DISTRICT OF WEST KELOWNA

Master Drainage Plan



Adopted: October 25, 2011

RSB
ENGINEERING

DISTRICT OF WEST KELOWNA

MASTER DRAINAGE PLAN

Prepared for:

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EXECUTIVE SUMMARY

INTRODUCTION

The enclosed report presents a summary of the drainage issues, concerns and opportunities within the District of West Kelowna. This report was commissioned by the District of West Kelowna to assess the condition of the existing drainage network in terms of the local hydrology, hydraulic, environmental and hydrogeological issues within the District's boundaries. Specific objectives include the following:

- Compile an inventory of the existing drainage infrastructure;
- Estimate the peak runoff rates;
- Identify areas that present risks for public safety, property damage or environmental concerns;
- Provide an update of the watercourse evaluation data including habitat and impact ratings as well as sensitive habitat Inventory information;
- Provide recommendations for addressing existing deficiencies

CRITERIA

The drainage inventory and infrastructure assessment were based on the available drawings for the existing facilities and supplemented with field reviews to confirm existing drainage routes, prepare the culvert inspection repo*rts*, and identify areas of concern. The topographic and cadastral mapping information, was provided from the Regional District of Central Okanagan.

The 1 in 5 year storm event was used to assess the performance of the minor system analysis, while the 1 in 100 year storm event was used to analyze the major system or overland runoff events. A Regional Analysis was also completed using data available from Water Survey of Canada to estimate the runoff from the upper watershed areas.

Previous watercourse and wetland inventories, as completed in 2001 and 2003 and these formed the basis of the biophysical review and analysis. These databases were then updated based on known alterations and major development projects within the District to provide a detailed account of the various watercourse attributes that have been identified in the respective watercourses.

A hydrogeological review was carried to assess the potential of storm water disposal to ground, and included the input from available soils reports within the study area as well as mapping from various sources including the BC Ministry of Environment and associated water well databases.

The criteria used in evaluation the potential suitability for disposal to ground included, the ground slope, soil type and the depth to a limiting condition such as groundwater table, bedrock or fine-grained soils that may limit the ability for water to migrate downwards.

EXISTING DRAINAGE SYSTEM

The existing drainage areas were modeled using the PCSWMM computer model for both the 1 in 5 year and 1 in 100 year storm events. The estimated flow rates from the computer model analysis are summarized for each drainage basin and presented within the enclosed report.

In general, the major creeks and the majority of the storm drainage network have adequate capacity to convey the expected peak flows from the 1 in 5 year storm event. Noted deficiencies within each drainage basin have been presented within each respective section of this report. The recommended improvement projects have been presented as High, Medium or Low Priority projects as related to the risk of flooding or property damage. Cost estimates for the recommended improvement projects have also been included. The locations of the High, Medium and Low priority projects have been shown in Figures 1, 2, and 3 respectively.

During the data assembly and field reviews, it was generally noted that there are very few storm water management facilities within the existing areas of urban development. An inventory of existing storm water management facilities in underway, as part of this study and to date there are approximately 20 stormwater management and water quality enhancement facilities within the District. These generally take the form of above ground detention basins with some underground chambers, infiltration galleries or large diameter pipes having controlled release rates.

With the increased impervious surfaces that accompany urban development, the amount of infiltration and absorption is reduced in comparison to pre-existing conditions, and the downstream areas will experience much high flow rates and increased volumes of runoff. This is evidenced in the downstream reaches of streams such as Smith Creek, where severe erosion and down-cutting in the channel have been noted. These locations have been documented within the watercourse evaluation (Section 12).

The watercourse and wetlands evaluation included a review of the biophysical attributes and values of respective drainage courses. The enclosed update was based on the previous inventory studies, and the data sets were merged and analyzed to obtain biological values intrinsic within the respective watercourses and wetlands. The results, rating scores, and channel stability attributes have been presented within this report, and the accompanying mapsheets have been presented as Volume II.

A hydrogeological review was carried out to evaluate on a cursory level, the suitability of specific development areas for stormwater disposal to ground and to identify areas which would be prone to impacts from up-slope disposal to ground. The suitability for infiltration of stormwater to ground was completed using Multiple Criteria Analysis for three dominant factors influencing infiltration including ground slope, soil type and the depth to a limiting condition. The categories of suitability of storm water to ground include *Not Suitable*; *Possibly Suitable* and *Well Suited*. The results of the hydrogeological review are presented within Section 11 of this report.

The majority of the Study Area is not considered to be well suited for disposal of stormwater to ground. The areas where it is considered feasible are generally limited to glacio-fluvial and alluvial sediments associated with McDougall Creek and Powers Creek. Figure 11.4 presents the mapping results of the Multiple Criteria Analysis.

Periodic water samples were obtained to review the runoff water quality in terms of chloride concentration, presence of nitrates as well as *E. Coli*. The chloride concentrations were found to be highest where runoff from Highway 97 entered the drainage system. *E coli* counts we law for the water in the upper reaches of every creek system of West Kelowna. Once the drainage system received runoff from urban areas, E Coli counts were noted to increase. Bacteria counts were particularly high along the urbanized Smith Creek and Tomat creek systems.

At the interface with Okanagan Lake, creek in West Kelowna carry stormwater carried 11 to 20 times the Nitrogen concentration as compared to the background level of Okanagan Lake. The stormwater nitrate loading causes a “halo” of enriched algae growth at the mouths of these creeks. Figure 13.5 presents a summary of the nitrate, chloride, and *E. Coli* sampling results.

CONCLUSIONS AND RECOMMENDATIONS

Recommended improvement projects have been categorized as High, Medium and Low Priority based on the anticipated risk of flooding or property damage. Improvements of high priority are those that will reduce the level of probable flooding and property damage during a major event. Improvement projects of High priority are estimated to cost $2,422,750 and the locations of these projects are shown in Figure 1.

Improvement works of Medium priority are estimated to cost $2,100,775 and are presented in Figure 2.

Improvement works of Low priority are estimated to cost $493,225 and are presented in Figure 3.

Key recommendations within this report include:

- Proceed with the recommended High priority projects as soon as funding is available
- Proceed with the Medium and Low priority projects once the High priority projects are complete
- Maintain pre-development drainage patterns and flow regime to protect wetland communities
- Pursue opportunities to reserve existing wetland areas and create large detention areas that will allow for settling of suspended solids and *E. Coli* bacteria loads
- Build upon and continually update the database of the drainage infrastructure, as initiated under this Master Drainage Plan
- Continue with and expand public education as it relates to storm water quality issues, and the impact on the downstream areas, including our wetlands, streams and Okangan Lake.

HIGH PRIORITY PROJECTS

PROJECT No. / BASIN	DESCRIPTION	EST. COST
3.2 - Glenrosa Basin	Drainage Improvements - McAllister Rd	$28,800
3.3 - Glenrosa Basin	Drainage Improvements - McMann Rd	$28,800
5.1 - Smith Creek Basin	Creek Restoration - Smith Creek	$647,500
5.6 - Smith Creek Basin	Construct Detention Storage - Rubicon Rd	$359,500
7.3 - McDougall Creek Basin	Drainage Improvements on Ponderosa Rd	$275,000
7.4 - McDougall Creek Basin	Channel Improvements - Hitchner Road to Jenner Road	$46,500
8.4 - Mount Boucherie Basin	Conveyance Improvements - Boucherie Rd to Okanagan Lake	$738,000
8.12 - Mount Boucherie Basin	Inspect / Clean Outfall Pipe - Green Bay Rd	$21,600
8.13 - Mount Boucherie Basin	Install Storm Overflow Pipe - Green Bay Rd	67,500
9.8 - Keefe Creek Basin	Channel Improvements / Easement - Spyglass Way to Westview Way	$23,250
9.9 - Keefe Creek Basin	Repair Detention Pond - Northeast of Westview Way	$21,550
9.12 - Keefe Creek Basin	Install Infiltration System - Stevens Road and Ross Road	$164,750
	TOTAL	$2,422,750

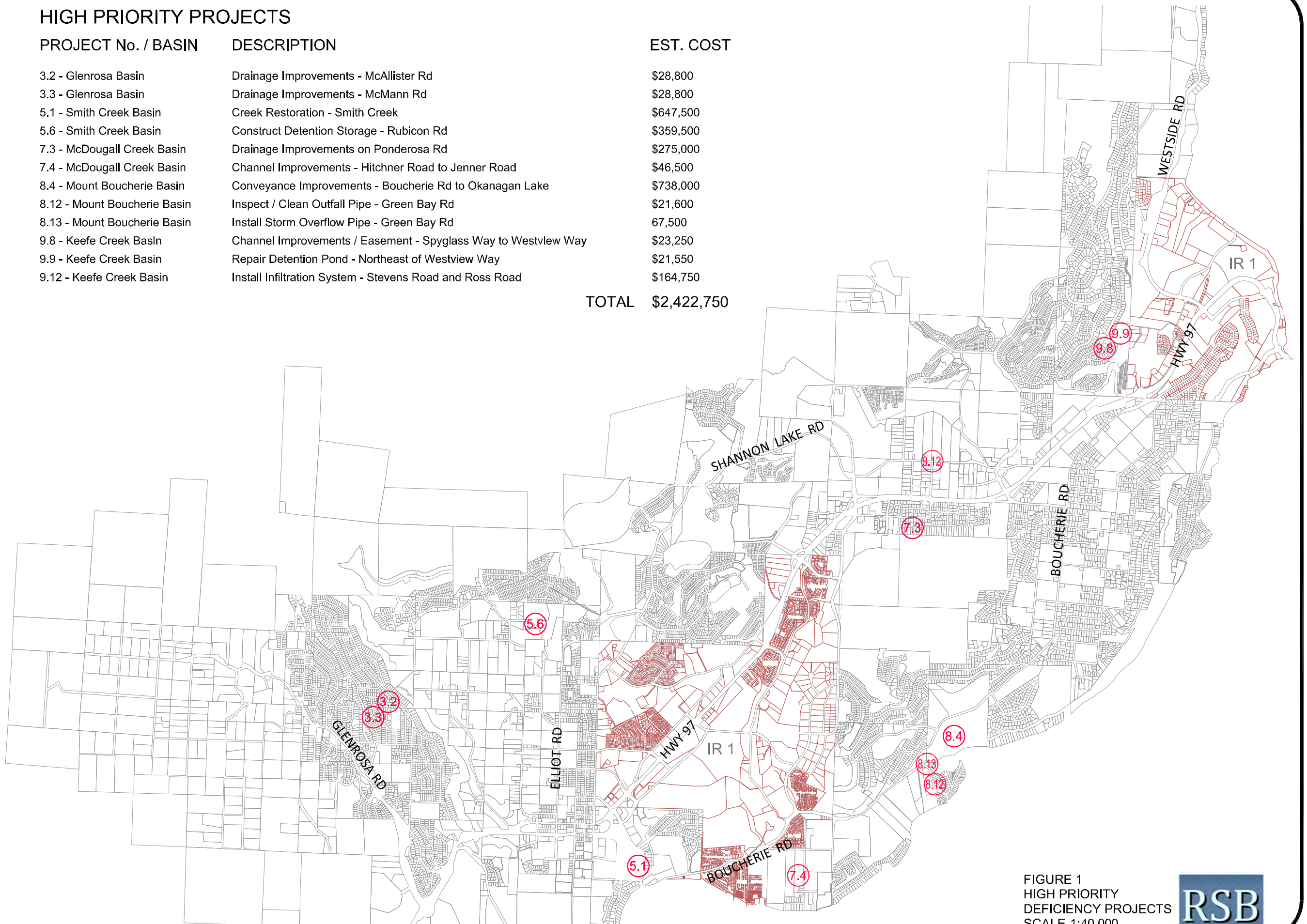


FIGURE 1
HIGH PRIORITY
DEFICIENCY PROJECTS
SCALE 1:40,000

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MEDIUM PRIORITY PROJECTS

PROJECT No. / BASIN	DESCRIPTION	EST. COST
3.1 - Glenrosa Basin	Erosion Protection - Glenrosa Rd from Gates Rd to Ranch Rd	$60,300
3.5 - Glenrosa Basin	Erosion Protection - Glenrosa Rd from McIvor Rd to Morningside Rd	$74,200
3.7 - Glenrosa Basin	Erosion Protection - Webber Rd to Inverness Rd	$31,500
5.3 - Smith Creek Basin	Stream Stabalizition - Smith Creek	$668,250
7.1 - McDougall Creek Basin	Bank Stabilization - Shanon Lake Rd to Pike Rd	$258,000
7.2 - McDougall Creek Basin	Detention Storage and Erosion Protection - Darrock Park to East Boundary Rd	$46,000
8.14 - Mount Boucherie Basin	Relocate Catchbasin Leads - Green Bay Rd	$17,000
9.1 - Keefe Creek Basin	Storm Infrastructure Inventory - Stevens Road Industrial Area	-
9.2 - Keefe Creek Basin	Channel Improvements/ DrainageEasement - Rosewood Drive to Westside Road	$200,400
9.3 - Keefe Creek Basin	Erosion Protection/ Drainage Easement - Grifiths Place to McNaughton Road	$152,725
9.4 - Keefe Creek Basin	Erosion Protection - Bear Creek Road from Vancouver Road to I.R boundary	$113,150
9.5 - Keefe Creek Basin	Erosion Protection/ Drainage Easement - Parkinson Road to Bear Creek Road	$46,825
9.6 - Keefe Creek Basin	Drainage Improvements - Horizon Drive	$3,650
9.10 - Keefe Creek Basin	Creek Improvements - Keefe Creek between Horizon Drive and Spyglass Way	$259,000
9.11 - Keefe Creek Basin	Erosion Protection/ Drainage Easement - Horizon Drive to Spyglass Way	$46,925
9.13 - Keefe Creek Basin	Erosion Protection - Spyglass Way to Keefe Creek	$38,750
9.14 - Keefe Creek Basin	Erosion Protection - Horizon Drive west of I.R. boundary near Hwy 97	$13,000
9.15 - Keefe Creek Basin	Erosion Protection/ Drainage Easement - Horizon Drive to Covington Court	$32,300
9.16 - Keefe Creek Basin	Erosion Protection - West Road southwest of Devon Court	$38,800
	TOTAL	$2,100,775

