ISL Engineering and Land Services

Inspiring sustainable thinking

Town of Okotoks

Final Report

Stormwater Management Master Plan and Flood Mitigation Plan

November 2014

ISL Engineering and Land Services

ISL Engineering and Land Services Ltd. is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, land, and environmental projects.

ISL Engineering and Land Services

Inspiring sustainable thinking

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November 3, 2014

Our Reference: 25476

Town of Okotoks
P.O. Box 20, Stn Main
5 Elizabeth Street
Okotoks, AB T1S 1K1

Attention: Marley Oness, P.Eng., Municipal Engineer

Dear Sir:

Reference: Town of Okotoks – Stormwater Master Plan and Flood Mitigation Plan

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Enclosed is the final report for the Town of Okotoks Stormwater Master Plan and Flood Mitigation Plan. We trust that it meets your needs.

This project was initiated as a study to define the existing stormwater drainage system capacity along with the required upgrades, and to define the future drainage planning goals of the undeveloped areas within Town of Okotoks.

We sincerely appreciate the opportunity to undertake this project on your behalf. Should you have any questions or concerns, please do not hesitate to contact the undersigned at (403) 254-0544.

Sincerely,

Geoffrey Schulmeister, P.Eng.
Municipal Manager

Corporate Authorization

This document entitled Town of Okotoks Stormwater Master Plan and Flood Mitigation Plan has been prepared by ISL Engineering and Land Services Ltd. (ISL) for the use of the Town of Okotoks. The information and data provided herein represent ISL's professional judgment at the time of preparation. ISL denies any liability whatsoever to any other parties who may obtain this report and use it, or any of its contents, without prior written consent from ISL.

Fadi Maalouf, P. Eng., CPESC
Senior Municipal Engineer

PERMIT TO PRACTICE
ISL ENGINEERING AND LAND SERVICES LTD.
Signature
Date 04 November 2014
PERMIT NUMBER: P 4741
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Acknowledgements

ISL Engineering and Land Services Ltd. would like to thank the following individuals for their valuable contributions to this study:

Town of Okotoks	Marley Oness, P.Eng. James Greenshields, B.Sc. Dan Kutzner, C.E.T. Jeremy Huet, P.Eng.
ISL	Calvin McClary, P.Eng. Geoffrey Schulmeister, P.Eng. Fadi Maalouf, P.Eng.
Aquafor Beech	Chris Denich, M.Sc., P.Eng.

Executive Summary

ISL Engineering and Land Services Ltd. (ISL) was commissioned by the Town of Okotoks to develop a Stormwater Management Master Plan and Flood Mitigation Plan for the Town. This project was initiated as a study to define the existing stormwater drainage system capacity along with the required upgrades, and to define the future drainage planning goals of the undeveloped areas within Town of Okotoks.

The objective of this study is to address the following tasks:

1. To compile and review existing reports and drainage system information.
2. To analyze the capacity of the existing stormwater infrastructure within the Town and to define the associated flooding issues under a variety of storm conditions.
3. To assess the required upgrade works to the existing stormwater drainage conveyance system and to provide budgetary level cost estimates for these works.
4. To provide operational strategies to prevent property damage in the event of flooding.
5. To provide Stormwater Management guiding policies for future developments including potential low impact development style measures.

To summarize study outputs, the storm drainage system within the Town of Okotoks performs well. There are a few surface ponding issues occurring during 1:5 Year storm events in the area north of the Sheep River that have been reported by the Town's engineering staff which require addressing. Other probable surface ponding issues suggested by modelling results require close inspection during critical storm events to define the need of any future mitigation action. As expected, there is substantial surface flooding under 1:100 Year events.

The following are the recommendations for the storm drainage system for existing development conditions listed in order of priority:

1. At the Poplar Ave and Elma Place area. Two upgrading options are proposed. The first option would reduce the stormwater flooding volumes by about 50% for the 1:5 year rainfall event. The second option would reduce the stormwater flooding volumes by about 90% for the 1:5 year rainfall event. It is recommended that the Town review these options to develop a preferred alternative.
2. At the Northridge Drive. Two upgrading options are proposed. The first option includes the construction of a stormwater pond that will mitigate the surface flooding issues during the 1:5 year rainfall events. The second option would reduce the stormwater flooding volumes by about 60% for the 1:5 year rainfall event. It is recommended that the Town review these options to develop a preferred alternative.
3. At the northwest corner of the Air Ranch, a number of mitigation options are proposed. At this time, it is suggested that the preferred option could include the construction of an earth berm along the northwest boundary of the Air ranch to control the release rates of the melt water volumes.
4. Consider end of pipe quality treatment upgrades as noted. Staging could be as permitted by the Town's budget.
5. Future developments are required to provide stormwater management ponds such that post-development 1:100 Year flows into the Sheep River do not exceed pre-development 1:100 Year runoff rates. For the preliminary estimated runoff rate of 2.5L/s/ha, the areas dedicated for stormwater ponds should be in the range of 5.4% of the developed area.
6. The Town should consider adopting volume control at some point, either short term or in the future. If this were desired, then the annual stormwater runoff volume from future developments for the 1:100 Year storm events should not exceed the estimated post-development runoff volume of 98mm. Runoff Reduction Management Practices to be used are discussed in this report. The selection and design of the suitable management practices shall be fixed at the time of the detailed design. It is noted that rainwater harvesting could reduce water demands in Town and extend the life of current water licensing by not using it for irrigation purposes.

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FIGURES

1.0 Introduction

1.1 Authorization

ISL Engineering and Land Services Ltd. (ISL) was retained by the Town of Okotoks to develop a Stormwater Management Master Plan and Flood Mitigation Plan for the Town. This project was initiated as a study to define the existing stormwater drainage system capacity along with the required upgrades, and to define the future drainage planning goals of the undeveloped areas within Town of Okotoks.

1.2 Purpose of Study

The objective of this study is to address the following tasks:

1. To compile and review existing reports and drainage system information.
2. To analyze the capacity of the existing stormwater infrastructure within the Town and to define the associated flooding issues under a variety of storm conditions.
3. To assess the required upgrade works to the existing stormwater drainage conveyance system and to provide budgetary level cost estimates for these works.
4. To provide operational strategies to prevent property damage in the event of flooding.
5. To provide Stormwater Management guiding policies for future developments including potential low impact development style measures.

1.3 Background

The Town of Okotoks is located on Highway 2A, just North of Highway 7. The Town primarily consists of residential development, but also contains industrial and commercial areas located mainly along the north side of the railroad tracks and in the downtown core.

Topographically, Okotoks lies within the Sheep River Watershed. All stormwater runoff drains from high areas in the north and south down towards the Sheep River that runs through Okotoks from west to east, with ultimate discharge to the Bow River.

2.0
Existing Drainage System

2.1 Existing Drainage Patterns

The Town of Okotoks is split in two main drainage areas located on the north and south sides of the Sheep River. These two areas drain from higher terrain in the north and the south parts of the Town to the Sheep River. The drainage patterns of the stormwater system associated with the existing outfalls to the Sheep River define fourteen drainage basins. These drainage basins and main drainage patterns within the Town were defined using digital contours and as-built stormwater drainage mapping data provided by the Town of Okotoks, and can be seen on Figure 2.1.

2.2 Existing Drainage Infrastructure

2.2.1 Drainage Infrastructure Overview

The stormwater conveyance systems within the developed areas of Okotoks are grouped in two categories.

- The first category consists of stormwater collection system discharging into detention ponds prior to conveying the collected flows at controlled rates to the Sheep River.
- The second category consists of stormwater collection systems discharging directly into the Sheep River uncontrolled.

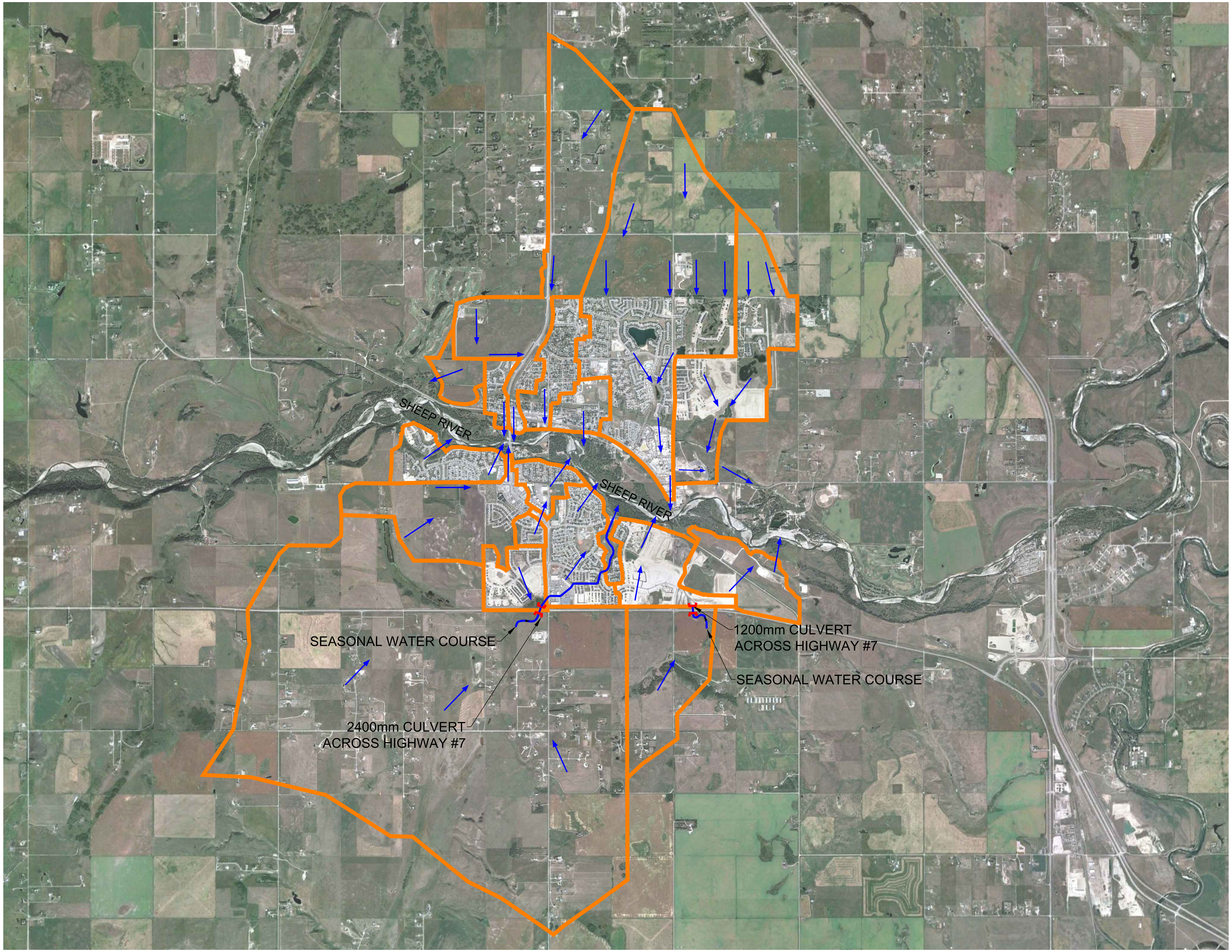
Stormwater runoff from upstream areas outside of the current Town boundary is generally conveyed by roadway ditches into the Town, where it is then intercepted by the Town's stormwater collection system. There are some cases where upstream runoff is conveyed directly to the Sheep River via separate open channels.

In the above context, after investigating the scheme of these drainage open channels, it appears that the natural interim creek that crosses Highway#7 via 1200mm pipe culvert conveying offsite flows across Cimarron East development to the Sheep river has not been maintained, as indicated in previous Stormwater Master Plans submitted by the Cimarron (east) and the Burnswest developers to the Town. The interim creek has been diverted along Highway#7 towards the east. No defined channel route or discharge location could be confirmed on site. It is recommended that the Town confirms any changes on the original drainage concept in the area.

Low terrain areas north of the Sheep river are subject to surface flooding due to the high water level in the river at the discharge outlets of the stormwater system. Effectively, the storm system cannot drain when high water levels exist in the river.

The general scheme of the existing main stormwater collection system, ponds, and outfalls can be seen on Figure 2.2, with the overall piped storm network including pipe sizes shown on Figure 2.3.

FIGURE 2.1



LEGEND:

DRAINAGE BOUNDARY

DRAINAGE DIRECTION

Okotoks

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

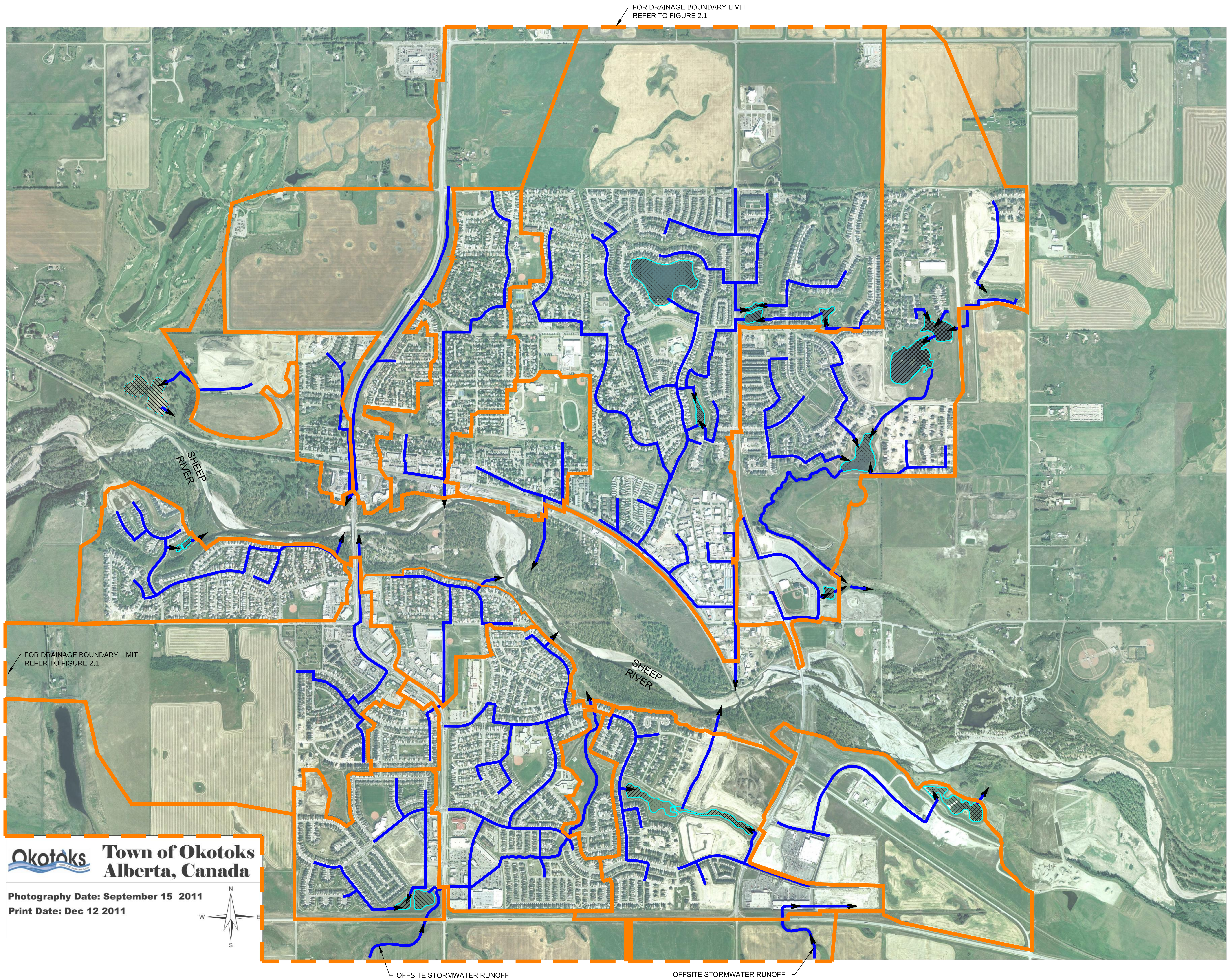
DRAINAGE CATCHMENTS
AND MAIN DRAINAGE PATTERNS
LAYOUT

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:05:08 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 2.1.DWG

FIGURE 2.2



LEGEND:

MAIN STORM COLLECTION PATTERNS

STORMWATER POND / BODY

DRAINAGE BOUNDARY

Okotoks

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

EXISTING STORMWATER DRAINAGE

GENERAL SCHEME

NOV 2014

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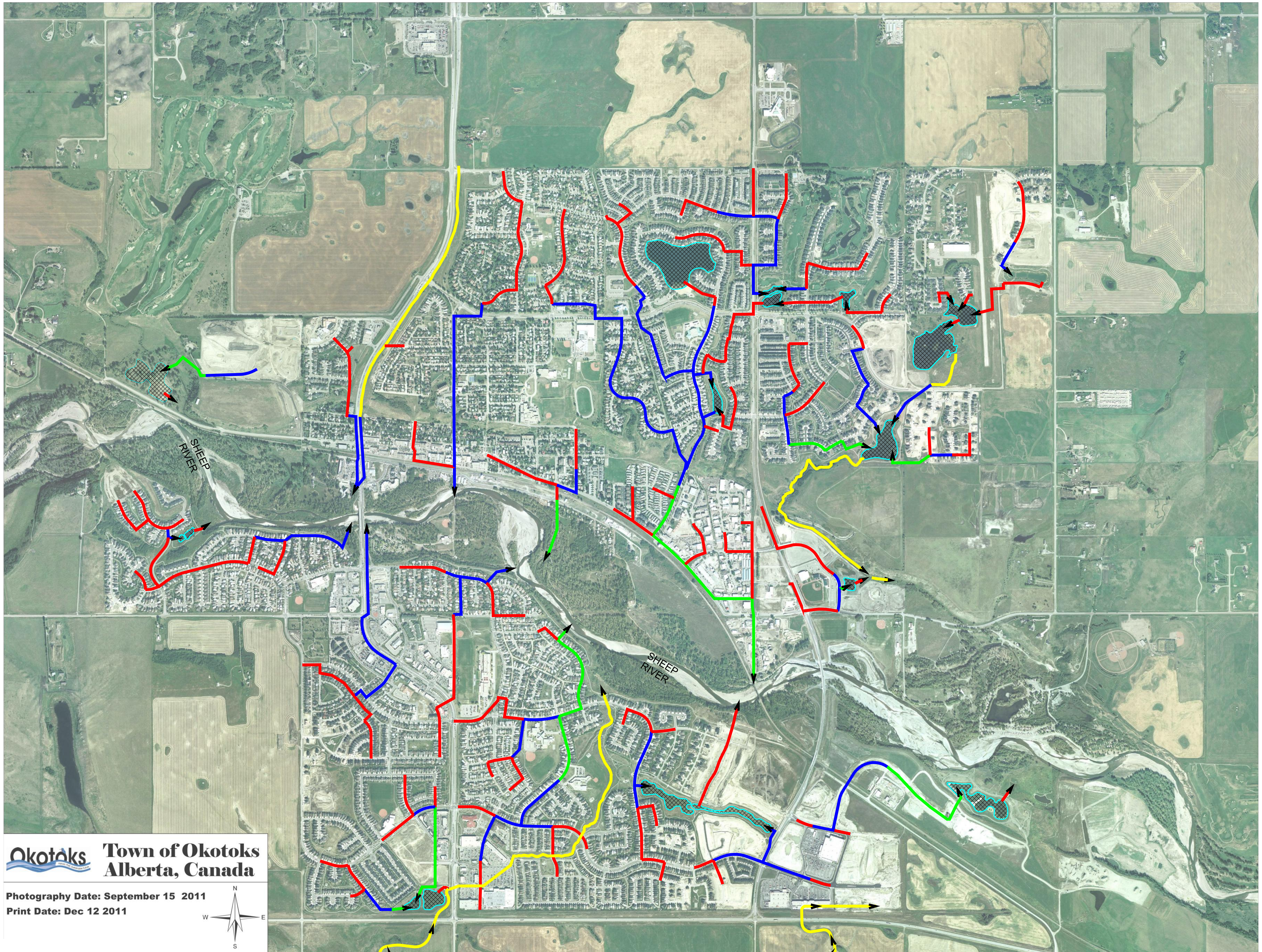
FIGURE 2.3



LEGEND:

- 300-750mm STORM PIPE
- 900-1200MM STORM PIPE
- 1350-1600mm STORM PIPE
- OPEN CHANNEL
- STORMWATER POND / BODY

Okotoks

TOWN OF OKOTOKS
STORMWATER MANAGEMENT
MASTER PLAN

EXISTING STORMWATER
DRAINAGE

OVERALL PIPED NETWORK

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:05:36 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 2.3.DWG

3.0
Hydrologic/Hydraulic Model Development

3.1 Design Criteria and Hydrologic Model Parameters

The design criteria used to assess the Town's drainage system area was taken from a variety of sources including design guidelines for the Town of Okotoks and the City of Calgary as well as past work undertaken by ISL for smaller municipalities in the Province of Alberta. The design criteria selected was then used for input into a computer model to design and assess the stormwater drainage system.

The XP-SWMM computer model was selected to perform the analysis. XP-SWMM is a dynamic model capable of unsteady flow simulation that is more accurate than most hydraulic models and is thus, more capable of delivering closer to life results. XP-SWMM features an enhanced graphical user interface making for easy review of models created and allowing for customized graphical output. For this application, XP-SWMM calculates runoff and routes that through the physical collection system in order to simulate the stormwater conveyance system throughout the different catchment areas and performs a sophisticated hydraulic analysis of the system.

The following criteria were used for the assessment of the existing drainage infrastructure, the upgrades, and the future development requirements:

- Depression storage of 7.5mm in pervious areas and 2.5mm in impervious areas.
- Manning's "n" roughness value of 0.25 for pervious areas and 0.016 for impervious areas.
- Initial infiltration rate of 75mm/hr.
- Ultimate infiltration rate of 7.5mm/hr, reflective of soil types in the area.
- Infiltration decay rate coefficient of 0.00115/s.
- Ground slopes as obtained from topographic data.
- Imperviousness data for different land uses as follows in Table 3.1.
- Manning's "n" roughness value of 0.013 for stormwater pipes and 0.035 for grassed ditches.

Table 3.1 – Imperviousness data for different land uses

Area	Imperviousness
Landscaped	10%
Residential	55%
Industrial and Commercial	85%
Highway ROW	30%

3.2 Model Set-Up

To set-up this model, the topography of the Town of Okotoks and the drainage service area associated to each outfall into the Sheep River were used to split the Town into storm catchments. Areas were then calculated for these basins, and then the hydrologic data was applied to the hydrologic model for each catchment.

As-built information for the main stormwater lines and the ponds was obtained from the Town and was input into the model.

For the 1:100 Year event analyses, the water levels into the Sheep River at the different stormwater outfalls were determined using the 100 Year River flood hazard mapping prepared by Alberta communities under the “Flood Hazard Identification Program”. For the 1:5 Year event analysis, the water levels at the different stormwater outfalls were determined using the natural ground level range at the outfall area.

For the upstream undeveloped areas outside of the current Town boundary, the hydrological parameters of each area were calibrated separately in order to maintain the generated runoff flow discharging into the Town’s stormwater system within the pre-development runoff release rate (later determined to be 2.5 L/s/ha). The derivation and use of the pre-development runoff release rate is discussed in section 5.9 of this report.

3.3 Design Rainfall Events

Since the Town of Okotoks is spread out and is divided into different catchment areas with a time of Concentration ranging between 15 and 90 minutes, the 1:5 Year, Chicago (1 hour duration) rainfall distribution &1:5 year Chicago (3 hour duration) rainfall distribution, which represents twice the catchments’ time of concentration, as well as the 1:5 year, 24 hour duration Chicago rainfall distribution were used in assessing the performance of the minor (piped) storm drainage system. This tests the system capability of accommodating short duration, high intensity storm events, as well as longer duration events with a similar high intensity peak.

Since the Town stormwater drainage system contains storm ponds, the 1:100 Year, 24 hour Chicago rainfall distribution was employed to analyze the major drainage system.

The employed rainfall distributions are shown in Appendix A. Rainfall data is as obtained from City of Calgary’s Stormwater Management and Design Manual based on Environment Canada data for the Calgary Airport.

4.0 Existing system Assessment and Capacity Upgrading Recommendations

4.1 Hydraulic Analysis of Existing Storm Drainage System

To assess the capacity of the existing storm drainage system, the hydraulic model was run using the 1:5 year, (1 hour, 3 hour & 24 hour) rainfall events and the 1:100 year, 24 hour rainfall event (Chicago distribution). The modelling results for the 1:5 year return period storm indicated that the 24 hour rainfall event yields higher peak flows than the 1 hour and the 3 hour storm events. The results of the analyses are illustrated graphically on Figures 4.1, 4.2 and 4.3.

On these figures, the blue color nodes indicate that the water level in the manholes would surcharge to level greater than 50cm depth below the ground surface, the yellow color nodes indicate that the water level in the manholes would surcharge to within 50cm of the ground surface, while the red color nodes indicate that the water level would surcharge to or above the ground surface. Surcharging above ground level indicates a relatively high risk of surface flooding due to an inadequate capacity in the storm sewer system. For ditch drainage systems, surcharging above ground level means that the ditch has overtopped its banks based on the definition of surface conduits in the model.

4.2 System Assessment

4.2.1 Area South of the Sheep River

The modelling results do not indicate surface flooding issues in the south part of Okotoks under the 1:5 year rainfall events. The capacity of the existing system appears to be adequate for conveying the generated flows.

For the 1:100 year rainfall event, the results indicate that the stormwater collection system experiences surface flooding a number of locations, but the capacity of the stormwater ponds appears to be adequate:

a) Off-site flows inlets into the system:

The results show that flooding of undeveloped areas at the inlets into the stormwater collection system, mainly at Big Rock Trail, might occur during higher intensity rains. It is noted, however, that the chance of issues at these locations is limited due to several factors:

- At many of the inlets, there is area for water to pond.
- Overland flows to these locations could be dampened by routing effects given the distance from the furthest point in the respective catchments to the inlet will yield high times of concentration that could exceed the storm peaks.

Given that to date, no flooding issues were reported at these areas, measures for flooding protection are not required at the present time.

b) Local low spot areas and inlets to secondary stormwater lines:

Based on discussions with the Town's engineering staff, no flooding issues were reported at these locations. It is suggested that potential surface flooding could be conveyed away overland the Major drainage system at the surface towards the downstream areas .The detailed analysis of these overland flows does not fall under the scope of this study. Given that typically overland flows under 1:100 year storm events are considered acceptable, except if certain critical roads are made impassable or if property damage results, the flooding results under this rainfall event do not indicate the necessity of upgrades as neither of these conditions has occurred based on information from the Town.

4.2.2 Area North of the Sheep River

The developed area north of Sheep River can be split in two topographical areas. These include the low terrain area situated along the River's north embankment at a level close to the 100-Year river flood plain level, and the high terrain area located along the top of escarpment north of the low terrain area.

For the 5 year storm event, the model results indicate the following:

a) Low Terrain area:
- Surface flooding within the developed area of Okotoks at Northridge Drive, Poplar Ave area and Elma Place is noted in the model. Based on discussions with the Town's engineering staff, flooding issues were reported at these areas. Consequently, upgrading measures to mitigate these flooding issues are required.
- Risk of flooding at Fisher Crescent area is suggested by the model. To date, no flooding issues were reported at this area. Close inspection during critical storm events is required to define any surface flooding issues. If issues are noted at some time in the future, then remedial measures can be considered at that time.

b) High Terrain area:
- Surface flooding at the Recreation Center at Milligan Drive and the adjacent section of Okotoks Drive. The capacity of the 400mm pipe conveying the collected stormwater flows from this area appears to be not sufficient. To date no surface flooding issues were reported in this area. Close inspection during critical storm events is required to define any surface flooding issues and to take necessary mitigation action if needed.

For the 100 year event, the model results indicate the following:

a) Low Terrain area:
- Surface flooding throughout the entire low terrain area due to the high water level in the Sheep River at the discharge outlets of the stormwater system. This shows a clear link between flooding in the low areas and high water levels in the Sheep River. Effectively, the storm system cannot drain when high water levels exist in the river. There are some flap gates in the system that keep river water from backing up into the system, but this does not help the system to drain, it merely provides some storage (i.e. combined pipe and manhole volume) to hold flows until the river levels drop. While this helps, the time it would take the river levels to drop in a flooding event would be much longer than a storm event, there is risk here until the river levels drop.
- The stormwater pond at the business park east of 32nd street might be at risk of flood damage. The top level of the pond embankment is in the range of 1040.50m (based on as-built information provided by the Town), while the 100-Year flood plain is in the range of 1041.0 m (as identified by the Province of Alberta's Flood Hazard Identification Program). The following is noted in this regard:
  - Any pond flooding should not have any impact on the extent of the surface flooding throughout the business park. The limit of the surface flooding is being controlled by the high water level in the Sheep River, which is below the elevations in the business park.
  - It is suggested that the Town confirm the structural integrity of the pond in case of any pond flooding.
- The stormwater pond of the Spyglass Hill / Mountain View development might be at risk of flood damage. The top level of the pond embankment is in the range of 1058.50m (based on information provided by the Town), while the 100-Year flood plain is in the range of 1059.5 m (as identified by the Province of Alberta's Flood Hazard Identification Program). Based on the above, the following is noted:

- o The pond flooding is not expected to generate any surface flooding at the development, which is located at the top of escarpment north of the pond at a level higher than 1070 m.
- o The Town to confirm the structural integrity of the pond in case of any pond flooding.

b) High Terrain area:

In the high terrain area, the results indicate that the stormwater collection system experiences surface flooding at a number of locations as noted below. That said, the capacity of the stormwater ponds appears to be adequate.

- o Many spots located between Northridge Drive and Crystal Ridge:

  Based on discussions with the Town's engineering staff, no flooding issues were reported at these areas. It is suggested that potential surface flooding could be conveyed away overland the Major drainage system at the surface towards the downstream areas; the topography of the site sloping towards the south favours this assumption. Detailed analysis of these overland flows does not fall under the scope of this study. As noted previously, typically overland flows under 1:100 year storm events are considered acceptable provided critical roads remain passable and property damage does not occur. Accordingly, the flooding results under this rainfall event does not indicate the necessity of upgrades at these locations.

