to 40+075 East Bank	38+800 to 40+450 West Bank
Elevation Range of Compensation	92.1 to 93.5	Part 2a – 92.7-93.5 Part 2b – 92.5-93.5	92.1-93.5
Physical Area Impacted by Grading	12.4 Ha	Part 2a – 10.4 Ha Part 2b – 1.3 Ha	18.2 Ha
Compensation Volume Provided	63,690 m3	Part 2a – 56,624 m3 Part 2b – 6,467m3	50,899.3 m3
Excavation Volume above 100yr Floodwater Elevation	Approx 140,000 m3	Approx 140,000 m3	Approx 25,726.2 m3

Figure 18 illustrates the spatial extents of the floodplain compensation options summarized in **Table 7.** The limits shown for each option represent the physical grading limits required to achieve the required floodplain compensation volumes within given elevation ranges. The grading limits vary based on the existing topography and application of some basic grading design criteria such as using a minimum 0.5% transverse slope and a maximum 4:1 grading 'daylight' slopes.

OPTION 1

OPTION 2

OPTION 3

CARP RIVER

TERRY FOX DRIVE

HUNTMAR DRIVE

RICHARDSON SIDE ROAD

LEGEND:

- FLOODPLAIN COMPENSATION OPTION 1
- FLOODPLAIN COMPENSATION OPTION 2
- FLOODPLAIN COMPENSATION OPTION 3
- FLOODPLAIN DISPLACEMENT
- ESTIMATED CARP RIVER FLOODPLAIN (93.5m)
- 39+500 HEC-RAS CROSS SECTION ID

FIGURE 18

TERRY FOX DRIVE FLOODPLAIN COMPENSATION OPTIONS

TERRY FOX DRIVE EXTENSION

RICHARDSON SIDE ROAD
TO SECOND LINE ROAD
STORMWATER MANAGEMENT REPORT

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6.1.6 Evaluation of Floodplain Compensation Alternatives

Based on information available to date, there is no significant difference between the three options with respect to fishery resources, surface water resources or archaeology resources. From the perspective of terrestrial resources, Options 1 and 2 have slightly greater impacts on trees and related avian habitat.

The lands required for Options 1 and 2 are designated "General Urban" in the Official Plan. An application for an Official Plan amendment for the Richcraft Homes Ltd. lands has been submitted but has been deemed incomplete since applications to expand the urban boundary are not permitted by the Planning Act. As well, an application for Draft Plan of Subdivision approval has been submitted for the Richardson Ridge Inc and Uniform Real Estate Holding Corp lands but has not been approved (although draft conditions have been prepared). The draft plan conditions include a condition requiring all lands west of Terry Fox (between Terry Fox and Carp River) be dedicated to the city at no cost at time of registration as open space. The lands required for Option 3 are designated "Agricultural Resource" in the Official Plan. No planning applications are currently active for these lands.

Currently, geotechnical information available for the area required for Options 1 and 2 indicates a combination of rock and clay material is expected to be encountered. Although the geotechnical investigation of Option 3 area is not yet complete, the area is expected to consist of clay material. From a geotechnical perspective, a possible advantage of using Option 1 or 2 is that the rock cut material may be used for rock fill in the Terry Fox Drive embankment in the flooplain area.

However, given the sensitivity of the Carp River floodplain related issues, it is felt that the section by section compensation provided by Option 3 is preferred. Further, the section by section approach to floodplain compensation is endorsed by the Third Party Review Report as the most technically appropriate. On this basis, Option 3 is recommended.

6.2 Shirley's Brook Tributary Realignment

Two projects, in close proximity to each other, are being proposed in the Shirley's Brook Sub-watershed, including the Kanata Lakes North Development and the extension of Terry Fox Drive. A position paper was been prepared to outline the planning and coordination principles used to assess and mitigate the environmental impacts of the Kanata Lakes and Terry Fox Drive projects. The primary purpose of the Shirley's Brook Position Paper, prepared in May 2003 was to summarize, in a single document for review by the regulatory agencies, the drainage and storm water works proposed for the two projects.