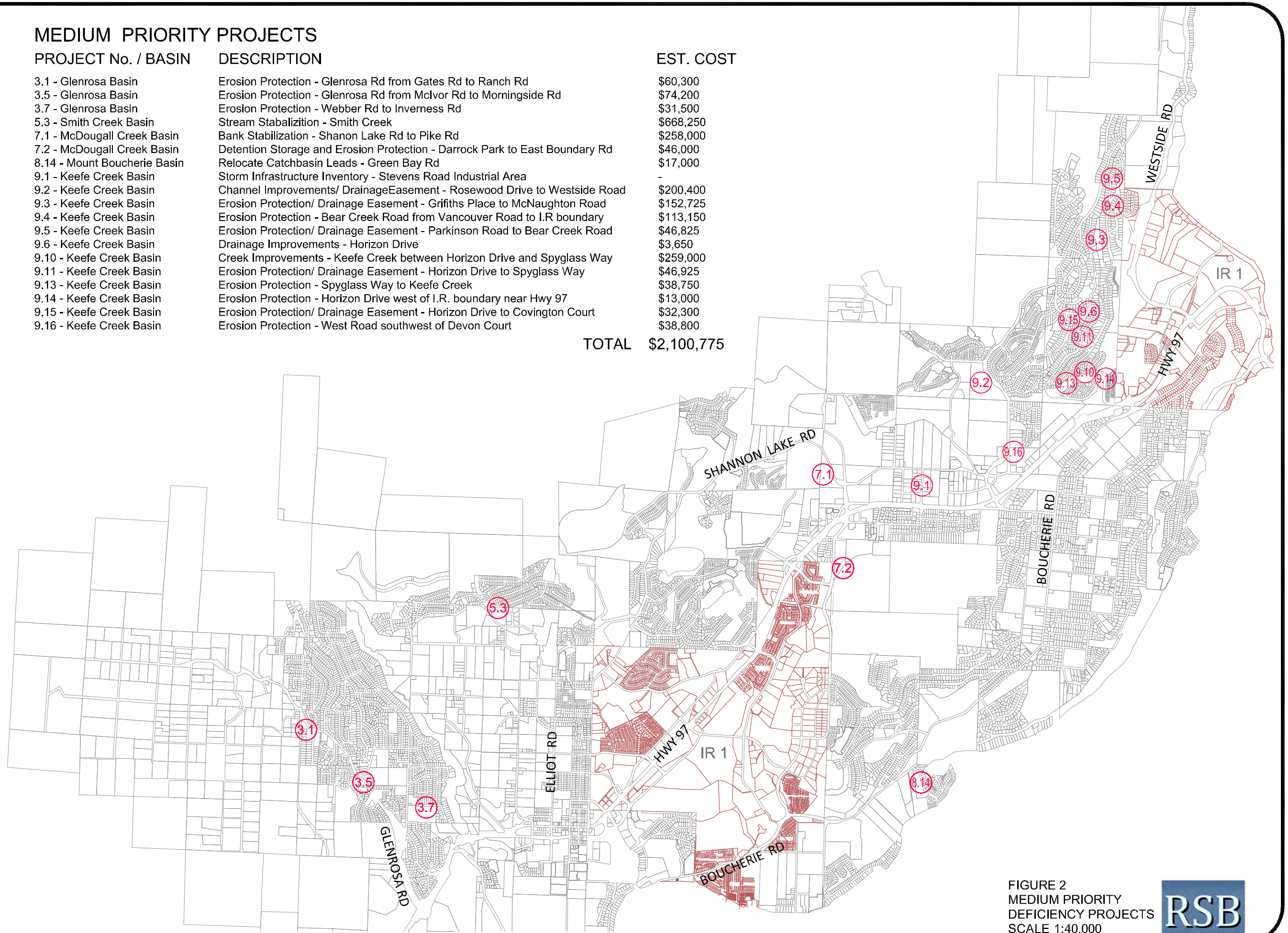


FIGURE 2
MEDIUM PRIORITY
DEFICIENCY PROJECTS
SCALE 1:40,000

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LOW PRIORITY PROJECTS

PROJECT No. / BASIN	DESCRIPTION	EST. COST
3.4 - Glenrosa Basin	Drainage Easement - Webber Rd to Powers Creek	-
3.6 - Glenrosa Basin	Drainage Easement - Webber Rd to Inverness Rd	-
5.2 - Smith Creek Basin	Drainage Easement - Doucette Dr to Elliot Rd	-
5.4 - Smith Creek Basin	Drainage Easement - Bridlehill Rd to Rubicon Rd	-
5.5 - Smith Creek Basin	Storm Pipe Installation - Copper Ridge Dr to Wild Horse Dr	$46,600
6.1 - Shannon Lake Basin	Drainage Improvements - Shannon Hills Place to Walkway	$2,800
6.2 - Shannon Lake Basin	Drainage Easement - Shannon Lake Golf Course	-
6.3 - Shannon Lake Basin	Drainage Easement - Ridge Place to Shannon Lake	-
8.1 - Mt Boucherie Basin	Drainage Easement - Braeburn Ct to Mission Hill Rd	-
8.2 - Mt Boucherie Basin	Erosion Protection - Menu Rd to Gregory Rd	$55,075
8.3 - Mt Boucherie Basin	Erosion Protection/ Drainage Easement - Gregory Rd to Mission Hill Rd	$113,150
8.5 - Mount Boucherie Basin	Storm Sewer Upgrades - Sunnyview Rd	$275,600
8.6 - Mt Boucherie Basin	Drainage Easement - Stevenson Rd to Douglas Rd	-
8.7 - Mt Boucherie Basin	Drainage Easement - Douglas Rd to Ogden Rd	- TOTAL $493,225
8.8 - Mt Boucherie Basin	Drainage Easement - Lakeview Cove Rd to Ourtoland Rd	-
8.9 - Mt Boucherie Basin	Drainage Easement - Ogden Rd to Westbrook Rd	-
8.10 - Mt Boucherie Basin	Drainage Easement - McCartney Rd to Montigny Rd	-
8.11 - Mt Boucherie Basin	Drainage Easement - Bazett Rd to Sunnyside Road	-
9.7 - Keefe Creek Basin	Drainage Easement - Bear Creek Road to Westside Road	-
10.1 - Lakeview Heights Basin	Drainage Easement - Harmon Rd to Boucherie Rd	-
10.2 - Lakeview Heights Basin	Drainage Easement - Hayman Rd to Boucherie Rd	-
10.3 - Lakeview Heights Basin	Drainage Easement - Bridgeway Rd to Campbell Rd	-
10.4 - Lakeview Heights Basin	Drainage Easement - Kelview Rd to Boucherie Rd	-
10.5 - Lakeview Heights Basin	Drainage Easement - Thacker Dr Rd to Boucherie Rd	-
10.6 - Lakeview Heights Basin	Drainage Easement - Lakeridge Rd to Boucherie Rd	-
10.7 - Lakeview Heights Basin	Drainage Easement - Weatherhill Cr to Okanagan Lake	-
10.8 - Lakeview Heights Basin	Drainage Easement - Graymar Rd to Okanagan Lake	-
10.9 - Lakeview Heights Basin	Drainage Easement - King Rd to Okanagan Lake	-

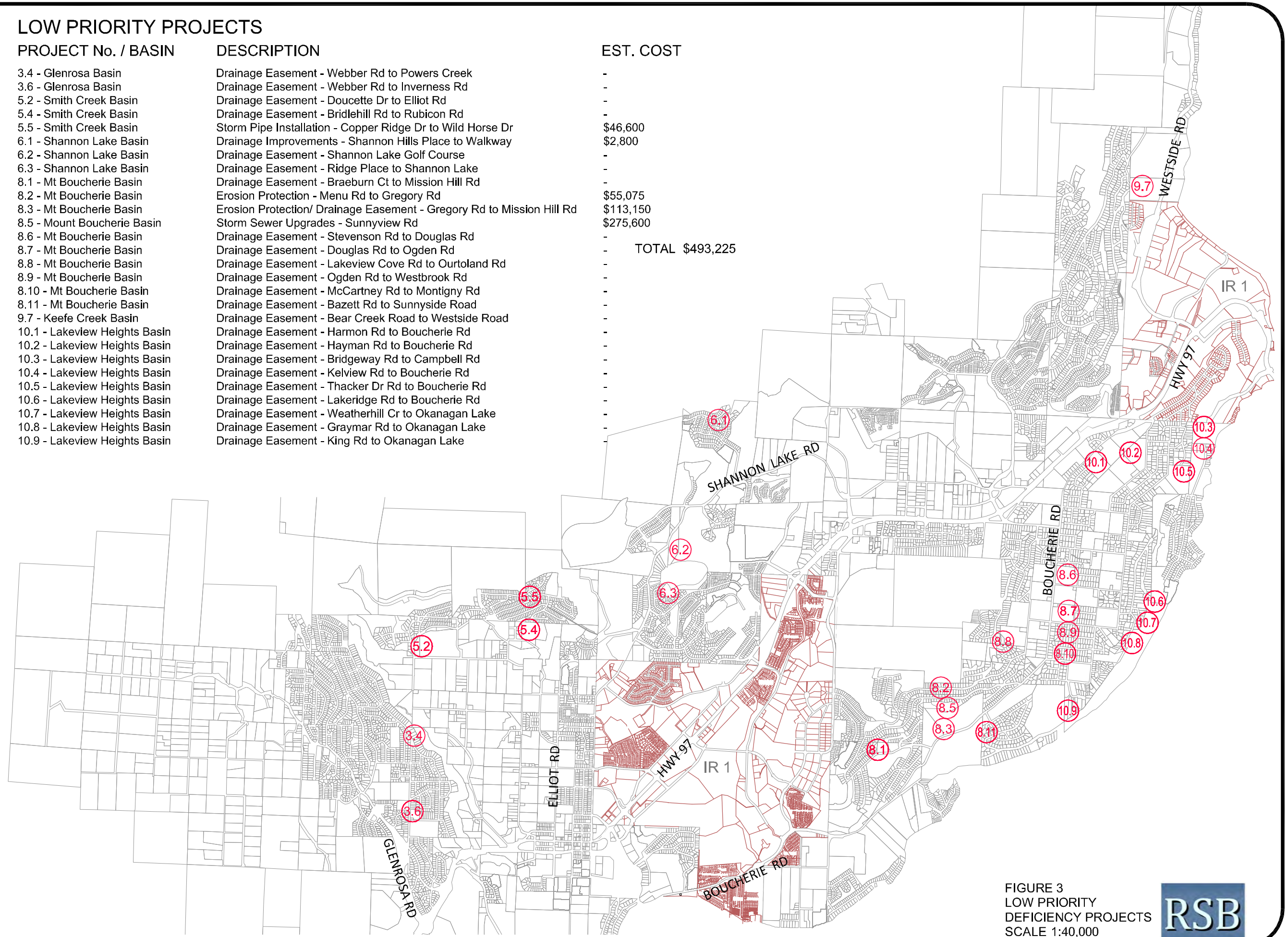


FIGURE 3
LOW PRIORITY
DEFICIENCY PROJECTS
SCALE 1:40,000

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

As a newly incorporated community, the District of West Kelowna does not presently have an overall storm drainage document for planning and funding storm water infrastructure needs. The enclosed Master Drainage Plan will allow the District to address current drainage system deficiencies, provide a basis for meeting long term water quantity and quality control objectives and establish a basis for funding the required components of a successful and cost effective drainage system.

1.2 AUTHORIZATION

In September 2009, RSB Engineering was authorized by the District of West Kelowna to assess the existing drainage system and develop a Mater Drainage Plan that would address the current and future drainage requirements.

1.3 OBJECTIVES AND GOALS

General

The underlying goals in managing an effective Municipal drainage network are to provide protection for public safety, property and the environment from loss, injury or degradation caused by flooding, erosion or other hazards that may result from urban runoff conditions.

Guiding Principles

Managing stormwater and mitigating the impact of urban development are key components in protecting the quality of life and the health of the watershed's natural environment. An integrated Stormwater Management Plan is a key infrastructure planning document that gives direction and guiding principles on how and what to implement to successfully manage the stormwater resource.

Before development, rainfall in watersheds was absorbed into the soils, where it infiltrated, was stored as ground water and discharged (seeps) into natural watercourse and springs over a longer period. As development occurs, there is an increase in imperviousness (pavement, buildings, etc.) and corresponding loss of natural vegetation and soil. As a result, less rainfall is able to infiltrate into the soil, and there is an increase in stormwater runoff that is collected in ditches and storm sewers and piped directly to a watercourse.

To this end, the primary objectives of an integrate Stormwater Management Plan are to:

- Safeguard human life by mitigating property damage from stormwater runoff;
- Maintain and improve the watershed(s) health;
- Provide a sustainable management plan that protects the natural environment while facilitating development;
- Provide a cost-efficient strategy that integrates utility rehabilitation, growth planning and asset management; and
- Give guidance on how to implement the ISMP and adapt the recommendations based on continued monitoring.

The intent of this study is to analyze the District of West Kelowna's existing storm water system and provide a framework for addressing existing deficiencies and serve as a guiding document towards meeting long term stormwater controls, water quality objectives and environmental protection or remediation.

Specific objectives in the development of the District of West Kelowna's Master Drainage Plan include:

- Compile an inventory of the existing drainage infrastructure
- Document existing conditions
- Provide recommendations for future requirements to address stormwater management issues

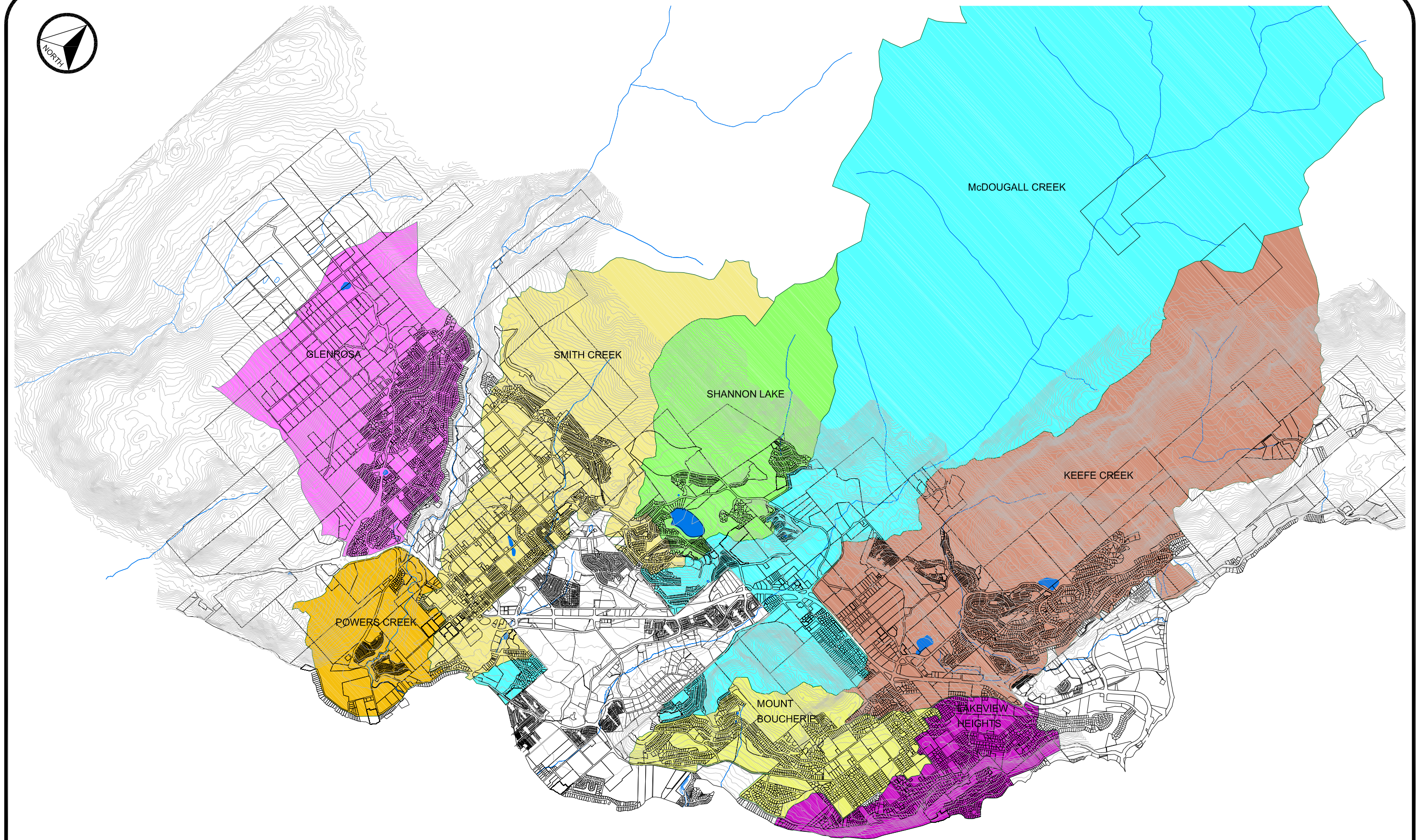
1.4 STUDY AREA CHARACTERISTICS

General

District of West Kelowna (District) is situated along the west shores of Okanagan Lake, located in the center of the Okanagan Valley. In general, the District is bounded by the Regional District of the Central Okanagan (RDCO) to the west and north and by Okanagan Lake to the east and south. Two First Nations reserves also form boundaries within the District Limits. The study area includes the entire lands within District's municipal limits, and the tributary upstream catchment areas in RDCO. ***Figure 1.1*** is a location map of the District, which depicts these major watershed areas and basin boundaries, as reviewed within this stormwater management plan.

Climate

The Okanagan Valley is a dry, semi-arid climate that is at the northern tip of the Sonora Desert and located in the rain shadow of the Cascade Mountain Range. The Okanagan



LEGEND

10m CONTOUR

FIGURE 1.1
LOCATION PLAN
SCALE 1:50,000

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climate consists of low humidity, warm summers with average temperature highs of 28^{o} Celsius. Winters are relatively mild, with average lows in the range of -5^{o} Celsius. Average annual rainfall in the Kelowna area is 300mm, with the larger rainfall events being intense, short-duration thunder showers that occur mostly in the months of June to September.

Topography

Topography in the District generally slopes to the south and east, towards Okanagan Lake. The upper reaches of the watersheds originate in RDCO land around a peak elevation of 1,600m above mean sea level. Runoff from the upper forested hillside drains through numerous watercourses and crosses into District Limits at an elevation of 600-700m, and eventually discharge into Okanagan Lake (elev. 342m).

System Mapping and Watershed Boundaries

The contour and cadastral mapping was extracted through the RDCO GIS information and incorporated into the stormwater modeling work. Information related to the existing drainage infrastructure was obtained from the available as-built drawings within the RDCO files. Unfortunately, there are a number of areas in which no drawings could be located to reflect the existing infrastructure components.

The watershed and basin boundaries have been compiled using the available topographic information. On an overall scale, the District has been divided and reviewed based on eight watershed basins to examine the existing urban infrastructure. These basins include:

- Glenrosa Basin
- Powers Creek Basin
- Smith Creek Basin
- Shannon Lake Basin
- McDougall Creek Basin
- Mount Boucherie Basin
- Keefe Creek Basin
- Lakeview Heights Basin

1.5 WORK PLAN

This section outlines the general work plan and methodology RSB Engineering followed to develop the Master Drainage Plan and meet the overall objectives.

In establishing the Master drainage Plan, the project team compiled as much information as available including, but not limited to as-built drawing, previous reports, existing SHIM data, groundwater well information and GIS database information from the RDCO.

The information related to existing drainage infrastructure was entered into the PCSWMM computer model, to form the basis for the hydraulic modeling and analysis. The contour and topographical information from the RDCO was incorporated within the enclosed analysis to complete the hydrologic modeling, and estimates of the runoff rates. These contours were used to delineate the boundaries of the various sub-catchment areas and to identify the direction of overland flow routes.

Field review and reconnaissance was also used to supplement the available drawings to confirm primary drainage paths and overland flow directions and identify visible deficiencies or potential problem areas. During this field review stage, a culvert inventory sheet was completed for each roadway culvert that was encountered. These culvert inventory sheets have been provided under separate cover.

The hydrologic and hydraulic analysis was then carried out for the 5 year and 100 year storm events. Based on the estimated flow rates, the existing system was reviewed to assess the hydraulic conveyance capacities and potential flooding areas.