4.3 Upgrading Recommendations

This section of the report discusses proposals to improve the performance of the existing stormwater system to limit potential flooding incidents at specific locations. The below discussed mitigation measures are based on existing topographic and stormwater pipe size data obtained from the Town of Okotoks. Prior to commencing any detailed design, it is highly recommended that a site investigation be carried out to verify the accuracy of the existing data, as this could have a potential impact on the outcome of the design and recommendations.

4.3.1 Poplar Avenue and Elma Place

The modelling results show surface flooding at the low terrain section of Poplar Ave. This is due to the joint occurrence of a storm event and high water level in the Sheep River at the stormwater system outlet which is relatively close to the existing ground low spots at the Poplar Avenue.

The modelling results also suggest potential surface flooding at Elma Place and the public service area at the east. This is due to the size of the 375mm pipe conveying the stormwater drainage flows from these two areas to the stormwater system at Stanley Avenue.

In order to minimize the impact of the surface flooding, the following two options were reviewed:

Option 1: This option proposes to connect the drainage system at Poplar Avenue to the stormwater system along North Railway Street at the east end of Poplar Ave using a 450mm pipe, and to upgrade the existing 375mm pipe connection from the Elma Place area to a 450mm pipe. The model results for the 1:5 year rainfall event show that this option would reduce the stormwater flooding volumes at the Poplar Avenue by about 40% and at Elma Place area by about 65%. The model assumes complete urban development at the public service area at Elma Place. The results show also that increasing the size of the proposed pipe connections to a diameter greater than 450mm will overload the downstream system along the North Railway Street which might generate additional surface flooding in the industrial district east of 32 Street. The result of this analysis is illustrated on Figure 4.4.

Option 2: This option proposes to reroute the stormwater outfall associated with the stormwater drainage system at Poplar Avenue to a downstream section of the Sheep River with a 100 Year River flood level at 1m below the lowest ground spot at Poplar Avenue, and to upgrade the existing 375mm pipe connection from the Elma Place area to a 525mm pipe. The results for the 1:5 year rainfall event show that no surface flooding will occur at the Poplar Avenue, and that the surface flooding volume at the Elma Place area will be reduced by about 90%. The result of this analysis is illustrated on Figure 4.5.

4.3.2 Northridge Drive

The stormwater system along Northridge Drive includes two main stormwater trunks along both sides of Northridge Drive that convey the generated stormwater runoff from the developed areas within Okotoks along Northridge Drive as well as from the higher terrain undeveloped areas north of Okotoks. These collected flows are conveyed directly to the Sheep River without any prior discharge into a storage structure that controls the flow rates to the Sheep River.

The modelling results show surface flooding at the low terrain part of Northridge Drive. This is due to the high water level in the Sheep River at the stormwater system outfall; which is relatively close to the existing ground level in the area. Based on discussions with the Town, it was felt that mitigating flows to the low terrain area from these storm trunks could be an effective mitigation measure for flooding in the area. On this basis, in order to minimize the flooding impact, the two following options were assessed:

Option 1: The provision of a detention pond within the south east corner of D'Arcy Ranch Golf Club. This pond will receive the generated stormwater runoff from the upstream developed and undeveloped areas totalling roughly 310 ha and discharges the attenuated peak flows into the downstream Northridge Drive stormwater system at a controlled flow rate of 2.5 L/s/ha for the 1:100 year rainfall event.

The model results indicate that an area of about 1.0 ha should be allocated for the construction of this pond based on an active storage depth of 1.1m and a 5H:1V pond side slope. No surface flooding is indicated for the 1:5 year rainfall event with this upgrade in place. The surface flooding for the 1:100 year rainfall remains, as this is related to the 100 year flood plain level of the Sheep River which falls within the same level range of the low terrain area of Northridge Drive. Theoretically, however, the storm system downstream of the pond will fill less slowly, so there is some possible improvement in the downstream area, but not enough to show major differences under river flood conditions. The results of the analysis are illustrated graphically on Figure 4.6.

Option 2: The provision of small detention areas in the form of a series of check dams, across the existing open drainage ditches along the Northridge Drive ROW was considered. This arrangement will assist in attenuating the stormwater peak flows. The water depth within the ditches shall not exceed 75cm. The results for the 1:5 year rainfall event show a reduction of about 60% of the stormwater flooding volumes due to this option providing a reasonable amount of additional storage, plus the ability to control flows downstream of the potential pond site noted above. The results of this analysis are illustrated graphically on Figure 4.7.

4.3.3 North West Corner of the Air Ranch

Spring runoff creating surface flooding issues at the northwest corner of the Air Ranch has been reported. This is due to spring snow melt in the field north of the Air Ranch that ends by releasing large volumes of water into the drainage swale system. These released volumes exceed the capacity of the drainage swale that is normally operating with reduced capacity because of the remaining accumulated snow within the swale during this period of the year, and end by backing up and releasing large volumes of water into the drainage swale entering between two lots on the northwest part of the Air Ranch, which discharges onto Ranch Road. From here it drains southwards along the roadway, eventually discharging south to an existing stormwater management facility. This issue could not be identified by analyzing the modelling results as this is not related to rainwater direct runoff (this system is designed for typical rain events, though flow down the middle of a roadway is not ideal). The event appears to be primarily caused by rapid snowmelt on exposed portions of the land to the north, coupled with snow accumulation in shaded areas along the swale leading to a "dam-break" type of event.

In order to limit the flooding impact the following options are proposed:

Option 1: Maintain the drainage swale throughout the winter to keep it cleared and available for discharge (this could also require some snow removal from the lands to the north). This option requires a continuous site follow-up throughout the winter. It is expected that costs would be limited to Town staff for snow removal.

Pros:
- Relatively inexpensive, depending on snow accumulation.
- If future development happens to the north, the problem goes away through stormwater management, so no major capital outlay.

Cons:
- Requires ongoing vigilance throughout the winter and action throughout the winter.
- Risk of release events remains if not constantly maintained (weather can change quickly, before maintenance can be undertaken).

Synopsis:
- Feasible, but with some drawbacks.

Option 2: Monitor the area for build-up of water north of the swale. In the event that ponding is observed, pump the flows out of the low area, either to the drainage swale (or bypassing it to Ranch Road) at desired flow rates. Flows could also be pumped west to the swale running south along the west side of the Air Ranch (along the east side of Crystal Ridge Golf Course). This option requires a continuous site follow-up throughout the winter. It is expected that costs would be limited to Town staff for observation and pumping, unless pump rental was required.

Pros:
- Relatively inexpensive.
- If future development happens to the north, the problem goes away through stormwater management, so no major capital outlay.

Cons:
- Requires ongoing vigilance.
- Risk of release events remains if not constantly maintained (weather can change quickly, before maintenance can be undertaken).
- Could require repeated action during the winter.

Synopsis:
- Feasible, but with some drawbacks.

Option 3: Consider an upgrade of Ranch Road. This could include the installation of a stormwater drainage system with drainage inlets along the Ranch Road that collects snow melt runoff as well as generated stormwater and conveys these flows south to the existing stormwater management facility. This option would likely cost upwards of $1,800,000.

- Pros:
  - Permanent solution.
- Cons:
  - High capital cost.
- Synopsis:
  - Feasible, but not recommended due to high capital cost.

Option 4: Construct an earth berm along the north west boundary of the Air ranch that contains and releases the melt water volumes at controlled rates to avoid flooding the downstream stormwater drainage system. This option would cause local field flooding at the northern boundary of the Air Ranch during snow melt periods, though this is believed to occur before the release events currently (this would just prolong the inundation of the lands). The estimated berm length is around 175 m, with a height ranging 50-75 cm. The cost of this option would likely be in the order of $40,000.

Pros:
- Relatively inexpensive.
- If future development happens to the north, the problem goes away through stormwater management, so no major capital outlay.

Cons:
- Additional ponding on land to the north.
- Access to area to construct berm could be limited; could require some land acquisition.
- Possible icing up of discharge structure.

Synopsis:
- Feasible, but with some minor drawbacks.

Option 5: Regrade the north edge of the Air Ranch to divert flows west to the swale running south between Crystal Ridge and the Air Ranch. This could be challenging as it might be difficult to get flows to proceed west without using extremely flat grades. The estimated length of the regraded area is 110m. The cost of this option would likely be in the order of $35,000.

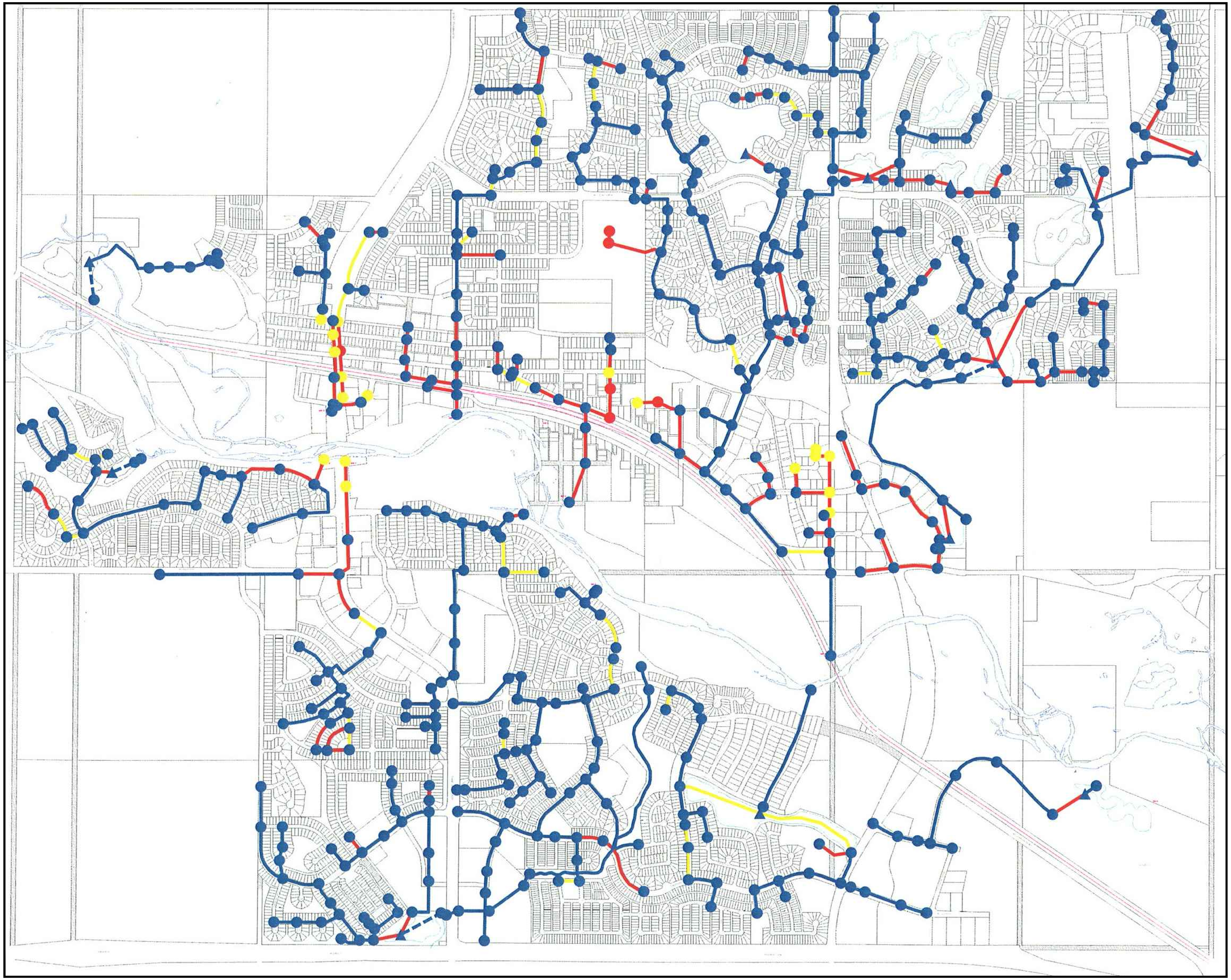
Pros:
- Relatively inexpensive.
- If future development happens to the north, the problem goes away through stormwater management, so no major capital outlay.

Cons:
- The swale between the Air Ranch and Crystal Ridge might have the same issues as the existing one, ponding in this case could be on lots within the Town rather than agricultural land. In addition, the overland flow issue onto Ranch Road might remain at a reduced amount.
- Access to area to regrade could be limited; could require some land acquisition.
- Homeowners may have compromised the capacity of the west boundary swale, so it is not certain it can handle its current flows, much less the diverted ones.

Synopsis:
- Feasible subject to capacity review, but with some drawbacks.

The above mentioned options present effectively temporary mitigation solutions for the surface flooding issues at the Air Ranch. At the current time, the land annexation process to accommodate the expected growth in Okotoks is still being assessed. Should the area north of the Air Ranch be annexed to the future development in Okotoks, the spring runoff issue in the area can be dealt with as part of the Stormwater Management Master Plan. On the basis of the above, it is suggested that constructing a berm to control the release events may be the preferred option

FIGURE 4.1



LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED WITHIN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED ABOVE RIM LEVEL
- POND OVERFLOW ABOVE CREST LEVEL
- POND FILLED WITHIN 50cm BELOW CREST LEVEL
- POND FILLED WITHIN MORE THAN 50cm BELOW CREST LEVEL
- CONDUIT SURCHARGED
- CONDUIT FLOWING AT (80-100%) FULL
- CONDUIT FLOWING AT LESS THAN 80% FULL

NOTE: WATER LEVELS INTO THE SHEEP RIVER AT THE STORMWATER OUTFALLS WERE DETERMINED BASED ON THE NATURAL GROUND LEVEL AT THE OUTFALL AREA

Okotoks

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

EXISTING STORMWATER SYSTEM

1:5 YEAR, 3 HOUR STORM

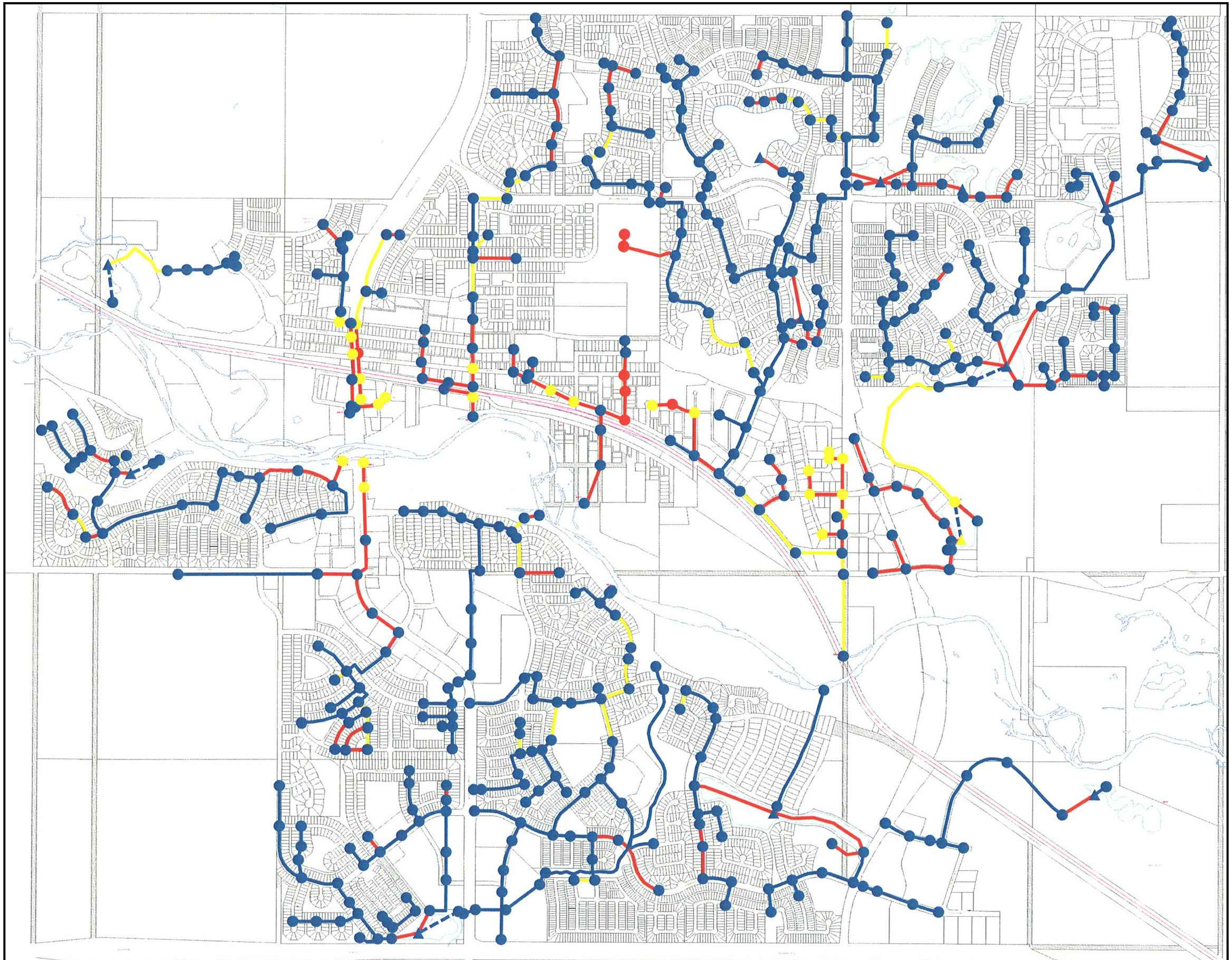
HYDRAULIC MODELLING RESULTS

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:05:46 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 4.1.DWG

FIGURE 4.2



LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
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NOTE: WATER LEVELS INTO THE SHEEP RIVER AT THE STORMWATER OUTFALLS WERE DETERMINED BASED ON THE NATURAL GROUND LEVEL AT THE OUTFALL AREA

Okotoks

Historic Past, Sustainable Future

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

EXISTING STORMWATER SYSTEM

1:5 YEAR, 24 HOUR STORM

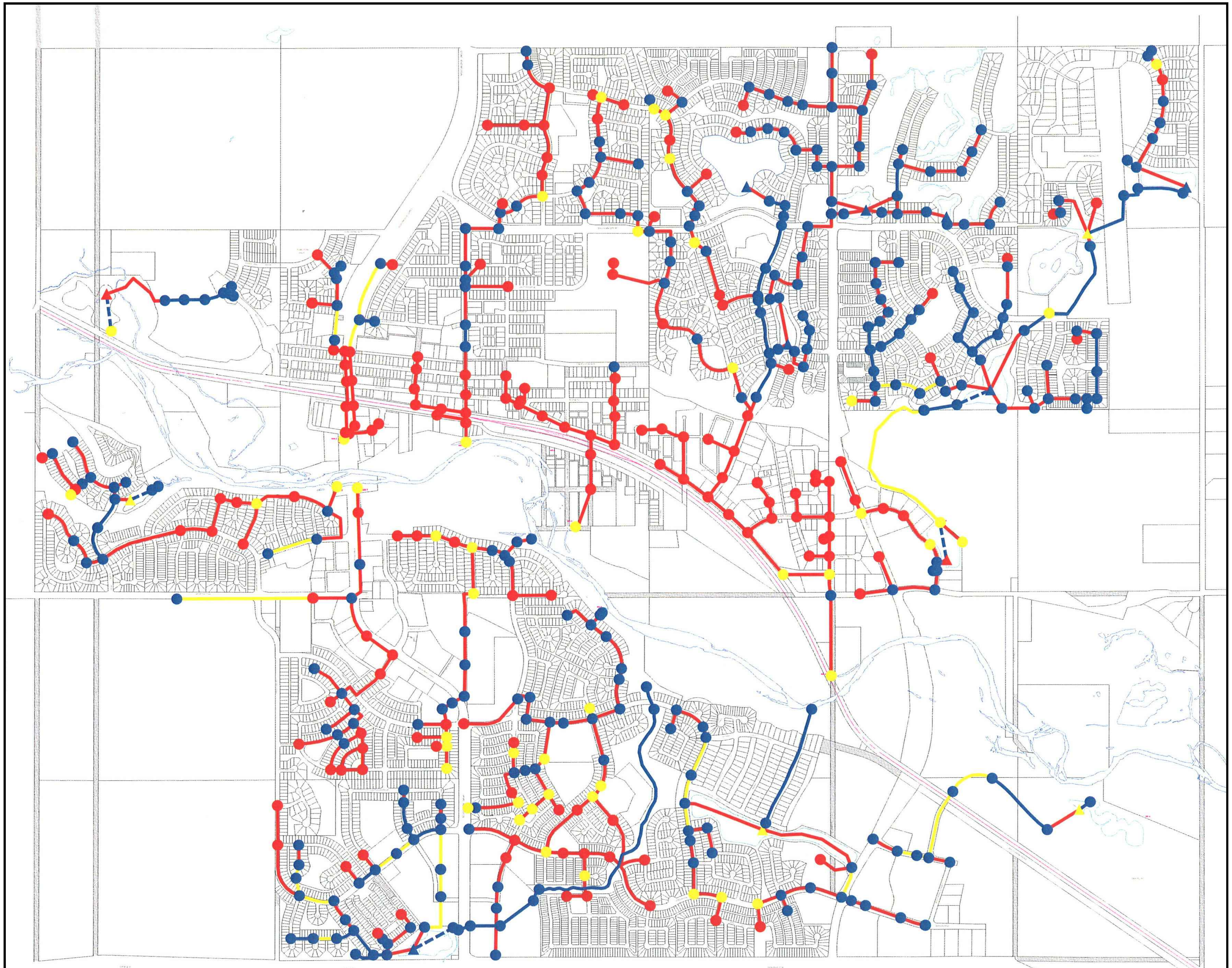
HYDRAULIC MODELLING RESULTS

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:05:55 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 4.2.DWG

FIGURE 4.3



LEGEND:

MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL

MANHOLE SURCHARGED WITHIN 50cm BELOW RIM LEVEL

MANHOLE SURCHARGED ABOVE RIM LEVEL

POND OVERFLOW ABOVE CREST LEVEL

POND FILLED WITHIN 50cm BELOW CREST LEVEL

POND FILLED WITHIN MORE THAN 50cm BELOW CREST LEVEL

CONDUIT SURCHARGED

CONDUIT FLOWING AT (80-100%) FULL

CONDUIT FLOWING AT LESS THAN 80% FULL

NOTE: WATER LEVELS INTO THE SHEEP RIVER AT THE STORMWATER OUTFALLS ARE DETERMINED USING THE 100 YEAR RIVER FLOOD HAZARD MAPPING BY ALBERTA COMMUNITIES

Okotoks

Historic Past, Sustainable Future

TOWN OF OKOTOKS

STORMWATER MANAGEMENT MASTER PLAN

EXISTING STORMWATER SYSTEM

1:100 YEAR, 24 HOUR STORM

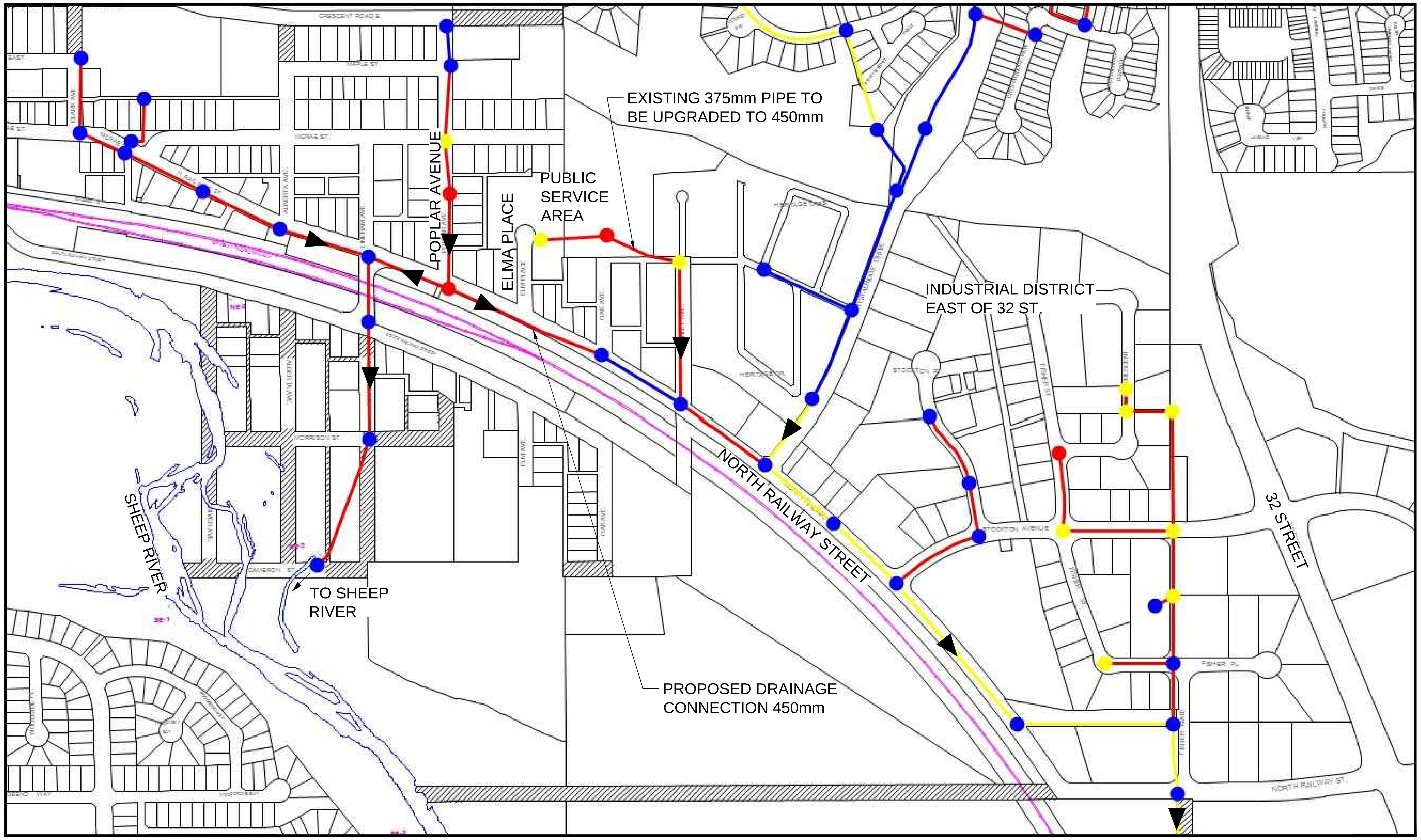
HYDRAULIC MODELLING RESULTS

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:06:04 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 4.3.DWG

FIGURE 4.4



LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED WITHIN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED ABOVE RIM LEVEL
- DIRECTION OF FLOW
- CONDUIT SURCHARGED
- CONDUIT FLOWING AT (80-100%) FULL
- CONDUIT FLOWING AT LESS THAN 80% FULL

NOTE: WATER LEVELS INTO THE SHEEP RIVER AT THE STORMWATER OUTFALLS WERE DETERMINED BASED ON THE NATURAL GROUND LEVEL AT THE OUTFALL AREA

Okotoks
Historic Past, Sustainable Future

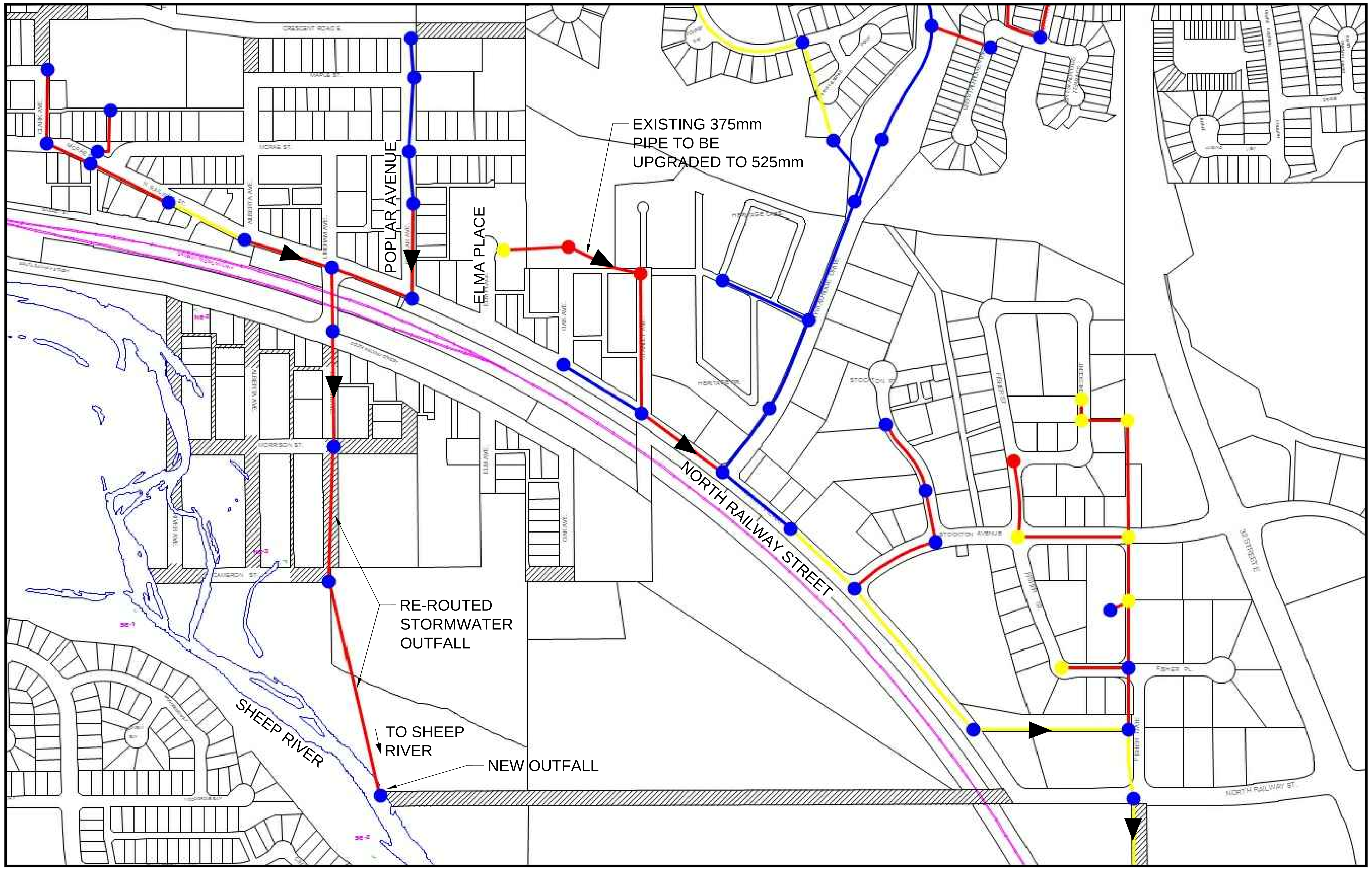
TOWN OF OKOTOKS
STORMWATER MANAGEMENT
MASTER PLAN

POPLAR AVENUE AND ELMA PLACE
1:5 YEAR, 24 HOUR STORM
HYDRAULIC MODELLING RESULTS
PROPOSED UPGRADING (OPTION 1)
NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:06:12 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 4.4.DWG