As discussed in detail in Section 4.3 of this report, the ultimate realignment of Shirley's Brook is not required at this time, as part of the initial 2-lane construction of Terry Fox Drive. Interim measures related to Shirley's Brook are also detailed in Section 4.3.

6.3 Drainage Area Designs

6.3.1 Design Criteria and Hydraulic Assessment

Currently, most of the land surrounding the proposed Terry Fox Drive alignment is undeveloped, natural lands, with the exception of the south end of the alignment where development is underway. Stormwater facility SWMF#2 was built prior to 2004 and runoff from the current development is conveyed to the facility prior to discharging to the Carp River. Current development plans for property adjacent to the road are being considered as part of the update to the 2007 PDR, to coordinate drainage infrastructure, where feasible.

The major flow concept in the 2007 Preliminary Design will be used to manage flows from upstream of the Terry Fox Drive right-of-way. Major flow from Terry Fox Drive will be managed as outlined in the 2007 Report except through the area of the Carp River Floodplain, which was designed with a saw tooth (0.5%) profile.

The analysis and design of the temporary and permanent culverts was carried out as indicated in the *City of Ottawa Sewer Design Guidelines (November 2004)* and the *MTO Drainage Management Manual (1995)*.

Terry Fox Drive is considered an urban arterial road based on the City of Ottawa Official Plan Schedule G. The design storm return period for an urban arterial for spans up to 6m is 50 years as per the City of Ottawa standards (*City of Ottawa Sewer Design Guidelines, Section 6.4.2)*. The culverts located in the Station 13+360 (CV3a, CV3b, CV3c) were for the 1:100 year event, as these culverts are intended to provide connectivity between the floodplain embayment located on the east or upstream side of Terry Fox Drive and the main portion of the Carp River floodplain.

The drainage areas and watershed slopes for all three watersheds were determined using 0.5 m contours provided by the City of Ottawa in the 1:2000 topographic mapping. The watershed characteristics were interpreted from mapping, satellite imagery, and a field visit. Soil data for the area was obtained from a soil map of Carleton County. The soil survey was performed by the Department of Chemistry, Ontario Agricultural College, Guelph, and the Experimental Farms Service, Dominion Department of Agriculture, Ottawa. Four soil types dominate the area and are summarized in **Table 10**. The CN values for each drainage area were calculated based on a weighted CN value approach depending on the percentage of each soil type within the drainage area. The Hydrologic soil groups were selected based on MTO Design Chart 1-08. CN values were selected based on MTO Design Chart 1-09 and confirmed according to City of Ottawa Sewer Design Guidelines Table 5.9.

Table 10: Soil Types in the Terry Fox Drive Study Area

Soil ID	Soil Name	Description	Hydrologic Soil group	CN value	Runoff Coefficient*
Ccl	Carp Clay Loam	Dark grey brown clay over grey clay grading into brown and grey clay loam, clay and silty clay; gently undulating moderate to slop drainage	C	76	0.3 (Flat pasture)
A	Anstruther Sand	Shallow brown sandy soils over granitic rocks; large areas of bare rock, local clay pockets. Rolling (to hilly) excessive drainage	AB - B	59	0.3 (rolling – hilly open sandy loam)
Ns	Nepean Sand	Shallow sandy soils with sandstone bedrock within 3 feet; gently undulating moderate to excessive drainage	AB	55	0.2
Rc-R	Rideau Clay – rock knob phase	Mixed areas of Rideau clay, sand spote phase and Precambrian rock knobs	C	76	0.3

** for 100 year storms increased by 25% c=0.38 (as per City of Ottawa Sewer Design Guidelines p. 5-28)*

The City of Ottawa Sewer Design Guidelines suggests that the rational method be only applied to drainage areas less than 40ha. Therefore, hydrologic modelling software Visual OTTHYMO V.2.2 was used to calculate peak flows for the CR-3 and Shirley's Brook drainage area, but the rational method was applied to the smaller areas. Total precipitation was calculated based on the IDF curves for the region provided in the *City of Ottawa Sewer Design Guidelines*. The SCS-Type II 12-hour storm distribution was applied, as this is the distribution recommended for rural drainage area by the MTO and City of Ottawa. The 12-hour and 24-hour events were both modelled and the 12-hour storm was found to provide the highest peak flows. The watershed slope was calculated based on the equivalent slope method and the time of concentration for each drainage area was calculated using the Airport formula. The Airport method is appropriate as it is recommended for drainage basins with runoff coefficients less than 0.4.