The watercourse and wetland evaluation works included a review of the previous watercourse and wetland evaluation inventories along with field inspections to document changes since the initial surveys were completed. These data sets were merged to generate an updated baseline catalogue of the watercourses and wetlands for reference in stormwater management and landuse planning.

Samples of stormwater runoff were also obtained at periodic intervals throughout the study period to review the water quality based on these selected parameters. These included:

- Chloride concentration – a persistent constituent of salt and possibly septic contribution
- Nitrate – indicates nutrient loading from urban and agricultural areas
- E Coli – bacteria that indicates fecal contamination

The hydro-geotechnical assessment included an analysis and assessment of the factors affecting groundwater recharge potential. The assessment included a review of available

geotechnical data, provincial mapping information and waterwell resource data to identify potential suitability for disposal to ground.

1.6 REPORT FORMAT

The study area was divided into eight primary basin areas. The primary basins were then further delineated into the various sub-catchment basins as part of the detailed analysis within each basin. The eight primary basin areas, have been presented in Table 1.1, along with the approximate drainage area for each basin. Within the enclosed report, each primary basin has been presented as a separate section to include a description of the basin characteristics, a summary of the analysis and existing deficiencies within each basin, as well as the recommended improvements and costs estimates associated with those improvements.

Table 1.1 - Primary Drainage Basins

Basin Name	Catchment Area (Ha)	Report Section
Glenrosa	885	3.0
Powers Creek Basin		4.0
Smith Creek	1170	5.0
Shannon Lake		6.0
McDougall Creek	4770	7.0
Mount Boucherie		8.0
Keefe Creek	2008	9.0
Lakeview Heights	330	10.0

In addition to the detailed evaluation of each drainage basin, this report also includes a summary of the watercourse and wetlands evaluation, as presented in Section 14. As a part of the integrated drainage plan, Ecoscape Environmental Consultants have completed a review of the previous watercourse and wetland inventories including existing discharge sites and channel condition, review of channel and bank stability, as well as a review of existing habitat condition and habitat creation opportunities.

Section 15 presents a summary of the water quality sampling analysis, intended to provide a snapshot of the water quality samples as various locations in the watershed as

completed by Larratt Aquatic Consultants. This section includes the results of the water quality sampling study, which examined the water quality in terms of chloride concentration, nitrates and the presence of *E. Coli* bacteria

Section 16 includes the analysis and results of the Hydro-geotechnical assessment, in which the factors affecting groundwater recharge potential have been reviewed by Sustainable Subsurface Solutions Inc. This section presents a discussion on the existing conditions and evaluation on the suitability of specific areas for stormwater disposal to ground, and to identify areas which may be prone to impacts from up-slope disposal to ground.

The conclusion and report recommendations are included within Section 17. It should be noted that the conclusions and recommendations section has been omitted from the Draft report submittal, pending review and discussions with City staff.

The conclusions and report recommendations are included within Section 18. It should be noted that the conclusions and recommendations section has been omitted from the Draft report submittal, pending review and discussions with City staff.

1.7 LIMITATIONS

Although every effort has been made to include the most up to date and reliable information, the content of the report, drawings or stormwater model should not be considered as complete and accurate as-constructed information. This report is intended solely as a planning guide for the District of West Kelowna staff to assist in coordinating, planning and budgeting for future stormwater requirements. The results of the enclosed analysis also provide staff with a basis for discussion with development proponents in regards to existing flow rates and proposed release rates from storm water detention facilities.

This report does not represent a detailed design of existing or proposed improvement works, and it is the designer’s responsibility to fulfill the requirements for a detailed and site-specific drainage analysis, prior to implementing any improvement works. Groundwater and soils conditions presented in this report are presented on a general basis to provide an indication of anticipated or potential conditions. The detailed stormwater management works or decisions contingent upon groundwater or soil condition should be based on a site-specific basis by the design Engineer.

SECTION 2
FRAMEWORK AND CRITERIA

2.1 INTRODUCTION

Outlined in this section is the framework for the policy, land-use, hydrology tools, and inventory planning tools used to develop the Integrated Stormwater Management Plan. Design criteria such as rainfall information, storm sewer sizing and hydrologic/hydraulic modeling are also presented in this section.

2.2 DRAINAGE BYLAW

Prior to incorporation of the District in 2007, the drainage infrastructure in the area was managed and maintained by the Ministry of Transportation and infrastructure. Following the District's incorporation, a set of drainage or storm servicing bylaws have yet to be formally prepared and established.

As part of this assignment, RSB Engineering is developing a Draft Drainage Bylaw for the District to review, amend and ultimately incorporate within the subdivision and development servicing bylaw document. This Draft Drainage Bylaw is provided to the District under a separate covering report; however the relevant bylaw criteria (IDF curves, servicing standards, BMP's, etc.) have been utilized in preparing the Integrated Stormwater Management Plan and particular criteria are discussed later in this section.

2.3 LAND-USE

Existing Land-Use

The District is bounded to the west and north by the Region of Central Okanagan – rural undeveloped hillside terrain. To the east and south, the District is bounded by Okanagan Lake. Wedged between the District and the lake are two First Nation Reserves: IR 9 in the south central region and IR 10 to the east.

Across the District, the land-use varies from rural, agricultural, residential, commercial and light industrial. The majority of the developed land in the District is used for single-family residential lots. ***Figure 2.1*** illustrates the existing land-use in the District.

On an area basis, the rural and agricultural usage makes up a significant percentage of the District. These areas include the hillside terrain to the north, the steep rocky slopes of Mt. Boucherie and approximately 1,500 hectares of zoned agricultural land which is mostly used for orchards and vineyards.

DISTRICT OF WEST KELOWNA
OFFICIAL COMMUNITY PLAN
BYLAW 0100

Schedule 1

LAND USE PLAN

TSINSTIKEPTUM
INDIAN
RESERVE 10

TSINSTIKEPTUM
INDIAN
RESERVE 9

Legend

- 5.68% RURAL RESIDENTIAL
- 11.69% SINGLE FAMILY RESIDENTIAL
- 0.77% LOW DENSITY MULTI-FAMILY
- 0.60% MEDIUM DENSITY MULTI-FAMILY
- 0.13% CORE CENTRE MULTI-FAMILY
- 0.08% MIXED USE
- 0.40% COMMERCIAL
- 0.06% TOURIST COMMERCIAL
- 1.43% INDUSTRIAL
- 0.26% BUSINESS PARK
- 1.16% INSTITUTIONAL
- 6.45% PARKS AND NATURAL AREAS
- 7.74% AGRICULTURAL
- 53.55% RESOURCE LAND
- 5.92% COMPREHENSIVE DEVELOPMENT AREAS
- WEST KELOWNA MUNICIPAL BOUNDARY
- WESTBANK FIRST NATION COMMUNITY FOREST

NOTE:

LAND USE PERCENTAGES FOR THE DESIGNATIONS NOTED IN THE LEGEND ABOVE ARE BASED ON A TOTAL D.W.K. LAND AREA OF 12,140 Ha. PER THE MUNICIPAL LETTERS PATENT.
ROAD ALLOWANCES AND INLAND LAKES MAKE UP FOR THE MISSING AREA NOT INCLUDED IN THE LEGEND FOR A TOTAL OF 100%.

DRAFT SEPT 29th 2010

Figure 2.1

0 250 500 750 1,000 2,000 3,000
Metres

Commercial and Industrial development is largely situated along the Highway 97 corridor. Commercial usage includes an urban town core, the historic Westbank area, near Main Street Gellatly Road. Industrial usage tends to be light industrial, and is mainly located along Highway 97 between Daimler Road and Westlake Road.

Future Land-Use

With the recent incorporation, the District originally adopted the Regional District's Official Community Plan (OCP) Bylaw. The District of West Kelowna is currently in the draft stages of developing an updated OCP that will provide direction, guidance and infrastructure servicing requirements for future development in the District.

The District's Draft OCP was used to establish a future planning projection / horizon for the purposes of this ISMP. The land-use designations as shown on Figure 2.1 were overlaid onto the stormwater modeling figures to determine the approximate extents of future development areas.

For the future stormwater planning level analysis, the ISMP framework and recommendations are based on the following assumptions:

- All future development will incorporate a stormwater management plan (BMP's, source control and detention) that will provide peak flow attenuation to "pre-development" levels for all events up to a 1 in 100-year return period;
- Land within the Agricultural Land Reserve (ALR) will remain in the ALR, with no potential for development, over the timeframe of the OCP; and
- Steep terrain over 30% gradient is considered undeveloped over the timeframe of the OCP.

2.4 DRAINAGE INVENTORY

The drainage inventory was compiled through a combination of field visits and a review of available drawings from the RDCO and Ministry of Transportation and Infrastructure. The drainage infrastructure within the study area is comprised of a combination of overland flow channels and underground piped systems. A field reconnaissance review was carried out, in the initial stages of the study, to confirm overland flow directions, localized depression areas and to indentify the locations of major infrastructure components such as roadway culvert crossings and detention facilities. This information was collected and then utilized to supplement available drawing information. The flow directions, culvert locations and notable items were documented on the working drawings for future use in the hydraulic assessment tasks.

The field investigation included an inventory of the existing conditions of each major culvert crossing. These results have been documented and assembled under separate cover.

The assembly of drainage system inventory also included compilation of relevant data for the District's Asset Management Plan. Where available, the basic elements of the underground infrastructure were obtained from the record drawings and entered into the modeled data. This included the year of installation and pipe material such as PVC, concrete or corrugated metal. Similar data and separate identification were also included for manholes (MH) and drywells (DW) to assist the District in extracting the date and establishing a future maintenance program for drywells. The location of individual catch basins was not included within the scope of this study.

2.5 EROSION AREAS

In conjunction with the environmental field reviews, the stormwater modeling assignment placed significant emphasis on erosive or potentially erosive conditions. With much focus on protecting and preserving our natural environment, an effective integrated stormwater management plan to attempt to target pollutants at the source rather than treating the runoff at points further downstream. With this objective in mind, the enclosed analysis identifies locations either in streams, channels or ditches that produce unstable or potentially erosive conditions. Throughout our analysis, we have used a velocity of 1.5 m/s as a threshold for creating erosive conditions. The channel and bank stability conditions have also been documented within the watercourse evaluation section.

2.6 REGIONAL ANALYSIS

Flowing through the District area, there are a number of watercourses including Powers Creek, McDougall Creek, and Lambly Creek, whose watershed headwaters originate in large undeveloped areas. The watershed characteristics in these upper areas differ considerably from the lower urban areas and consist primarily of forested catchments, steep hillsides at higher elevations. Hydrology and runoff from these watersheds is primarily influenced by snowmelt as opposed to rainfall events.

Hydrologic algorithms used in the SWMM based computer programs are applicable for accurately modeling runoff from urbanized areas where runoff is dictated by rainfall. These programs are limited in terms of accurately predicting peak flows and runoff hydrographs from large watersheds where peak runoff is dictated by snowmelt.

To this end, SWMM based software was used to model rainfall runoff for all areas inside the District Limits, and a *Regional Analysis* was completed to predict runoff from the large catchments outside District Limits.

A *Regional Analysis* involves a statistics based evaluation of hydrology (stream flow records) from various watersheds and then using these results to compare and predict runoff from watersheds entering the District of West Kelowna. Key factors in the analysis include utilizing stream flow records for Okanagan watersheds only, and preferably ones that have similar geography including:

(i) size of catchment area;

(ii) altitude/elevation range;

(iii) topography – slope and aspect (direction mountain faces);

(iv) soil characteristics – tree cover and surface soil (i.e. soil or exposed bedrock)

Stream flow records for Okanagan watercourses were collected from Water Survey of Canada (WSC), and then used to complete the *Regional Analysis*. WSC is a national agency, under Environment Canada, responsible for collecting and distributing hydrometric information such as: streamflows, lake and river levels, and temperature. WSC has been collecting data since 1908, and while there are only a few "active" streamflow gauges remaining in the Okanagan, there are a number of watercourses where historical information is available. The following ***Table 2.1*** summarizes the stream flow gauges used for this analysis.

Table 2.1 – Streamflow Gauges

Creek	Location	WSC Gauge ID	Years of Data	Catchment Area	Catchment Altitude	Aspect
Bellevue Creek	Kelowna	08NM035	28	73.3	480 – 2,170m	North facing
BX Creek	Vernon	08NM020	45	55.7	570 – 1,811m	Southwest
Kelowna Creek	Kelowna	08NM053	47 (1950-1996)	221	370 – 1,473m	West facing
Lambly Creek	West Kelowna	08NM165	26 (1971-1996)	76.1	853 - 1,500m	South facing
Mission Creek	Kelowna	08NM116	60 (1949-2008)	811	460 - 2,040m	West facing
Pearson Creek	Near Big White	08NM172	18 (1971-1987)	73.6	920 - 1700m	West facing
Penticton Creek	Penticton	08NM168	29 (1971-1999)	35.5	1,500 - 2,135m	South facing
Whiteman Creek	West of Vernon	08NM174	38 (1971-2008)	112	640 – 1,920m	East facing

Using information from the WSC stream gauges listed above, a *Regional Frequency Analysis* was completed. The software program HYDSTAT was used to perform the statistical analysis, which was based on "peak instantaneous flows" recorded for each year. In the event a "peak instantaneous flow" was not recorded for a particular year, the "maximum daily flow" was used in its place.

Results from the *Regional Analysis* are presented graphically in ***Figure 2.2***. As shown in this figure, the results are relatively consistent for the various watercourses, which is as expected because their catchment location (Okanagan), altitude and catchment area are all relatively similar. Pearson Creek, east of Kelowna, appears to be an outlier from the other rating curves. This is most likely attributed to the fact that the measured peak flows did not vary significantly from year-to-year, even during low snowpack freshets. For the purposes of this report, it is recommended that the results from Pearson Creek are not included in the overall analysis.

Excluding Pearson Creek, the unit flow relationships for the other watercourses are very comparable. These flow relationships are based on historical flow data, therefore they do not include the impact of climate change, forest fires and the Mountain Pine Beetle. Each of these factors impact natural hydrological processes and the combination of any two or more can result in significant cumulative effects on increased surface runoff and erosion of natural watercourses.

Figure 2.2 – Regional Analysis Flow Relationships

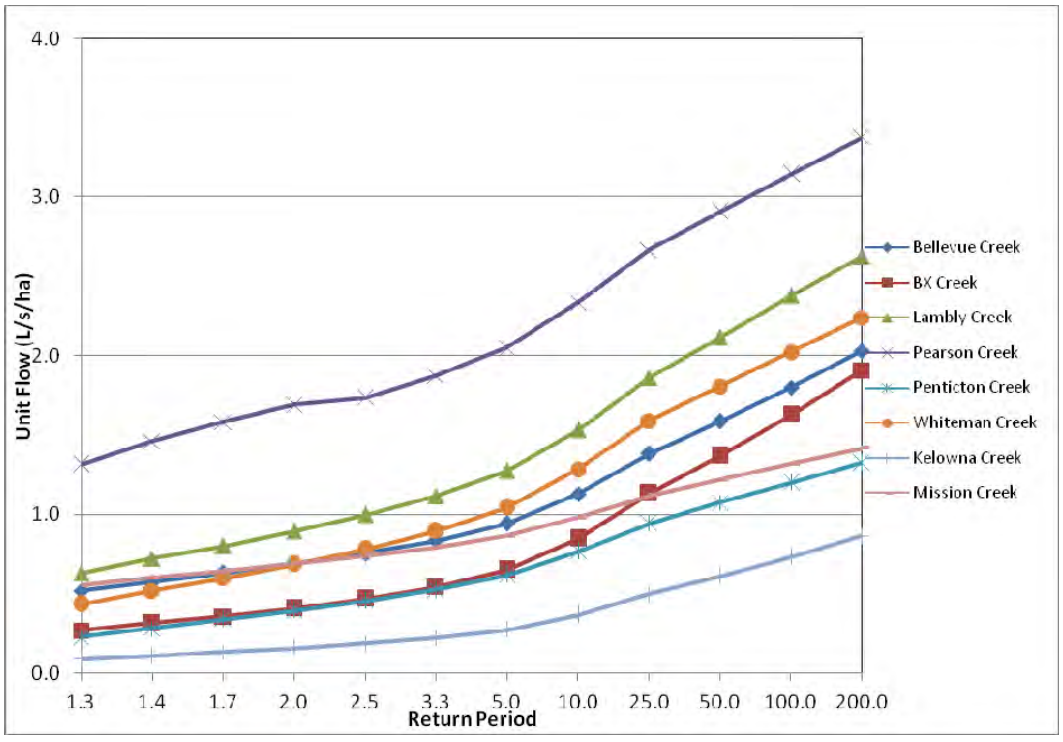


Table 2.2 summarizes the graphical results for key return period frequencies. The unit flow results represent all evaluated watercourses, excluding Pearson Creek. It is expected that runoff from the large undeveloped, hillside areas north of the District are in this same range.