FIGURE 4.5



LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
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Okotoks

Historic Past, Sustainable Future

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

POPLAR AVENUE AND ELMA PLACE

1:5 YEAR, 24 HOUR STORM

HYDRAULIC MODELLING RESULTS

PROPOSED UPGRADING (OPTION 2)

NOV 2014

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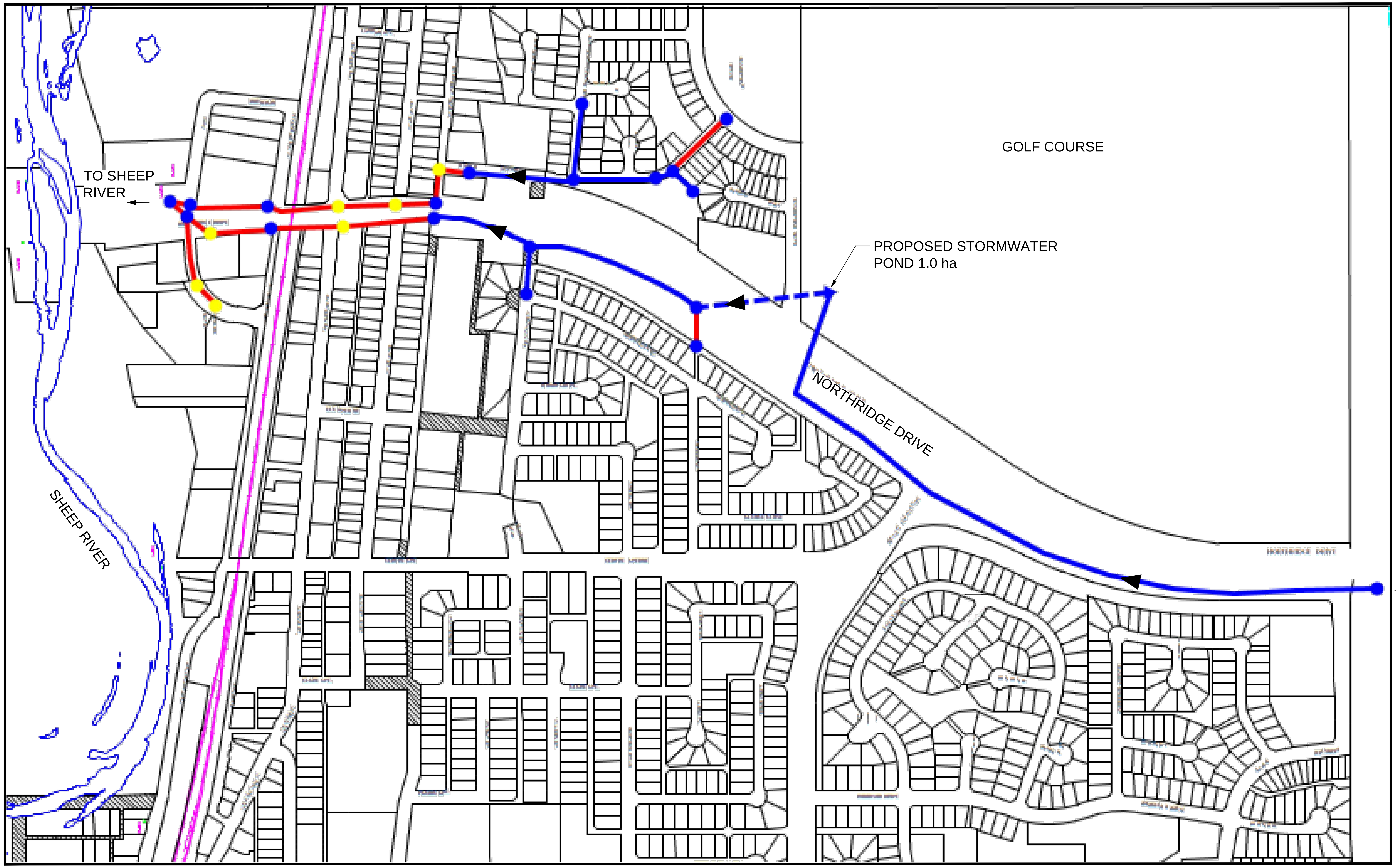
FIGURE 4.6



OFF-SITE FLOWS

LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED WITHIN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED ABOVE RIM LEVEL
- POND FILLED WITHIN MORE THAN 50cm BELOW CREST LEVEL
- DIRECTION OF FLOW
- CONDUIT SURCHARGED
- CONDUIT FLOWING AT (80-100%) FULL
- CONDUIT FLOWING AT LESS THAN 80% FULL

NOTE: WATER LEVELS INTO THE SHEEP RIVER AT THE STORMWATER OUTFALLS WERE DETERMINED BASED ON THE NATURAL GROUND LEVEL AT THE OUTFALL AREA

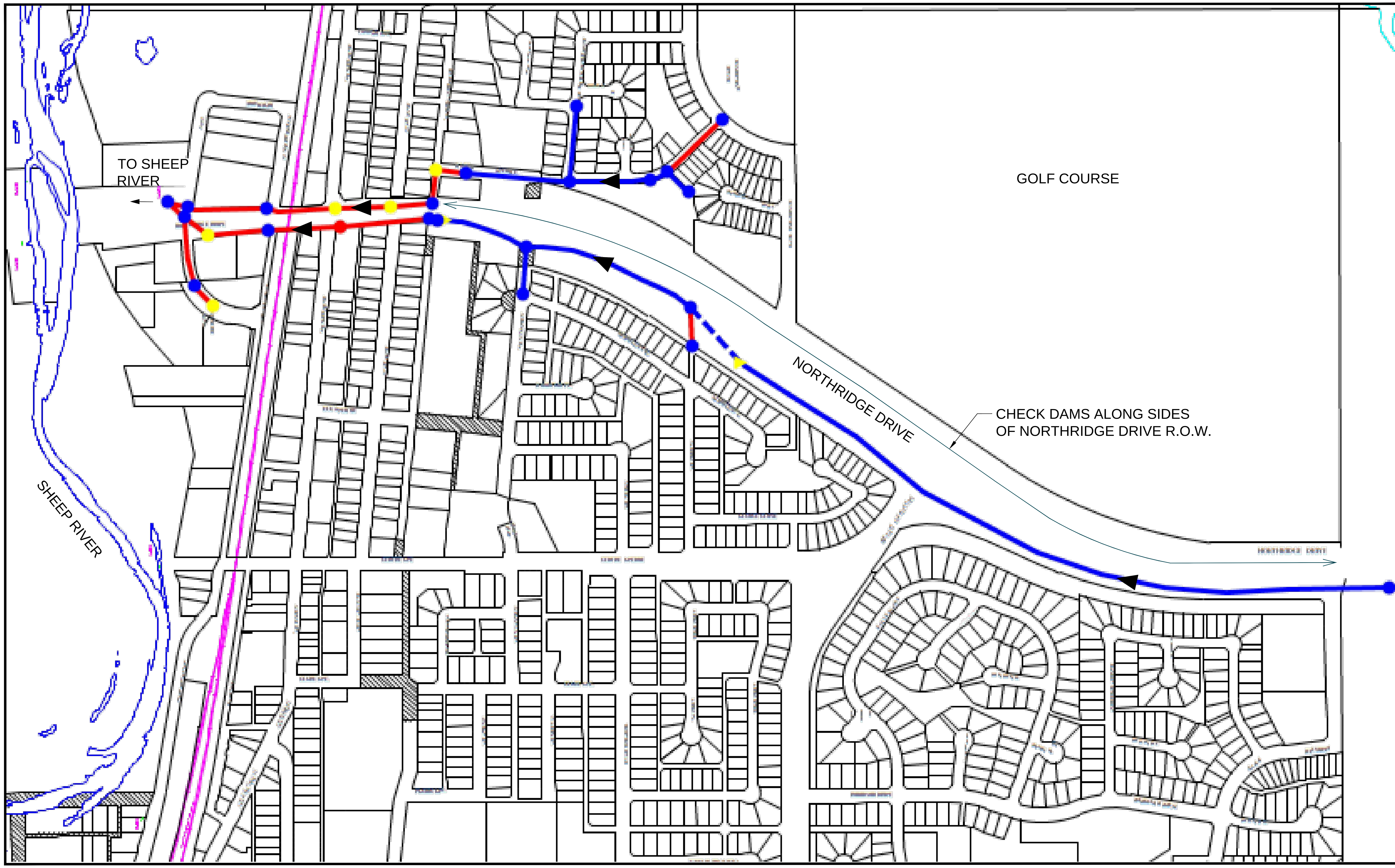
Okotoks

TOWN OF OKOTOKS
STORMWATER MANAGEMENT
MASTER PLAN

NORTHRIDGE DRIVE
1:5 YEAR, 24 HOUR STORM
HYDRAULIC MODELLING RESULTS
PROPOSED UPGRADING (OPTION 1)
NOV 2014

ISL Engineering and Land Services

FIGURE 4.7



LEGEND:

- MANHOLE SURCHARGED WITHIN MORE THAN 50cm BELOW RIM LEVEL
- MANHOLE SURCHARGED WITHIN 50cm BELOW RIM LEVEL
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Okotoks

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

NORTHRIDGE DRIVE

1:5 YEAR, 24 HOUR STORM

HYDRAULIC MODELLING RESULTS

PROPOSED UPGRADING (OPTION 2)

NOV 2014

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5.0
Existing System Upgrades for Water Quality Improvement

The Town of Okotoks has a significant portion of Town that does not have proper stormwater controls on it at the present. This area is illustrated on Figure 5.1. Given that the majority of these areas are developed, with existing storm trunks generally not proximal to open spaces, it was determined that, by in large, retrofit for rate control would not be feasible unless end of pipe management was employed. This is typical with practices in the City of Calgary as it pertains to stormwater retrofit programs. Accordingly, and as per direction from the Town, a focus was put on stormwater quality treatment retrofits for existing areas. It is noted that end of pipe controls, such as stormwater management facilities, is also contemplated here, but noting that rate control potential of such facilities would be considered a bonus to the stormwater quality focus.

5.1 Overview

A significant portion of the previously developed basins within the Town of Okotoks currently have no provision for stormwater quality treatment. This includes areas north and south of Sheep River within the aforementioned low terrain and high terrain areas (see Figure 5.1). The developed areas are largely residential and serviced by a storm drainage system comprised of a combination of subsurface stormsewer systems and open channel systems. These previously developed basins are a source of nonpoint source (NPS) pollution to Sheep River.

Unlike pollution from industrial and sewage treatment plants, that is conveyed by pipes and conduits (i.e. point source pollution), NPS pollution from urban stormwater runoff comes from many diffuse sources and when left untreated is ultimately discharged to surface water systems such as Sheep River.

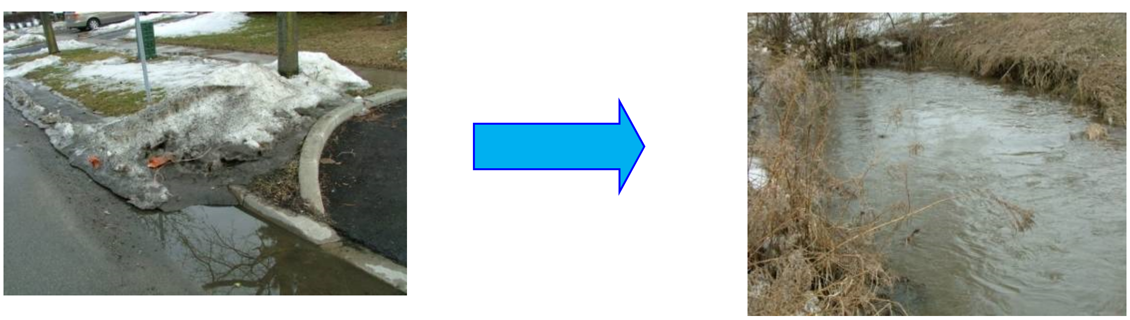


Figure 5.2 – NPS Contaminant Transport to Surface Water (Source: Aquafor Beech, 2012)

As the runoff moves over impervious areas, it picks up and carries away natural and man-made pollutants, finally depositing them into lakes, rivers, wetlands, and groundwater. Urban stormwater runoff can include elevated levels of suspended solids; bacteria and nutrients from livestock, pet wastes and faulty septic systems; excess fertilizers; and herbicides and insecticides from agricultural lands and residential areas. Stormwater runoff can also include oil and grease as well as toxic chemicals and chloride from road salt applications. Table 5.1 presents the common stormwater pollutants and their major contributors; and illustrates the broad nature of their sources.

Table 5.1 - Common Stormwater Pollutants and their Major Sources

Common Stormwater Pollutant	Major Non-Point Source Related to Human Land-use
Sediment and Particulates	Construction, winter road sanding, vehicle emissions, pavement wear
Hydrocarbons (PAHs)	Spills, leaks, dumping, vehicle emissions, asphalt breakdown, wood preservatives
Pathogens (Bacteria, Viruses)	Illicit connections of septic/sanitary sewer to storm system, (pet and bird feces)
Chloride, Sodium, Calcium	De-icing salt application and anti-caking agents
Nutrients (Nitrogen & Phosphorous)	Illicit connections of septic/sanitary sewer to storm system, detergents, fertilizers
Heavy Metals (Cd, Zn, Pb, Cu, Mn, Ni, Cr, & Fe)	Tire wear, insecticides and fungicides, wood preservatives, (metal plating), motor oil and grease, batteries, bearing wear, paint, vehicle exhaust, wear of moving engine parts, steels structures and rusting automobiles
PCBs	Leaks from electrical transformers, spraying of highway right-of-ways, catalyst in tire construction

The provision of water quality controls within urbanized areas can be both costly and difficult to implement based on the need for open lands, conflicts with existing services and utilities, existing topography and grading, local soils and public perception. As such a holistic strategy is required which considers the ‘triple bottom line’ (TBL) of social, economic and environmental factors is required to implement stormwater quality retrofits which are acceptable to the community, cost effective and provide the required water quality enhancements.

5.2 Rationale for Retrofits

In the last decade, the traditional paradigm of applying urban drainage infrastructure (e.g. storm sewers) to quickly and efficiently remove stormwater to streams and rivers has shifted towards stormwater management planning with broader scope that embraces ecosystem-based solutions in conjunction with evolving treatment technology and enlightened management practices. Issues with respect to water quality and volume management considerations have driven watershed managers, engineers, and planners to adopt alternative stormwater approaches that treat rainwater as a resource rather than as waste. A variety of measures (or Best Management Practices) including source control (measures on private property), conveyance control (measures within road right of ways) together with traditional end-of-pipe controls (dry ponds, wet ponds, wetland and subsurface facilities) applied sequentially and termed ‘the treatment train approach’ to stormwater’ has largely replaced traditional techniques. While end of pipe controls commonly form the primary water quality measures employed by municipalities, alternative approaches including source and conveyance controls within the suite of what is referred to as Low Impact Development (LID) are increasingly being applied to achieve enhanced water quality control .

The following sections are intended to present a series of water quality retrofit options broken into three (3) distinct categories of stormwater management:

1. Source Controls Retrofits
2. Conveyance Controls Retrofits
3. End-of-pipe (EOP) Controls Retrofits

A description of each retrofit category including relevant options, feasibility for Okotoks, typical cost as well as relevant implementation considerations are detailed within the following section.

5.3 Feasibility of LID

As described previously, the soils in the Calgary area are not ideal from a soil infiltration aspect. The dominant soils within the Town of Okotoks have been characterized as having an ultimate infiltration rate 7.5mm/hr which would suggest a loam to silt loam (SCS Class C) soil type and as such will require the provision of a subdrain for all LIDs.

This suggests a physical constraints which could limit the use of LID source and conveyance controls, but does not in any way indicate that area soils with lower relative infiltration rates be excluded from infiltration practices. The infiltration rate of soils will have an obvious effect on the drawdown-time of the facility between events and therefore should be sized accordingly based on design guidance from sources such as the City of Calgary Source Control Practices Handbook (2007) and TRCA/CVC LID Planning and Design Guide (2010). As such, the ultimate infiltration rate of the local soils should not be interpreted as a prohibition but as a caution that controls relying primarily on infiltration may not be as effective as they could be on soils with higher relative rate of infiltration.

LID stormwater management practices in soils with lower infiltration rates such as Class C soils are designed through the provision of an subdrain such that they utilize multiple mechanisms (beyond simply infiltration) such as, but not limited to:

- Filtration,
- Retention,
- Evaporation and/or Transpiration.

The primary function of LID practices in Class C soils in not infiltration. Through in-situ testing of the site specific native soils, the application of appropriate safety factors, the LID designs will function in a manner such that the facility only infiltrates what the local soils can reasonably accommodate within the recommended emptying times. The mechanisms of filtration, retention, and evaporation and/or transpiration can be used to improve water quality and reducing runoff volumes. Provided that the proposed LID techniques incorporate the appropriate runoff storage volumes, empty within inter-event periods and are otherwise appropriately sited, designed, monitored and maintained (similar to all other stormwater management facilities), there should be no impediment to the application of LID technologies for the realization of water quality in the Town of Okotoks. This is supported by the City of Calgary Source Control Practices Handbook (2007) which presents a summary overview of the potential applicability of LID controls measures within an urban context and in relation to Calgary soils and climate (Table 5.2).

Table 5.2 – Applicability Matrix

LID Practice	Suitability for Calgary Climate & Soils[1]	Land-use Type			
		Industrial	Commercial & Multi family	Residential	Parks and Open Space
Stormwater Re-use/ rainwater harvesting	High	✓✓	✓✓	✓✓	✓✓
Grass swale/ bioswales	High	✓✓	✓	✓✓	✓✓
Bioretention	High	✓	✓✓	✓✓	✓✓
Green Roofs	High	✓✓	✓✓	X	X
Porous Pavement	Medium	✓	✓✓	✓✓	✓✓
Absorptive Landscapes	High	✓✓	✓✓	✓	✓✓

✓ = somewhat applicable, ✓✓ = highly applicable, *X = not applicable*

[1] Subdrain system may be required

Adapted from Table I-2 & I-3, City of Calgary Source Control Practices Handbook (2007)

5.4 LID Performance

In general, water quality improvements begins with filtration of particulates as runoff flows over the surface of the LID and through vegetation, mulch, soil layers and or aggregate layers (City of Edmonton, 2011). For vegetated practices, soil microbes provide decomposition for pollutants such as hydrocarbons and nutrients. Soils also allow metals and chemicals to sorb to soil particles and compounds within the soil, preventing their release to receiving streams. Table 5.3 summarizes the environmental performance of LID practices.

Table 5.3 – Expected Performance

LID Practice (with subdrain)	Environmental Performance		
	Pollutant Removal	Peak Flow Reduction (small events)	Volume Reduction (Estimated)
Stormwater Re-use/ rainwater harvesting	n/a	Medium	Medium (40%)[1]
Grass swale/ bioswales	High	Medium	Medium (45-55%)[1]
Bioretention	High	Medium	Medium (45%)[1]
Green Roofs	Medium	Medium	Medium (45-55%)[1]
Porous Pavement	Medium	Medium	Medium (45%)[1]
Absorptive Landscapes	High	Medium	High (varies)
Perforated Pipe Systems	Medium	High	High (89%)[1]

Adapted from Table I-3 - City of Calgary Source Control Practices Handbook (2007) and amended by TRCA/CVC 2011 [1]

5.5 Source Controls

a) Description:

Source control measures are physical measures that are located at the beginning of a drainage system, generally on private properties which may include:

- Residential properties
- Community centers
- Municipal buildings
- Place of worship
- Schools and
- Parks

b) Options:

Source control retrofit options include bioretention, infiltration trenches & chambers, permeable pavement, absorptive landscapes, green roofs, stormwater re-use/rainwater harvesting (RWH) and roof downspout disconnections (Figure 5.3). These measures primarily treat the more frequent storm events in terms of water quality.

Figure 5.3 - Source Control Measures(From L to R) Bioretention, Downspout Disconnection, Permeable Pavement & RWH

c) Feasibility:

Source controls can provide significant improvements in water quality control when applied in sufficient numbers across an uncontrolled basin.

Bioretention, infiltration trenches & chambers, permeable pavement in combination with roof downspout disconnections will require the provision of subdrains. Green roofs are generally limited industrial and commercial properties (Table 5.2) and will require analysis of the existing building structure. A summary of site constraints for all LID controls are detailed in Table 5.6.

Privately Owned Lands

LID measures on privately owned lands are generally installed within residential, commercial, industrial and institutional land uses (schools and places of worship) and as such, retrofits within these non-municipally owned lands will be undertaken by the individual landowner per the provisions of the Town's existing planning requirements and by-laws. The Town would be limited to a supportive role in regard to the implementation of source controls on such properties. The Town may wish to consider ways to encourage private property owners (particularly schools and place of worship) to raise their awareness to the environmental and socio-economic benefits for implementing source controls. In general schools and place of worship have been found to be primary and early adopters of LID technologies, as such initiatives often resonate with site users, can be integrated into curriculum and these groups generally have an established support structure. Other activities that the Town could perform include a review and revision of existing policy and by-law framework to allow for streamlined the implementation. An example of source control retrofits at a school and place of worship are provided below in Figure 5.4 and 5.5 respectively.

Figure 5.4 - Bioretention Source Control Retrofit at Green Glades Public School
(From L to R) Before and After (Source: Aquafor Beech Ltd.)

Figure 5.5 - Bioretention Source Control Retrofit at Portico Church
(Source: Aquafor Beech Ltd.)

Identified Opportunities within Privately Owned Lands

Within the previously developed basins of the Town of Okotoks which currently have no provision for stormwater quality treatment, a series of five (5) opportunities for source control retrofits were identified using aerial photography within the land uses of schools and places of worship, north and south of Sheep River, which include, but are not limited to:

North of Sheep River:

- Good Shepherd School (Robinson Drive)
- Percy Pegler School (Okotoks Drive)

South of Sheep River

- Foothills Composite High School (Woodhaven Dr), Big Rock School (Hunters Gate) , John Paul II Collegiate (Cimarron Dr) and Okotoks Evangelical Free Church (Westland Road)

Implementation Considerations for Privately Owned Lands

As part of the implementation of LID source controls on private property, the Town may wish to consider the need for assurances and long standing arrangements which ensure that these facilities continue to perform as designed into the future. Provided below are a series of potential assurances that may be required as part of the approval process for on-site LID techniques. Examples include:

- Agreements which make the removals of on-site source controls unlawful;
- Covenants placed on title of individually owned lots requiring owners, individually and collectively, to maintain repair and replace infrastructure;
- Maintenance agreements that assign long-term maintenance responsibility;
- On-site source controls to be placed/sited within easements which have adequate access for inspection and maintenance. Consideration should be given to easement requirements agreements which permit the Town to gain access to the private property to lawfully inspect, enforce maintenance requirements and undertake such maintenance or repair works should conditions of the maintenance agreement be violated.

Municipal Lands

Many opportunities exist for source control retrofits within municipally owned lands such as recreation centers, municipal buildings and parks. Given that these lands are owned and operated by the municipality, the municipality can control the process, is provided with a greater degree of freedom and in general the risks are more easily accounted for and managed.

Generally these urban elements are high profile, used extensively by the public/community and also serve secondary functions (i.e. individual uses by different elements of the community). These attributes make them ideal for source control retrofits (and pilot projects) and have the added benefit of having the potential to be utilized as part of public education platforms for broader environmental initiatives. Many municipalities are using their existing park assets to provide improved water quality control, while simultaneously improving park aesthetics and function (Figure 5.6 and 5.7).

Figure 5.6- Source Control Retrofit within Parks,
(From L to R) Permeable Pavement Parkette and Pervious Concrete Parking Lot
(Source: Aquafor Beech Ltd.)

Figure 5.7 - Source Control Retrofit at Municipal Buildings
Bioretention Retrofit at Glenmore WWTP (Source: Aquafor Beech Ltd.)

Identified Opportunities within Municipally Owned Lands

Within the previously developed basins of the Town of Okotoks which currently have no provision for stormwater quality treatment, a series of twenty seven (27) opportunities for source control retrofits were identified within parks, municipal buildings and recreation centers, north and south of Sheep River, which include but are not limited to:

North of Sheep River:

- Parks - Carr Park, Haynes Park, Hodson Park, Wylie Athletic Park, Banister Drive Park, Wilson Park, Cedar Grove Park, Kinsman Park, Crystal Ridge Point Park, Cassie Ravine, Ardiel Park and Knowles Park
- Municipal Building & Recreation Centres - Recreation Center at Milligan Drive. The Recreation Center at Milligan Drive was identified as having surface flooding during a 5 year storm and may present an opportunity to provide volume reductions, peak flow reductions and improvement in water quality through LID source control retrofits. This site is an ideal candidate for a water quality retrofit pilot project for the Town of Okotoks.

South of Sheep River

- Parks - Sheep River Heights Park, Sheep River Crescent Park, Sheep River Close Park, Westridge Close Park, Teskey Park, Wathren Park, Otterbein Park, Stewart Park, Hughes Park, Woodgrove Park, Grisdale Park, Tillotson Park and Kadey Park.
- Municipal Building & Recreation Centres - Centennial Arena, Foothills Community Centre

d) Implementation within Parks and Municipal Buildings

Implementation of source control measures within parks and municipal buildings may have additional implementation considerations, including, but not limited to:

- Generally subject to specific programming requirements (organized sports, passive and active recreation activities, community group usage, parking requirements etc.),
- Have specific requirements of use (seasonal vs. full year, capacity etc.)
- Are subject to maintenance protocols and policies;
- Municipally controlled but requires input and approval from multiple departments;
- Can have high public involvement and perceived ownership of the existing space;

e) Typical Implementation Costs

Typical unit construction costs for source control retrofits are detailed within Table 5.4 below. Cost may vary depending on site specific factors, including soil infiltration rates. By performing in-situ testing of the site specific soils using a Guelph Permeameter, double ring infiltrometers, pit tests and others, the infiltration rate of the native site soils can be scientifically verified and utilized in developing cost estimates and in subsequent phases of design.

Table 5.4 – Typical Source Control Unit Costs

LID Technique	Unit Construction Cost (avg)
Rainwater Harvesting	\$250- \$1,000 / m^3 stored (\$620)
Green Roofs	\$120 - \$300 / m^2 roof area
Downspout Disconnection	Retrofit = \$100/ disconnection
Infiltration Trenches and Chambers	\$430 - \$550 / m^3 stored (\$500)
Bioretention	600-750/m^2 of facility (\$52,000 / imp. ha treated)
Bioretention Planters (contained within concrete curbing or urban container)	Bioretention Planter (small) \$1,000 - \$1,600 (\$1,200)/m^3 treated Stormwater Tree Pits \$2,400 - \$3,400 (\$2,900)/m^3 treated
Permeable Pavement	Unit Pavers: 120- 140/ m^2 Porous Concrete: \$140 - \$175/ m2

All figures in Canadian Dollars (Source: TRCA, 2010, TRCA 2013, MacMullan et. Al., 2008, Wise, 2008, Aquafor Beech 2013)

5.6 Conveyance Controls

a) Description:

Conveyance control s are physical measures that are generally located within the municipal road right-of-way (ROW) where flows are concentrated and conveyed. A right-of-way is a measure of the total width needed to accommodate the street pavement, sidewalk(s), drainage, street trees, and utility easements.

b) Options:

Conveyance controls typically include stormsewers and ditches, but more recently have begun to include LID conveyance techniques such as bioswales, grass and vegetated channels and sub-surface perforated pipe systems (Figure 5.8) as means to provide water quality control with the municipal ROW. The right-of-way is publically owned land that is maintained by the municipality. Canadian municipalities that have incorporated conveyance control works into the road design process include Edmonton, Calgary, Victoria, Toronto, Mississauga, and Hamilton.

Figure 5.8 - Conveyance control measures.(From L to R): Vegetated Channel (Calgary), Bioretention/bioswale (Edmonton) and Perforated Pipe System (Mississauga)

c) Feasibility

Like source controls, conveyance controls can provide significant improvements in water quality control when applied in sufficient numbers across an uncontrolled basin. In order to provide water quality treatment to areas that do not/will not have end-of-pipe treatment facilities (ponds or OGS systems), conveyance control are recommended as a viable alternative. LID conveyance controls can be used to improve water quality, generally at a lower cost to the municipality, verses conventional approaches.

Because the municipal ROW account for a significant share of the Town's total impervious surface area, conveyance controls located within the ROW present an important opportunity to improve downstream water quality conditions. The best opportunities to implement stormwater quality treatment measures in the municipal right-of-way are within:

- Boulevards - grassed area located between the curb and the sidewalk
- Existing roadside ditches
- On the road surface adjacent to the curb (in the form of bump-outs).

A summary of site constrains for all LID controls are detailed in Table 5.6.

Figure 5.9–Bioswale Retrofit of an Existing Ditched ROW From L to R) Before and After (Source: Aquafor Beech Ltd.)

Figure 5.10 –Bioretention Retrofit of the Boulevard (Source: Aquafor Beech Ltd.)

Figure 5.11 –Bioretention Bump-out Retrofit (L: Before (Source: City of Victoria), R: After (Source: Aquafor Beech Ltd.)

d) Identified Opportunities within the ROW

Section 4.3.2 of this report discusses options for flood mitigation along Northridge Drive. Option 2 includes the provision of small detention areas in the form of a series of check dams across the existing open drainage ditches to attenuate peak flows. Through design modifications which would include the use of an engineered biomedia, and a perforated subdrain encased in clear gravel in combination with the recommended check dams, option 2 has the ability to function as a series of bioswales and can provide the added benefit of improved water quality. Figure 5.12 below illustrates a typical bioswales detail for water quality control which incorporates check-dams.