The parameters used to calculate peak flows and the resulting design flows are presented in **Table 11.**

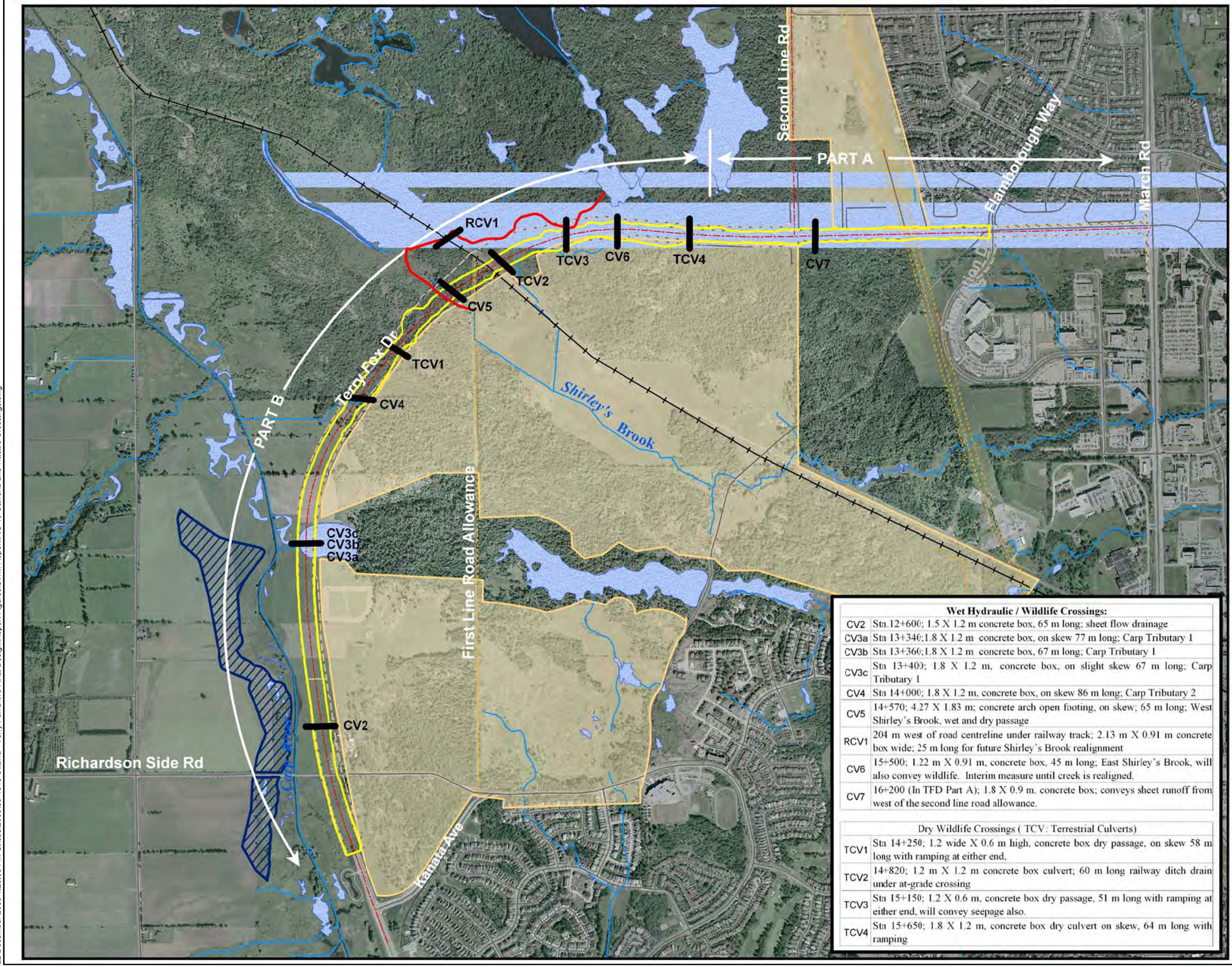
Table 11: Hydrologic Characteristics of Carp River Drainage Areas