Table 2.2 – Unit Flow Rates for Select Return Period

Return Period	Unit Flow Range (L/s/ha)	Average Flow (L/s/ha)
1 in 2 Year	0.16 – 0.89	0.56
1 in 5 Year	0.27 – 1.27	0.81
1 in 10 Year	0.37 – 1.53	0.99
1 in 25 Year	0.50 – 1.86	1.22
1 in 100 Year	0.73 – 2.38	1.58

2.7 RAINFALL CRITERIA

The District of West Kelowna has neither rainfall design standards, applicable intensity–duration–frequency (IDF), nor active rainfall monitoring stations in DWK boundaries. Historically the Ministry of Transportation (MoT) utilized the IDF curve from the City of Kelowna's *Subdivision, Development and Servicing Bylaw – Design Standards*, which is based on the Kelowna Airport rainfall gauge maintained by Environment Canada.

The City of Kelowna operates 14 rainfall gauges, some of which are closer to DWK than the Airport gauge. However the Environment Canada's IDF curve is the longest active station (1969 – 2010) and provides the most accurate data with respect to predicting events larger than a 1 in 10-year return period.

For hydraulic modeling purposes, design hyetographs are required to develop runoff hydrographs (flow vs time). Hyetographs are developed using two sets of information: (1) IDF to represent volume of rainfall for specific duration and return period and (2) storm distribution pattern typical of the Okanagan Valley. Hyetographs for shorter duration events (30-min to 4 hour) are used to size storm sewers due to higher peak flows, whereas, the longer duration events (6 hour – 24hour) are used to design detention facilities due to larger runoff volumes.

The City of Kelowna previously developed design hyetographs as part of their *Design Standards*. These hyetographs were based on the then current Airport IDF

curve, which was dated up to 1997. In 2009 Environment Canada released an updated IDF curve for the Kelowna Airport, for rainfall events up to 2007. This new IDF curve was obtained (provided as Figure 2.3) and used to develop updated design hyetographs for application in the District's ISMP.

For the enclosed assessment, the following rainfall criteria/hyetographs were applied:

Minor System:
1 in 5-year return period (1 hour duration) to asses peak flows and sizing for storm sewers, and local roadway culverts.

Major System:
1 in 100-year return period (1 hour duration) to asses overland flow route, sizing of detention facilities, and sizing of major roadway culverts and bridges.

2.8 DRAINAGE INFRASTRUCTURE SERVICING CRITERIA

As mentioned previously, a Draft Drainage Bylaw is being developed for the District. Summarized in this section is the relevant servicing criteria that was used to evaluate the existing drainage system, determine capital upgrades and identify future development requirements.

Storm Sewers and Culverts

- Storm sewers should be sized to convey 5-year peak flow without surcharging;
- Major overland flow route shall be provided for 100-year peak flow;
- Driveway / local road culverts shall be sized to convey 5-year peak flow without surcharging and (ii) 100-year peak flow with minimum 500mm freeboard from road surface; and
- Major roadway culverts (collector, arterial, highway) shall be sized to convey 100-year peak flow without surcharging.

Detention Facilities

Detention ponds should be design using a multi-stage approach to control runoff, from varying return period events, in a manner that maintains base flows, promotes infiltration and provides flow control for various levels of service.

The following are the primary hydrologic and hydraulic criteria for detention facilities:

- Dry-weather base flows should not be routed through detention facilities in order to maintain water quality and temperature;
- Post development runoff should be detained and released at pre-development rates (for 2-year, 5-year and 100-year return periods);

- All inlet piping shall be sized to convey 100-year flow; and
- An overflow spillway and overland flow route should be sized for 100-year flow.

2.9 HYDROLOGIC / HYDRAULIC MODEL

The estimate of stormwater runoff rates was carried out with the use of the computer simulation model, PCSWMM 2009. PCSWMM 2009 is a GIS based graphical support system that utilizes the EPA SWMM5 storm sewer modeling engine. The EPA SWMM5 model is an open-source, comprehensive model for continuous and single-event simulation of runoff quantity and quality.

The model has a variety of input parameters such as rainfall data, amount of previous and impervious area, infiltration and watershed slope to estimate the stormwater runoff.

The following is a list of typical values used to model the sub-catchment's characteristics throughout the study areas:

- Impervious percentage
- Initial abstractions
- Soil infiltration
- Drywell losses
- Sub-catchment slope
- Sub-catchment width

Under ideal conditions, the estimated runoff routes from the modeling analysis would be calibrated to measured rainfall data and corresponding runoff rates as may be measured in creeks and/or storm sewer pipes. Unfortunately, there is no measured flow data available for the drainage network within the District and as such, field verification and calibration is not possible. The modeling parameters used within this study are similar to those used on recent projects within Kelowna. The results obtained within the Kelowna basins have been found to compare well with observed data. Although field measurement data may not be available, anecdotal information can also yield valuable insight into the performance of an existing drainage system. This information was obtained from local maintenance staff and residents regarding past problem areas and recurring flooding events to assist in validating the predicted runoff rates and flow routes.

2.10 FUTURE DEVELOPMENT

As with much of the Okanagan Valley, the District of West Kelowna has experienced significant growth over the past 10 years. Growth within the District has largely been in the form of single-family and multi-family residential development. Although commercial/retail development has grown substantially in the past 5 years, these development projects are largely situated outside the District's boundaries and are within the lands owned by the Westbank First Nations.

As an integral part of new growth and re-development projects, additional roadway construction and widening projects will be required. The District of West Kelowna has undertaken the preparation of a Transportation Master Plan that will identify the approximate roadway construction and widening projects. Roadway projects inherently have a significant impact on drainage patterns and the design of these roads, whether they are local or large arterial, should strive to maintain natural drainage conditions.

It is our understanding that the future development areas will incorporate a comprehensive stormwater management plan that will include current and emerging trends in Best Management Practices for improving runoff quality, peak flow alternatives and volumetric reduction. For the purposes of this study, the future development areas as identified within each drainage basin were modeled to determine the existing flow rates for a 1 in 5 year storm event.

The objective of this review is to provide the District with an order-of-magnitude estimate of pre-development flows in comparison to post-development flows. Preliminary estimates for detention storage facilities have been identified that may benefit the maximum number of users and that limit the number of sites. In general, it is preferred to keep the number of detention facilities to a minimum in an effort to minimize the operation and maintenance requirements of these facilities. These are a number of factors that will influence the location, size and type of facilities including drainage area, soil characteristics, property boundaries and the influence of Low Impact Development (LID) initiatives within each development site.

It should be noted that the enclosed estimates for runoff amounts and detention storage are intended for use by the District for planning purposes only. The design engineer for each development

area is responsible to carry out the detailed stormwater management plan, for pre-development and post-development conditions, in conformance with the District's criteria and good engineering practices.

2.11 COST ESTIMATE CRITERIA

The estimates of probable construction costs have been prepared based on prices from major suppliers and from data on projects of similar nature and scope. Although the actual costs may vary due to market conditions and economy of scale, or other factors, these costs are considered reasonable for budgeting and planning purposes. These costs are based on 2011 dollars and do not include HST. Table 2.3 presents a summary of the more commonly used drainage infrastructure components.

Table 2.3 – Standardized Storm Drainage Unit Costs

Pipe	**Material**	**$/m**		**Manholes**		**$/unit**
250mm	PVC UR	175.00		1050mm		2,500.00
300mm	PVC UR	200.00		1200mm		3,000.00
375mm	PVC UR	225.00		1500mm		4,000.00
450mm	PVC UR	250.00		1050mm Tee		2,500.00
525mm	PVC UR	300.00				
600mm	PVC UR	375.00		**Drywells**		
675mm	PVC UR	400.00		1200mm		5,000.00
750mm	PVC UR	450.00				
900mm	Concrete	600.00				
1050mm	Concrete	750.00		**Catchbasins (complete with lead)**		
1200mm	Concrete	1,000.00		900mm	Side Inlet	2,500.00
(Assumes average depth 2.5m, import backfill)						
Perforated Pipe Subdrain				**Headwalls (with grate)**		
200mm	PVC	200.00		300-375mm		2,000.00
250mm	PVC UR	225.00		450-525mm		3,000.00
300mm	PVC UR	250.00		600-675mm		4,000.00
375mm	PVC UR	275.00		750-900mm		5,000.00
450mm	PVC UR	300.00				
				Connect to Existing Pipe		1,000.00
Box Culvert				**Break into Existing MH**		2,000.00
1800 x 900mm		2,000.00				
1800 x 1200mm		2,500.00		**Treatment Systems**		
2400 x 1200mm		3,000.00				
				CDS Unit		
Dewatering		200.00		Stormceptor		
Culverts				**Storage Systems**		
400mm	CSP, HDPE	200.00		Atlantis		
500mm	CSP, HDPE	250.00				
600mm	CSP, HDPE	300.00				
900mm	CSP, HDPE	400.00				
Road Restoration		**Width (m)**	Cost ($/m2)	Cost ($/m)		
Boulevard		5	20.00	100.00		
Minor Road (50mm AC)		5	30.00	150.00		
Major Road (100mm AC)		5	45.00	225.00		
(Road work includes removals, sawcut, gravels)						

SECTION 3
GLENROSA BASIN PLAN

3.1 BASIN DESCRIPTION

Glenrosa is the western most part of the District. This drainage basin consists of large rural properties to the west, Gorman's Mill to the south and suburban single-family residential properties situated along Glenrosa Road.

Drainage limits for the basin range from Preston Road in the west to Dunbarton Road in the east. Most of the local drainage is collected and conveyed through roadside ditches and culverts. As the basin drains south, stormwater runoff is cut-off by Highway 97 and drainage is piped into Powers Creek.

The basin was divided into 48 sub catchments over the 885 ha total area, with larger sub catchments delineated for rural areas and more discrete sub catchments delineated for the residential subdivisions.

3.2 EXISTING SYSTEM ANALYSIS

The majority of the Glenrosa drainage basin is serviced with roadside ditches and culverts. The newer residential development areas, particularly to the west of Glenrosa Road contain curb and gutter with storm sewer service.

Runoff from these areas to the west of Glenrosa Road generally flows towards Glenrosa Road and conveyed through the ditches and culverts along Glenrosa Road.

There is an existing detention facility along Glenrosa Road, at the intersection with Glen Abbey Place. Based upon the field inspections, there is a flow control structure on Glenrosa Road west of the detention facility. A metal flap valve within the control structure was closed, prohibiting flow from the west ditch into the detention facility. The as built drawings for this facility did not indicate the design flow rates or storage volumes. There is no outlet from the detention facility, other than the 250 mm overflow pipe on Glen Abbey Court. Based upon discussions with current maintenance staff, the flap gate is opened manually during heavy runoff periods, but is rarely utilized.

Downstream of this detention facility, the runoff is conveyed through a piped system across Webber Road, and discharges into the Powers Creek System. The site grading and fill near the old Webber Road School, combined with the existing 600 mm culvert pipe function as stormwater detention facility, and restrict the flows to the downstream reaches.

There are two pocket wetland areas on the north side of Highway 97 in the vicinity of Glenway Road. The storage volume at each facility is small; however they are beneficial for water quality improvements and are in keeping with current Best Management Practices. It should be noted that during field inspections of storm drain manholes near Glenrosa Road and Glen Abbey Place, an odour was detected that would be consistent with a sanitary sewer system. This may be attributed to groundwater seepage from nearby septic fields or potentially from cross-connections with the sanitary sewer system. It is recommended that a cross-connection program be implemented to minimize the potential for cross-connections between the storm sewer and sanitary sewer systems.

PCSWMM was used to estimate the stormwater runoff. The model nodes for the system are presented within Figures 3.1 through to 3.7. Runoff was estimated by simulating 1 in 5 year and 1 in 100 year storms, with 1 hour duration. The results of the stormwater modeling are presented within Table 3.2 at the end of this section. Note, the flows shown within Table 3.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

3.3 EXISTING SYSTEM DEFICIENCIES

During both the minor and major storm events localized flooding and depression storage is expected to occur at a number of locations. A number of driveways have been constructed without positive drainage away from the building and may present nuisance drainage and/or flooding problems due to on-site drainage issues.

For the purposes of the Master Drainage Plan, we have focused primarily on these conditions that are expected to receive flow contributions from off-site or roadway areas.

Ditch Erosion along Glenrosa Road

The existing ditch along the west side of Glenrosa Road is subject to high flow rates and high velocity due to the steepness of grade. The ditch section from Gates Road to Ranch Road has a velocity in the order of 1.8 m/s and is subject to erosion. Erosion protection measures such as riprap, check dams or geofabric lining should be installed to minimize the resulting erosion and sedimentation problems. This deficiency and recommended improvements, have been presented in Project 3.1.

Flooding Along McAllister Road

Flooding is expected to occur on McAllister Road, just west of Webber Road. Runoff from the upstream areas along McAllister will collect within the localized depression area resulting in surface ponding. The potential flooding extent will be reduced with the implementation of Project 3.2.

Flooding on McMann Road

Similar to the condition on McAllister Road, there is a localized depression area at the western end of McMann Road. This area will receive runoff from the surrounding areas and with no positive outlet may result in flooding and/or property drainage. A below grade storage and infiltration facility has been proposed within Project 3.3 to minimize the flooding potential during the design storm events.

Drainage Easement – Webber Road to Powers Creek

Runoff from Webber Road is conveyed to an existing outlet, north of Dunbarton Road. The existing cadastral information did not identify if an easement for drainage purposes is present. Project 3.4 has been presented for District staff to confirm if an easement exists, and if not, it is recommended that a drainage easement be established.

Ditch Erosion along Glenrosa Road

The existing ditch from McIvor Road to Morningside Drive is showing signs of erosion due to the high velocity. Erosion protection such as riprap or geofabric lining should be installed as recommended in Project 3.5 to protect the ditch bottom and minimize sedimentation in the downstream sections.

Drainage Easement - Webber Road to Inverness Road

A localized low-point exists on Webber Road, south of Scotstown Road. This area will collect runoff from Webber road and the surrounding area. Based on the existing terrain, the overland flow will travel across private property, enroute towards Powers Creek. Since this route will carry runoff from the municipal system, a safe drainage route and protected drainage easement should be established. This has been presented as Project 3.6.

Erosion Protection – Webber Road to Inverness Road

The conveyance channel, from the outlet of the existing 600 mm pipe has high velocity and is subject to erosion. Erosion protection measures such as riprap lining, check dams or geofabric lining should be installed as presented in Project 3.7, to protect the channel from further erosion.

3.4 FUTURE DEVELOPMENT AREAS

Figures 3.8 through to Figure 3.10 depict the existing developed areas, as well as the anticipated future development areas. These future development parcels have been obtained from the District of West Kelowna, Official Community Plan, and the Land Use Plan. Based on the Land Use Plan, these remaining parcels are expected to be developed as single-family residential developments.

Canary Drive

The future development area, north of Canary Drive, encompasses approximately 5.6 ha of relatively steep terrain. The steep terrain and anticipated rock conditions may limit the development potential and restrict the use of groundwater infiltration for stormwater management purposes. Low impact development alternatives should be pursued however, to promote effective rainwater management and reduce any impact on the downstream areas. Currently, the flow rate is estimated to be in the range of 13 L/s for a 1 in 5 year storm with 1 hour duration. To limit the impact on downstream areas, it is anticipated that approximately 875m^3 of detention storage would be required to detain the 1 in 100 year storm event.

Ranch Road

As shown in Figure 3.9, the areas south of Ranch Road are designated as future single-family development areas. The terrain within this area is steeply sloped and drains in a west to east direction. The steep terrain and shallow rock conditions may limit development potential and restrict the use of rainwater infiltration. Low impact development opportunities such as rainwater gardens or similar on-site detention facilities should be examined to assist in reducing the downstream impacts. Currently, the pre-development run-off rate is estimated to be in the range of 25 L/s for the 1 in 5 year design storm. To reduce the overall impact on the downstream systems, the post-developed flow rate should be restricted to that of existing conditions. It is anticipated that approximately 1,580 m^3 of detention storage would be required; however this should be confirmed during a detailed drainage study for the development site.

Gorman Road

As shown on Figure 3.9, the future development area south of Gorman Road contains a mix of sloped areas to the west, with flatter development areas towards the east. The areas downstream of the future development parcel do not contain a well-defined drainage network, and any increase as concentrated discharge point is likely to result in drainage problems for the downstream areas. Low impact development options should be explored as much as possible to limit any impacts on downstream areas. In addition, a

detailed review of the post development flow rates and proposed drainage routes and runoff volumes do not result in downstream drainage problems. Based on existing conditions, the pre-development flow rates are estimated to be in the range of 8L/s for the 1 in 5 year design storm.

Morningside Drive

Figure 3.10 depicts the future single-family development area to the south of Morningside Drive. Development within this area may be restricted by the steeper slopes south of Belcourt Road. Runoff from this development is likely to contribute to the existing drainage system within Morningside Drive, and then into the existing basin south of Webber Road. As with all future development areas, low impact alternatives should be incorporated into the neighbourhood design to reduce the hydrologic impact on the downstream channels. Under existing conditions, the pre-development flow rate from this area is expected to be in the range of 65L/s for a 1 in 5 year design storm. Much of the existing site drains towards Glenrosa Road, as it is sloped towards the east. A diversion of flow towards Morningside Drive will require a detailed review of the downstream system to ensure that these are not adverse impacts on the existing infrastructure.

Inverness Road

As shown on Figure 3.10, there is a future single-family development area encompassing approximately 2.0 ha to the south of Inverness Road. This development site is immediately adjacent to the Powers Creek tributary that flows through the old Webber Road school site. It is anticipated that runoff from this future development site would contribute into this tributary and as such, the water quality concerns will be paramount. Based on the existing conditions, the pre-development flow is anticipated to be in the range of 4.7L/s. Low impact development options should be fully explored to reduce the overall runoff quantities and to maximize the potential water quality improvement opportunities.