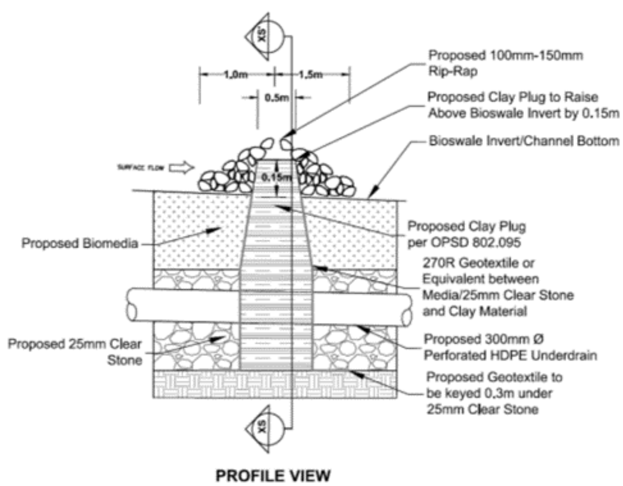


Figure 5.12–Typical Detail of a Bioswale with Check-dams (Source: Aquafor Beech Ltd.)

e) Typical Costs

The most cost effective means of implementing LID retrofits in the municipal right-of-way is to complete the retrofit/construction concurrent with capital improvement and municipal road works projects. The opportunity to incorporate conveyance control measures will likely come as a result of redevelopment pressures (which require replacement of the infrastructure) or replacement due to deteriorating condition of the infrastructure. In the latter case, replacement of the drainage infrastructure may well occur as part of the overall reconstruction of the roadway. Typical unit construction costs for conveyance control retrofits are detailed within Table 5.5 below.

Table 5.5 – Typical Conveyance Control Unit Costs

LID Technique	Unit Construction Cost (avg)
Vegetated Channels	\$32,000 – \$105,000/ ha treated (\$52,000 / ha treated)
Bioswales	\$30,000 – \$105,000/ ha treated (\$52,000 / ha treated) \$500 / m^3 treated \$300 - \$375 / m^2 of facility
Perforate Pipes	150-200/m^2 of facility

All figures Canadian Dollars (Source: TRCA, 2010, TRCA 2013, MacMullan et. Al., 2008, Wise, 2008, Aquafor Beech 2013)

5.7 Implementation of LID Retrofits

Implementation considerations with respect to individual LID source and conveyance control retrofits are summarized within Table 5.6 as attached.

5.8 End of Pipe (EOP) Controls

End-of-pipe controls for water quality retrofit applications can be divided into surface and sub-surface facilities. Surface facilities such as wet ponds, wetlands and hybrid facilities (combination of wet pond and wetland features) comprise the most common form of stormwater quality treatment in most municipalities, however in areas where opportunities are limited, sub-surface facilities are more common and can be more cost effective and less land intense (Figure 5.13). All end-of-pipe facilities can be constructed to improve water quality, while also abating in-stream erosion problems and downstream flooding conditions.

Figure 5.13 – End-of Pipe Controls (From L to R): Wet pond, Wetland, Hybrid and Sub-surface Facility (Source: Aquafor Beech Ltd.)

Surface EOP Controls

a) Description:

Surface EOP controls include wet ponds, wetlands and hybrid facilities (combination of wet pond and wetland features) whose primary functions can include water quality in combination with flood control.

b) Options:

In general surface EOP retrofits within developed basins include two (2) primary options:

1. EOP Controls Retrofits at the Stormwater System Outlet
2. EOP Controls Retrofits within the Drainage Network (upstream of the outlet)

1. EOP Controls at the Stormwater System Outlet

Locating surface end-of-pipe controls within the aforementioned low terrain areas immediately upstream of the stormwater pipe terminus has inherent constraints including floodplain conflicts and generally high water levels within Sheep River as previously discussed within the report.

2. EOP Controls Retrofits within the Drainage Network

Commonly referred to as an "up-pipe" solution, this option includes locating EOP facilities within the existing stormsewer drainage network upstream of the pipe terminus/outlet. Facilities are typically located within open areas (parks, hydro corridors, vacant lands) or on other municipally owned lands (public works yards, municipal operations facilities etc.) where the existing stormsewer system is in close proximity or crosses through the target area. The surface EOP control is then integrated into the fabric of the existing land use as an amenity through the inclusion of park elements, trails, enhanced plantings etc. Figure 5.14 illustrates an "up-pipe" solution whereby a wet pond facility for water quality was retrofitted into the stormsewer network at the intersection of the existing piping within a park and trail network system.

Figure 5.14 – Surface EOP Control Retrofit within the Drainage Network (From L to R): Before and After (Source: Aquafor Beech Ltd.)

c) Feasibility

Locating surface facilities such as wet ponds, wetlands and hybrid facilities within developed basins is largely dependent on several key considerations including but not limited to:

- Available area (typically must be >0.5 to 1ha);
- Land Ownership;
- Surrounding Infrastructure/Potential Future Requirements;
- Topographic Constraints;

- Significant Vegetation;
- Pipe Depth;
- Drainage Area;

To identify potential retrofit sites, a general three (3) step evaluation process is typically undertaken which includes:

1. Desktop based Land Assessment - analyzing available GIS databases to locate potential SWM retrofit sites using the aforementioned key considerations. Study resolution in regards to the existing stormsewer piping network is typically increased and combined with existing property boundaries.
2. Performance Assessment – of retrofit locations carried forward from step 1. Analyzed based on technical considerations and optimization opportunities of the following environmental components:
    a. The potential water quality benefit; and
    b. The potential to maintain/improve the flood control.
3. Field Reconnaissance/ Impact Assessment - of the available retrofit locations carried forward from previous steps. The field assessment typically involves identifying potential impacts related to the EOP facility retrofits proposed for each site location. The field assessment evaluated each feasible location for impacts and/or opportunities based on three (3) criteria which included:
    •Environmental;
    •Social; and
    •Economic.

d) Typical Costs

Typical costs for surface EOP retrofits are summarized below:

- The cost to excavate down to the existing stormsewer invert can be estimated using a rate of \$100/m3 of excavate material removed
- The cost to excavate the permanent pools can be estimated using a rate of \$140/m3 of water quality storage volume provided.
- For simplicity, cost estimates can be determined using a rate of \$120/m3 of total excavated material removed (i.e. extended detention + permanent pool volumes).
- A minimum construction cost of \$250,000 per facility should be applied.

Sub-surface EOP Controls

a) Description:

Subsurface stormwater storage, consisting of pre-manufactured units, can reduce peak flow rates by providing storage of a large volume of stormwater in small areas. When used strictly as storage facilities these stormwater structures typically provide only marginal water quality improvements through the settlement of coarse sediment. However, most pre-manufactured underground storage units have the capability to be used as combination detention/ infiltration facilities, thereby providing water quality enhancements.

The benefits beyond water quality improvements associated with subsurface stormwater storage faculties may include, but are not limited to:

- Maximization of land area
- Ability to infiltrate stormwater
- Eliminates thermal discharge loadings to receiving water bodies
- Replenished groundwater supplies
- Subsurface installation, minimize open water liabilities
- Can be installed near the stormwater source thereby eliminating contaminant entrainment during conveyance

b) Options:

The six general types of subsurface controls are presented below in Table 5.7. Classes 1-2 & 4-5 can be combined with LID controls described in pervious sections to enhance sub-surface storage capabilities. Class 3 and 6 are generally utilized as stand-alone subsurface facilities.

c) Feasibility

Generally, underground storage facilities are utilized at:

- sites which lack sufficient space to construct typical surface EOP controls;
- locations that would require excessive excavation due to depth of the existing stormsewer; or
- in areas of high constraint (existing uses such as sports fields, play structure, and or parking areas).

Figure 5.15 illustrates a sub-surface EOP retrofit (in combination with a surface EOP retrofit) beneath a soccer field of an existing park area.

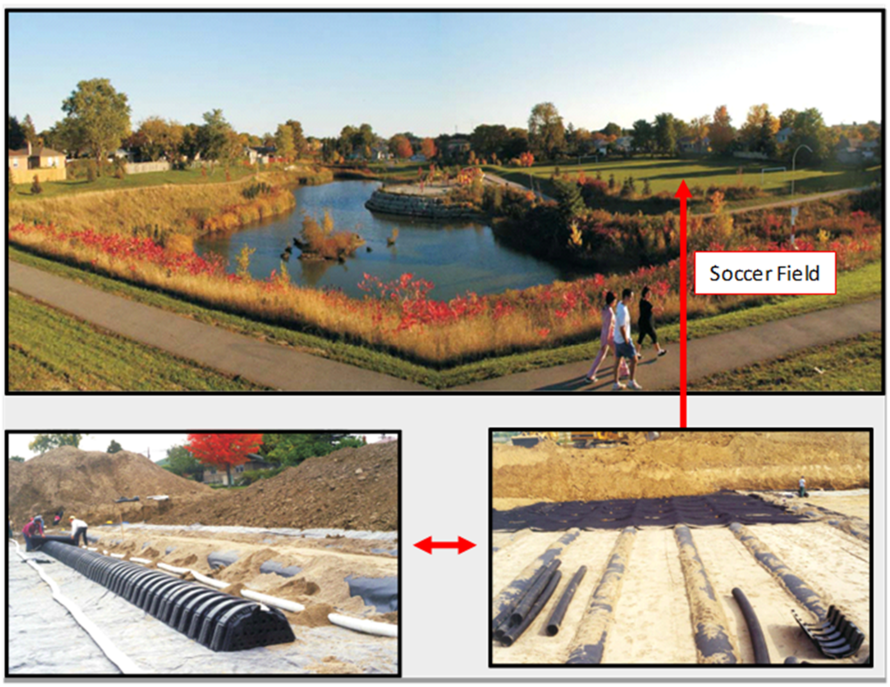


Figure 5.16 – Sub-surface EOP Control Retrofit within the Drainage Network (Bottom L & R): Arched Chamber subsurface system (Source: Aquafor Beech Ltd.)

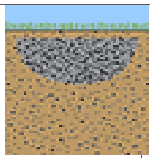
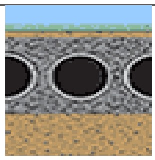
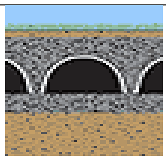
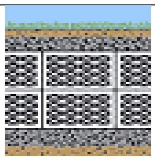
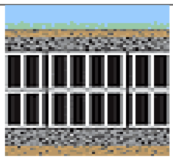
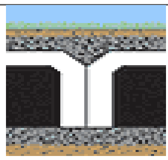
d) Typical Costs

With the large variety of prefabricated modules available the costs associated with storage facilities can vary greatly. Table 5.7 provides relative cost categories for each product classes 1-6.

In general, the typical costs for sub-surface EOP retrofits are summarized below:

- The cost to excavate down to the existing stormsewer invert can be estimated using a rate of $100/m3 of excavate material removed
- Costing of each subsurface storage unit can be assumed to be $225 – 300/m3 of the water quality storage volume provided.
- A minimum construction cost of $250,000 per facility should be applied.

Table 5.7 - Types of Subsurface EOP Facilities

Subsurface Storage System Types	 **French Drain**	 **Pipe**	 **Arched Chamber**	 **"Milk Crate"**	 **Hybrid "Milk Crate"**	 **Vault**
Class	**1**	**2**	**3**	**4**	**5**	**6**
Material Type	Aggregate	HDPE or CMP	HDPE or Concrete	Polypropylene or PVC	Polypropylene and PVC	Concrete
Ability to provide Water Quality	Yes	Yes	Yes	Yes	Yes	Yes
Footprint Required	Large	Medium	Large	Small	Small	Small
Stackable	No	No (yes with no infiltration)	No (yes with no infiltration)	Yes	Yes	Yes
On-Site Component Assembly	N/a	Some	Yes	Yes	Yes	No
Void Space	25-40%†	60-65%†	50-65%†	95%†	95%*	75-85%†
Adaptability	Limited	Moderate	Moderate	Excellent	Excellent	Moderate
Surface Cover	Minimal	Minimal	Min-Moderate	Minimal	Minimal	Min-moderate
Infiltration capability	Yes	Yes	Yes	Yes	Yes	Yes
Strength	N/a	H-20*	H-20*	H-20*	HS-25*	H-25*
Maintenance Access	Re-install	Moderate	Moderate	Difficult	Difficult	Excellent
Safety Concerns	Low	Low	Low	Low	Low	Low
Relative Cost	Low	Low	Moderate	Moderate	Moderate	High
Manufacturer	N/a	Contech	Contech Stormchamber Cultech	EcoRain Atlantis	Stormtank	Contech Stormtrap Rotondo

*As claimed by manufacturer
† Estimated generalized value

5.8.1 Proposed End of Pipe (EOP) Control Works

This section discusses general concepts for EOP control works for the existing uncontrolled stormwater collection systems discharging directly into the Sheep River without any water quality improvement arrangements. This assessment is based on available existing topographic, stormwater collection and land use data provided by the Town of Okotoks. Prior to commencing any detailed planning in this regard, it is highly recommended to conduct further investigation to verify the accuracy of the used data, as this could have a potential impact on the outcome.

The possibility of constructing EOP control works within the drainage network was investigated. The option of providing surface control structures was considered not applicable in general, due to the lack of vacant lands that could be used to accommodate the construction of new ponds/wetlands within the developed areas. The option of installing Sub-Surface control structures at the level of small stormwater sub-catchment areas is attainable, the detailed analysis to determine the location and sizes of these Sub-Surface structures does not fall under the scope of this study.

The possibility of constructing EOP control works at the existing stormwater system outfalls was investigated using the following criteria for the sizing of the proposed works. It is noted that due to the flooding risks at these low terrain areas during high water levels within the Sheep River, the efficiency of these structures might be impacted during these periods:

- 24hr, 5 year return period storm event.
- 85% removal of TSS for particles sizes >= 50 µm.

The following two EOP controls options were assessed:

Option 1: The construction of detention ponds, prior to discharging into the Sheep River. This option was found achievable at some locations in terms of available vacant open spaces. Construction would be relatively simplistic, and would be limited to earthworks and simplistic control structures (e.g. pipe with flap gate, no structure with overflow). The proposed location and estimated required areas for the construction of these works are indicated on Figures 5.16.

Option 2: The installation of compact stormwater treatment detention systems (i.e. Vortechs, Stormceptor…) in line with the stormwater collection trunks, at the up-stream of the discharging points into the Sheep River. This option requires smaller areas than the first option. The estimated cost of these systems is higher than the first option.

For comparison purposes, Table 5.8 below table highlights the outcome of the assessed outfalls and the estimated preliminary cost of the proposed works.

Table 5.8 - Proposed EOP Control Works at Uncontrolled Outfalls

Outfall	Option 1 Cost $	Option 2 Cost $	Comments
NW-1 & 2	$250,000	$1,720,000	Option1 is recommended, after confirmation of the availability of the required Land.
NE-1	$360,000	$1,015,000	Option1 is recommended, after confirmation of the availability of the required Land.
NE-3		$1,130,000	Option 2 is recommended. Limited available land at the outfall.
NE-4		$2,720,000	Option 2 is recommended. Limited available land at the outfall.
SW-1		$1,130,000	Option 2 is recommended. Limited available land at the outfall.
SW-2	$545,000	$1,150,000	Option1 is recommended, after confirmation of the availability of the required Land.
SE-1	$290,000	$1,130,000	Option1 is recommended, after confirmation of the availability of the required Land.
SE-2		$2,255,000	Option 2 is recommended. No available land at the outfall. The proposed location of works, at 300m up-stream of the outfall to be confirmed.

5.9 Pre-Development Runoff Conditions

Traditional stormwater management approaches in the Province of Alberta have focussed on the control of peak discharge rates, but not on total discharge volumes. Provincial guidelines as per the Stormwater Management Guidelines for the Province of Alberta (Alberta Environment, 1999) restrict post-development flow rates to pre-development flow rate levels, but do not deal with total discharge volumes. This report will include the peak discharge rate required as well as the discharge volume as requirements.

To assess pre-development stormwater runoff conditions in the Study Area, historic stream flow data obtained from gauging stations was used. In order to define the generated stormwater flow rates in the Okotoks area and minimize the effect of the mountain/foothills snow pack on the Sheep River flow. The data from the Okotoks gauging station on the Sheep River was assessed versus three other gauging stations on the Sheep River's tributaries along the foothills. Due to limited amount of matching data between the Okotoks and the other foothills stations (<11 years), the Okotoks station was deemed to be not useful since it would not give good results for the 1:100 year conditions (typically at least 50 years of data is required to accurately determine 1:100 year flow rates). As a result, streamflow gauging stations proximal to the Study Area, with a reasonable amount of data (>20 years) were considered. Data was obtained from the Water Survey of Canada. Resultant annual maximum daily stream flow data associated to the following two groups of gauging stations was considered:

a) Group 1: "Highwood River Near Aldersyde" versus "Stimson Creek", "Pekisko Creek," & "Diebel's Ranch". This yields a resultant watershed area of 1070 km².
b) Group 2: "Highwood River Near the Mouth" versus "High River", "Black Diamond" & "Three Point Creek". This yields a resultant watershed area of 900 km².

A statistical analysis of the obtained flow data was undertaken by fitting the data to probability distributions using the computer program Hydrostat. The software was then used to determine the best fit distribution and the 1:100 year flow rates. These flows were determined to be 236.9 m^3/s using a Log Pearson Type 3 distribution for Group 1 as shown on Figure 5.17, and 233.2 m^3/s using a Log Normal distribution for Group 2 as shown on Figure 5.18 Details of the statistical analysis are shown in Appendix C.

Inspiring sustainable thinking

Figure 5.17 – Statistical Analysis of Pre-Development Flow Rates – Group 1

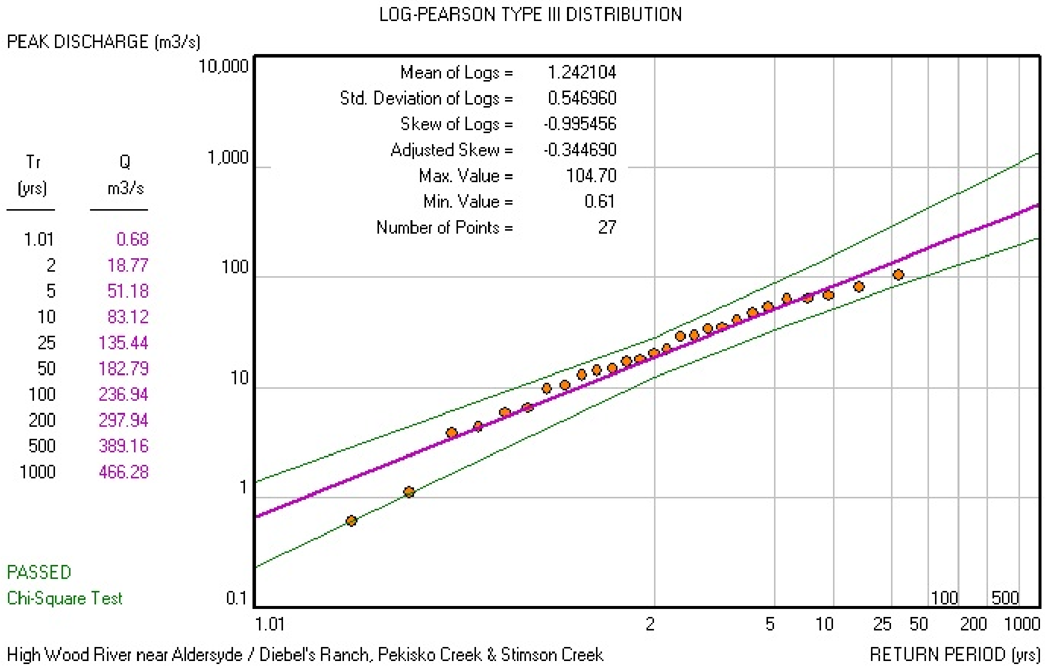
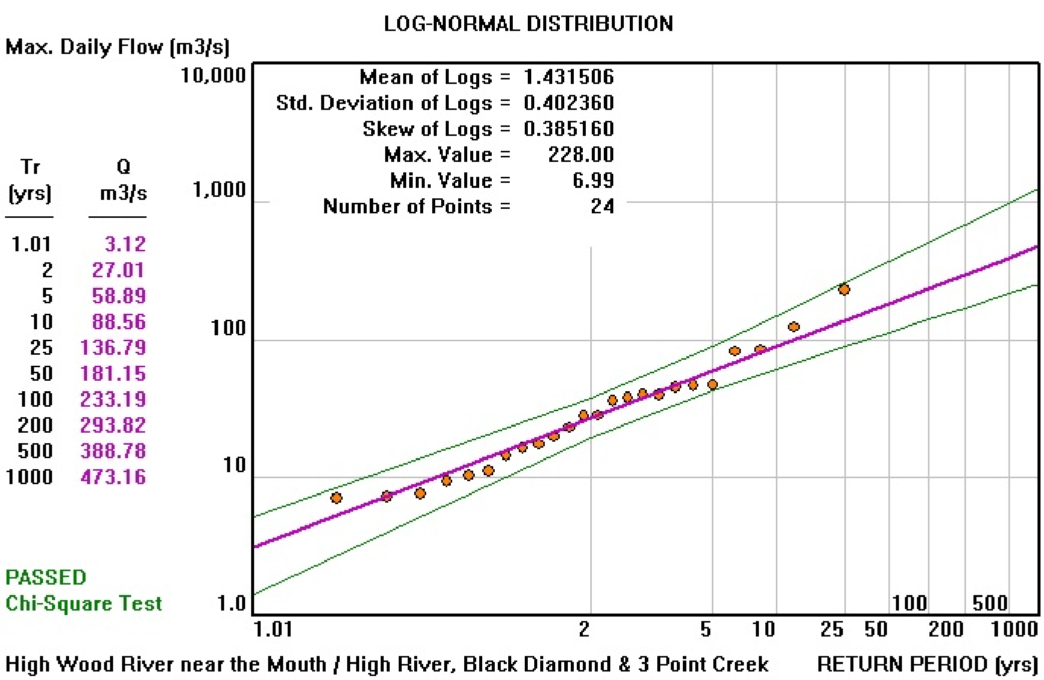


Figure 5.18 – Statistical Analysis of Pre-Development Flow Rates – Group 2



To convert these rates to a value for the Town of Okotoks, the Comparative Basin Formula by the water Survey of Canada was used:

$$Q_{proj} = Q_{watershed} * \left(\frac{A_{proj}}{A_{watershed}} \right)^{k}$$

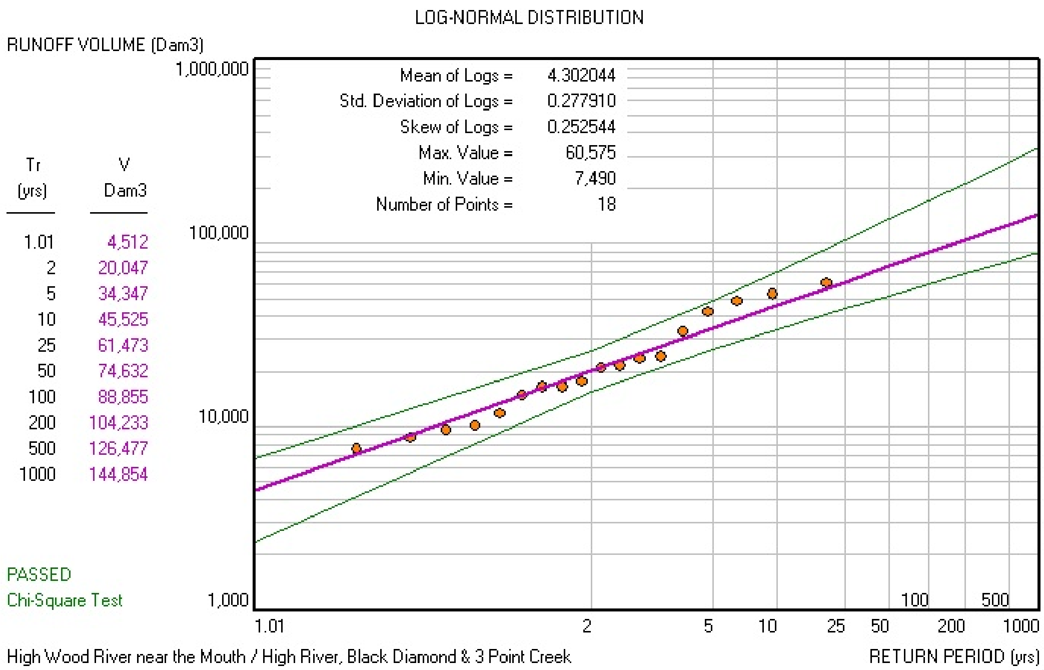
Where k is an exponent equal to:

1.0 for a uniform application over the watershed
0.8 for area based distribution over the watershed (recommended and used for this study).

Using this formula, and considering the drainage catchment area of the Town of Okotoks to be 110 km², the obtained stormwater release rates for pre-development conditions are 3.4 L/s/ha for Group 1, and 3.9 L/s/ha for Group 2. The obtained release rates are considered in the same range of the rate of 2.5 L/s/ha, which is a typical rate employed in the City of Calgary. The slightly higher rates here could be due to some of the more varied terrain in areas around Okotoks, particularly in the foothills. It is noted that release rates ranging between (2.5 - 6.2) L/s/ha with a mean value of 3.2L/s/ha have been used for the previous and on-going development projects in Okotoks.

In assessing the pre-development runoff volume, the data for the gauging stations of Group 2 was analyzed. A statistical analysis of the obtained yearly runoff volume data was undertaken by fitting the data to probability distributions using the computer program Hydrostat. The 1:100 year runoff volume was estimated around 88,855,000 m3 as shown on Figure 5.19 over an effective drainage area of 900 km2 .This results in an annual runoff depth of 98 mm under current development conditions. Details of the statistical analysis of pre-development runoff volume are shown in Appendix D.

Figure 5.19 – Statistical Analysis of Pre-Development Runoff Volume



As a result of the above and based on the fact that the Town of Okotoks has a hydrologic regime similar to the City of Calgary, it is recommended that the stormwater design in the future developed areas in Okotoks is based on a stormwater release rate of 2.5 L/s/ha to the Sheep River and on an annual runoff volume of 98mm. These recommended rates are presented as a guide that must be considered at each development proceeds. It will be necessary for the developers' consultant to confirm these rates for each development separately, taking into account the relevant existing conditions.

5.10 Future Stormwater Ponds

The construction of stormwater ponds to control the increased rates of released runoff due to development has been used very effectively in the area. This section will provide guidance for the required land to be allocated for ponds construction in the future developed areas of Okotoks. The following criteria will be used for the estimate:

- Ponds will be sized to collect 100 year, 24 hour return period, Chicago distribution storms with approximately a 2.0 meter rise from pond bottom to high water level.
- Pond outlet structures will restrict post-development flows to the flow rate of 2.5 L/s/ha.
- The developed areas have a rate of 55% of impervious areas, which is equivalent to developed residential areas.

It is noted that ponds will not, as proposed here, have a significant impact on gross runoff volume. This is discussed in further detail below in Section 5.11. The ponds discussed in this section will be sized to control runoff only, and could be upsized to allow increased evaporation, if desired as discussed below.

In assessing the required area to be allocated for stormwater ponds, a developed area of a typical quarter section area was selected. Using an XP-SWMM model and the above mentioned criteria, it has been found that a pond area of around 3.5 ha which presents a ratio of 5.4% of the developed area is needed per quarter section. This includes a net pond area of 2.0 ha with an active storage depth of 1.6m, as well as other associated works, including landscaping, structures, service road, etc. The estimated cost of this pond would likely be in the order of $2,000,000.

The expected generated runoff volume for the above considered typical quarter section area with a pond of 3.5ha has been assessed. The use of a synthetic rainfall event has limitations in the overall effectiveness of considering longer periods of rainfall where antecedent moisture conditions and evaporation rates may impact the obtained runoff volumes. Accordingly, continuous simulation of stormwater runoff was considered. Rainfall data from 1960 to 2009 was obtained for the City of Calgary International Airport in hourly increments. This data was used to simulate the obtained runoff depth for each year and consequently, statistical analysis has been run to project the 1:100 Year runoff. This analysis, developed using Hydrostat, indicated a 1:100Year annual runoff depth of 238mm, which results in a generated runoff volume of 152,000 m^3.

The obtained total runoff depth of 238 mm exceeds the recommended pre-developed annual runoff of 98 mm. As a result, a total runoff volume reduction of 90,000 m^3 is required for full volume control to be implemented. The application of runoff volume management practices to match the pre-developed annual rate is recommended for consideration on this basis.

5.11 Runoff Reduction Best Management Practices

There are numerous tools available to assist in reducing the overall runoff volume from a developed area. In order to approach the Pre- Development volume of 98mm of annual runoff for the Town of Okotoks, a combination of the below volume control methods could be used:

Stormwater Re-Use / Rainwater Harvesting for irrigation
Source Control Practices
Bioswales / Vegetated Swales
Bioretention areas
Evaporation Facilities

Each of the potential options is discussed below:

5.11.1 Stormwater Re-Use / Rainwater Harvesting

a) Description:
   - Stormwater could be captured using stormwater management facilities or private rainwater harvesting systems and used for irrigation. The City of Calgary defines the amount of water for weekly lawn watering to be roughly one inch (25.4mm). It should be noted that the larger the used storage pond, the larger the volume reduction as evaporation could be considered over the net irrigated area, thus further enhancing the benefit of this stormwater volume reduction method

b) Driving Forces:
   - Difficulty of obtaining water in Southern Alberta makes any solution that increases water supply very positive.
   - Irrigation water could be readily used with minimal, if any, treatment.
   - Potential significant use of stormwater runoff (if 40% of land is irrigated, one inch per week could use up to 6,000m3/week over a single quarter section). This could use up in the order of 50,000m3 of stormwater over the course of an average year.
   - Stormwater pollutants primarily retained by storage ponds.

c) Restraining Forces:
   - Require storage facilities that are designed to ensure availability of water in dry years. Significant stormwater is available in wet years when it is not needed and often not enough is available in high demand dry years.
   - Irrigation users would not have demand during wet periods, thus resulting in significant amounts of runoff that must be stored.

d) Synopsis:
   - Stormwater harvesting and re-use could work very well for Okotoks. This method could significantly reduce potential water demands, thus allowing for a greater service area/population to be served with the available water.