Drainage Area ID	Drainage Area (ha)	Runoff Coefficient	Time to Concentration (min)	10-year Peak Flow (m3/s)	50-yr Peak Flow (m^3/s)	100-yr Peak Flow (m^3/s)	Historical Event
CR-2	26	0.35	48	1.15	1.52	1.67	n/a
CR-3*	60.1 (or 73ha)	0.45	63	2.27	3.65	4.27	5.53
CR-4	21	0.46	45	1.26	1.7	n/a	n/a

** - with consideration of future diversion from CV-2*

The hydraulic performance analysis of culvert options was based on CulvertMaster software. The hydraulic requirements were assessed in accordance with the *Canadian Highway Bridge Design Code (CSA-S6-06)* and the City of Ottawa Sewer Design Guidelines. For the class of road over the Terry Fox Drive culverts, a freeboard of 1000 mm is required. Freeboard if measured from the edge of the traveled lane to the high water elevation. The culverts must also be able to pass the event corresponding to twice the normal design flood without endangering the integrity of the structure and without approaching embankment failure.

The following subsections summarize the existing and proposed conditions within the drainage areas impacted by the extension of Terry Fox Drive. Concrete box culverts were the selected culvert type for all of the cross-drainage features. The drainage areas referred to in the following subsections are illustrated on **Figure 2**. **Figure 19** provides a plan of the road crossing culverts.



Legend

- Hydraulic Culverts and Wildlife Passage
- Proposed Shirley's Brook Realignment
- Grading Limit Footprint
- TFD Right of Way
- Road Centreline
- Railway
- Hydro Lines
- Wetland
- Floodplain Cut Area
- Watercourse
- Future Baseline Development

Wet Hydraulic / Wildlife Crossings:	
CV2	Stn.12+600; 1.5 X 1.2 m concrete box, 65 m long; sheet flow drainage
CV3a	Stn 13+340;1.8 X 1.2 m concrete box, on skew 77 m long; Carp Tributary 1
CV3b	Stn 13+360;1.8 X 1.2 m concrete box, 67 m long; Carp Tributary 1
CV3c	Stn 13+400; 1.8 X 1.2 m, concrete box, on slight skew 67 m long; Carp Tributary 1
CV4	Stn 14+000; 1.8 X 1.2 m, concrete box, on skew 86 m long; Carp Tributary 2
CV5	14+570; 4.27 X 1.83 m; concrete arch open footing, on skew; 65 m long; West Shirley's Brook, wet and dry passage
RCV1	204 m west of road centreline under railway track; 2.13 m X 0.91 m concrete box wide; 25 m long for future Shirley's Brook realignment
CV6	15+500; 1.22 m X 0.91 m, concrete box, 45 m long; East Shirley's Brook, will also convey wildlife. Interim measure until creek is realigned.
CV7	16+200 (In TFD Part A); 1.8 X 0.9 m. concrete box; conveys sheet runoff from west of the second line road allowance.