3.5 RECOMMENDED IMPROVEMENTS

Based on the review of the existing drainage system, hydraulic system, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 3.1.

Table 3.1 – Improvement Projects for Existing Deficiencies
Glenrosa Road Drainage Basin

Project	Priority	Location	Cost Estimate
3.1	Medium	Ditch erosion along Glenrosa Road	$60,300
3.2	High	Flooding along McAllister Road	$28,800
3.3	High	Flooding on McMann Road	$28,800
3.4	Low	Drainage Easement – Webber Road to Power Creek	-
3.5	Medium	Ditch erosion along Glenrosa Road	$74,200
3.6	Low	Drainage Easement - Webber Road to Inverness Road	-
3.7	Medium	Erosion Protection – Webber Road to Inverness Road	$31,500

Table 3.2 Existing System Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Size	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
GJ-1	GJ-173	357.5	Trapezoidal	600	7%	20	109
GJ-10	GJ-9	77.6	Circular	1050	0.1%	118	387
GJ-100	GJ-112	41.9	Circular	375	18%	118	387
GJ-108	GJ-109	154.7	Circular	1200	16%	356	848
GJ-109	GJ-7	61.0	Trapezoidal	600	14%	355	839
GJ-11	GSU-3	43.9	Triangular	600	1%	728	1987
GJ-112	GJ-10	31.1	Circular	375	14%	118	387
GJ-115	GJ-118	42.9	Circular	375	11%	53	201
GJ-116	GJ-115	37.6	Circular	375	5%	53	201
GJ-118	GJ-120	53.8	Circular	375	9%	53	201
GJ-120	GJ-121	99.7	Circular	525	1%	53	201
GJ-121	GJ-122	23.5	Circular	450	3%	53	201
GJ-122	GJ-123	27.4	Circular	450	3%	53	201
GJ-123	GJ-124	35.4	Circular	450	8%	53	201
GJ-124	GJ-125	41.5	Circular	450	11%	53	201
GJ-125	GJ-126	53.7	Circular	450	12%	53	201
GJ-126	GJ-127	37.0	Circular	450	2%	53	201
GJ-127	GJ-128	141.7	Trapezoidal	800	11%	53	201
GJ-128	GJ-211	216.8	Trapezoidal	600	5%	277	**895**
GJ-135	GJ-168	220.8	Trapezoidal	600	0%	19	104
GJ-136	GJ-175	79.3	Circular	600	8%	307	565
GJ-137	GJ-202	17.9	Circular	300	3%	42	83
GJ-138	GJ-204	39.1	Circular	600	3%	71	129
GJ-139	GJ-201	37.7	Circular	500	2%	**334**	**334**
GJ-142	GJ-193	20.4	Trapezoidal	600	9%	46	241
GJ-143	GJ-128	162.8	Trapezoidal	600	6%	253	839
GJ-144	GJ-145	227.0	Trapezoidal	600	14%	8	54
GJ-145	GJ-146	455.0	Trapezoidal	600	13%	7	53
GJ-146	GJ-128	319.0	Trapezoidal	600	10%	12	79
GJ-149	GJ-185	63.7	Trapezoidal	600	3%	86	200
GJ-150	GJ-151	251.3	Trapezoidal	600	5%	33	69
GJ-151	GJ-152	20.2	Circular	300	2%	30	61
GJ-152	GJO-6	188.2	Trapezoidal	600	3%	29	60
GJ-154	GJ-155	213.3	TRIANGULAR	300	0%	**102**	**103**
GJ-155	GJ-156	224.9	TRIANGULAR	300	4%	103	104
GJ-156	GJ-163	134.7	Trapezoidal	600	10%	102	103
GJ-157	GJ-158	113.5	TRIANGULAR	300	14%	37	78
GJ-158	GJ-159	55.6	Trapezoidal	600	4%	33	71
GJ-159	GJ-160	29.2	Circular	300	3%	90	**96**
GJ-160	GJ-161	55.6	Circular	500	28%	90	96
GJ-161	GJ-154	118.2	Trapezoidal	600	8%	377	430

Up Node	Down Node	Length (m)	Cross-Section	Existing Size	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
GJ-163	GJ-11	285.2	Trapezoidal	600	5%	242	513
GJ-164	GJ-165	30.5	Circular	500	2%	61	194
GJ-165	GJ-166	89.1	Trapezoidal	600	7%	61	194
GJ-166	GJ-173	56.6	Circular	600	4%	61	194
GJ-167	GJO-2	11.5	Trapezoidal	600	9%	151	567
GJ-168	GJ-195	34.7	Trapezoidal	600	2%	18	104
GJ-169	GJ-197	121.4	Trapezoidal	600	5%	79	147
GJ-170	GJ-92	188.0	Trapezoidal	600	5%	75	143
GJ-171	GJ-209	152.0	Trapezoidal	600	6%	183	738
GJ-172	GJ-194	24.8	Circular	700	7%	44	240
GJ-173	GJ-50	234.2	Trapezoidal	600	7%	133	472
GJ-174	GJ-198	150.4	Trapezoidal	600	3%	121	245
GJ-175	GJ-176	68.9	Circular	600	6%	306	564
GJ-176	GJ-179	70.8	Circular	600	1%	305	**404**
GJ-177	GJO-8	480.3	Trapezoidal	600	3%	31	59
GJ-178	GJ-200	50.2	Trapezoidal	600	3%	362	572
GJ-179	GJ-178	162.1	Trapezoidal	600	18%	304	397
GJ-180	GJ-171	98.0	Trapezoidal	600	7%	189	740
GJ-181	GJ-143	304.6	Trapezoidal	600	5%	244	760
GJ-182	gj-167	334.7	Trapezoidal	600	8%	151	566
GJ-183	GJ-187	20.5	Circular	600	10%	20	59
GJ-184	GJ-191	179.5	Trapezoidal	600	9%	22	110
GJ-185	GJ-186	22.2	Circular	300	3%	83	**106**
GJ-186	GJO-4	329.1	Trapezoidal	600	3%	68	105
GJ-187	GJ-189	616.4	Trapezoidal	600	8%	15	57
GJ-188	GJ-142	266.3	Trapezoidal	600	9%	42	217
GJ-189	GJ-188	35.7	Circular	800	10%	42	218
GJ-190	GJ-189	494.9	Trapezoidal	600	9%	18	109
GJ-191	GJ-190	34.4	Circular	500	9%	22	110
GJ-192	GJ-206	493.4	Trapezoidal	600	9%	45	241
GJ-193	GJ-192	21.4	Circular	500	9%	46	241
GJ-194	GJ-208	189.8	Trapezoidal	600	7%	129	543
GJ-195	GJ-196	21.7	Circular	600	2%	18	104
GJ-196	GJ-169	300.6	Trapezoidal	600	3%	17	101
GJ-197	GJ-170	25.5	Circular	600	5%	78	146
GJ-198	GJ-199	24.4	Circular	300	3%	87	**99**
GJ-199	GJ-136	223.3	Trapezoidal	600	3%	87	99
GJ-200	GJ-220	163.6	Trapezoidal	600	3%	394	660
GJ-201	GJ-161	301.3	Trapezoidal	600	2%	334	335
GJ-202	GJ-150	234.1	Trapezoidal	600	3%	38	78
GJ-203	GJ-204	33.1	Circular	300	3%	31	55
GJ-204	GJ-178	220.9	Trapezoidal	600	3%	101	182
GJ-205	GJ-177	31.7	Circular	300	2%	43	**66**
GJ-206	GJ-207	18.5	Circular	600	9%	44	240
GJ-207	GJ-172	107.0	Trapezoidal	600	9%	44	240

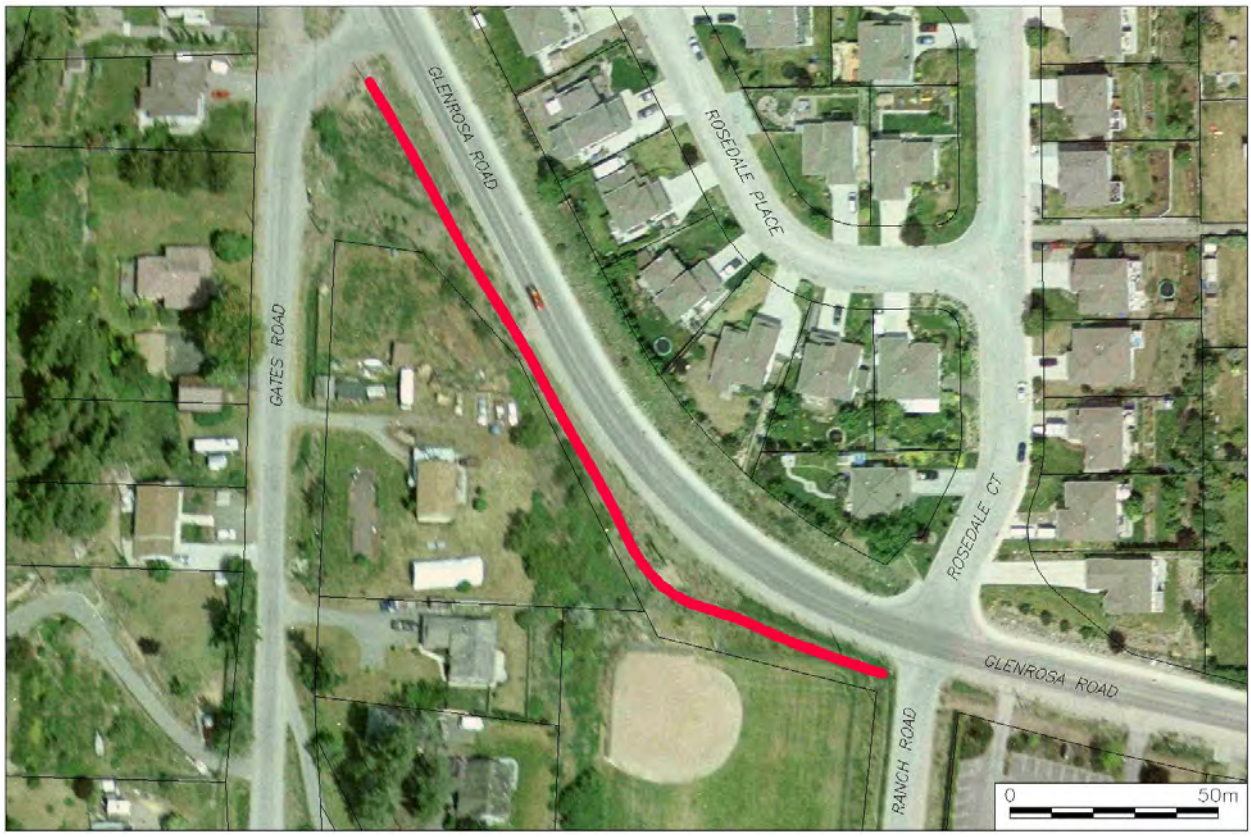
Up Node	Down Node	Length (m)	Cross-Section	Existing Size	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
GJ-208	GJ-180	17.6	Circular	800	7%	128	542
GJ-209	GJ-181	26.9	Circular	600	6%	252	760
GJ-210	GJ-55	252.0	Circular	600	5%	327	652
GJ-211	GJ-63	35.8	Circular	1200	5%	277	895
GJ-212	GJ-213	21.6	Circular	600	5%	19	62
GJ-213	GJ-214	242.7	Trapezoidal	600	5%	18	62
GJ-214	GJ-215	34.1	Circular	600	3%	57	153
GJ-215	GJ-216	88.6	Trapezoidal	600	5%	56	153
GJ-216	GJ-217	23.5	Circular	600	4%	55	153
GJ-217	GJ-218	7.4	Trapezoidal	600	7%	55	153
GJ-218	GJ-219	17.6	Circular	600	3%	55	153
GJ-219	GJ-164	45.8	Trapezoidal	600	8%	55	153
GJ-220	GJ-139	35.1	Trapezoidal	600	3%	393	729
GJ-221	GJ-149	23.9	Trapezoidal	600	4%	87	201
GJ-4	GJ-5	19.6	Circular	375	14%	118	389
GJ-40	GJ-45	93.4	Circular	200	11%	61	**119**
GJ-41	GJ-40	14.5	Circular	200	1%	61	**125**
GJ-42	GJ-41	56.8	Circular	200	12%	49	104
GJ-43	GJ-41	94.2	Circular	200	6%	12	37
GJ-44	GJ-43	51.3	Circular	200	3%	12	37
GJ-45	GJ-46	26.5	Circular	200	2%	**56**	**56**
GJ-46	GJ-47	60.1	Circular	200	7%	56	55
GJ-47	GJ-50	15.0	Circular	200	7%	55	55
GJ-5	GJ-6	20.6	Circular	375	28%	118	390
GJ-50	GJ0-1	9.8	Trapezoidal	600	10%	245	707
GJ-53	GJ-55	20.2	Circular	600	27%	62	200
GJ-55	GJ-108	64.6	Circular	1200	11%	356	850
GJ-58	GJ-53	51.5	Circular	600	14%	62	200
GJ-59	GJ-58	90.3	Circular	300	5%	62	200
GJ-6	GJ-100	85.4	Circular	375	14%	118	389
GJ-60	GJ-59	29.8	Circular	250	5%	62	**199**
GJ-62	GJ-63	35.4	Circular	375	2%	75	**213**
GJ-63	GJ-210	28.3	Circular	600	3%	327	**728**
GJ-64	GJ-68	42.1	Circular	250	8%	2	12
GJ-68	GJ-60	27.8	Circular	250	5%	2	12
GJ-7	GJ-11	44.2	Circular	1050	7%	501	1359
GJ-70	GJ-71	64.4	Circular	250	2%	2	12
GJ-71	GJ-72	84.6	Circular	250	5%	2	12
GJ-72	GJ-73	44.6	Circular	250	6%	2	12
GJ-73	GJ-64	37.7	Circular	250	4%	2	12
GJ-74	GJ-75	25.5	Circular	250	7%	0	6
GJ-75	GJ-84	55.2	Circular	250	8%	76	**213**
GJ-8	GJ-7	27.3	Circular	1050	2%	149	540
GJ-84	GJ-62	41.0	Circular	250	22%	76	213
GJ-85	GJ-86	42.1	Circular	600	5%	186	384

Up Node	Down Node	Length (m)	Cross-Section	Existing Size	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
GJ-86	GJ-136	100.9	Trapezoidal	600	1%	182	379
GJ-87	GJ-88	30.0	Circular	600	16%	131	252
GJ-88	GJ-89	33.4	Circular	600	5%	131	252
GJ-89	GJ-90	64.5	Circular	750	1%	130	251
GJ-9	GJ-8	34.9	Circular	1050	6%	149	541
GJ-90	GJ-85	43.7	Circular	675	13%	187	386
GJ-92	GJ-87	9.2	Circular	600	3%	131	252

Project 3.1 Erosion Protection – Glenrosa Road from Gates Road to Ranch Road

Proposed Works:	Install erosion protection along the Glenrosa Road ditch, from Gates Road to Ranch Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2

Location:



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	200	$180	$36,000
Fine Grading	Sq.m	600	$10	$6,000
Contingency(25%)				$10,500
Engineering(15%)				$7,800
Total Project Cost				**$60,300**

RSB ENGINEERING

Project 3.2 Drainage Improvements – McAllister Road

Proposed Works:	Construction of a storm drainage collection system, and below grade storage/infiltration system to reduce the flooding risks and promote groundwater recharge.
Implementation:	The localized depression area on McAlister Road will collect runoff from the nearby properties and roadway. This work is considered a High priority, since there is a risk of flooding and/or property damage. Environmental benefits can also be achieved with the implementation of the infiltration facilities.
Consequences if not completed:	Since there is no overland flow route runoff will collect in this low-lying area, and there is a risk of flooding on private property.
Priority:	1

Location:



Description	Unit	Quantity	Unit Price	Total
Storage/Infiltration	Ls	1	$15,000.00	$15,000
Drainage Collection System	Ls	1	$5,000.00	$5,000
Contingency (25%)				$5,000.
Engineering (15%)				$3,800.
Total Project Cost				**$28,800**

RSB ENGINEERING

Project 3.3 Drainage Improvements – McMann Road

Proposed Works:	Construction of a storm drainage collection system, and below grade storage/infiltration system to reduce the flooding risks and promote groundwater recharge.
Implementation:	The localized depression area on McMann Road will collect runoff from the nearby properties and roadway. This work is considered a High priority, since there is a risk of flooding and/or property damage. Environmental benefits can also be achieved with the implementation of the infiltration facilities.
Consequences if not completed:	Since there is no overland flow route runoff will collect in this low-lying area, and there is a risk of flooding on private property.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Storage/Infiltration	Ls	1	$15,000.00	$15,000
Drainage Collection System	Ls	1	$5,000.00	$5,000
Contingency (25%)				$5,000
Engineering (15%)				$3,800
Total Project Cost				**$28,800**

RSB ENGINEERING

Project 3.4 Drainage Easement – Webber Road to Powers Creek

Proposed Works:	Establish a drainage easement or Right-of-Way from Webber Road to Powers Creek.
Implementation:	
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 3.5 Erosion Protection – Glenrosa Road from McIvor Road to Morningstar Road