5.11.2 Bioswales / Vegetated Swales

a) Description:
   - Stormwater is diverted into surface drainage swales that are vegetated. The net effect is similar to a combination of a grassed swale and an infiltration trench. Significant vegetation is planted to provide additional quality treatment. Ditch blocks are often installed to promote pollutant settling. Subdrains are often installed in soils with infiltration rates below 12.5mm/hr.

b) Driving Forces:
   - Could work well upstream in subdivisions.
   - Provide a high amount of volume and rate control.
   - Provide a high amount of stormwater pollutant control by retaining pollutants in the swales.
   - Would reduce the size of stormwater management facilities downstream.

c) Restraining Forces:
   - Soils in the Calgary area are not ideal from soil infiltration aspects. As a result, subdrains would likely be required.
   - Relatively maintenance intensive (to remove sediment particularly).

d) Synopsis
   - Bioswales/vegetated swales could work very well for Okotoks, particularly where integrated with subdivision design. They would work best in the areas upstream of the stormwater management facility network. This method of volume reduction would require further review at the time of subdivision design.

5.11.3 Bioretention Areas

a) Description:
   - Stormwater is diverted into holding areas that allow for infiltration. Significant vegetation is planted in the area to provide additional quality treatment. Evaporation also contributes to volume reduction.
   - Driving Forces:
   - Could work well upstream in subdivisions.
   - Provide a high amount of volume and rate control.
   - Provide a high amount of stormwater pollutant control by retaining pollutants within the bioretention area.
   - Would reduce the size of stormwater management facilities downstream.
   - Assuming that 1% of a single quarter section area will be developed as bioretentions within public green areas. This will provide a potential stormwater runoff storage of around 1,000m3 over the course of a year (if the installed gravel infiltration storage layer has a porosity of 30% and a thickness of 50cm).

b) Restraining Forces:
   - Soils in the Calgary area are not ideal from soil infiltration aspects. As a result, subdrains would likely be required.
   - Relatively maintenance intensive (to remove sediment particularly).

c) Synopsis:
   - Bioretention areas could work very well for Okotoks, particularly where integrated with subdivision design. They could be incorporated in boulevards etc. in the road network and on private lots. They would work best in the areas upstream of the stormwater management facility network. This method of volume reduction would require further review at the time of subdivision design.

5.11.4 Evaporation Facilities

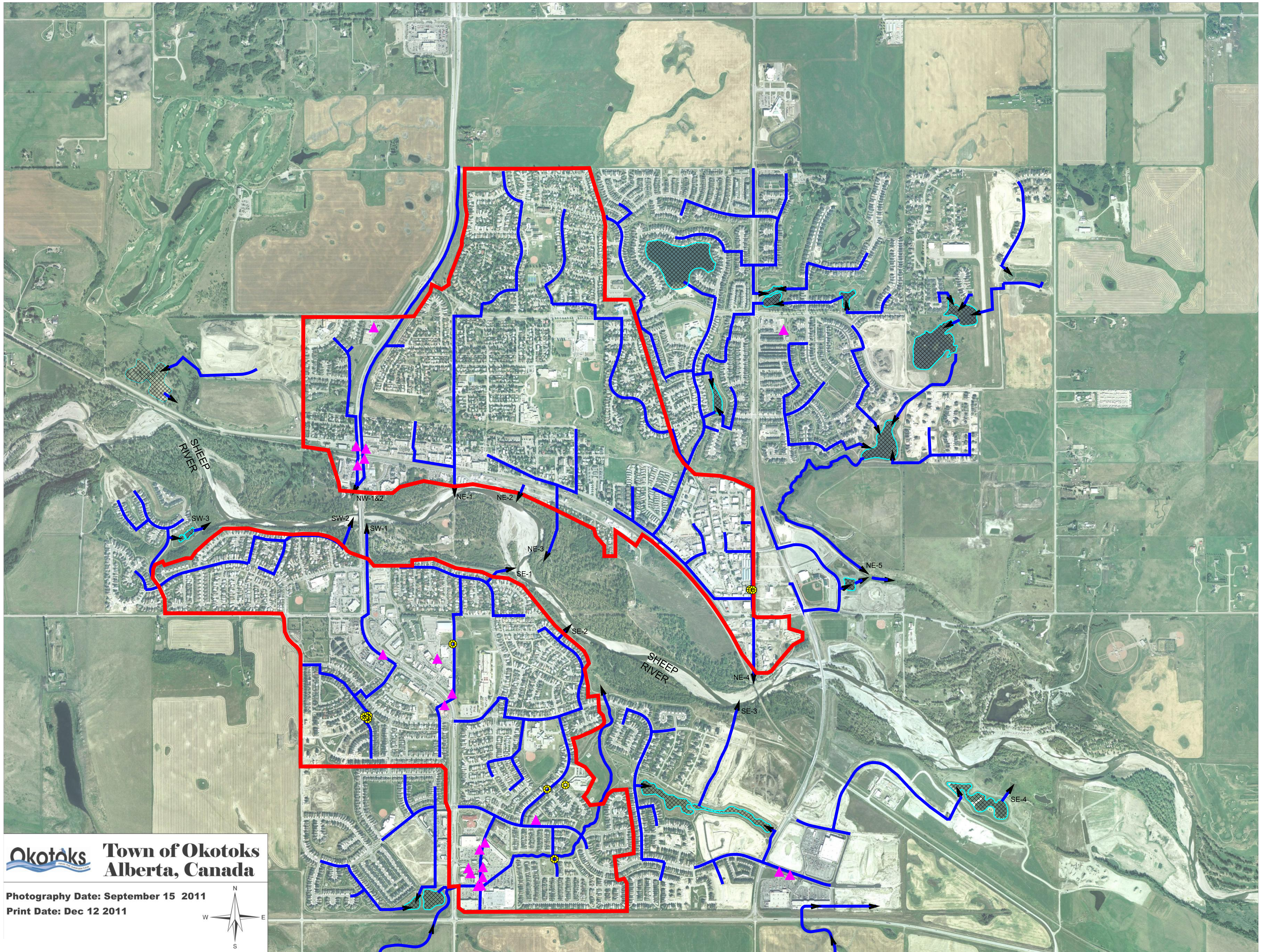
a) Description:
   - Large stormwater management facilities could be designed to promote evaporation. These could either be wet or dry ponds with designs governed by continuous simulation to ensure that adequate volumes can be evaporated on an annual basis. To work properly, outlet rates must be virtually non-existent with at most an overflow provided for wet years (preliminary analysis indicated annual evaporation from a pond ranges from 1 to 20mm of runoff depth over a quarter section depending on the design depth and how much precipitation fell during the year.

b) Driving Forces:
   - Relatively simple facilities to design.
   - Eliminate up to virtually 100% of runoff volume.
   - Stormwater pollutants retained in the pond.

c) Restraining Forces:
   - High amount of land.
   - Lack of evaporation in wet years.

d) Synopsis:
   - Evaporation facilities could work well in the area. However, they will require a significant amount of land in order to maximize surface area to allow for maximum effectiveness. As a result, they would work best in conjunction with other volume reduction methods. Assuming the above mentioned practices for volume reduction are applied using the same described design parameters, it is anticipated that for a developed single quarter section area, an evaporation facility needs to be up to roughly 3.2 times larger than the conventional stormwater pond facility described in section 5.10 above. Consequently, up to 17.5% of the developed area is needed for evaporation facility construction. The estimated cost of this pond would likely be in the order of $6,000,000.

FIGURE 5.1



LEGEND:

- MAIN STORM COLLECTION PATTERNS
- STORMWATER POND / BODY
- UNCONTROLLED STORM DRAINAGE BASIN BOUNDARY
- STORM WATER TREATMENT FACILITY (STORM CEPTOR)
- PRIVATE STORM WATER TREATMENT FACILITY (STORM CEPTOR)

Okotoks
Historic Past, Sustainable Future

TOWN OF OKOTOKS
STORMWATER MANAGEMENT
MASTER PLAN

UNCONTROLLED
STORMWATER DRAINAGE BASINS

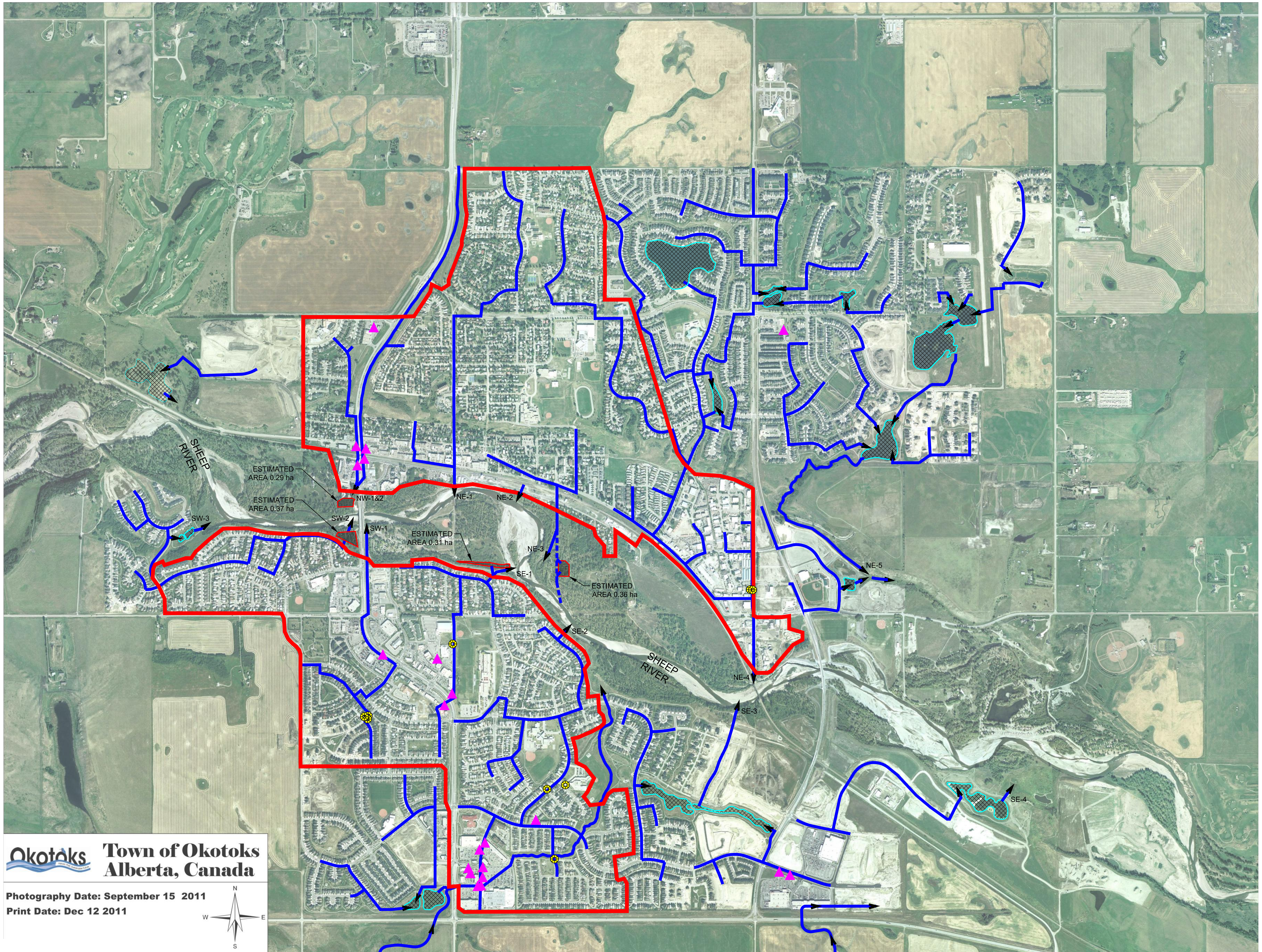
GENERAL SCHEME

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Oct. 31, 14 5:06:58 PM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 5.1.DWG

FIGURE 5.16



LEGEND:

- MAIN STORM COLLECTION PATTERNS
- STORMWATER POND / BODY
- UNCONTROLLED STORM DRAINAGE BASIN BOUNDARY
- STORM WATER TREATMENT FACILITY (STORM CEPTOR)
- PRIVATE STORM WATER TREATMENT FACILITY (STORM CEPTOR)
- PROPOSED EOP CONTROL WORKS

Okotoks

Historic Past, Sustainable Future

TOWN OF OKOTOKS

STORMWATER MANAGEMENT

MASTER PLAN

UNCONTROLLED

STORMWATER DRAINAGE BASINS

PROPOSED (EOP) CONTROL WORKS

OPTION 1

NOV 2014

ISL Engineering and Land Services

CHRIS CLARKE Nov. 3, 14 10:30:46 AM N:\25400\25476_OKOTOKS_STORMWATER_MP\02_CADD\20_DRAFTING\REPORT FIGURES\FIGURE 5.16.DWG

6.0 Stormwater System Operational Strategies

A number of operational strategies should be considered for operation and maintenance of the Town's stormwater system, both in terms of maintaining full operational efficiency, as well as to reduce flooding risks.

6.1 Ongoing Maintenance

In terms of ongoing maintenance, a number of routine maintenance tasks should be undertaken:

- Inspect sewers on a regular basis, to ensure sediment deposition in pipes is not sufficiently accumulated to affect capacity. This should key in particular on areas with flat pipes or the low areas where the water could sit for a time while the river levels subside. This could be done by visual checks at manholes on a regular basis, and cameraing older or problematic lines on an as-needed basis.
- Regular catchbasin cleaning should be undertaken to ensure full operational capacity is maintained.
- Ponds should be checked for sediment accumulation and cleaned out as needed (this should not be needed more often than once every five years at a minimum).
- Any control structures in the system (i.e. pond outlets) should have routine maintenance performed. This would typically include the following:
    - Clean the structure to remove debris, keying on any gates or orifice plates.
    - Inspect the seals and slides where applicable.
    - Inspect stem threads and lift nut threads where applicable.
    - Check fasteners for correct tightening where applicable.
    - Operate any slide gates to ensure proper operation, then reset to proper opening.
- Any oil/grit separators in the system should be cleaned out every year or two, depending on the size and rate of sediment accumulation.
- Flap gates should be maintained on an annual basis. This would include:
    - Cleaning the gate to remove debris.
    - Ensure that gate seats against the neoprene seat.
    - Check hinges for premature wear.
    - Check fasteners for correct tightening.

6.2 Flood Risk Mitigation

In terms of operational strategies to reduce flooding risk, a number of strategies are recommended:

- Ensure routine maintenance is performed, with particular focus on flushing catchbasins and sewers in the low areas, as well as critical locations. Flap gate maintenance is also extremely important to ensure the system can drain, while ensuring the river water cannot backup into the low areas.
- In the winter, keep catchbasins in low areas free of ice to help keep areas from flooding during warm Chinook periods that cause rapid thawing. If ponding is occurring, consider pumping to dewater areas with this issue if the water cannot be drained otherwise (this could also help with the issues in the Air Ranch).
- In the event of high water levels in the river, it is suggested that storm sewers in low areas be monitored to ensure river water is not backing up into the pipes past flap gates. If it is, then the flap gates require maintenance/repair. In the event of a rainfall event during high river water levels, it is recommended that the Town consider pumping out storm sewers directly to the river to help keep water levels in the storm sewer system low and guard against flood damage.

- Off-site flows entering the system should be monitored to ensure factors outside Town control do not cause an increase in flows. The Town should also monitor inlets to the storm system from overland areas to ensure these do not become blocked, either with ice in the winter or debris otherwise. If either occurs, the inlets should be cleared posthaste.

7.0
Preliminary Cost Estimates

7.1 Cost Estimates for Recommended Upgrades

Preliminary cost estimates for the discussed upgrades in this report are given in Table 7.1 below. These contain a 15% contingency. Detailed cost estimates are shown in Appendix E.

Table 7.1 – Upgrading Works - Preliminary cost estimates

Stormwater Upgrades	Estimated Cost
Poplar Avenue & Elma Place (Option 1)	$610,000
Poplar Avenue & Elma Place (Option 2)	$1,530,000
Northridge Drive (Option 1)	$560,000
Northridge Drive (Option 2)	$130,000
Air Ranch - North West Corner (Options 1 & 2)	operational
Air Ranch - North West Corner (Option 3)	$1,800,000+
Air Ranch - North West Corner (Option 4)	$40,000
Air Ranch - North West Corner (Option 5)	$35,000

8.0
Conclusions and Recommendations

In general, the storm drainage system within the Town of Okotoks performs well. There are few surface ponding issues occurring during 1:5 Year storm events in the area north of the Sheep River that have been reported by the Town's engineering staff, that require addressing, other probable surface ponding issues suggested by modelling results require close inspection during critical storm events to define the need of any future mitigation action. As expected, there is substantial surface flooding under 1:100 Year events. Concerns with this flooding have been addressed in the recommendations made in this report.

The following are the recommendations for the storm drainage system for existing development conditions listed in order of priority:

1. At the Poplar Ave and Elma Place area. Two upgrading options are proposed. The first option would reduce the stormwater flooding volumes by about 50% for the 1:5 year rainfall event at a cost of $610,000. The second option would reduce the stormwater flooding volumes by about 90% for the 1:5 year rainfall event at a cost of $1,530,000. It is recommended that the Town review these options to develop a preferred alternative.

2. At the Northridge Drive. Two upgrading options are proposed. The first option includes the construction of a stormwater pond at a cost of $560,000 that will mitigate the surface flooding issues during the 1:5 year rainfall events. The second option would reduce the stormwater flooding volumes by about 60% for the 1:5 year rainfall event at a cost of $130,000. It is recommended that the Town review these options to develop a preferred alternative.

3. At the northwest corner of the Air Ranch, a number of mitigation options are proposed. At this time, it is suggested that the preferred option could include the construction of an earth berm along the northwest boundary of the Air ranch to control the release rates of the melt water volumes at a cost of $40,000.

4. Consider end of pipe quality treatment upgrades as noted. Staging could be as permitted by the Town's budget.

For the future developed areas in Okotoks, the following are the recommendations for the future storm drainage system to ensure compliance with Alberta Environment and Town standards:

5. Future developments are required to provide stormwater management ponds such that post-development 1:100 Year flows into the Sheep River do not exceed pre-development 1:100 Year runoff rates. For the preliminary estimated runoff rate of 2.5L/s/ha, the areas dedicated for stormwater ponds should be in the range of 5.4% of the developed area.

6. The Town should consider adopting volume control at some point, either short term or in the future. If this were desired, then the annual stormwater runoff volume from future developments for the 1:100 Year storm events should not exceed the estimated post-development runoff volume of 98mm. Runoff Reduction Management Practices to be used are discussed in this report. The selection and design of the suitable management practices shall be fixed at the time of the detailed design. It is noted that rainwater harvesting could reduce water demands in Town and extend the life of current water licensing by not using it for irrigation purposes.

9.0 References

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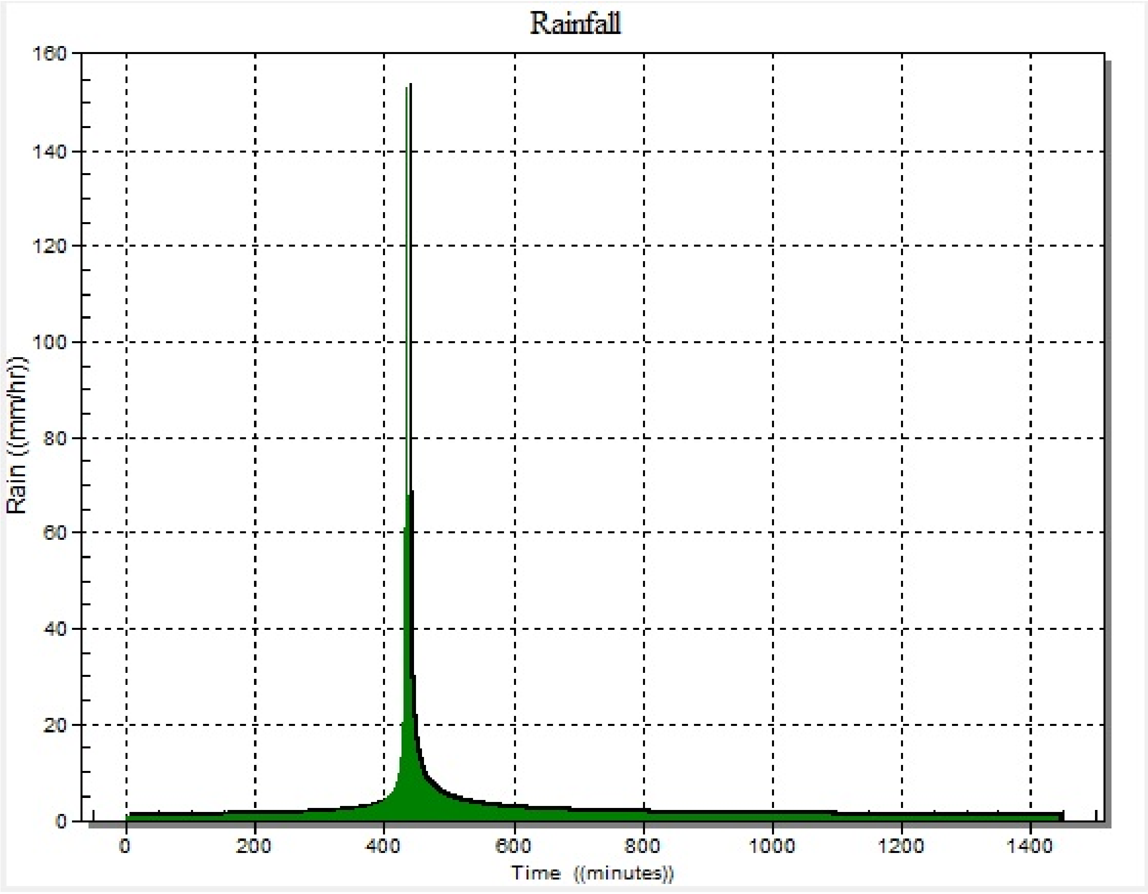
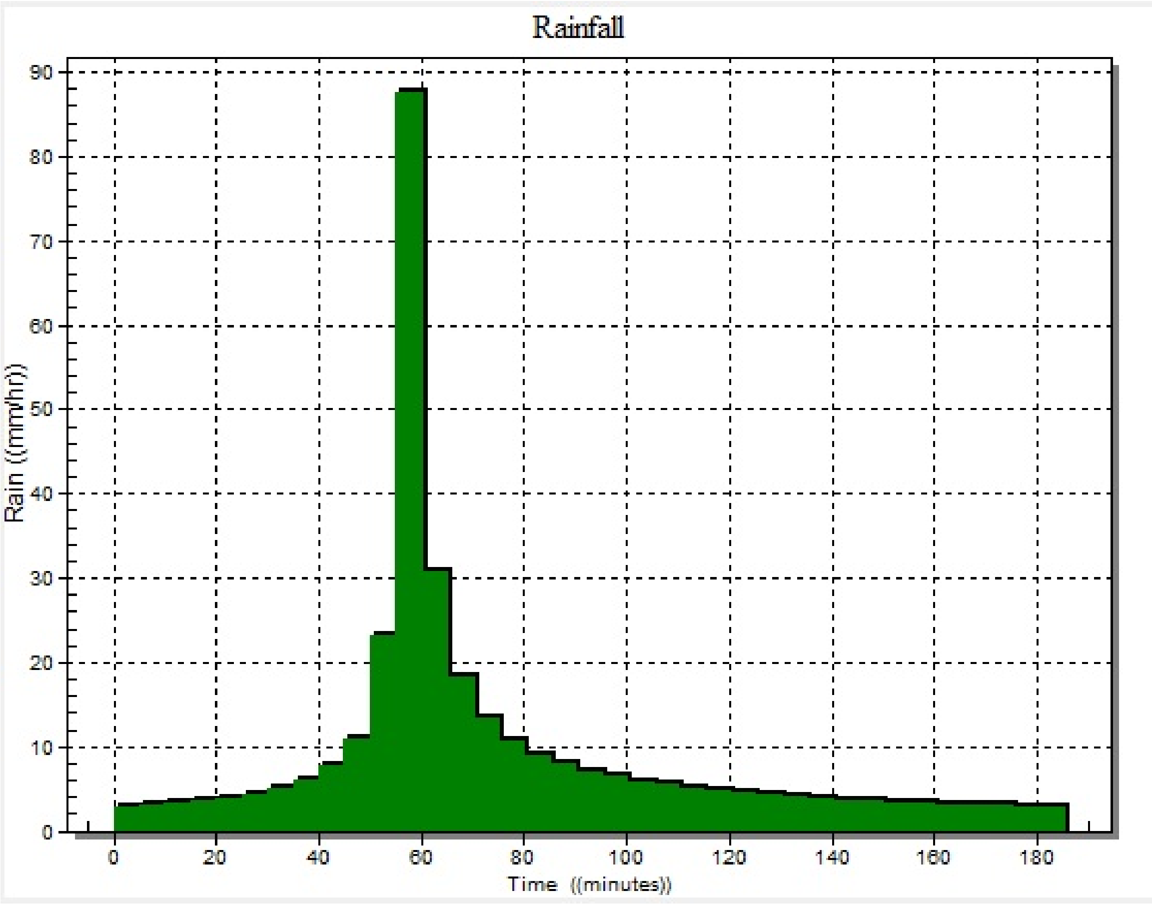
Appendix A
Rainfall Distributions

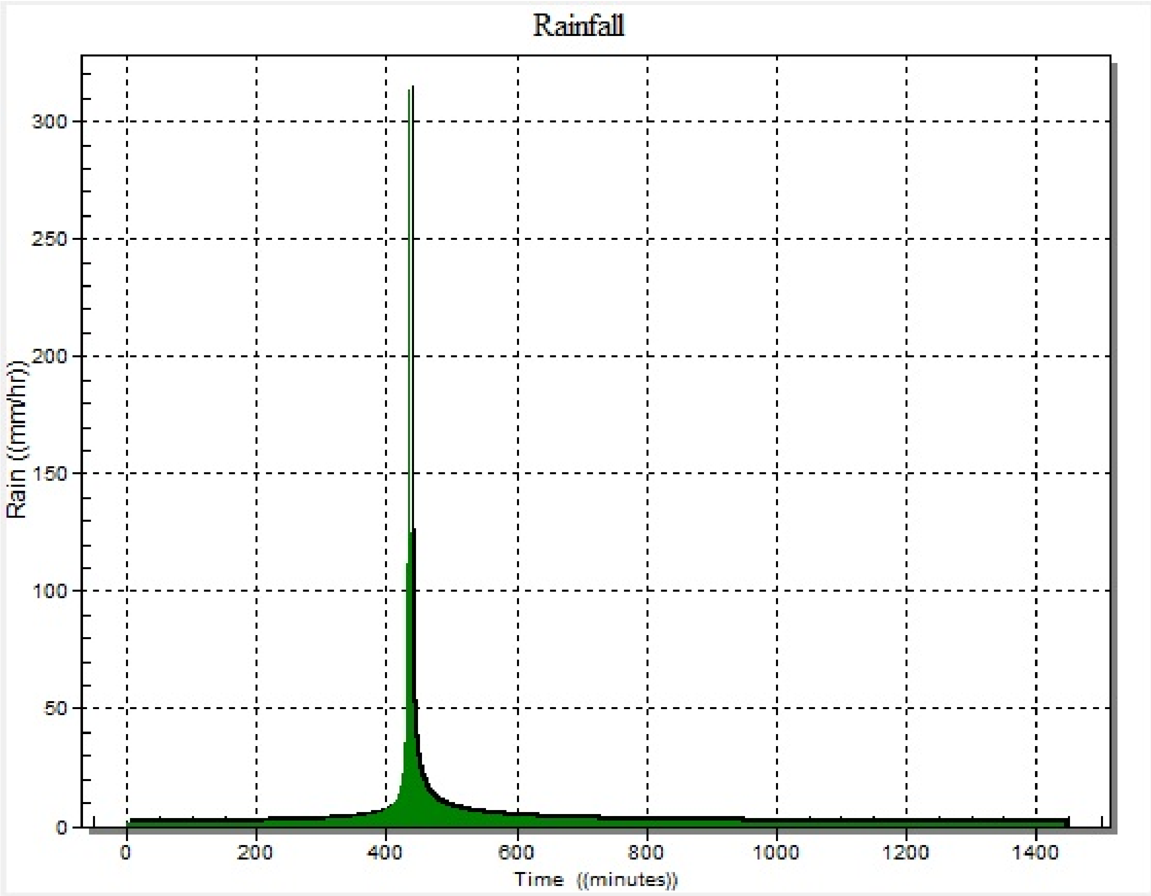
1:5 Year, 24 Hour Chicago Rainfall Distribution



1:5 Year, 3 Hour Chicago Rainfall Distribution



1:100 Year, 24 Hour Chicago Rainfall Distribution



Appendix B

XP-SWMM Model Files

Appendix C

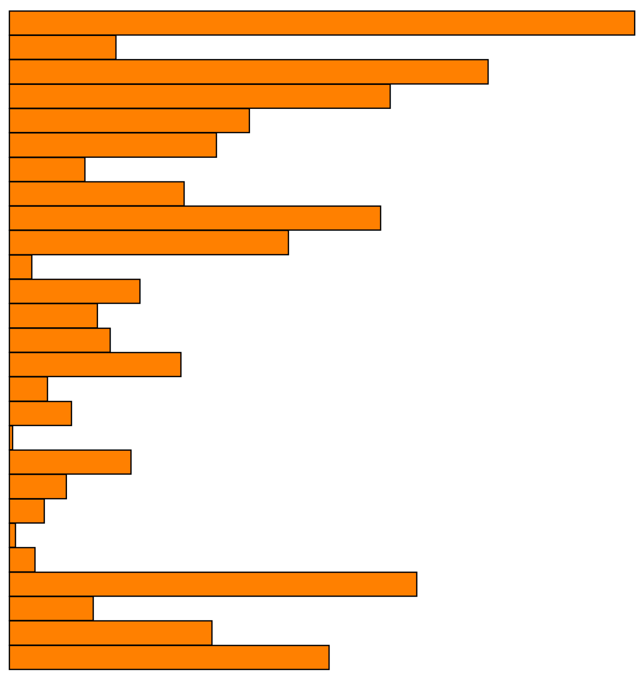
Statistical Analysis of Pre-Development Runoff Flows

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

This data is an ANNUAL MAXIMUM series.

DATA ENTERED

Water Year	PEAK DISCHARGE Q m3/s
1967	104.70
1968	17.90
1969	80.17
1970	63.80
1971	40.25
1972	34.70
1973	12.68
1974	29.34
1975	62.20
1976	46.80
1977	3.82
1978	21.90
1979	14.79
1980	16.94
1981	28.75
1982	6.43
1983	10.45
1984	0.61
1985	20.40
1986	9.58
1987	5.89
1988	1.10
1989	4.34
1990	68.24
1991	14.08
1992	33.96
1993	53.60



End of Data Series ==============================
This series contains 27 years of data.