Dry Wildlife Crossings (TCV: Terrestrial Culverts)	
TCV1	Stn 14+250; 1.2 wide X 0.6 m high, concrete box dry passage, on skew 58 m long with ramping at either end.
TCV2	14+820; 1.2 m X 1.2 m concrete box culvert; 60 m long railway ditch drain under at-grade crossing
TCV3	Stn 15+150; 1.2 X 0.6 m, concrete box dry passage, 51 m long with ramping at either end, will convey seepage also.
TCV4	Stn 15+650; 1.8 X 1.2 m, concrete box dry culvert on skew, 64 m long with ramping

FIGURE 19
HYDRAULIC CULVERTS AND WILDLIFE PASSAGE

TERRY FOX DRIVE EXTENSION
RICHARDSON SIDE ROAD TO SECOND LINE ROAD
STORMWATER MANAGEMENT REPORT

DILLON CONSULTING

DATE: DECEMBER 2009

SCALE: N.T.S.

09-1518

22 December 2009 4:29:09 PM G:\cad\2009\09-1518 Ottawa - Terry Fox Drive Final Design\Report Figures\SWM Report\FIG 19 Culverts and Wildlife Crossings.dwg

6.3.2 Drainage Design - Area CR 1

Crossing Design

The existing upstream drainage area consists of approximately 9 ha of undeveloped rural land with varying topography and soil conditions. The majority of this upstream drainage area is designated for future residential uses.

In the 2007 Draft SWM Report, the conceptual drainage design developed to meet the project's SWM goals was to maintain the overland flow route with the use of interceptor ditches on the upstream side of Terry Fox Drive, directing overland flow to a proposed culvert located at Station 12+250. This proposed culvert conveys flow to the downstream side of Terry Fox Drive ultimately discharging to the Carp River through a naturalized outfall. The proposed culvert (CV1) consisted of the following design elements:

Location = Sta 12+250 (skewed)
Length = 62-metres
Size = 2400 x 1220 mm (embedded 20%)*
U/S Invert = 92.51-metres
D/S Invert = 92.16-metres
T/W Elevation = 93.50-metres
Allowable Headwater Elevation (1.0m freeboard) = 93.7
**based on existing condition flow of 2.77 m3/sec, with an assumed embedment of 20%.*

Currently, the area upstream of Terry Fox Drive in this area is being developed as part of the Broughton Lands subdivision. A July 27, 2009 Technical Memorandum (Novatech Engineering) for this development indicates that the runoff from upstream of Terry Fox Drive will be conveyed under the roadway near Station 12+000, adjacent to the current constructed limit of Terry Fox Drive. This flow will be conveyed in a storm sewer, with the first flush flow directed to a Vortechnics Unit for quality control (OGS-1) and larger runoff events directed to a proposed natural outlet channel to the Carp River. Novatech has indicated that MOE issued a Certificate of Approval for this outlet, which was based on a 3.45 ha area of Terry Fox Drive contributing to the Vortechnics Unit.

Based on the proposed design of the drainage system servicing the Broughton property, the culvert identified in the 2007 Preliminary Design Report (CV1) is no longer required.

Major Flow Provision

Within this roadway segment, the high point in the roadway profile is at Sta. 12+188. From this high point major flow from Terry Fox Drive will be conveyed to the south to the roadway low point at Sta. 12+020. From Sta. 12+188 northerly, the major flow is directed to the Carp River either along Richardson Side Road, or via the storm water outlet at Sta. 12+475.

Temporary Culverts

The need for temporary culverts in this area will be dependant on the extent of pre-loading required in this area.

6.3.3 Drainage Design - Area CR 2

Crossing Design

The existing upstream drainage area conditions consist of approximately 26 ha of undeveloped rural and agricultural land with varying topography and soil conditions. As part of the 2007 PDR, a culvert was proposed at Sta. 12+640 to convey overland flow from this drainage area

Currently, the plans provided by IBI show major flows from an entire block of the Richardson Ridge subdivision discharging to Terry Fox Drive and being conveyed across the road at approximately Sta.13+200, within drainage area CR 3.