Proposed Works:	Install erosion protection along the Glenrosa Road ditch, from McIvor Road to Morning Star Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	200	$225.00	$45000.00
Fine Grading	Sq.m	400	$20.00	$8000.00
Contingency (25%)				$13250.00
Engineering (15%)				$7950.00
Total Project Cost				**$74200.00**

RSB ENGINEERING

Project 3.6 Drainage Easement – Webber Road to Inverness Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Webber Road to Inverness Road.
Implementation:	
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 3.7 Erosion Protection – Webber Road to Inverness Road

Proposed Works:	Install erosion protection measures along creek bank from Webber Road to Inverness Road
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2

Location:



Description	Unit	Quantity	Unit Price	Total
Drainage Protection	Lm	100	$225.00	$22500.00
Contingency (25%)				$5625.00
Engineering (15%)				$3375.00
Total Project Cost				**$31500.00**

RSB ENGINEERING

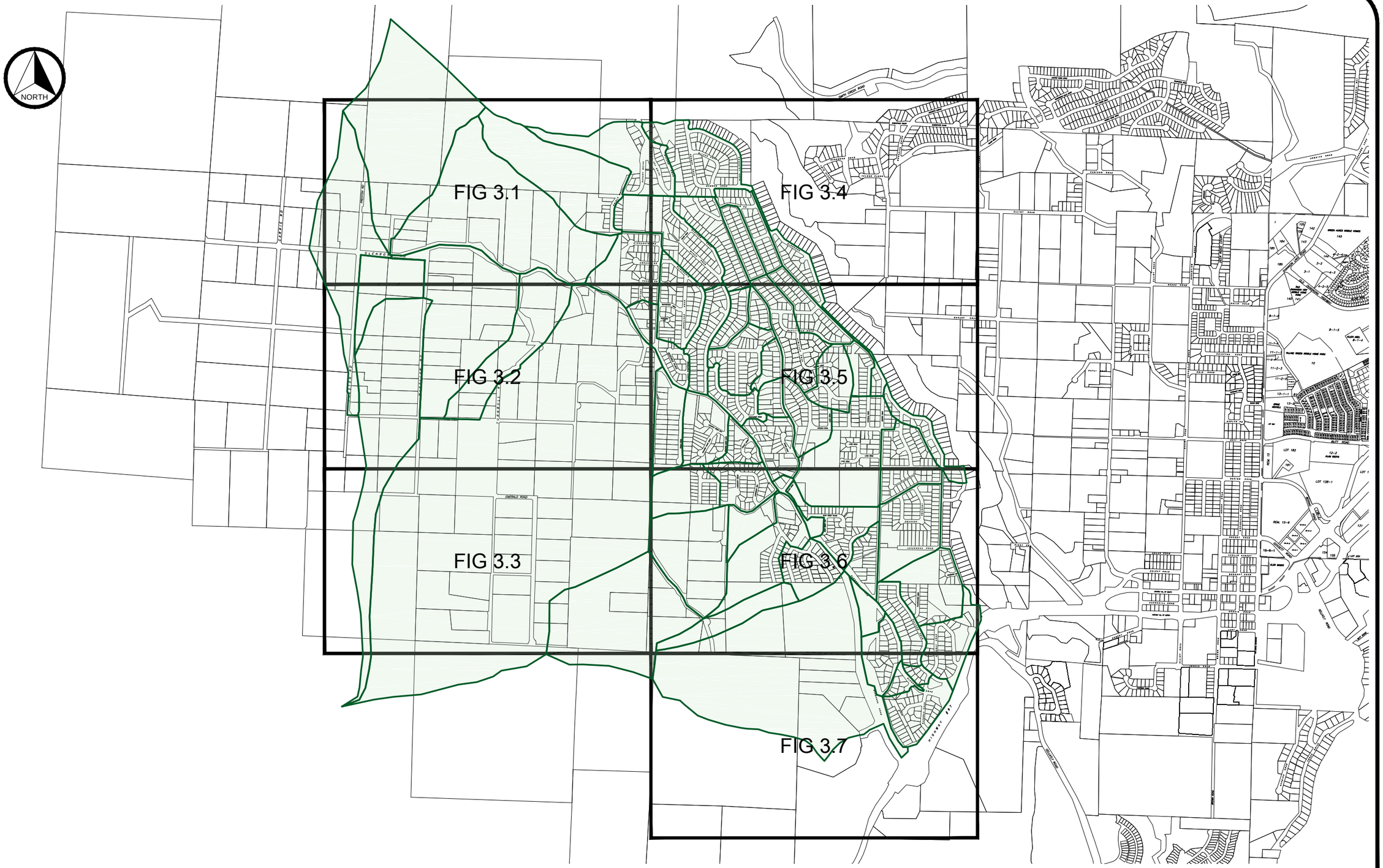


FIGURE 3.0
GLENROSA BASIN
KEY MAP
N.T.S.

RSB
ENGINEERING

NORTH

GS-31

GS-3

GS-2

GS-4_2

GS-19_3

GS-19_2

GS-4_3

PRESTON RD

GLENROSA RD

CANARY DRIVE

BLUE JAY DRIVE

ORIOLE PKWY

MCLEOD

STONEGATE RD

CORRAL RD

REGENT RD

HELSEA RD

GATES CRT.

GJ-184

GJ-191

GJ-190

GJ-189

GJ-188

GJ-142

GJ-193

GJ-192

GJ-135

GJ-168

GJ-195

GJ-196

GJ-169

NO AS-CONSTRUCTED INFORMATION

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	3.1	3.4
	3.2	3.5

FIGURE 3.1
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

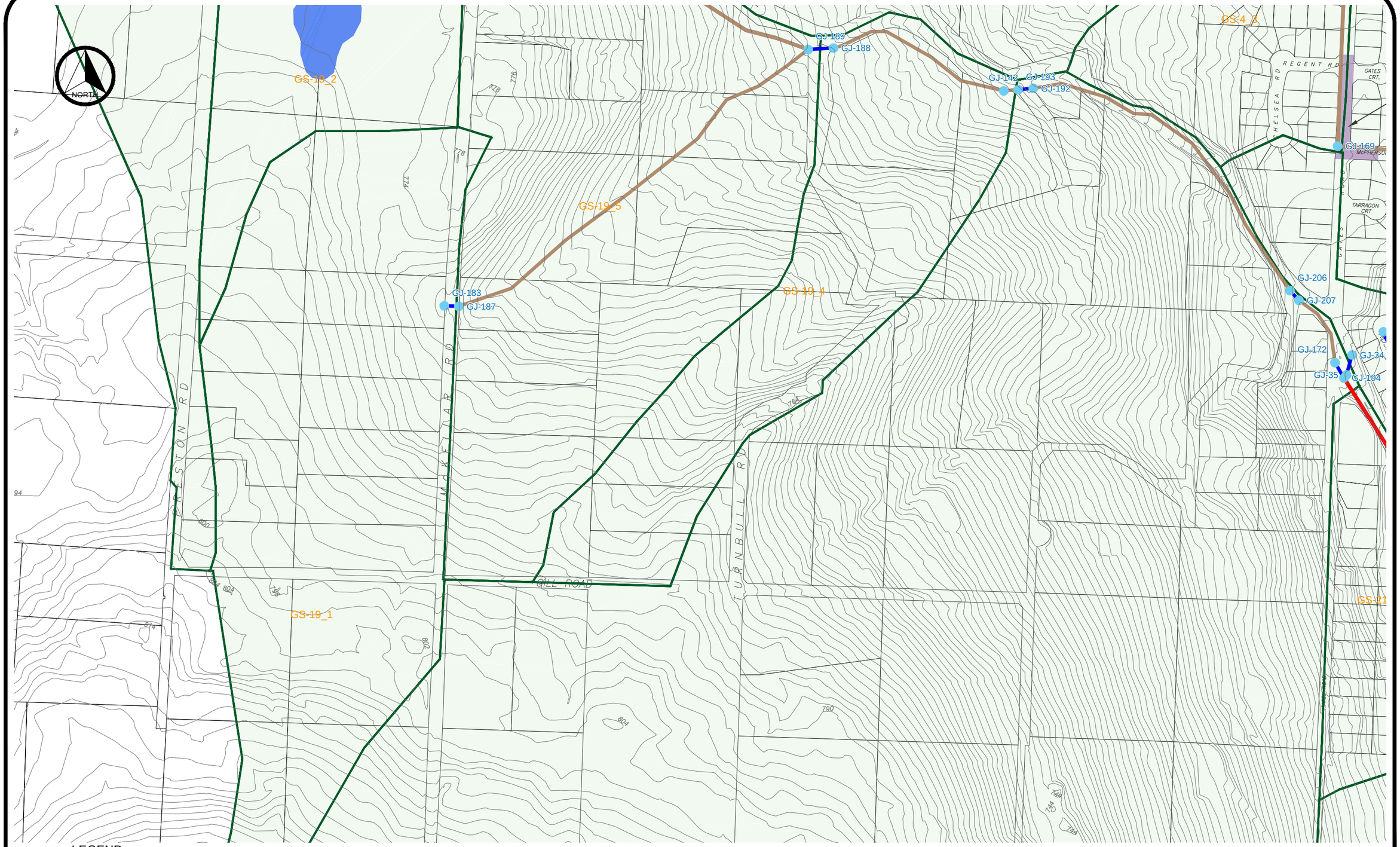
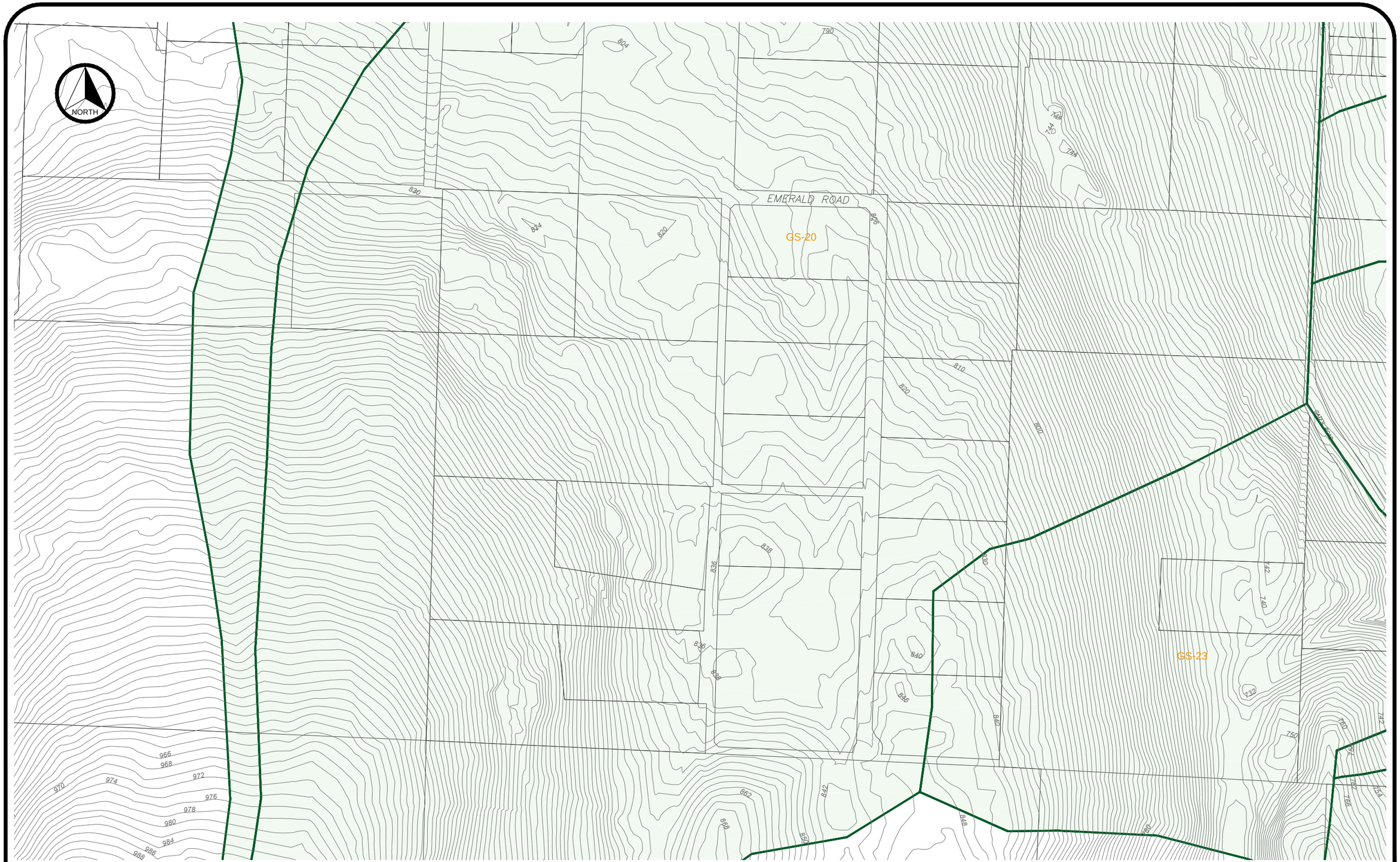


FIGURE 3.2
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

	3.2	3.5
	3.3	3.6

FIGURE 3.3
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

NO AS-CONTRUCTED INFORMATION

NO AS-CONTRUCTED INFORMATION

SMITH CREEK ROAD

DOUCETTE AVENUE

SUMMERVIEW COURT

SUMMERVIEW PLACE

DOUCETTE DRIVE

SALISH ROAD

HAROLD ROAD

SANDBERG ROAD

TWIN PLACE

TELCOR PLACE

CANARY DRIVE

BLUE JAY DRIVE

McLEOD ROAD

WEBBER ROAD

McIVER ROAD

COVENTRY CRES.

HUNAIR RD

McCOY ROAD

McGREGOR

STONEGATE RD

CORRAL RD

REGENT RD

HELSEA RD

GATES CRT.

GS-1

GS-6

GS-8_2

GS-9

GJO-3

GJO-4

GJ-221

GJ-149

GJ-185

GJ-186

GJ-168

GJ-195

GJ-196

GJ-174

GJ-137

GJ-202

GJ-138

GJ-203

GJ-204

GJ-205

644 642 640 638 636 634 632 630 628 626 624 622 620 618 616 614 612 610 608 606 604 602 600 598 596 594 592 590 588 586 584 582 580 578 576 574 572 570 568 566 564 562 560 558 556 554 552 550 548 546 544

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

3.1	3.4	
3.2	3.5	

FIGURE 3.4
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

NO AS-CONTRUCTED INFORMATION

INSTALL UNDERGROUND STORAGE/INFILTRATION AS PER PROJECT

3.2

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT

3.4

NO AS-CONTRUCTED INFORMATION

INSTALL UNDERGROUND STORAGE/INFILTRATION AS PER PROJECT

3.3

INSTALL EROSION PROTECTION AS PER PROJECT

3.1

GJ-169 GJ-197 GJ-170 GJ-174 GJ-137 GJ-202 GJ-138 GJ-203 GJ-204 GJ-205 GJ-177 GJ-198 GJ-199 GJ-150 GJ-178 GJ-151 GJ-152 GJ-179 GJ-176 GJ-175 GJ-136 GJ-200 GJ-206 GJ-207 GJ-87 GJ-92 GJ-95 GJ-88 GJ-89 GJ-172 GJ-34 GJ-35 GJ-194 GJ-94 GJ-90 GJ-85 GJ-86 GJ-98 GJ-36 GJ-91 GJ-37 GJ-180 GJ-38 GJ-39 GJ-171 GJ-220 GJ-139 GJ-201 GJ-209 GJ-181 GJ-157 GJ-158 GJ-159 GJ-160 GJ-161 GJ-154 GJ-117 GJ-28 GJ-29 GJ-31 GJ-116 GJ-115 GJ-118 GJ-120 GJ-129 GJ-33 GJ-30 GJ-143 GJ-155 GJ-156

GS-4_1 GS-10_2 GS-11 GS-5_1 GS-5_3 GS-12 GS-10_1 GS-10_4 GS-13 GS-7_1 GS-15 GS-10_3 GS-21_1 GS-21_2 GS-21_3 GS-14_1 GS-14_2 GS-16 GS-17 GS-18

GJO-5 GJO-6 GJO-7 GJO-10 GJO-8 GJO-9

GATES CRT. TARRAGON CRT HELSEA RD REGENT RD MCMURCHIE ROAD MORELAND ROAD McPHERSON ROAD MCMILLAN ROAD McMANN ROAD SCHARF ROAD PARKHURST ROAD GLENROSA ROAD COUNTRY PINES WAY COUNTRY PINES DRIVE COUNTRY PINES GATE RANCH ROAD SHAW COURT SANDSBURY COURT CLOSED ROAD FICKE ROAD MALCOLM ROAD WEBBER ROAD GORMAN ROAD LYON ROAD ABERDEEN ROAD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