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

DATA AS CONTAINED IN: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CI

UNSORTED				SORTED			
Q (m3/s)	Rank	Plotting Position	Plotted Period (yrs)	Q (m3/s)	Rank	Plotting Position	Plotted Period (yrs)
104.70	1	.0357	28.000	104.70	1	.0357	28.000
17.90	15	.5357	1.867	80.17	2	.0714	14.000
80.17	2	.0714	14.000	68.24	3	.1071	9.333
63.80	4	.1429	7.000	63.80	4	.1429	7.000
40.25	8	.2857	3.500	62.20	5	.1786	5.600
34.70	9	.3214	3.111	53.60	6	.2143	4.667
12.68	19	.6786	1.474	46.80	7	.2500	4.000
29.34	11	.3929	2.545	40.25	8	.2857	3.500
62.20	5	.1786	5.600	34.70	9	.3214	3.111
46.80	7	.2500	4.000	33.96	10	.3571	2.800
3.82	25	.8929	1.120	29.34	11	.3929	2.545
21.90	13	.4643	2.154	28.75	12	.4286	2.333
14.79	17	.6071	1.647	21.90	13	.4643	2.154
16.94	16	.5714	1.750	20.40	14	.5000	2.000
28.75	12	.4286	2.333	17.90	15	.5357	1.867
6.43	22	.7857	1.273	16.94	16	.5714	1.750
10.45	20	.7143	1.400	14.79	17	.6071	1.647
0.61	27	.9643	1.037	14.08	18	.6429	1.556
20.40	14	.5000	2.000	12.68	19	.6786	1.474
9.58	21	.7500	1.333	10.45	20	.7143	1.400
5.89	23	.8214	1.217	9.58	21	.7500	1.333
1.10	26	.9286	1.077	6.43	22	.7857	1.273
4.34	24	.8571	1.167	5.89	23	.8214	1.217
68.24	3	.1071	9.333	4.34	24	.8571	1.167
14.08	18	.6429	1.556	3.82	25	.8929	1.120
33.96	10	.3571	2.800	1.10	26	.9286	1.077
53.60	6	.2143	4.667	0.61	27	.9643	1.037

Note that the UNSORTED listing will give the same rank to identical values occuring in the input data file. The SORTED listing shows all ranks.

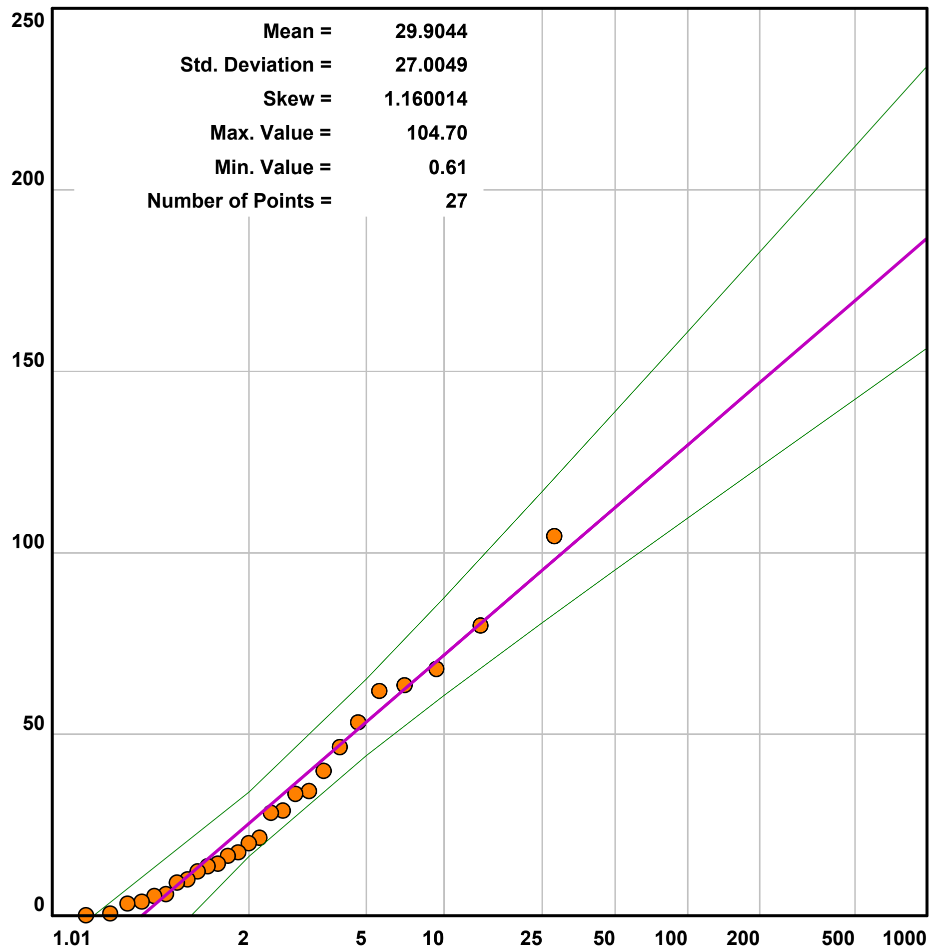
Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

PEAK DISCHARGE (m3/s)

Tr (yrs)	Q m3/s
1.01	-20.71
2	25.83
5	53.66
10	72.08
25	95.36
50	112.63
100	129.77
200	146.85
500	169.39
1000	186.41

PASSED
Chi-Square Test



High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek **RETURN PERIOD (yrs)**

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean =	29.9044	Maximum Input Value =	104.70
Std. Deviation =	27.0049	Minimum Input Value =	0.61
Skew =	1.16001400	Number of Points =	27

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	-20.71	-1.8743	-38.50	-8.47
2	25.83	-0.1507	16.78	34.45
5	53.66	0.8797	44.49	65.44
10	72.08	1.5619	60.98	87.82
25	95.36	2.4239	80.92	116.99
50	112.63	3.0634	95.41	138.93
100	129.77	3.6982	109.67	160.84
200	146.85	4.3306	123.79	182.75
500	169.39	5.1650	142.35	211.74
1,000	186.41	5.7956	156.33	233.68

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean =	29.9044	Maximum Input Value =	104.70
Std. Deviation =	27.0049	Minimum Input Value =	0.61
Skew =	1.16001400	Number of Points =	27

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	-2.49	3.0000	0	3.0000
2	-2.49	6.81	3.0000	6	3.0000
3	6.81	14.53	3.0000	4	0.3333
4	14.53	21.98	3.0000	5	1.3333
5	21.98	29.88	3.0000	2	0.3333
6	29.88	39.00	3.0000	2	0.3333
7	39.00	50.74	3.0000	2	0.3333
8	50.74	69.35	3.0000	4	0.3333
9	69.35	Infinity	3.0000	2	0.3333

COMPUTED CHI-SQUARE = 9.3333
CHI-SQUARE FROM TABLE = 10.6000

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

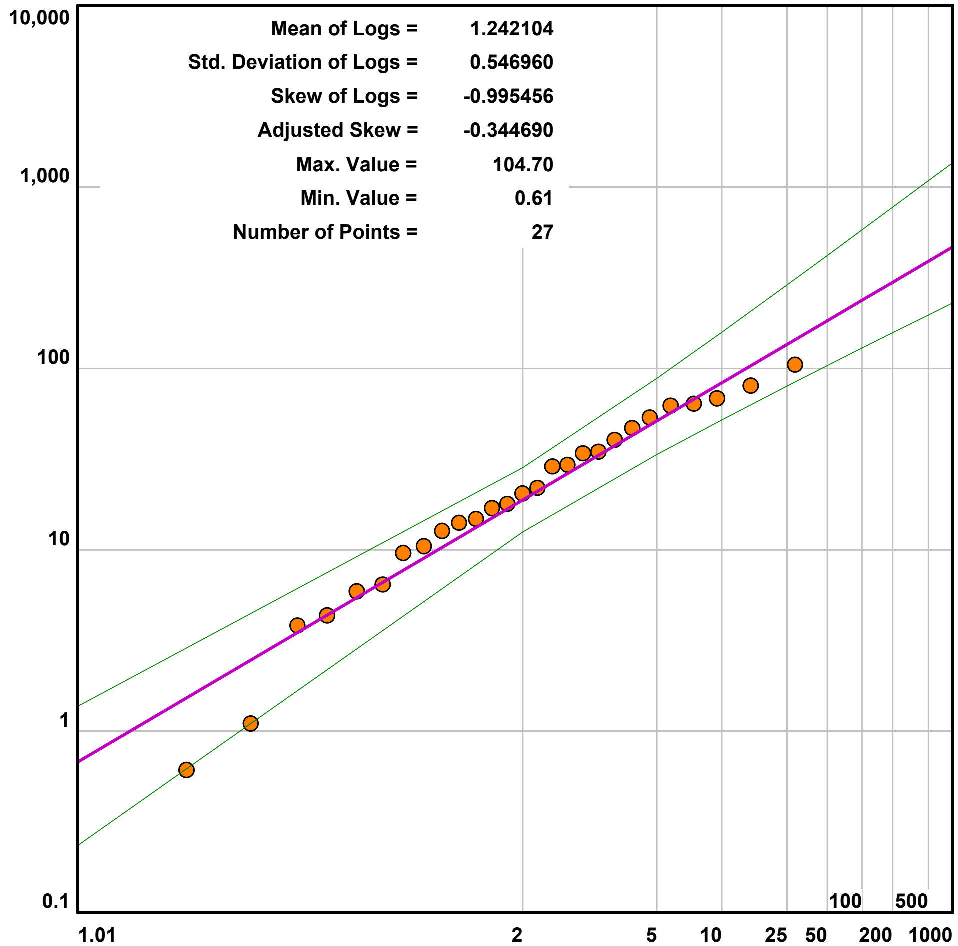
Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

LOG-PEARSON TYPE III DISTRIBUTION

PEAK DISCHARGE (m3/s)

Tr (yrs)	Q m3/s
1.01	0.68
2	18.77
5	51.18
10	83.12
25	135.44
50	182.79
100	236.94
200	297.94
500	389.16
1000	466.28

PASSED
Chi-Square Test



High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek **RETURN PERIOD (yrs)**

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean of Logs =	1.242104	Maximum Input Value =	104.70
Std. Deviation of Logs =	0.546960	Minimum Input Value =	0.61
Skew of Logs =	-0.995456	Number of Points =	27
Adjusted Skew =	-0.344690	Generalized Map Skew =	0.3

LOG-PEARSON TYPE III DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	0.68	-2.5824	0.23	1.37
2	18.77	0.0573	12.51	28.39
5	51.18	0.8538	33.45	88.13
10	83.12	1.2389	51.96	157.84
25	135.44	1.6265	79.85	287.67
50	182.79	1.8646	103.48	417.85
100	236.94	2.0706	129.23	578.41
200	297.94	2.2525	157.05	771.78
500	389.16	2.4646	196.87	1,081.62
1,000	466.28	2.6081	229.26	1,360.13

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean of Logs =	1.242104	Maximum Input Value =	104.70
Std. Deviation of Logs =	0.546960	Minimum Input Value =	0.61
Skew of Logs =	-0.995456	Number of Points =	27
Adjusted Skew =	-0.344690	Generalized Map Skew =	0.3

LOG-PEARSON TYPE III DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	3.58	3.0000	2	0.3333
2	3.58	6.84	3.0000	4	0.3333
3	6.84	10.74	3.0000	2	0.3333
4	10.74	15.73	3.0000	3	0.0000
5	15.73	22.32	3.0000	4	0.3333
6	22.32	31.85	3.0000	2	0.3333
7	31.85	47.18	3.0000	4	0.3333
8	47.18	78.76	3.0000	4	0.3333
9	78.76	Infinity	3.0000	2	0.3333

COMPUTED CHI-SQUARE = 2.6667
CHI-SQUARE FROM TABLE = 9.2400

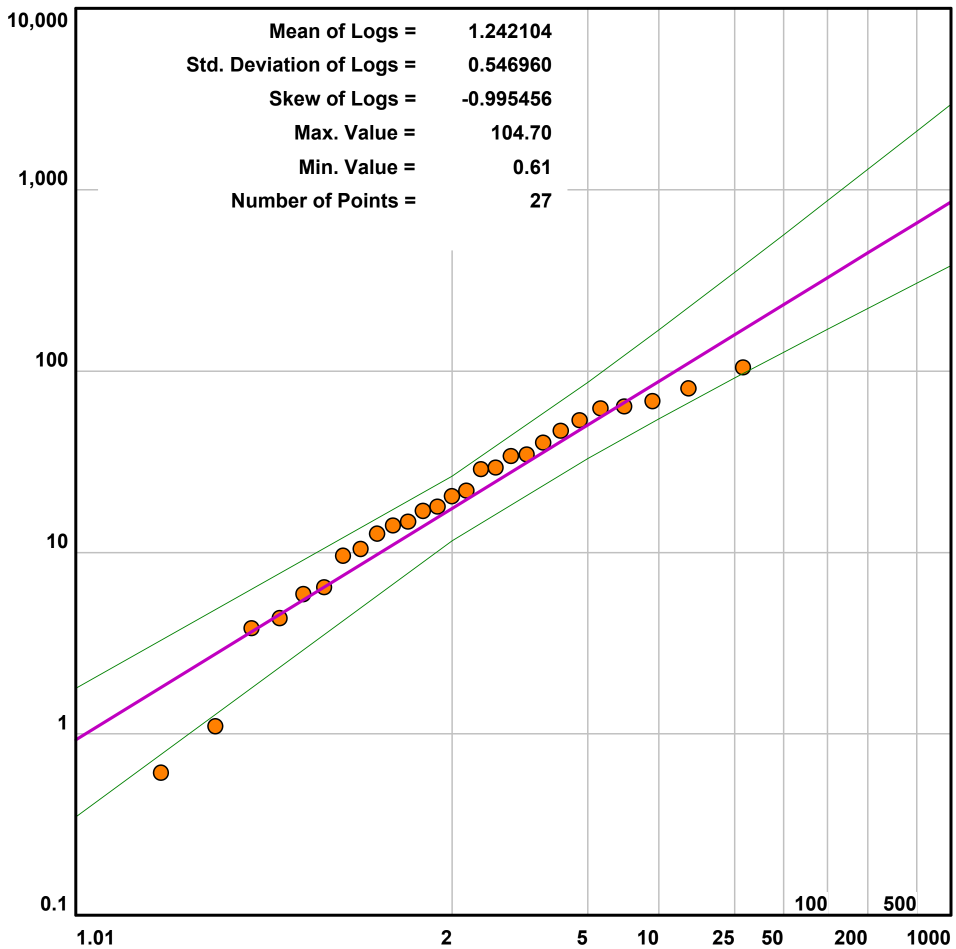
CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-PEARSON TYPE III DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

LOG-NORMAL DISTRIBUTION

PEAK DISCHARGE (m3/s)

Tr (yrs)	Q m3/s
1.01	0.93
2	17.46
5	50.39
10	87.73
25	158.44
50	232.09
100	327.16
200	447.92
500	655.44
1000	856.04



PASSED
Chi-Square Test

High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek **RETURN PERIOD (yrs)**

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean of Logs =	1.242104	Maximum Input Value =	104.70
Std. Deviation of Logs =	0.546960	Minimum Input Value =	0.61
Skew of Logs =	-0.995456	Number of Points =	27

LOG-NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	0.93	-2.3305	0.35	1.79
2	17.46	0.0000	11.59	26.30
5	50.39	0.8415	32.97	86.52
10	87.73	1.2817	54.51	168.57
25	158.44	1.7511	91.48	349.60
50	232.09	2.0542	126.97	563.59
100	327.16	2.3268	170.01	868.51
200	447.92	2.5762	221.64	1,292.57
500	655.44	2.8785	305.09	2,096.53
1,000	856.04	3.0905	381.36	2,946.13

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean of Logs =	1.242104	Maximum Input Value =	104.70
Std. Deviation of Logs =	0.546960	Minimum Input Value =	0.61
Skew of Logs =	-0.995456	Number of Points =	27

LOG-NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	CLASS LIMITS Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	NUMBER OF VALUES Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	3.75	3.0000	2	0.3333
2	3.75	6.67	3.0000	4	0.3333
3	6.67	10.16	3.0000	1	1.3333
4	10.16	14.65	3.0000	3	0.0000
5	14.65	20.81	3.0000	4	0.3333
6	20.81	30.02	3.0000	3	0.0000
7	30.02	45.73	3.0000	3	0.0000
8	45.73	81.25	3.0000	6	3.0000
9	81.25	Infinity	3.0000	1	1.3333
				COMPUTED CHI-SQUARE =	6.6667
				CHI-SQUARE FROM TABLE =	10.6000

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-NORMAL DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

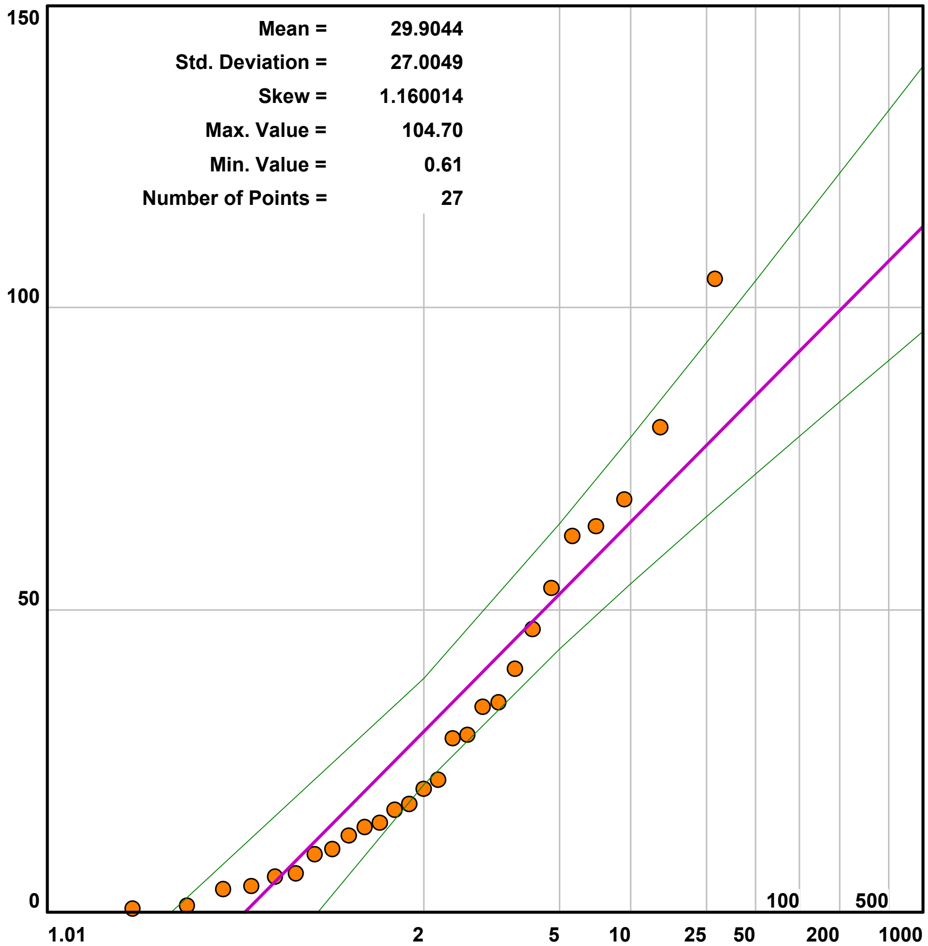
Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

NORMAL DISTRIBUTION

PEAK DISCHARGE (m3/s)

Tr (yrs)	Q m3/s
1.01	-33.03
2	29.90
5	52.63
10	64.52
25	77.19
50	85.38
100	92.74
200	99.48
500	107.64
1000	113.36

FAILED
Chi-Square Test



High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek **RETURN PERIOD (yrs)**

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean =	29.9044	Maximum Input Value =	104.70
Std. Deviation =	27.0049	Minimum Input Value =	0.61
Skew =	1.16001400	Number of Points =	27

NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	-33.03	-2.3305	-53.99	-18.98
2	29.90	0.0000	21.12	38.69
5	52.63	0.8415	43.53	64.22
10	64.52	1.2817	54.31	78.52
25	77.19	1.7511	65.41	94.16
50	85.38	2.0542	72.44	104.40
100	92.74	2.3268	78.70	113.67
200	99.48	2.5762	84.39	122.20
500	107.64	2.8785	91.24	132.57
1,000	113.36	3.0905	96.03	139.86

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean =	29.9044	Maximum Input Value =	104.70
Std. Deviation =	27.0049	Minimum Input Value =	0.61
Skew =	1.16001400	Number of Points =	27

NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	CLASS LIMITS Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	NUMBER OF VALUES Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	-3.06	3.0000	0	3.0000
2	-3.06	9.26	3.0000	6	3.0000
3	9.26	18.28	3.0000	7	5.3333
4	18.28	26.14	3.0000	2	0.3333
5	26.14	33.67	3.0000	2	0.3333
6	33.67	41.52	3.0000	3	0.0000
7	41.52	50.55	3.0000	1	1.3333
8	50.55	62.87	3.0000	2	0.3333
9	62.87	Infinity	3.0000	4	0.3333

COMPUTED CHI-SQUARE = 14.0000
CHI-SQUARE FROM TABLE = 10.6000

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the NORMAL DISTRIBUTION does NOT apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near Aldersyde / Diebel's Ranch, Pekisko Creek & Stimson Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - ALDERSYDE & DIEBEL RANCH & PEKISKO CREEK & STIMSON C

Mean =	29.9044	Maximum Input Value =	104.70
Std. Deviation =	27.0049	Minimum Input Value =	0.61
Skew =	1.16001400	Number of Points =	27
Mean of Logs =	1.242104	Generalized Map Skew =	0.3
Std. Deviation of Logs =	0.546960		
Skew of Logs =	-0.995456		
Adjusted Skew =	-0.344690		

COMPARISON OF STATISTICAL DISTRIBUTIONS

Number of Chi-Square class intervals used = 9

DISTRIBUTION	CHI-SQUARE COMPUTED	CHI-SQUARE TABULATED	
EXTREME VALUE TYPE I (GUMBEL)	9.333	10.600	Passed
LOG-PEARSON TYPE III	2.667	9.240	Passed
LOG-NORMAL	6.667	10.600	Passed
NORMAL	14.000	10.600	FAILED

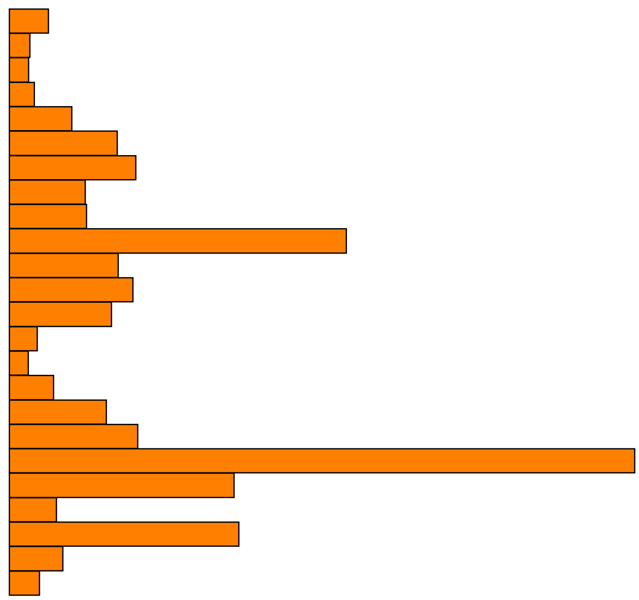
BASED ON A 10-PERCENT SIGNIFICANCE LEVEL, THE
LOG-PEARSON TYPE III
DISTRIBUTION RESULTS IN THE BEST FIT OF THE DATA.

Project:	High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User:	ISL
Date:	11 March 2013, Monday
Time:	9:25 am
Input:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

This data is an ANNUAL MAXIMUM series.

DATA ENTERED

Water Year	Max. Daily Flow Q m3/s
1986	14.35
1987	7.56
1988	7.17
1989	9.31
1990	22.90
1991	39.50
1992	46.20
1993	27.80
1994	28.20
1995	123.00
1996	39.85
1997	45.11
1998	37.40
1999	10.30
2000	6.99
2001	16.30
2002	35.50
2003	46.90
2005	228.00
2006	82.00
2007	17.34
2008	83.80
2009	19.66
2010	11.09



End of Data Series ==============================
This series contains 24 years of data.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

DATA AS CONTAINED IN: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.H

UNSORTED				SORTED			
Q (m3/s)	Rank	Plotting Position	Plotted Period (yrs)	Q (m3/s)	Rank	Plotting Position	Plotted Period (yrs)
14.35	18	.7200	1.389	228.00	1	.0400	25.000
7.56	22	.8800	1.136	123.00	2	.0800	12.500
7.17	23	.9200	1.087	83.80	3	.1200	8.333
9.31	21	.8400	1.190	82.00	4	.1600	6.250
22.90	14	.5600	1.786	46.90	5	.2000	5.000
39.50	9	.3600	2.778	46.20	6	.2400	4.167
46.20	6	.2400	4.167	45.11	7	.2800	3.571
27.80	13	.5200	1.923	39.85	8	.3200	3.125
28.20	12	.4800	2.083	39.50	9	.3600	2.778
123.00	2	.0800	12.500	37.40	10	.4000	2.500
39.85	8	.3200	3.125	35.50	11	.4400	2.273
45.11	7	.2800	3.571	28.20	12	.4800	2.083
37.40	10	.4000	2.500	27.80	13	.5200	1.923
10.30	20	.8000	1.250	22.90	14	.5600	1.786
6.99	24	.9600	1.042	19.66	15	.6000	1.667
16.30	17	.6800	1.471	17.34	16	.6400	1.563
35.50	11	.4400	2.273	16.30	17	.6800	1.471
46.90	5	.2000	5.000	14.35	18	.7200	1.389
228.00	1	.0400	25.000	11.09	19	.7600	1.316
82.00	4	.1600	6.250	10.30	20	.8000	1.250
17.34	16	.6400	1.563	9.31	21	.8400	1.190
83.80	3	.1200	8.333	7.56	22	.8800	1.136
19.66	15	.6000	1.667	7.17	23	.9200	1.087
11.09	19	.7600	1.316	6.99	24	.9600	1.042

Note that the UNSORTED listing will give the same rank to identical values occuring in the input data file. The SORTED listing shows all ranks.