Culvert CV-2 is located at 12+600 and provides a crossing location for the overland flow from CR-2 drainage area. There is no defined channel in this existing drainage area. The farm fields to the west of Terry Fox Drive have very small drainage ditches running to the Carp River. The location of the culvert was adjusted slightly to accommodate the sewer system design. Although in the long term this drainage scenario will eliminate the need for the proposed culvert at Sta. 12+640, given that timing remains uncertain, the design includes a permanent structure designed to accommodate the 1:50 year event. The tailwater condition was assumed to be the Carp River 1:100 year water elevation because the road is located right on the edge of the regulatory floodplain in this location. Although some of the drainage area from CR-2 will eventually be diverted to CR-3, the design allows for flow from the entire CV 2 drainage area.

Location = Sta 12+600
Length = 65 metres
Size = 1800 x 1200 mm (embedded 20%)
U/S Invert = 93.26 metres
D/S Invert = 92.62-metres
T/W Elevation = 93.50-metres
Allowable Headwater Elevation (1.0m freeboard) = 96.36

Major Flow Provision

Two scenarios are available for the provision of major flow routes for roadway runoff within this drainage area. Given the relatively small drainage areas, the design of the storm sewer system and catchbasins can be completed to capture and direct the 100 year event to the Carp River. Alternatively, the provision of a 'joint-use' major flow route along the east side of the Terry Fox right-of-way may be possible, if the design can be coordinated with the adjacent development. In this scenario, major flow would be directed to the roadway crossing culverts CV 3a, 3b and 3c

Temporary Culverts

If temporary culverts are required due to preloading, they will consist of two 1500 mm corrugated steep pipes (or other flexible equivalent). One temporary culvert should be elevated by approximately 0.5m to allow for the settlement of the lower culvert. A single 1500 mm culvert will convey the 1:10 year flow adequately. The design is intended to compensate for loss of efficiencies from deformation and settlement of the culverts.

6.3.4 Drainage Design - Area CR3

Crossing Design

The existing upstream drainage area consists of approximately 60 ha of both undeveloped and developed land. A portion of this area is designated as City of Ottawa conservation lands with no development planned. Secondly, a portion of the Carp River floodplain extends across the road in this drainage area.

Thus, the culvert crossing of Terry Fox Drive within this roadway segment serves two purposes: to provide for the conveyance of upstream flows to the Carp River; and to provide a hydraulic connection between the Carp River and the upstream floodplain area.

The majority of the upstream drainage area is part of the Regional Group's Richardson Ridge subdivision. The Richardson Ridge Conceptual Site Servicing Report (2007) indicates major and minor flow being directed to Terry Fox Drive in the area of Sta. 13+350. In the absence of the Richardson Ridge servicing design being advanced adequately to be coordinated with the Terry Fox Drive work, it is recommended that the culvert concept proposed in the 2007 PDR be constructed at Sta. 13+350, to accommodate existing condition flows. A multiple barrel culvert configuration is recommended due to geotechnical constraints and the desire to provide for terrestrial animal crossings at this location.

A majority of the immediate upstream and downstream area is a low-lying area dominated by willows and grasses that is part of the regulatory floodplain. The area is very hummocky and flat. As a result, the watershed does not have a defined channel with the exception of a very small ditch located near Station 13+360. By installing one large culvert to convey the flow from the entire drainage area under Terry Fox Drive the peak flow would be concentrated into one channel which would most likely change the upstream and downstream characteristics of the area including increased erosion on the downstream side of the road and ponding on the upstream side. To minimize changes to the area, a series of smaller culverts were selected instead. The sites were selected based on field observations and an examination of the 1:500 and 1:2000 topography data and they are:

- Sta 13+340 (CV-3a)
- Sta 13+360 (CV3-b)
- Sta 13+400 (CV-3c)

The total existing drainage area for CR3 is 60.2 ha. In the future, a portion of CR-2 will also be diverted via upstream ditches to CR-3. Therefore the drainage area used for design is 73 ha. Tail water conditions were assumed to be the 100-year Carp River floodplain elevation of 93.5. The downstream inverts of the culverts were set to approximately 92.0m, the normal water elevation in the Carp River. The maximum allowable headwater elevation for this series of culverts was taken to be 1000 mm below the lowest edge of pavement elevation through this section of road.