3.1	3.4	
3.2	3.5	
3.3	3.6	

FIGURE 3.5
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

INSTALL EROSION PROTECTION AS PER PROJECT 3.5

DETENTION FACILITY

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT 3.6

INSTALL EROSION PROTECTION AS PER PROJECT 3.7

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

3.2	3.5	
3.3	3.6	
	3.7	

FIGURE 3.6
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

GS-24

GS-32_2

GS-36

GS-35_1

GS-32_3

GS-35_2

GJ-40 GJ-42 GJ-41 GJ-46 GJ-45 GJ-50 GJ-47 GJ01

GJ-214 GJ-215 GJ-43 GJ-49 GJ-48 GJ-44

GJ-216 GJ-217 GJ-219 GJ-218 GJ-164 GJ-165 GJ-166 GJ-173

GJ-1

GLENROSA ROAD

GLENWAY ROAD

HIGHWAY # 97

LEGEND

CATCHMENT BOUNDARY	MODEL JUNCTION	GJ-191	JUNCTION ID	*524*	CONTOUR ELEVATION
MODEL CHANNEL/DITCH	MODEL OUTFALL	GJO-5	OUTFALL ID		
MODEL PIPE	GS-19_2 CATCHMENT ID		2m CONTOUR		

3.3	3.6	
	3.7	

FIGURE 3.7
GLENROSA BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 3.53 ha
Pre-development flow
Q_5=8.8 L/s
Post-development flows
Q_5=170 L/s
Q_{100}=325 L/s
Approx. Estimated
Required Storage: 554m³

Area 2.02 ha
Pre-development flow
Q_5=4.2 L/s
Post-development flows
Q_5=97 L/s
Q_{100}=186 L/s
Approx. Estimated
Required Storage: 320m³

SMITH CREEK ROAD
SANDBERG ROAD
TWIN PLACE
TELCOR PLACE
CANARY DRIVE
BLUE JAY DRIVE
McLEOD ROAD
WEBBER ROAD
McIVER ROAD
COVENTRY CRES.
McNAIR RD
McGREGOR
McCLEOD ROAD
McCOY ROAD
McGEE ROAD
McMURCHIE ROAD
STONEGATE RD
CORRAL RD
REGENT RD
GATES CRT.
HELSEA RD
GRIDDLE CREEK

GJO-3
GJO-4
GJ-221
GJ-149
GJ-185
GJ-186
GJ-135
GJ-168
GJ-195
GJ-196
GJ-189
GJ-188
GJ-142
GJ-193
GJ-192
GJ-174
GJ-138
GJ-203
GJ-204
GJ-137
GJ-202

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 3.8
GLENROSA BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 4.88 ha
Pre-development flow
Q_5=12 L/s
Post-development flows
Q_5=235 L/s
Q_{100}=449 L/s
Approx. Estimated
Required Storage: 766m³

Area 5.19 ha
Pre-development flow
Q_5=13 L/s
Post-development flows
Q_5=249 L/s
Q_{100}=478 L/s
Approx. Estimated
Required Storage: 814m³

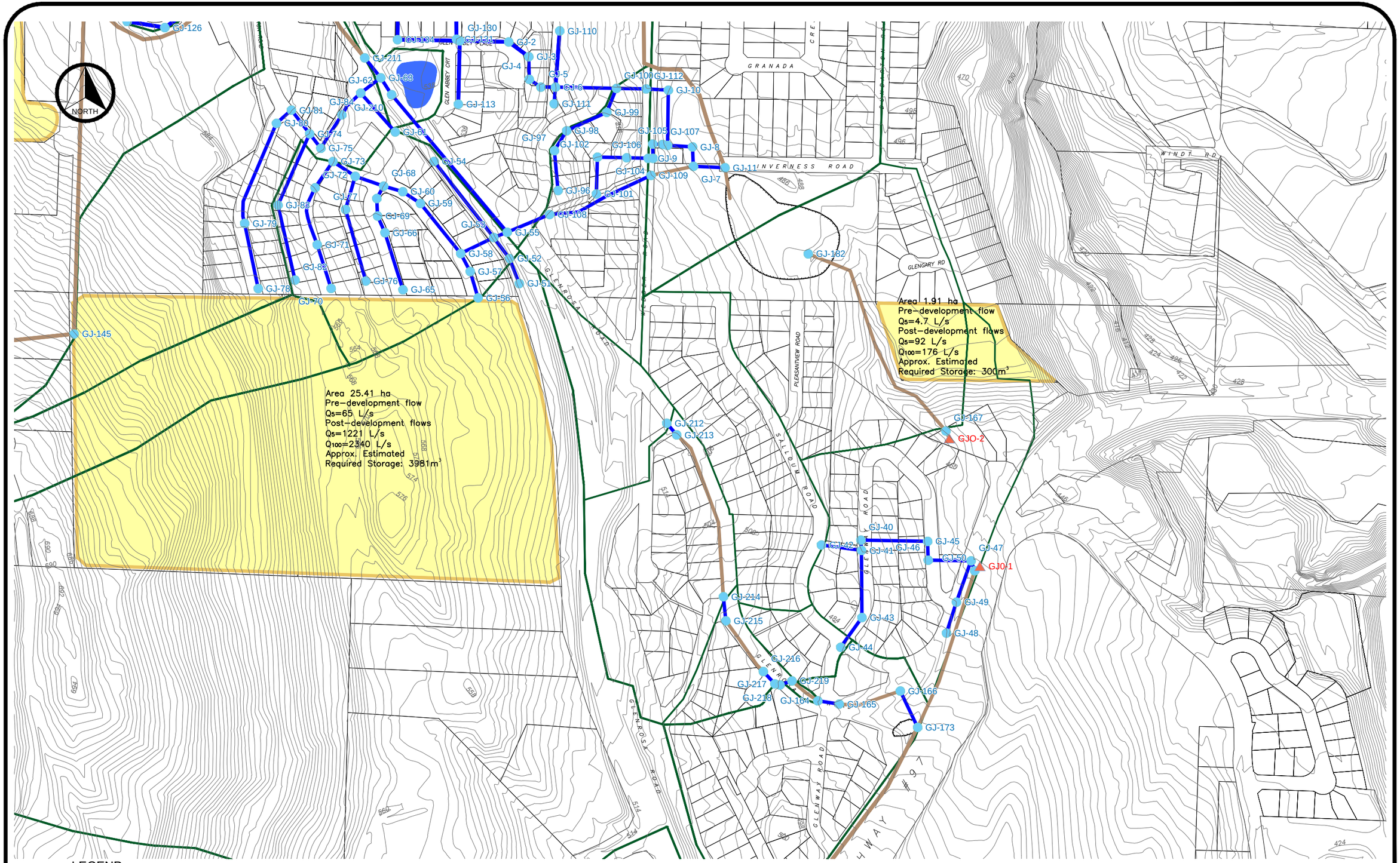
Area 3.61 ha
Pre-development flow
Q_5=8 L/s
Post-development flows
Q_5=173 L/s
Q_{100}=332 L/s
Approx. Estimated
Required Storage: 570m³

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 3.9
GLENROSA BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

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LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- GS-19_2 CATCHMENT ID
- GJ-191 JUNCTION ID
- GJO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 3.10
GLENROSA BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 4
POWERS CREEK BASIN PLAN

4.1 BASIN DESCRIPTION

Powers Creek is the largest watershed in the study area. The headwaters originate near Carrot Mountain at elevation 1,538m and drain southerly to Okanagan Lake.

Through the District Limits, Powers Creek resides in a natural, v-shaped deep ravine. The watercourse follows a relatively straight alignment, with minimal meanders, at a gradient of 5-10%.

Peak flows through the creek are governed by snowmelt and freshet conditions, and are partially regulated by Westbank Irrigation District which is now part of the District of West Kelowna who withdraws surface runoff from the creek and provide treatment for potable water supply.

There is minimal drainage infrastructure along the creek. Powers Creek crosses below Highway 97 through a 4.6 m x 4.1 m multi-plate culvert. The District has a limited amount of drainage infrastructure within the Powers Creek Basin.

4.2 EXISTING SYSTEM ANALYSIS

As noted above, flow within the creek is largely regulated by the Westbank Irrigation intake system. The urbanized areas above Highway 97 are predominately part of the Glenrosa Basin with connection to the Powers Creek Tributaries.

The areas below Highway 97 include a mix of undeveloped lands, agricultural areas and pockets of urban development

Runoff from the Glen Canyon Drive development, to the east of Gellatly Road, drains into stormwater detention tanks and the outfalls into Powers Creek, east of Gellatly Road. Through field reconnaissance, we were unable to locate the concrete detention tank. The outfall area is heavily overgrown with difficult access for any maintenance or repair activities.

The strata developments near the south end of Gellatly Road appear to contain on site infiltration systems to assist in discharging runoff to ground. It is not known if these systems have been designed to dispose of the 1 in 100 year flow rates.

The majority of the Powers Creek Basin area, within the District boundaries, consists of open channels and roadside ditches, with the exception of the area on Gellatly Road near the Wastewater Treatment facility. This section of the roadway contains a storm sewer

pipe, along with an outlet into Powers Creek near the nursery. No information could be found on this pipe; however it was included in the model as a 600 mm pipe.

The Highway 97 culvert is perched and poses a barrier to fish passage. Water samples obtained by Larratt Aquatic Consulting in the vicinity of this culvert outlet and associated storm outfalls were also found to be of concern for water quality in regards to chloride concentrations. The watercourse evaluation for Powers Creek, including its tributaries, has been presented in further detail within Section 12.3.

Table 4.1 Summary of Flow Rates

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
PCJ-1	15	580.1	Circular	600	6%	13	31
PCJ-12	PCJ-13	81.0	Circular	250	2%	21	38
PCJ-13	PCJ-14	102.1	Circular	250	2%	21	38
PCJ-14	PCJ-15	64.5	Circular	375	2%	43	77
PCJ-15	PCJ-16	25.8	Circular	375	1%	43	77
PCJ-16	PCJ-1	794.6	Trapezoidal	600	4%	21	48
PCJ-20	PCJ-21	35.2	Circular	250	5%	12	22
PCJ-21	PCJ-24	65.1	Circular	250	9%	12	22
PCJ-24	PCJ-27	29.9	Circular	250	21%	12	22
PCJ-27	PCJ-25	17.2	Circular	250	3%	12	22

4.3 EXISTING SYSTEM DEFICIENCIES

With the exception of some relatively minor ditch erosion occurrences along Gellatly Road, there are no observed deficiencies or noted problem areas within the Powers Creek Basin.

4.4 FUTURE DEVELOPMENT AREAS

Figures 4.4 and 4.5 depict the existing development areas as well as those that are designated as future development areas within the District of West Kelowna, Official *Community Plan, Land Use Plan.*

Gellatly Road

As indicated in Figure 4.4, there are large parcels of land designated as future single-family development areas. The areas to the west of Gellatly Road encompass

approximately 68 ha of land. These future development areas slope from west to east, and generally drain towards Gellatly Road. The steep terrain and anticipated rock conditions may limit the development potential and restrict the use of groundwater infiltration methods for stormwater disposal. Low impact development alternatives should be pursued however, to reduce any impact on the downstream areas due to increased urban development. Currently the flow rate is estimated to be in the range of 179L/s for a 1 in 5 year storm. To limit the impact of the downstream system, it is anticipated that approximately 10,500 m^3 of detention storage would be required to detain the 1 in 5 year storm event under developed conditions.

The future development area to the east of Gellatly Road is situated on a relatively flat bench, above Powers Creek. Similar to other development sites, low impact development options should be included within the site design, to limit the impact on the downstream areas, particularly, in considering the proximity to Powers Creek. Currently, the pre-development runoff rate is estimated to be in the range of 31 L/s for the 1 in 5 year design storm. To reduce the overall impact on the downstream systems, the post-development runoff should be restricted to that of existing conditions.

Pineridge Place

As shown on Figure 4.4 there is a future development area to the west of Brown Road, south of Pineridge Place. This future development area is designated as medium density, multi-family and encompasses an area of approximately 4.9 ha. The western limits of the site are steeply sloped, and situated above the banks of Powers Creek. The pre-development runoff route is estimated to be in the range of 12 L/s for the 1 in 5 year design. To reduce the overall impact on the downstream systems, the post-development flow rate should be restricted to that of existing conditions.

4.5 RECOMMENDED IMPROVEMENTS

There are no recommended improvement projects within the Power Creek Basin.

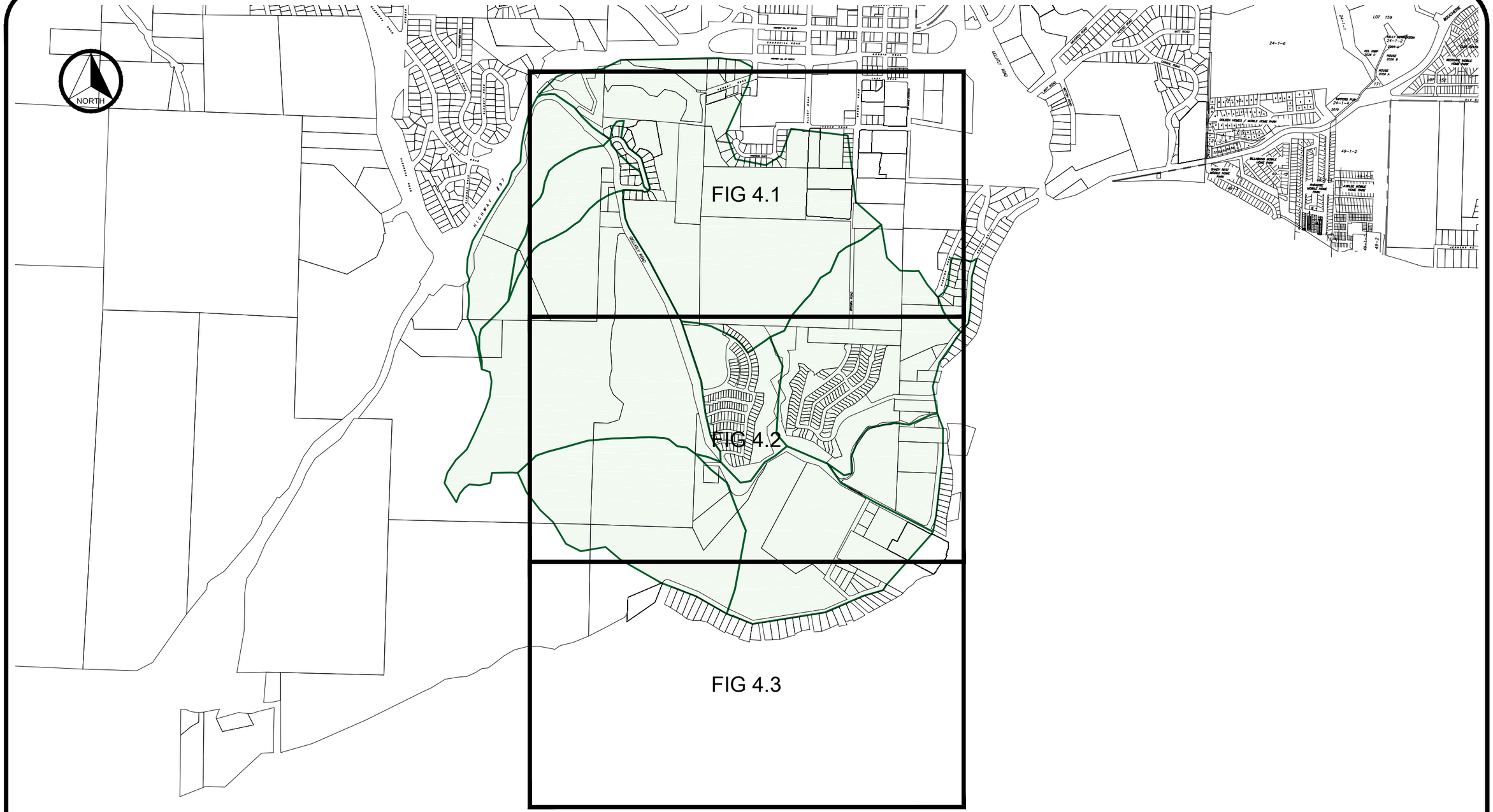
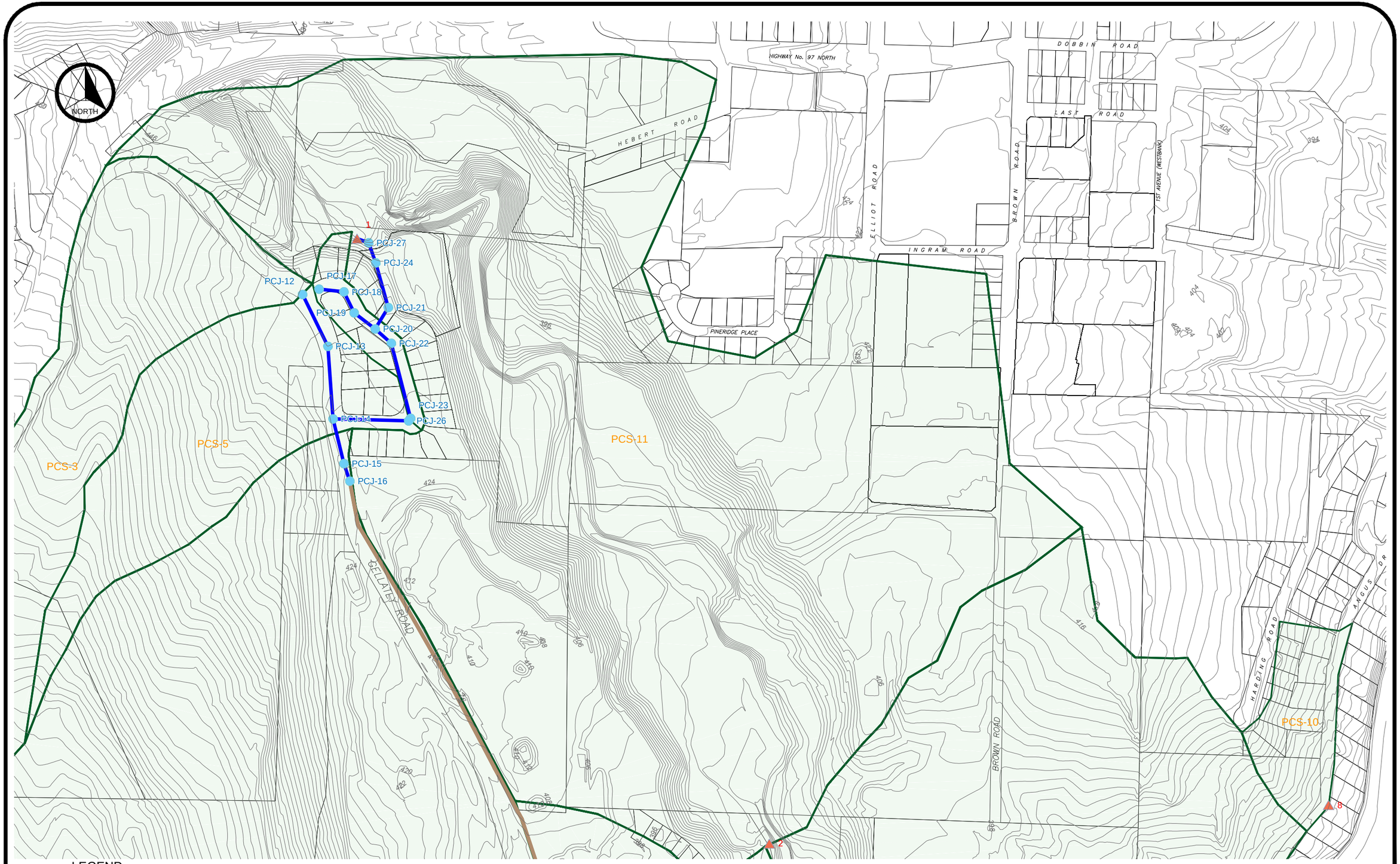


FIGURE 4.0
POWERS CREEK BASIN
KEY MAP
N.T.S.