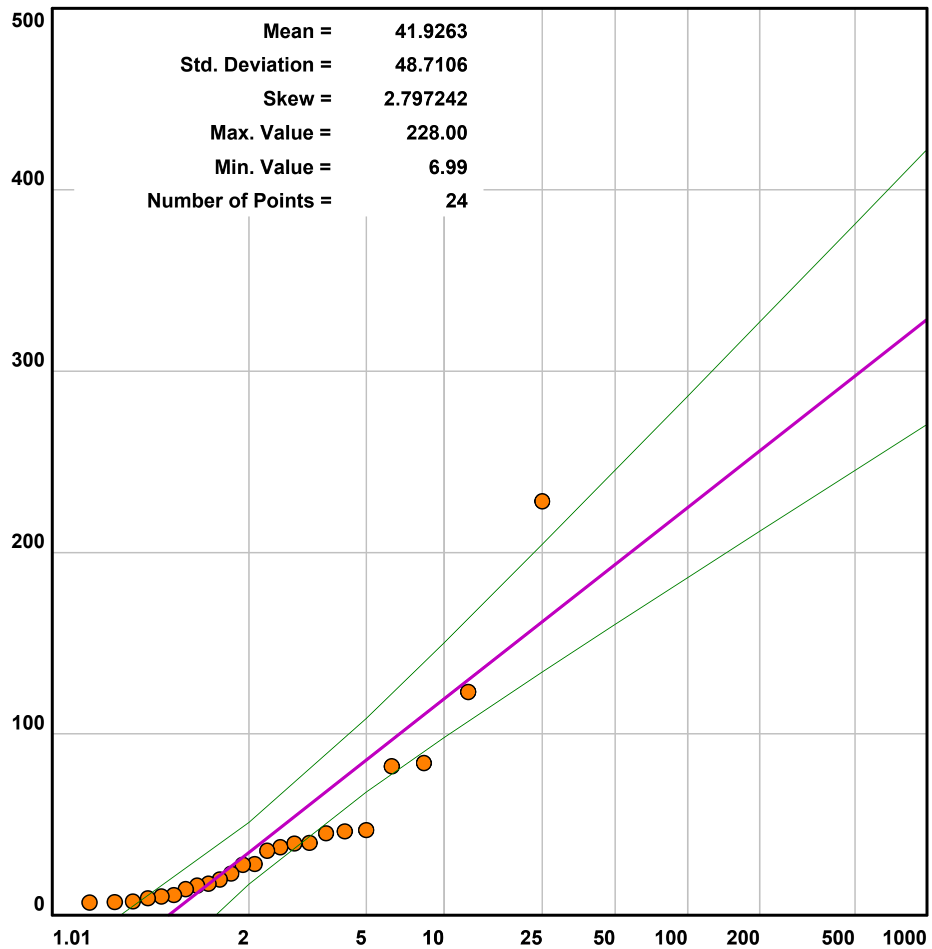
Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

Max. Daily Flow (m3/s)

Tr (yrs)	Q m3/s
1.01	-50.42
2	34.65
5	85.51
10	119.19
25	161.73
50	193.30
100	224.63
200	255.85
500	297.03
1000	328.16

FAILED
Chi-Square Test



High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean =	41.9263	Maximum Input Value =	228.00
Std. Deviation =	48.7106	Minimum Input Value =	6.99
Skew =	2.79724200	Number of Points =	24

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Q 90% CONFIDENCE LIMITS Upper (m3/s)
1.01	-50.42	-1.8958	-85.35	-27.03
2	34.65	-0.1493	17.24	51.16
5	85.51	0.8948	67.98	108.50
10	119.19	1.5861	97.93	150.11
25	161.73	2.4596	134.05	204.40
50	193.30	3.1076	160.26	245.26
100	224.63	3.7508	186.04	286.06
200	255.85	4.3916	211.57	326.86
500	297.03	5.2371	245.11	380.84
1,000	328.16	5.8761	270.38	421.71

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean =	41.9263	Maximum Input Value =	228.00
Std. Deviation =	48.7106	Minimum Input Value =	6.99
Skew =	2.79724200	Number of Points =	24

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	-11.67	3.4286	0	3.4286
2	-11.67	8.10	3.4286	3	0.0536
3	8.10	25.64	3.4286	8	6.0952
4	25.64	44.26	3.4286	6	1.9286
5	44.26	67.08	3.4286	3	0.0536
6	67.08	102.11	3.4286	2	0.5952
7	102.11	Infinity	3.4286	2	0.5952

COMPUTED CHI-SQUARE = 12.7500
CHI-SQUARE FROM TABLE = 7.7800

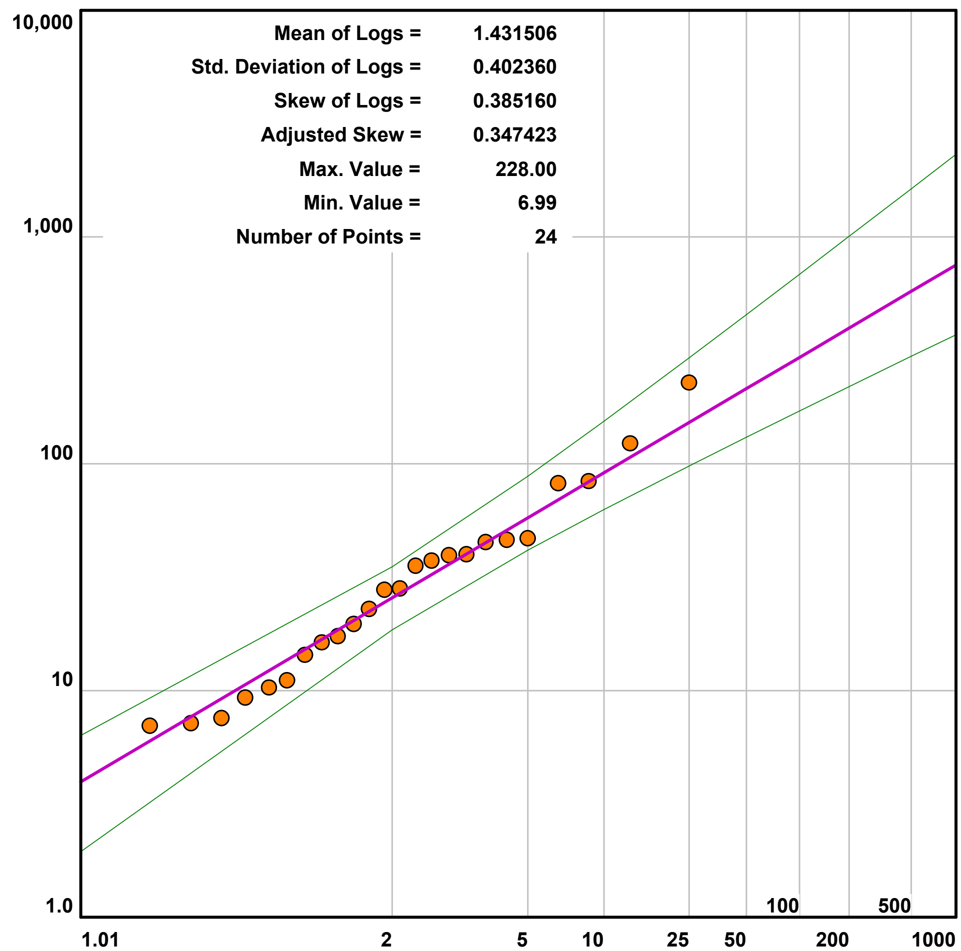
CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION does NOT apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

LOG-PEARSON TYPE III DISTRIBUTION

Max. Daily Flow (m3/s)

Tr (yrs)	Q m3/s
1.01	3.96
2	25.60
5	57.75
10	91.15
25	151.90
50	214.13
100	294.29
200	396.70
500	575.32
1000	751.59



PASSED
Chi-Square Test

High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean of Logs =	1.431506	Maximum Input Value =	228.00
Std. Deviation of Logs =	0.402360	Minimum Input Value =	6.99
Skew of Logs =	0.385160	Number of Points =	24
Adjusted Skew =	0.347423	Generalized Map Skew =	0.3

LOG-PEARSON TYPE III DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	3.96	-2.0722	1.95	6.33
2	25.60	-0.0578	18.51	35.17
5	57.75	0.8203	41.59	88.18
10	91.15	1.3128	62.81	153.99
25	151.90	1.8641	97.77	292.87
50	214.13	2.2348	130.78	454.19
100	294.29	2.5780	170.69	683.93
200	396.70	2.9003	218.77	1,006.50
500	575.32	3.3015	297.42	1,631.24
1,000	751.59	3.5900	370.53	2,310.51

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean of Logs =	1.431506	Maximum Input Value =	228.00
Std. Deviation of Logs =	0.402360	Minimum Input Value =	6.99
Skew of Logs =	0.385160	Number of Points =	24
Adjusted Skew =	0.347423	Generalized Map Skew =	0.3

LOG-PEARSON TYPE III DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

	CLASS LIMITS		NUMBER OF VALUES		
CLASS	Lower (m3/s)	Upper (m3/s)	Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	9.99	3.4286	4	0.0952
2	9.99	15.42	3.4286	3	0.0536
3	15.42	21.73	3.4286	3	0.0536
4	21.73	30.27	3.4286	3	0.0536
5	30.27	44.06	3.4286	4	0.0952
6	44.06	74.96	3.4286	3	0.0536
7	74.96	Infinity	3.4286	4	0.0952

COMPUTED CHI-SQUARE = 0.5000
CHI-SQUARE FROM TABLE = 6.2500

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-PEARSON TYPE III DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

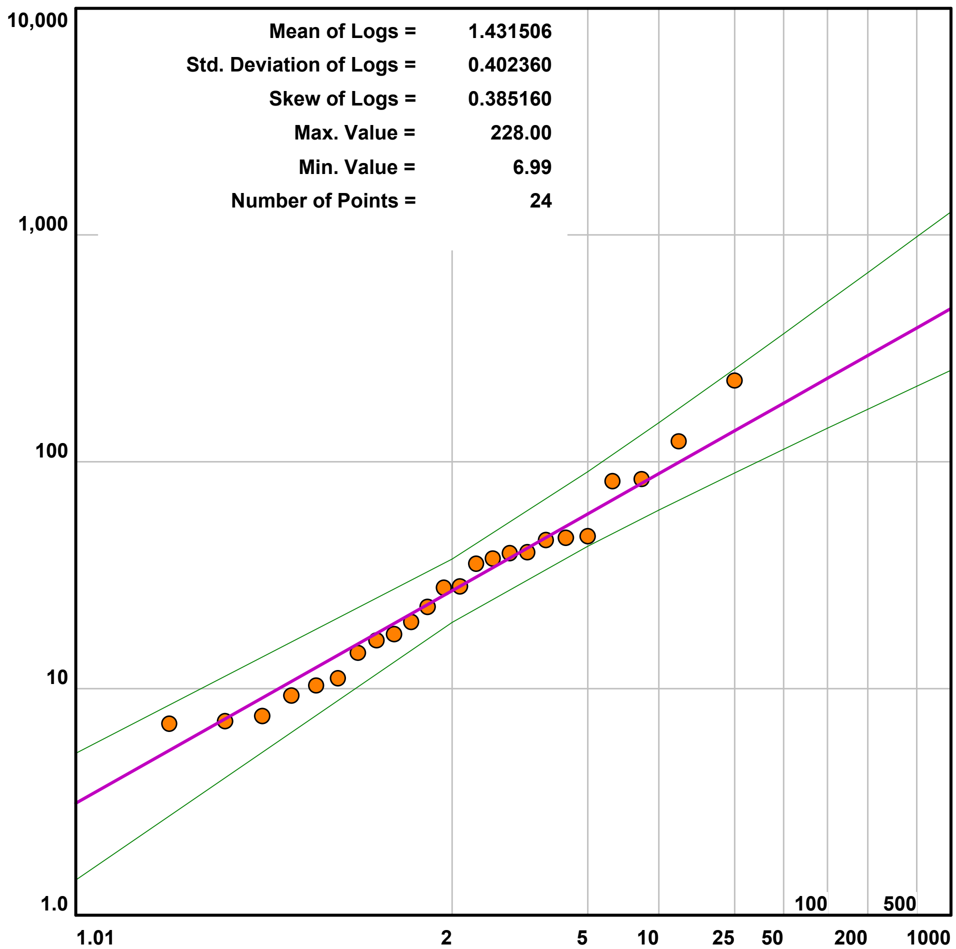
Project:	High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User:	ISL
Date:	11 March 2013, Monday
Time:	9:25 am
Input:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

LOG-NORMAL DISTRIBUTION

Max. Daily Flow (m3/s)

Tr (yrs)	Q m3/s
1.01	3.12
2	27.01
5	58.89
10	88.56
25	136.79
50	181.15
100	233.19
200	293.82
500	388.78
1000	473.16

PASSED
Chi-Square Test



High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean of Logs =	1.431506	Maximum Input Value =	228.00
Std. Deviation of Logs =	0.402360	Minimum Input Value =	6.99
Skew of Logs =	0.385160	Number of Points =	24

LOG-NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	3.12	-2.3305	1.43	5.18
2	27.01	0.0000	19.60	37.22
5	58.89	0.8415	42.35	90.28
10	88.56	1.2817	61.23	148.58
25	136.79	1.7511	89.39	256.41
50	181.15	2.0542	113.56	366.58
100	233.19	2.3268	140.49	506.76
200	293.82	2.5762	170.46	682.53
500	388.78	2.8785	215.15	980.51
1,000	473.16	3.0905	253.12	1,265.14

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean of Logs =	1.431506	Maximum Input Value =	228.00
Std. Deviation of Logs =	0.402360	Minimum Input Value =	6.99
Skew of Logs =	0.385160	Number of Points =	24

LOG-NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	10.04	3.4286	4	0.0952
2	10.04	15.99	3.4286	3	0.0536
3	15.99	22.87	3.4286	3	0.0536
4	22.87	31.90	3.4286	3	0.0536
5	31.90	45.61	3.4286	5	0.7202
6	45.61	72.62	3.4286	2	0.5952
7	72.62	Infinity	3.4286	4	0.0952

COMPUTED CHI-SQUARE = 1.6667
CHI-SQUARE FROM TABLE = 7.7800

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-NORMAL DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

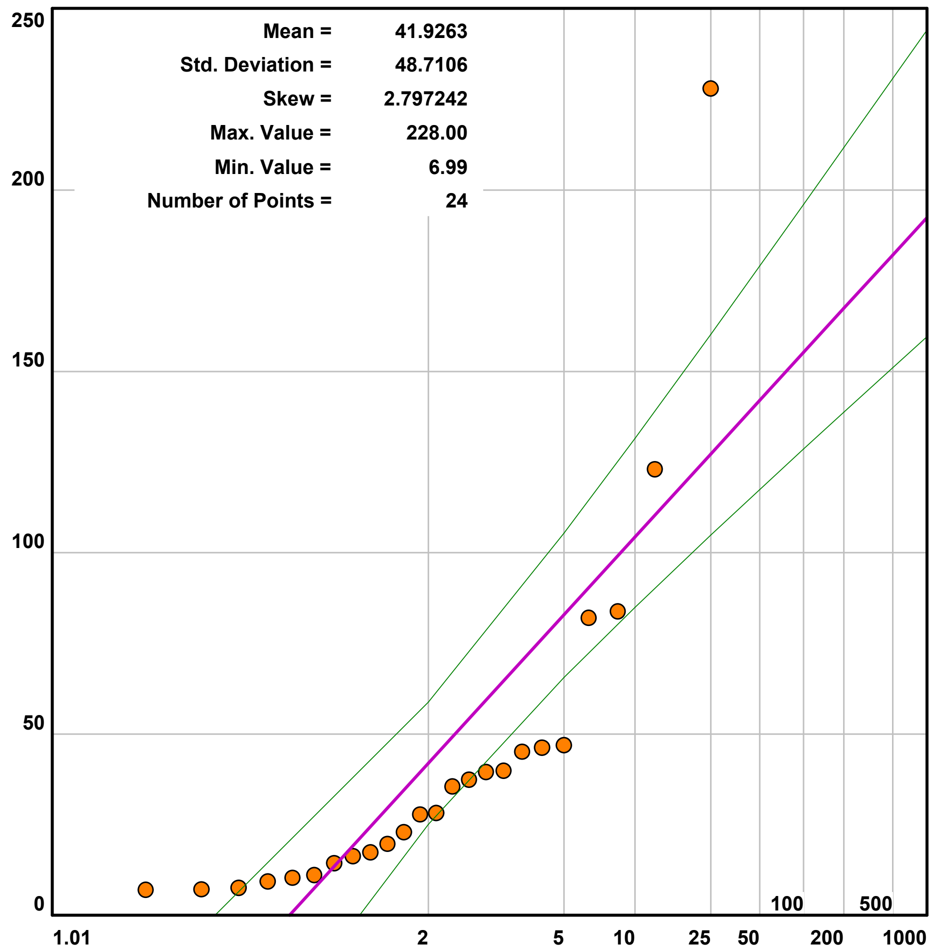
Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

NORMAL DISTRIBUTION

Max. Daily Flow (m3/s)

Tr (yrs)	Q m3/s
1.01	-71.59
2	41.93
5	82.91
10	104.36
25	127.22
50	141.99
100	155.27
200	167.42
500	182.14
1000	192.47

FAILED
Chi-Square Test



High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project:	High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User:	ISL
Date:	11 March 2013, Monday
Time:	9:25 am
Input:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean =	41.9263	Maximum Input Value =	228.00
Std. Deviation =	48.7106	Minimum Input Value =	6.99
Skew =	2.79724200	Number of Points =	24

NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	Q (m3/s)	FREQUENCY FACTOR	Q 90% CONFIDENCE LIMITS Lower (m3/s)	Upper (m3/s)
1.01	-71.59	-2.3305	-112.46	-44.93
2	41.93	0.0000	25.07	58.79
5	82.91	0.8415	65.58	105.37
10	104.36	1.2817	84.96	131.57
25	127.22	1.7511	104.85	160.26
50	141.99	2.0542	117.43	179.05
100	155.27	2.3268	128.63	196.07
200	167.42	2.5762	138.79	211.73
500	182.14	2.8785	151.03	230.78
1,000	192.47	3.0905	159.58	244.18

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project:	High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User:	ISL
Date:	11 March 2013, Monday
Time:	9:25 am
Input:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output:	C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean =	41.9263	Maximum Input Value =	228.00
Std. Deviation =	48.7106	Minimum Input Value =	6.99
Skew =	2.79724200	Number of Points =	24

NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (m3/s)	Upper (m3/s)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0.00	-10.08	3.4286	0	3.4286
2	-10.08	14.38	3.4286	7	3.7202
3	14.38	33.17	3.4286	6	1.9286
4	33.17	50.68	3.4286	7	3.7202
5	50.68	69.48	3.4286	0	3.4286
6	69.48	93.93	3.4286	2	0.5952
7	93.93	Infinity	3.4286	2	0.5952

COMPUTED CHI-SQUARE = 17.4167
CHI-SQUARE FROM TABLE = 7.7800

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the NORMAL DISTRIBUTION does NOT apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:25 am
Input: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\DIFFERENCE - HIGHWOOD RIVER - HIGH RIVER, BLACK DIAMOND, 3 POINT CREEK.OUT

Mean =	41.9263	Maximum Input Value =	228.00
Std. Deviation =	48.7106	Minimum Input Value =	6.99
Skew =	2.79724200	Number of Points =	24
Mean of Logs =	1.431506	Generalized Map Skew =	0.3
Std. Deviation of Logs =	0.402360		
Skew of Logs =	0.385160		
Adjusted Skew =	0.347423		

COMPARISON OF STATISTICAL DISTRIBUTIONS

Number of Chi-Square class intervals used = 7

DISTRIBUTION	CHI-SQUARE COMPUTED	CHI-SQUARE TABULATED	
EXTREME VALUE TYPE I (GUMBEL)	12.750	7.780	FAILED
LOG-PEARSON TYPE III	0.500	6.250	Passed
LOG-NORMAL	1.667	7.780	Passed
NORMAL	17.417	7.780	FAILED

BASED ON A 10-PERCENT SIGNIFICANCE LEVEL, THE
LOG-NORMAL
DISTRIBUTION RESULTS IN THE BEST FIT OF THE DATA.

Appendix D

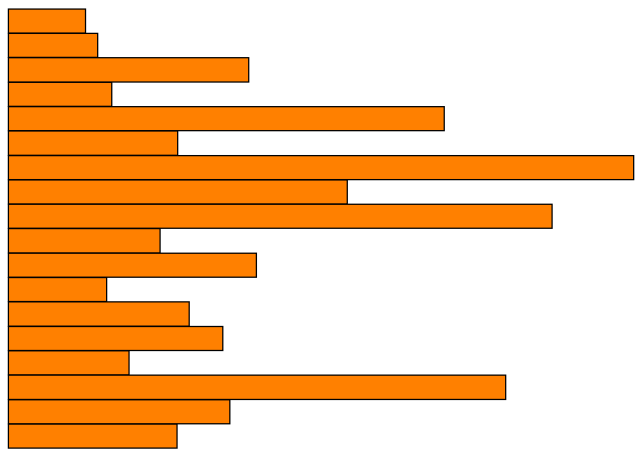
Statistical Analysis of Pre-Development Runoff Volume

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

This data is an ANNUAL MAXIMUM series.

DATA ENTERED

Water Year	RUNOFF VOLUME V Dam3
1987	7,490
1989	8,690
1991	23,315
1992	10,055
1993	42,250
1994	16,440
1996	60,575
1997	32,855
1998	52,695
1999	14,730
2000	24,060
2001	9,560
2002	17,550
2003	20,815
2006	11,730
2007	48,190
2008	21,490
2010	16,360



End of Data Series ==============================
This series contains 18 years of data.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

DATA AS CONTAINED IN: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF

UNSORTED				SORTED			
V (Dam3)	Rank	Plotting Position	Plotted Period (yrs)	V (Dam3)	Rank	Plotting Position	Plotted Period (yrs)
7,490	18	.9474	1.056	60,575	1	.0526	19.000
8,690	17	.8947	1.118	52,695	2	.1053	9.500
23,315	7	.3684	2.714	48,190	3	.1579	6.333
10,055	15	.7895	1.267	42,250	4	.2105	4.750
42,250	4	.2105	4.750	32,855	5	.2632	3.800
16,440	11	.5789	1.727	24,060	6	.3158	3.167
60,575	1	.0526	19.000	23,315	7	.3684	2.714
32,855	5	.2632	3.800	21,490	8	.4211	2.375
52,695	2	.1053	9.500	20,815	9	.4737	2.111
14,730	13	.6842	1.462	17,550	10	.5263	1.900
24,060	6	.3158	3.167	16,440	11	.5789	1.727
9,560	16	.8421	1.188	16,360	12	.6316	1.583
17,550	10	.5263	1.900	14,730	13	.6842	1.462
20,815	9	.4737	2.111	11,730	14	.7368	1.357
11,730	14	.7368	1.357	10,055	15	.7895	1.267
48,190	3	.1579	6.333	9,560	16	.8421	1.188
21,490	8	.4211	2.375	8,690	17	.8947	1.118
16,360	12	.6316	1.583	7,490	18	.9474	1.056

Note that the UNSORTED listing will give the same rank to identical values occuring in the input data file. The SORTED listing shows all ranks.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

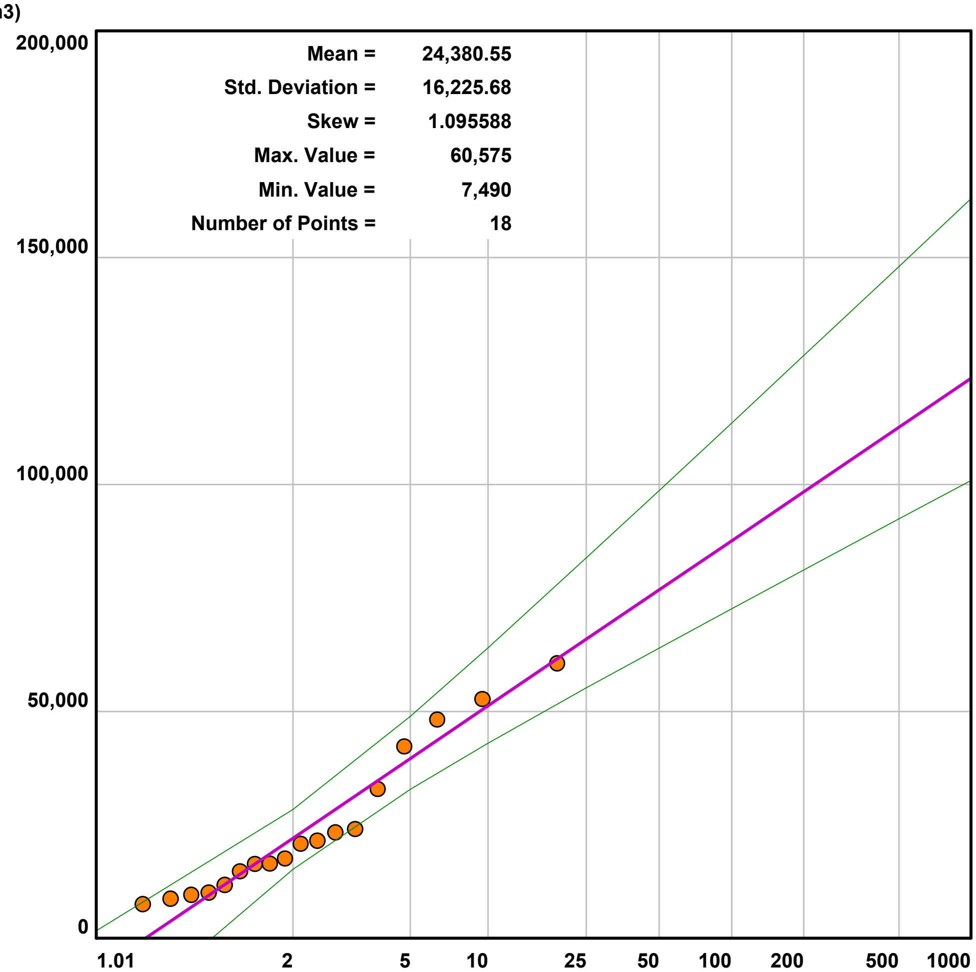
EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

RUNOFF VOLUME (Dam3)

Tr (yrs)	V Dam3
1.01	-7,363
2	22,013
5	39,576
10	51,204
25	65,896
50	76,796
100	87,614
200	98,394
500	112,615
1000	123,364

FAILED
Chi-Square Test

Mean = 24,380.55
Std. Deviation = 16,225.68
Skew = 1.095588
Max. Value = 60,575
Min. Value = 7,490
Number of Points = 18



High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean =	24,380.55	Maximum Input Value =	60,575
Std. Deviation =	16,225.68	Minimum Input Value =	7,490
Skew =	1.09558800	Number of Points =	18

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

RETURN PERIOD (yrs)	V (Dam3)	FREQUENCY FACTOR	V 90% CONFIDENCE LIMITS Lower (Dam3)	Upper (Dam3)
1.01	-7,363	-1.9564	-21,841	1,625
2	22,013	-0.1459	15,211	28,406
5	39,576	0.9365	32,847	48,933
10	51,204	1.6532	43,007	64,040
25	65,896	2.5586	55,171	83,801
50	76,796	3.2304	63,975	98,680
100	87,614	3.8971	72,621	113,544
200	98,394	4.5615	81,179	128,409
500	112,615	5.4380	92,417	148,074
1,000	123,364	6.1004	100,883	162,963

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean =	24,380.55	Maximum Input Value =	60,575
Std. Deviation =	16,225.68	Minimum Input Value =	7,490
Skew =	1.09558800	Number of Points =	18

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

	CLASS LIMITS		NUMBER OF VALUES		
CLASS	Lower (Dam3)	Upper (Dam3)	Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0	8,960	3.6000	2	0.7111
2	8,960	17,689	3.6000	7	3.2111
3	17,689	26,743	3.6000	4	0.0444
4	26,743	39,576	3.6000	1	1.8778
5	39,576	Infinity	3.6000	4	0.0444

COMPUTED CHI-SQUARE = 5.8889
CHI-SQUARE FROM TABLE = 4.6100

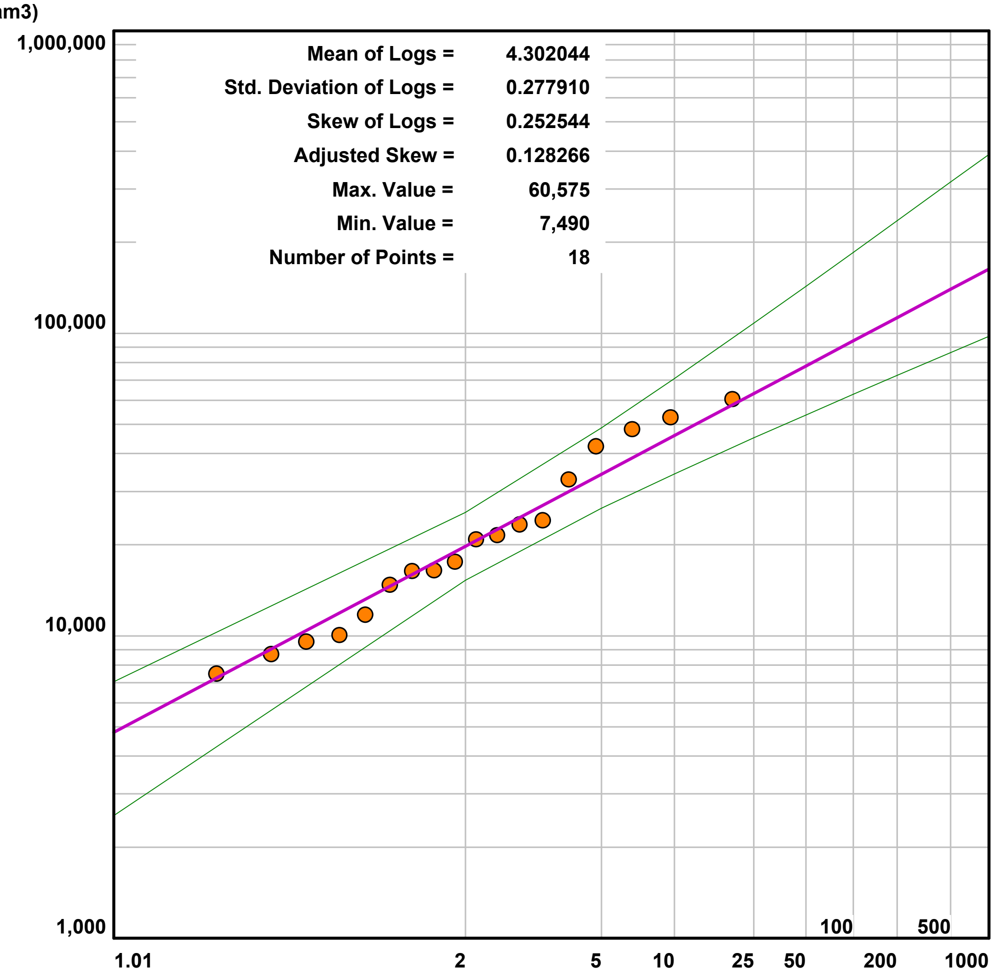
CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION does NOT apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

LOG-PEARSON TYPE III DISTRIBUTION

RUNOFF VOLUME (Dam3)

Tr (yrs)	V Dam3
1.01	4,793
2	19,775
5	34,199
10	45,896
25	63,182
50	77,930
100	94,324
200	112,542
500	139,725
1000	162,887



PASSED
Chi-Square Test

High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean of Logs =	4.302044	Maximum Input Value =	60,575
Std. Deviation of Logs =	0.277910	Minimum Input Value =	7,490
Skew of Logs =	0.252544	Number of Points =	18
Adjusted Skew =	0.128266	Generalized Map Skew =	0.0

LOG-PEARSON TYPE III DISTRIBUTION

RETURN PERIOD (yrs)	V (Dam3)	FREQUENCY FACTOR	V 90% CONFIDENCE LIMITS Lower (Dam3)	Upper (Dam3)
1.01	4,793	-2.2361	2,545	7,047
2	19,775	-0.0213	15,250	25,582
5	34,199	0.8347	26,372	48,642
10	45,896	1.2944	34,315	70,838
25	63,182	1.7939	45,088	107,983
50	77,930	2.1218	53,691	143,049
100	94,324	2.4201	62,808	185,158
200	112,542	2.6961	72,519	235,374
500	139,725	3.0342	86,374	316,227
1,000	162,887	3.2739	97,705	390,125

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean of Logs =	4.302044	Maximum Input Value =	60,575
Std. Deviation of Logs =	0.277910	Minimum Input Value =	7,490
Skew of Logs =	0.252544	Number of Points =	18
Adjusted Skew =	0.128266	Generalized Map Skew =	0.0

LOG-PEARSON TYPE III DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

	CLASS LIMITS		NUMBER OF VALUES		
CLASS	Lower (Dam3)	Upper (Dam3)	Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0	11,658	3.6000	4	0.0444
2	11,658	16,832	3.6000	4	0.0444
3	16,832	23,272	3.6000	3	0.1000
4	23,272	34,199	3.6000	3	0.1000
5	34,199	Infinity	3.6000	4	0.0444

COMPUTED CHI-SQUARE = 0.3333
CHI-SQUARE FROM TABLE = 2.7100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-PEARSON TYPE III DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