The proposed culverts consist of the following design elements:

Culvert CV 3a
Location Sta 13+340 (skewed)
Length 77 metres
Size 1800 x 1200 mm (embedded 20%)
U/S Invert 92.10 metres
D/S Invert 91.76 metres
T/W Elevation = 93.50-metres
Allowable Headwater Elevation (1.0m freeboard) = 93.87

Culvert CV 3b
Location Sta 13+360
Length 67 metres
Size 1800 x 1200 mm (embedded 20%)
U/S Invert 91.86 metres
D/S Invert 91.76 metres
T/W Elevation = 93.50-metres
Allowable Headwater Elevation (1.0m freeboard) = 93.87

Culvert CV 3c
Location Sta 13+400 (skewed)
Length 67 metres
Size 1800 x 1200 mm (embedded 20%)
U/S Invert 91.80 metres
D/S Invert 91.76 metres
T/W Elevation = 93.50-metres
Allowable Headwater Elevation (1.0m freeboard) = 93.87

Major Flow Provision

Two scenarios are available for the provision of major flow routes for roadway runoff within this drainage area. Given the relatively small drainage areas, the design of the storm sewer system and catchbasins can be completed to capture and direct the 100 year event to the Carp River. Alternatively, the provision of a 'joint-use' major flow route along the east side of the Terry Fox right-of-way may be possible, if the design can be coordinated with the adjacent development. In this scenario, major flow would be directed to the roadway crossing culverts CV 3a, 3b and 3c.

Temporary Culverts

Temporary crossing structures have been designed for the 10 year return period and consist of 2-1200mm diameter corrugated steel pipes. These will be located slightly away from the permanent culverts to allow the new concrete culverts to be constructed with the temporary culverts remaining in place.

6.3.5 Drainage Design - Area CR 4

Crossing Design

The proposed Terry Fox Drive alignment divides the drainage area into two sub-sections consisting of a drainage area to the west which is anticipated to remain rural, and the area to the east designated for urban development. The 2007 PDR recommended a new culvert crossing at Sta. 14+010 to convey upstream flows across Terry Fox Drive along an existing channel, which is tributary to the Carp River. Drainage from areas adjacent to Terry Fox Drive is conveyed to the proposed culvert via interceptor ditches for conveyance of external drainage. The existing upstream drainage area conditions consist of approximately 18 ha of undeveloped rural land with varying topography and soil conditions. Terry Fox Drive intersects this drainage area such that runoff from 12.7 ha will flow through the structure and 5.18 ha will be conveyed to the culvert outlet via a road-side ditch.

Roadway drainage is conveyed by a new storm sewer, with a northerly limit at about Sta. 14+200. The storm sewer flow is conveyed to an oil grit separator and a new outfall channel to the Carp River at Sta. 13+625. Major flow from the roadway is also conveyed to the sag at Sta. 13+625, then directed to the Carp River floodplain area on either side of Terry Fox Drive. This sewer system and outfall design will be completed to accommodate the future 4 lane configuration of Terry Fox Drive.

The following summarizes design criteria for the culvert at Sta.14+000.

Length = 86.0-metres (skewed)
Size = 1800 x 1200 mm* (embedded 20%)
U/S Invert = 102.93 metres
D/S Invert = 101.19 metres
T/W Elevation = n/a

Although the upstream area is designated for future development, the servicing configuration and location of storm water outlets or the storm water servicing concept is not finalized.

In the absence of the Richardson Ridge servicing design being advanced adequately to be coordinated with the Terry Fox Drive work, it is recommended that the culvert proposed in the 2007 PDR be constructed at Sta. 14+000, to accommodate existing condition flows.

The culvert downstream invert should be placed at an elevation of 101.19 m, to allow the proposed storm sewer to pass over it, with adequate clearance and cover.

Major Flow Provision

Major flow from this section of roadway will be directed to the roadway sag at CV 3, and conveyed across Terry Fox Drive through the new concrete culverts.

Temporary Culverts

Temporary culverts are not required for this drainage area.