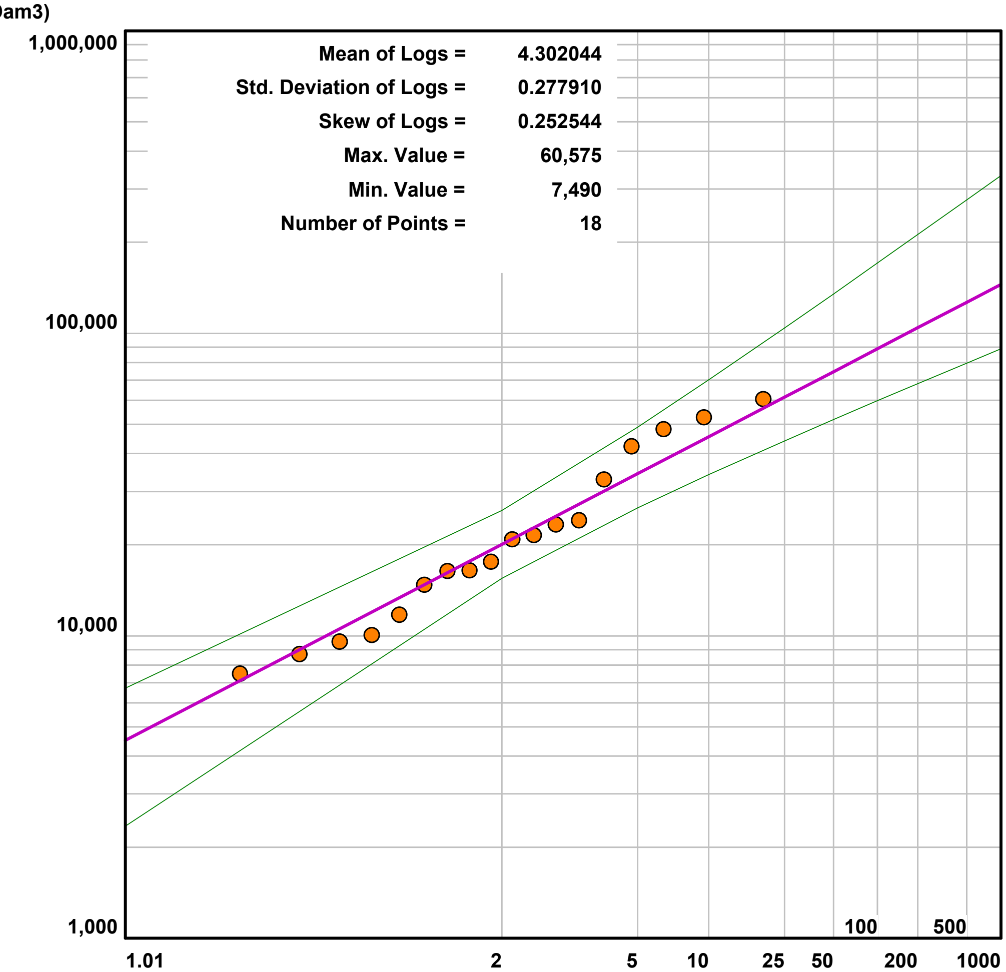
Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

LOG-NORMAL DISTRIBUTION

RUNOFF VOLUME (Dam3)

Tr (yrs)	V Dam3
1.01	4,512
2	20,047
5	34,347
10	45,525
25	61,473
50	74,632
100	88,855
200	104,233
500	126,477
1000	144,854

Mean of Logs =	4.302044
Std. Deviation of Logs =	0.277910
Skew of Logs =	0.252544
Max. Value =	60,575
Min. Value =	7,490
Number of Points =	18



PASSED
Chi-Square Test

High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean of Logs =	4.302044	Maximum Input Value =	60,575
Std. Deviation of Logs =	0.277910	Minimum Input Value =	7,490
Skew of Logs =	0.252544	Number of Points =	18

LOG-NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	V (Dam3)	FREQUENCY FACTOR	V 90% CONFIDENCE LIMITS Lower (Dam3)	Upper (Dam3)
1.01	4,512	-2.3305	2,346	6,706
2	20,047	0.0000	15,478	25,963
5	34,347	0.8415	26,477	48,905
10	45,525	1.2817	34,073	70,095
25	61,473	1.7511	44,060	104,108
50	74,632	2.0542	51,804	134,963
100	88,855	2.3268	59,811	170,769
200	104,233	2.5762	68,139	212,050
500	126,477	2.8785	79,705	275,983
1,000	144,854	3.0905	88,917	332,213

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean of Logs =	4.302044	Maximum Input Value =	60,575
Std. Deviation of Logs =	0.277910	Minimum Input Value =	7,490
Skew of Logs =	0.252544	Number of Points =	18

LOG-NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

CLASS	CLASS LIMITS Lower (Dam3)	Upper (Dam3)	NUMBER OF VALUES Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0	11,700	3.6000	4	0.0444
2	11,700	17,051	3.6000	4	0.0444
3	17,051	23,569	3.6000	4	0.0444
4	23,569	34,347	3.6000	2	0.7111
5	34,347	Infinity	3.6000	4	0.0444
				COMPUTED CHI-SQUARE =	0.8889
				CHI-SQUARE FROM TABLE =	4.6100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-NORMAL DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

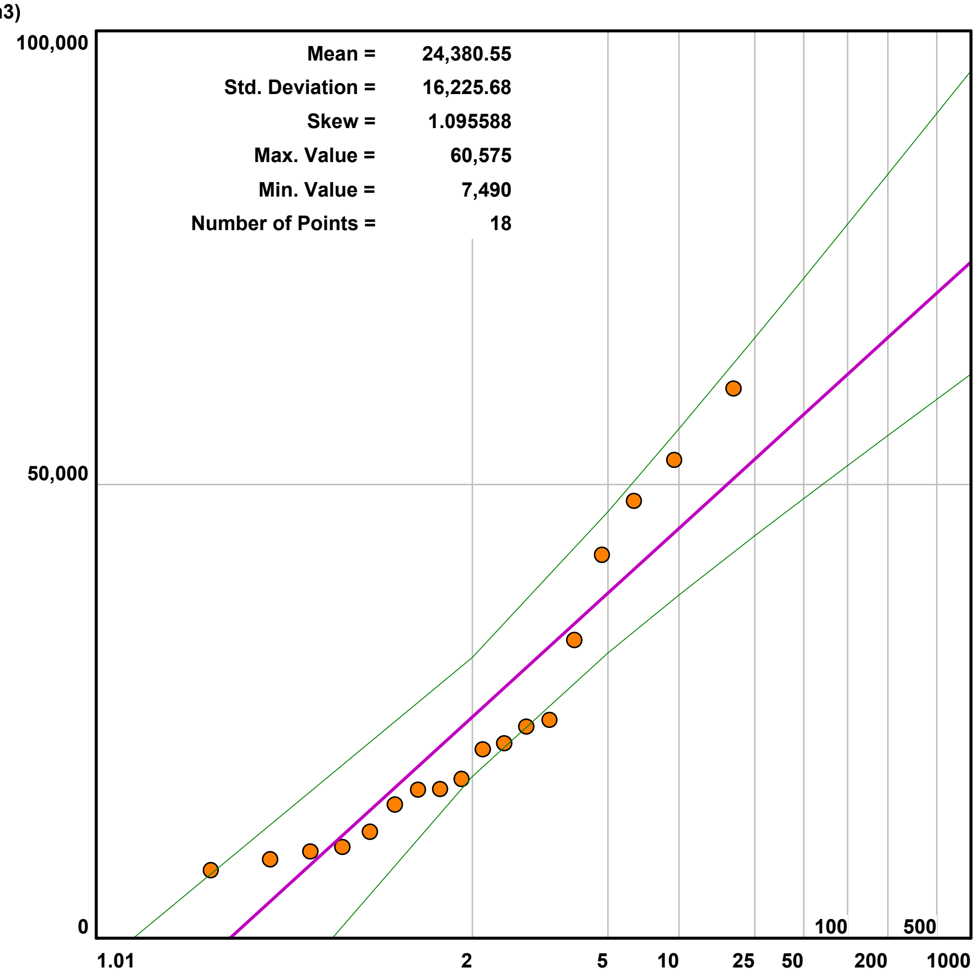
Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

NORMAL DISTRIBUTION

RUNOFF VOLUME (Dam3)

Tr (yrs)	V Dam3
1.01	-13,434
2	24,381
5	38,034
10	45,177
25	52,793
50	57,711
100	62,134
200	66,182
500	71,086
1000	74,526

PASSED
Chi-Square Test



High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek **RETURN PERIOD (yrs)**

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean =	24,380.55	Maximum Input Value =	60,575
Std. Deviation =	16,225.68	Minimum Input Value =	7,490
Skew =	1.09558800	Number of Points =	18

NORMAL DISTRIBUTION

RETURN PERIOD (yrs)	V (Dam3)	FREQUENCY FACTOR	V 90% CONFIDENCE LIMITS Lower (Dam3)	Upper (Dam3)
1.01	-13,434	-2.3305	-30,020	-3,387
2	24,381	0.0000	17,823	30,938
5	38,034	0.8415	31,435	46,993
10	45,177	1.2817	37,831	56,121
25	52,793	1.7511	44,348	66,151
50	57,711	2.0542	48,454	72,733
100	62,134	2.3268	52,098	78,700
200	66,182	2.5762	55,403	84,189
500	71,086	2.8785	59,379	90,871
1,000	74,526	3.0905	62,152	95,573

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean =	24,380.55	Maximum Input Value =	60,575
Std. Deviation =	16,225.68	Minimum Input Value =	7,490
Skew =	1.09558800	Number of Points =	18

NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

	CLASS LIMITS		NUMBER OF VALUES		
CLASS	Lower (Dam3)	Upper (Dam3)	Expected "Ei"	Observed "Oi"	$\frac{(Oi-Ei)^2}{Ei}$
1	0	10,727	3.6000	4	0.0444
2	10,727	20,277	3.6000	5	0.5444
3	20,277	28,485	3.6000	4	0.0444
4	28,485	38,034	3.6000	1	1.8778
5	38,034	Infinity	3.6000	4	0.0444

COMPUTED CHI-SQUARE = 2.5556
CHI-SQUARE FROM TABLE = 4.6100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the NORMAL DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Project: High Wood River near the Mouth / High River, Black Diamond & 3 Point Creek
User: ISL
Date: 11 March 2013, Monday
Time: 9:45 am
Input: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE.HDF
Output: C:\PROGRAM FILES (X86)\CAHH\OKOTOKS SMP - RUNOFF ESTIMATE - HIGHWOOD RIVER ANALYSIS.OUT

Mean =	24,380.55	Maximum Input Value =	60,575
Std. Deviation =	16,225.68	Minimum Input Value =	7,490
Skew =	1.09558800	Number of Points =	18
Mean of Logs =	4.302044	Generalized Map Skew =	0.0
Std. Deviation of Logs =	0.277910		
Skew of Logs =	0.252544		
Adjusted Skew =	0.128266		

COMPARISON OF STATISTICAL DISTRIBUTIONS

Number of Chi-Square class intervals used = 5

DISTRIBUTION	CHI-SQUARE COMPUTED	CHI-SQUARE TABULATED	
EXTREME VALUE TYPE I (GUMBEL)	5.889	4.610	FAILED
LOG-PEARSON TYPE III	0.333	2.710	Passed
LOG-NORMAL	0.889	4.610	Passed
NORMAL	2.556	4.610	Passed

BASED ON A 10-PERCENT SIGNIFICANCE LEVEL, THE
LOG-NORMAL
DISTRIBUTION RESULTS IN THE BEST FIT OF THE DATA.

Appendix E

Cost Estimates for Recommended Upgrades

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NW-1 & 2 – OPTION 1 (Detention Pond)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Trees cutting and site preparation	L.S.	1	25,000	25,000
2	Earthworks for pond construction	m^3	3,000	15	45,000
3	Weir structure	m	16	625	10,000
4	Pond access/service road	m^2	650	20	13,000
5	Fencing	m	200	20	4,000
6	Pond embankment lining	m^2	800	15	12,000
7	Miscellaneous works (water course cleaning & grading, ..etc)	L.S.	1	30% of above	32,700
8	Mobilization & Demobilization	L.S.	1	10% of above	14,170
TOTAL 1					**$155,870**
	Add Contingency	**25 %**			$38,970
TOTAL 2					**$194,840**
	Add Engineering	**20%**			$38,970
TOTAL 3					**$233,810**
	Add GST	**5%**			$11,690
GRAND TOTAL					**$245,500**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NE-1 – OPTION 1 (Detention Pond)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Trees cutting and site preparation	L.S.	1	25,000	25,000
2	Earthworks for pond construction	m^3	4,000	15	60,000
3	Weir Structure	m	32	415	13,280
4	Pond access/service road	m^2	800	20	16,000
5	Fencing	m	200	20	4,000
6	Pond embankment lining	m^2	1650	15	24,750
7	Pond inlet & outlet works	L.S.	1	15,000	15,000
8	Miscellaneous works (water course cleaning & grading, ..etc)	L.S.	1	30% of above	47,410
9	Mobilization & Demobilization	L.S.	1	10% of above	20,545
TOTAL 1					**$225,985**
	Add Contingency	**25 %**			$56,495
TOTAL 2					**$282,480**
	Add Engineering	**20%**			$56,495
TOTAL 3					**$338,975**
	Add GST	**5%**			$16,950
GRAND TOTAL					**$355,925**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SW-2 – OPTION 1 (Detention Pond)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Trees cutting and site preparation	L.S.	1	20,000	20,000
2	Earthworks for pond construction	m^3	3,850	15	57,750
3	Weir Structure	m	25	415	10,375
4	Pond embankment lining	m^2	1,520	15	22,800
5	Pond access/service road	m^2	860	20	17,200
6	Fencing	m	215	20	4,300
7	Pond inlet & outlet pipeworks	L.S.	1	120,000	120,000
8	Miscellaneous works (water course cleaning & grading, ..etc)	L.S.	1	30% of above	75,730
9	Mobilization & Demobilization	L.S.	1	10% of above	32,815
TOTAL 1					**$360,970**
	Add Contingency	**25 %**			$90,240
TOTAL 2					**$451,210**
	Add Engineering	**15%**			$67,680
TOTAL 3					**$518,890**
	Add GST	**5%**			$25,945
GRAND TOTAL					**$544,835**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SE-1 – OPTION 1 (Detention Pond)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Control weir for ponding area within the natural stream.	m	12	830	9,960
2	Pond inlet pipeworks	L.S.	1	104,000	104,000
3	Rip Rap Lining Works	m³	180	75	13,500
4	Miscellaneous works (water diversion & reinstatement of existing surfaces)	L.S.	1	30% of above	38,240
5	Mobilization & Demobilization	L.S.	1	10% of above	16,570
TOTAL 1					**$182,270**
	Add Contingency	**25 %**			$45,570
TOTAL 2					**$227,840**
	Add Engineering	**20%**			$45,570
TOTAL 3					**$273,410**
	Add GST	**5%**			$13,670
GRAND TOTAL					**$287,080**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NW-1 & 2 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	**UNIT**	**QUANTITY**	**RATE**	**COST**
1	1000mm stormwater sewer, including pipe and earthworks	m	17	1,100	18,700
2	1200mm stormwater sewer, including pipe and earthworks	m	16	1,500	24,000
3	1000mm dia. bends, including material and earthworks	e.a.	2	7,000	14,000
4	1200mm dia. Bends, including material and earthworks	e.a.	2	8,800	17,600
5	connection to existing/new manholes	e.a.	6	1,000	6,000
6	Vortechs Type VX16000	e.a.	2	155,000	310,000
7	Vortechs Type PC1319	e.a.	3	187,000	561,000
8	Manhole Type 1S (1.5m dia.)	e.a.	3	21,100	63,300
9	Manhole Type 1S (1.9m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	114,800
TOTAL 1					**$1,262,900**
	Add Contingency	**20 %**			$252,500
TOTAL 2					**$1,515,400**
	Add Engineering	**8%**			$121,200
TOTAL 3					**$1,636,600**
	Add GST	**5%**			$81,800
GRAND TOTAL					**$1,718,400**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NE-1 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	1350mm stormwater sewer, including pipe and earthworks	m	28	1,850	51,800
2	1350mm dia. Bends, including material and earthworks	e.a.	2	11,250	22,500
3	Connection to existing/new manholes	e.a.	3	1,000	3,000
4	Vortechs Type VX1600	e.a.	3	155,000	465,000
5	Manhole Type 1S (1.9m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	67600
TOTAL 1					**$743,400**
	Add Contingency	**20 %**			$148,700
TOTAL 2					**$892,100**
	Add Engineering	**8%**			$71,400
TOTAL 3					**$963,500**
	Add GST	**5%**			$48,175
GRAND TOTAL					**$1,011,700**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NE-3 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	**UNIT**	**QUANTITY**	**RATE**	**COST**
1	1200mm stormwater sewer, including pipe and earthworks	m	26	1,500	39,000
2	1200mm dia. Bends, including material and earthworks	e.a.	2	8,800	17,600
3	connection to existing/new manholes	e.a.	3	1,000	3,000
4	Vortechs Type PC1319	e.a.	3	187,000	561,000
5	Manhole Type 1S (1.9m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	75,400
TOTAL 1					**$829,500**
	Add Contingency	**20 %**			$165,900
TOTAL 2					**$995,400**
	Add Engineering	**8%**			$796,300
TOTAL 3					**$1,075,000**
	Add GST	**5%**			$53,750
GRAND TOTAL					**$1,128,800**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL NE-4 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	**UNIT**	**QUANTITY**	**RATE**	**COST**
1	1950mm stormwater sewer, including pipe and earthworks	m	40	4,300	172,000
2	1950mm dia. Bends, including material and earthworks	e.a.	2	19,800	39,600
3	1950mm connection to existing/new manholes	e.a.	4	1,500	6,000
4	Vortechs Type PC1319	e.a.	7	187,000	1,309,000
5	Manhole Type 1S (2.4m dia.)	e.a.	8	50,400	403,200
10	Mobilization & Demobilization	L.S.	1	10% of above	193,000
TOTAL 1					**$2,122,800**
	Add Contingency	**15 %**			$318,400
TOTAL 2					**$2,441,200**
	Add Engineering	**6%**			$146,500
TOTAL 3					**$2,587,700**
	Add GST	**5%**			$129,400
GRAND TOTAL					**$2,717,100**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SW-1 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	1000mm stormwater sewer, including pipe and earthworks	m	27	1,100	29,700
2	1000mm dia. Bends, including material and earthworks	e.a.	2	7,000	14,000
3	1000mm connection to existing/new manholes	e.a.	2	1,000	2,000
4	Vortechs Type PC1318	e.a.	3	187,000	561,000
5	Manhole Type 1S (1.5m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	74,000
TOTAL 1					**$814,200**
	Add Contingency	**20 %**			$162,900
TOTAL 2					**$977,100**
	Add Engineering	**10%**			$97,700
TOTAL 3					**$1,074,800**
	Add GST	**5%**			$53,700
GRAND TOTAL					**$1,128,500**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SW-2 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	1200mm stormwater sewer, including pipe and earthworks	m	26	1,500	39,000
2	1200mm dia. Bends, including material and earthworks	e.a.	2	8,800	17,600
3	Connection to existing/new manholes	e.a.	2	1,000	2,000
4	Vortechs Type PC1319	e.a.	3	187,000	561,000
5	Manhole Type 1S (1.9m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	75,300
TOTAL 1					**$828,400**
	Add Contingency	**20 %**			$165,700
TOTAL 2					**$994,100**
	Add Engineering	**10%**			$99,400
TOTAL 3					**$1,093,500**
	Add GST	**5%**			$54,700
GRAND TOTAL					**$1,148,200**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SE-1 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	1200mm stormwater sewer, including pipe and earthworks	m	26	1,500	39,000
2	1200mm dia. Bends, including material and earthworks	e.a.	2	8,800	17,600
3	connection to existing/new manholes	e.a.	3	1,000	3,000
4	Vortechs Type PC1319	e.a.	3	187,000	561,000
5	Manhole Type 1S (1.9m dia.)	e.a.	5	26,700	133,500
10	Mobilization & Demobilization	L.S.	1	10% of above	75,400
TOTAL 1					**$829,500**
	Add Contingency	**20 %**			$165,900
TOTAL 2					**$995,400**
	Add Engineering	**8%**			$796,300
TOTAL 3					**$1,075,000**
	Add GST	**5%**			$53,750
GRAND TOTAL					**$1,128,800**

OKOTOKS SWMMP
EOP CONTROL WORKS – OUTFALL SE-2 – OPTION 2 (Compact Treatment Detention)
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	1650mm stormwater sewer, including pipe and earthworks	m	70	2,700	189,000
2	1650mm dia. Bends, including material and earthworks	e.a.	2	15,700	31,400
3	1650mm connection to existing/new manholes	e.a.	3	1,500	4,500
4	Vortechs Type PC1319	e.a.	6	187,000	1,122,000
5	Manhole Type 1S (2.4m dia.)	e.a.	5	50,400	252,500
10	Mobilization & Demobilization	L.S.	1	10% of above	159,900
TOTAL 1					**$1,759,300**
	Add Contingency	**15 %**			$263,900
TOTAL 2					**$2,023,300**
	Add Engineering	**6%**			$121,400
TOTAL 3					**$2,144,700**
	Add GST	**5%**			$107,300
GRAND TOTAL					**$2,251,900**

OKOTOKS SWMMP
STORM UPGRADES – POPLAR AVENUE - OPTION 1
COST ESTIMATE

ITEM	DESCRIPTION	**UNIT**	**QUANTITY**	**RATE**	**COST**
1	Mobilization & Demobilization	L.S.	1	10% of civil	28,500
2	450mm Stormwater sewer connection to existing manhole.	ea	2	2,500	5,000
3	450mm stormwater sewer, including pipe and earthworks	m	230	275	63,250
4	Manhole Type 5A (1.2m dia.)	v.m.	2	2500	5,000
5	Catch Basin, Single Type C	ea	2	3500	7,000
6	250mm Catch Basin lead.	m	30	200	6,000
7	concrete gutter	m	10	110	1,100
8	Saw Cut Asphalt.	m	575	11	6,325
9	Remove existing road pavement.	m^2	1475	20	29,500
10	Subgrade Preparation.	m^2	1475	2	2,950
11	80mm Crushed Gravel Sub-Base, 450mm thick.	m^3	665	50	33,250
12	25mm Crushed Gravel Base, 50mm thick.	m^3	110	35	3,850
13	Base Course Asphalt Mix A, 150mm thick.	m^2	1475	45	66,375
14	Surface Course Asphalt Mix B, 50mm thick	m^2	1475	20	29,500
15	Prime Coat	m^2	1475	1.5	2,215
16	Tack Coat	m^2	1475	1.25	1,845
17	Manhole Cover Level Adjustment	ea	8	750	6,000
18	Hydrovac. Average depth (1-2)m	ea	20	800	16,000
19	Protection of Existing Utlities, complete	L.S.	1	5% of civil	14,250
TOTAL 1					**$327,910**
	Add Contingency	**15 %**			$49,190
TOTAL 2					**$377,100**
	Add Engineering	**12%**			$45,250
TOTAL 3					**$422,350**
	Add GST	**5%**			$21,120
GRAND TOTAL					**$443,470**

OKOTOKS SWMMP
STORM UPGRADES – ELMA PLACE - OPTION 1
COST ESTIMATE

ITEM	DESCRIPTION	**UNIT**	**QUANTITY**	**RATE**	**COST**
1	Mobilization & Demobilization	L.S.	1	10% of civil	10,700
2	450mm Stormwater sewer connection to existing manhole.	ea	2	2,500	5,000
3	450mm stormwater sewer, including pipe and earthworks	m	105	275	28,900
4	Manhole Type 5A (1.2m dia.)	v.m.	2	2500	5,000
5	Saw Cut Asphalt.	m	100	11	1,105
6	Remove existing road pavement.	m^2	550	20	11,000
7	Subgrade Preparation.	m^2	550	2	1,100
8	80mm Crushed Gravel Sub-Base, 450mm thick.	m^3	245	50	12,250
9	25mm Crushed Gravel Base, 50mm thick.	m^3	28	35	980
10	Base Course Asphalt Mix A, 150mm thick.	m^2	550	45	24,750
11	Surface Course Asphalt Mix B, 50mm thick	m^2	550	20	11,000
12	Prime Coat	m^2	550	1.5	825
13	Tack Coat	m^2	550	1.25	700
14	Manhole Cover Level Adjustment	ea	2	750	1,500
15	Hydrovac. Average depth (1-2)m	ea	4	800	3,200
16	Protection of Existing Utlities, complete	L.S.	1	5% of civil	5,350
TOTAL 1					**$123,360**
	Add Contingency	**15 %**			$18,500
TOTAL 2					**$141,860**
	Add Engineering	**12%**			$17,000
TOTAL 3					**$158,860**
	Add GST	**5%**			$7,940
GRAND TOTAL					**$166,800**

OKOTOKS SWMMP
STORM UPGRADES – ELMA PLACE - OPTION 2
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	11,250
2	525mm Stormwater sewer connection to existing manhole.	ea	2	2,500	5,000
3	525mm stormwater sewer, including pipe and earthworks	m	105	325	34,100
4	Manhole Type 5A (1.2m dia.)	v.m.	2	2500	5,000
5	Saw Cut Asphalt.	m	100	11	1,105
6	Remove existing road pavement.	m²	550	20	11,000
7	Subgrade Preparation.	m²	550	2	1,100
8	80mm Crushed Gravel Sub-Base, 450mm thick.	m³	245	50	12,250
9	25mm Crushed Gravel Base, 50mm thick.	m³	28	35	980
10	Base Course Asphalt Mix A, 150mm thick.	m²	550	45	24,750
11	Surface Course Asphalt Mix B, 50mm thick	m²	550	20	11,000
12	Prime Coat	m²	550	1.5	825
13	Tack Coat	m²	550	1.25	700
14	Manhole Cover Level Adjustment	ea	2	750	1,500
15	Hydrovac. Average depth (1-2)m	ea	4	800	3,200
16	Protection of Existing Utlities, complete	L.S.	1	5% of civil	5,625
TOTAL 1					**$129,385**
	Add Contingency	**15 %**			$19,410
TOTAL 2					**$148,795**
	Add Engineering	**12%**			$17,850
TOTAL 3					**$166,645**
	Add GST	**5%**			$8,330
GRAND TOTAL					**$174,975**

OKOTOKS SWMMP
STORM UPGRADES – POPLAR AVENUE - OPTION 2
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	91,000
2	1350mm Stormwater sewer connection to existing manhole.	ea	1	5,000	5,000
3	1350mm stormwater sewer, including pipe and earthworks	m	460	1,750	805,000
4	Manhole Type 1.9 1S	ea	1	28,000	28,000
5	Outfall Structure	ea	1	72,000	72,000
TOTAL 1					**$1,001,000**
	Add Contingency	**15 %**			$150,150
TOTAL 2					**$1,151,150**
	Add Engineering	**12%**			$138,140
TOTAL 3					**$1,289,290**
	Add GST	**5%**			$64,465
GRAND TOTAL					**$1,353,760**

OKOTOKS SWMMP
STORM UPGRADES – NORTHRIDGE DRIVE – OPTION 1
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	New Pond	L.S.	1		435,000
TOTAL 1					**$435,000**
	Add Contingency	**15%**			65,250
TOTAL 2					**500,250**
	Add Engineering	**12 %**			$60,030
GRAND TOTAL					**$560,280**

Notes: 1- The estimated price of this option is based on the construction price (including GST) of similar projects.
2- The above cost does not include any required Land Acquisition.

OKOTOKS SWMMP
STORM UPGRADES – NORTHRIDGE DRIVE – OPTION 2
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	7,800
2	Check dam, complete	ea	50	1,560	78,000
TOTAL 1					**$85,800**
	Add Contingency	**20 %**			$17,160
TOTAL 2					**$102,960**
	Add Engineering	**20%**			$20,590
TOTAL 3					**$123,550**
	Add GST	**5%**			$6,180
GRAND TOTAL					**$129,730**

OKOTOKS SWMMP
STORM UPGRADES – AIR RANCH (NORTH WEST CORNER) – OPTION 3
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	116,500
2	450-750mm stormwater sewer, including pipe and earthworks	m	1005	275-800	563,700
3	Manhole Type 5A (1.2m dia.)	v.m.	40	2500	100,000
4	Catch Basin, Single Type C	ea	25	3500	87,500
5	250mm Catch Basin lead.	m	200	200	40,000
6	concrete gutter	m	100	110	11,000
7	Saw Cut Asphalt.	m	2500	11	27,500
8	Remove existing road pavement.	m^2	2600	20	52,000
9	Subgrade Preparation.	m^2	2600	2	5,200
10	80mm Crushed Gravel Sub-Base, 450mm thick.	m^3	1170	50	58,500
11	25mm Crushed Gravel Base, 50mm thick.	m^3	130	35	4,550
12	Base Course Asphalt Mix A, 150mm thick.	m^2	2600	45	117,000
13	Surface Course Asphalt Mix B, 50mm thick	m^2	2600	20	52,000
14	Prime Coat	m^2	2600	1.5	3,900
15	Tack Coat	m^2	2600	1.25	3,250
16	Manhole Cover Level Adjustment	ea	10	750	7,500
17	Hydrovac. Average depth (1-2)m	ea	40	800	32,000
18	Protection of Existing Utlities, complete	L.S.	1	5% of civil	58,000
TOTAL 1					**$1,340,100**
	Add Contingency	**15 %**			$201,000
TOTAL 2					**$1,541,100**
	Add Engineering	**12%**			$184,930
TOTAL 3					**$1,726,030**
	Add GST	**5%**			$86,300
GRAND TOTAL					**$1,812,330**

OKOTOKS SWMMP
STORM UPGRADES – AIR RANCH (NORTH WEST CORNER) – OPTION 4
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	2,400
2	Berm Backfill, complete	m^3	400	20	8,000
3	Surface Preparation for Berm Construction	m^2	175	2	1,750
4	Berm Surface Erosion Control, complete	m^2	920	15	13,800
5	Pipe Outlet, Complete	L.S.	1	500	500
TOTAL 1					**$26,450**
	Add Contingency	**20 %**			$5,300
TOTAL 2					**$31,740**
	Add Engineering	**20%**			$6,350
TOTAL 3					**$38,090**
	Add GST	**5%**			$1,940
GRAND TOTAL					**$40,030**

Note: The above cost does not include any required Land Acquisition.

OKOTOKS SWMMP
STORM UPGRADES – AIR RANCH (NORTH WEST CORNER) – OPTION 5
COST ESTIMATE

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	COST
1	Mobilization & Demobilization	L.S.	1	10% of civil	2,075
2	Area Grading, complete	m^3	460	20	9,000
3	Graded area Surface Erosion Control, complete	m^2	450	15	6,750
4	Ancillary Construction works (site access,…etc)	L.S.	1		5,000
TOTAL 1					**$22,825**
	Add Contingency	**20 %**			$4,565
TOTAL 2					**$27,390**
	Add Engineering	**20%**			$5,480
TOTAL 3					**$32,870**
	Add GST	**5%**			$1,650
GRAND TOTAL					**$34,520**

Note: The above cost does not include any required Land Acquisition.