6.3.6 Drainage Design - Areas SB1, SB3, SB4 (Shirley's Brook – Ultimate Realignment)

Existing upstream drainage area conditions consist of approximately 159 ha of undeveloped rural land with varying topography and soil conditions. The Shirley's Brook Sub-watershed Report extensively documents both the biotic and abiotic natural resources within this portion of the study area. Due to the low-lying swampy nature of the upstream drainage area, future land use conditions are unlikely to change. The boundaries of the drainage area correspond to Terry Fox Drive between Sta. 14+350 and 14+800.

Aquatic and terrestrial biology surveys in the vicinity of the proposed crossing suggest that this area has an active fish, beaver and herpetofauna population. Shirley's Brook requires an 'enhanced' protection level and provides a natural corridor for wildlife movement within the "saddle" area.

Physical constraints, including profile, rail crossing, and watercourse alignment, limit the number of suggested alternatives. The recommended plan maintains the current Shirley's Brook alignment and provides interceptor ditches on the upstream (left) side of the Terry Fox alignment, maintaining existing overland drainage characteristics. It is recommended that a slightly over-sized combined drainage and wildlife crossing be located at Sta.14+560.

The culvert crossing of the Terry Fox Drive alignment is required to convey flow from a local upstream drainage area of approximately 159 ha, plus flow from the Shirley's Brook Tributary realignment crossing the CNR corridor resulting in an additional 112 ha. The total contributing drainage area upstream of this crossing location will be approximately 271 ha of undeveloped conservation forest and wetland. Design considerations for the culvert crossing at Station 14+560 of Terry Fox Drive include:

- convey the 50-year design flow with a minimum of 1.0 meters of freeboard;
- convey the 100-year design flow without overtopping the road;
- provide a minimum 0.3m deep meandering low-flow channel along the culvert bottom for fish passage during dry periods;
- provide minimum cover for frost protection and structural support; and,
- provide wildlife crossing (consideration given for small mammals, amphibians and reptiles).

The following is a summary of design criteria for the culvert at Sta.14+560.

4270 x 1830mm ConSpan Arch Culvert
Length = 62-metres
U/S Invert = 100.57-metres
D/S Invert = 100.51-metres
H/W Elevation = 102.09-metres
T/W Elevation = 101.6

This culvert (CV 5) has been sized to accommodate the ultimate Shirley's Brook realignment, ans as such is oversized significantly for the interim condition.

6.4 Provision for Terrestrial Crossings

Provisions for terrestrial crossings will be integrated into two of the hydraulic crossings outlined in Section 6.4. These terrestrial culverts have been provided for the sole purpose of maintaining terrestrial crossing connectivity across the ROW. Two additional culverts have been provided that will function as combination interim drainage culverts and terrestrial crossings.

Terrestrial crossing features to be integrated in the hydraulics culverts at Sta. 13+350 and Sta. 14+560 are:

- Concrete culverts (box or round) are recommended over metal
- Open bottom is recommended but if this is not a feasible option then a natural bottom must be installed (placement of substrate throughout the culvert). i.e., no bare culvert bottoms for animal crossing locations
- Minimum height from substrate to top of culvert is 1m
- Minimum width of terrestrial path (not including meander width of streams or flows) through culverts is 2m
- Placement of a grate (for light penetration) in the top of the culverts in the middle of the road, at the centre island (highly recommended)
- Boulder slope on west side of road from approx. Sta. 14+930 (after crossing culvert) to 15+750
- Boulder slope on west/south side of road from approx. Sta. 14+575 (after Shirley's Brook culvert) to 14+780.

Terrestrial only (dry) culvert crossings are recommended near Sta. 14+250 and 15+650. These consist of small concrete box culverts (1220 x 910 mm). The provision of boulder slopes and ramping at either end of the culvert is recommended at these locations to direct animals to the culvert opening. Combination drainage (interim) culvert/terrestrial culvert crossings are recommended near Sta. 14+820 and 15+150. These also consist of small concrete box culverts (1220 x 910mm) and will function as drainage features but remain dry between precipitation events.