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LEGEND

CATCHMENT BOUNDARY	MODEL JUNCTION	PCJ-15	JUNCTION ID	524	CONTOUR ELEVATION
MODEL CHANNEL/DITCH	MODEL OUTFALL	8	OUTFALL ID		
MODEL PIPE	PCS-7 CATCHMENT ID		2m CONTOUR		

	4.1	
	4.2	

FIGURE 4.1
POWERS CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

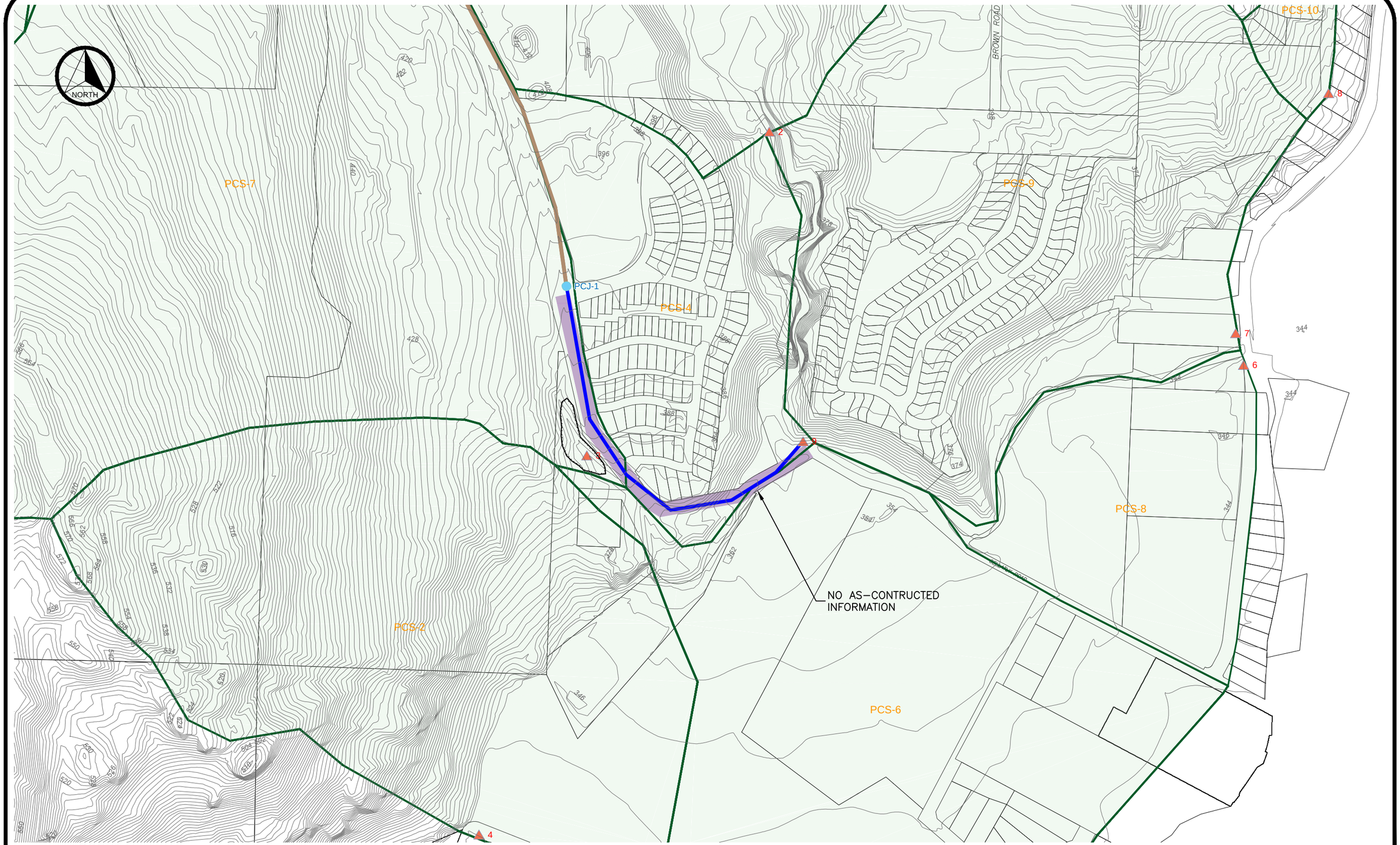
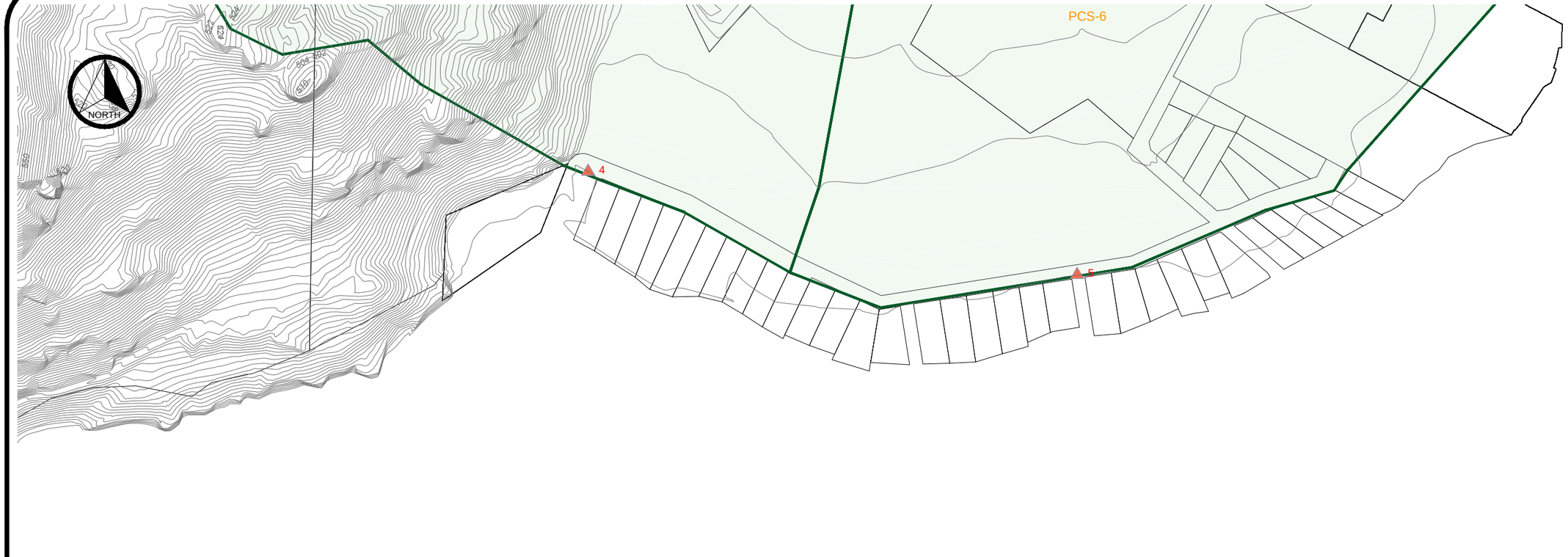


FIGURE 4.2
POWERS CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- PCS-7 CATCHMENT ID
- PCJ-15 JUNCTION ID
- 8 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

	4.2	
	4.3	

FIGURE 4.3
POWERS CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

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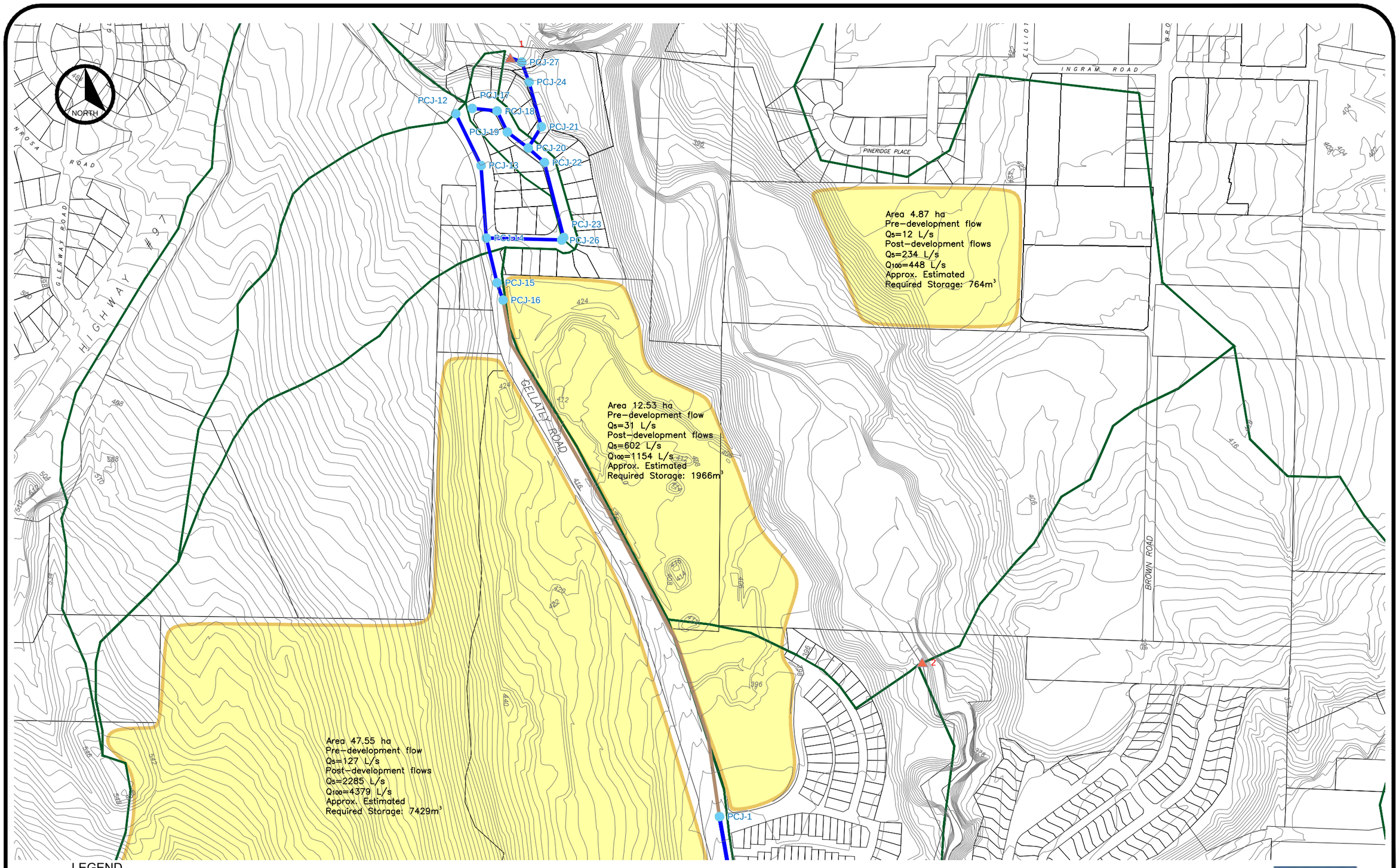


FIGURE 4.4
POWERS CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 47.55 ha
Pre-development flow
Q_5=127 L/s
Post-development flows
Q_5=2285 L/s
Q_{100}=4379 L/s
Approx. Estimated
Required Storage: 7429m^3

Area 19.58 ha
Pre-development flow
Q_5=52 L/s
Post-development flows
Q_5=941 L/s
Q_{100}=1803 L/s
Approx. Estimated
Required Storage: 3060m^3

PCJ-1

2

3

BROWN ROAD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- PCS-7 CATCHMENT ID
- PCJ-15 JUNCTION ID
- 8 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 4.5
POWERS CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 5
SMITH CREEK BASIN PLAN

5.1 BASIN DESCRIPTION

Smith Creek is a natural watercourse that originates north of the District limits and enters municipal boundaries near Copper Ridge Drive. The watercourse meanders through the District, crosses into First Nations property near Chieftan Road and Old Okanagan Highway, before re-entering District limits near Highway 97 and flowing alongside Gellatly Road and into the lake.

The Smith Creek basin encompasses a total of 1170 ha – which was delineated into 56 subcatchments within the District and hillside terrain upstream of District Limits. The basin ranges in elevation from 342m to 1,403m. Its boundaries are bordered to the west by the Powers Creek ridgeline and to the east by the Shannon Lake catchment.

Land-use in the basin includes residential properties near Reece Road, rural agricultural areas, dense commercial areas along Highway 97 as well as the downtown area of West Kelowna.

The natural creek features have been modified over time due to activities within the watershed and along the creek boundaries itself. The modifications included wooden pedestrian bridges, water withdrawal pipes, and discharge pipes.

5.2 EXISTING SYSTEM ANALYSIS

The upper watershed area consists of approximately 530 ha of hillside and undeveloped terrain. Within the District limits, Smith Creek watershed consists of a mix of rural agricultural properties and urban development including residential areas plus higher density commercial developments near Highway 97. The model nodes for the Smith Creek system are presented within Figures 5.1 to 5.11. The corresponding flow rates for the 1 in 5 year and 1 in 100 year storm events are presented in Table 5.2. Note, the flows shown within Table 5.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

The runoff from the upper residential developments discharges directly into Smith Creek, largely without peak flow attenuation or water quality improvement facilities. This connectivity to Smith Creek results in rapid runoff and high flow rates during rainfall events. With the increase in impervious surfaces due to urban development, the runoff rates have increased from that of natural conditions and in addition, the reduction in infiltration results in a decrease of base flow rates for the downstream areas.

The water course evaluation for Smith Creek, including its tributaries has been presented in further detail within Section 12.3. A total of seven (7) discharges were identified along Smith Creek and its tributary streams during the 2001 SHIM survey. At this time, there were five (5) storm drains recorded, with an average diameter of 340 mm and a maximum observed discharge pipe of 750 mm.

Obstructions included all features that had the potential to prevent the normal passage of fish during all or part of the year. A summary of potential obstructions or barriers to upstream fish migration is summarized in Table 12.9.

Runoff from earlier residential developments and the downtown area contain a mix of overland and piped storm drainage systems. Very little as-built drawing information could be located regarding the piped systems in the older development areas. In the absence of these as-built drawings, the topographic information and the results of the field visits were used to identify the probable flow routes connectivity. The downtown areas and earlier residential developments contribute to the Smith Creek drainage corridor in the area of Highway 97.

There is existing oil/water separation located near the intersection of Gellatly Road and Witt Road. This facility was installed and maintained by the Ministry of Transportation and Infrastructure.

The recent commercial developments with Westbank First Nations (WFN) lands also contribute to the flows within Smith Creek, in the vicinity of Highway 97. The peak flow rates, storm detention facilities or water quality improvement facilities within WFN developments are not known and not included within the District of West Kelowna Master Drainage Plan. In considering the cumulative input of the increased impervious surfaces however, inter-agency coordination and a coordinated effort towards long term creek improvements is strongly recommended.

Downstream of Highway 97, the creek is subject to high flow rates and severe erosion potential. The increases in impervious surfaces and high runoff rates compared to natural conditions have resulted in erosive conditions and severe down cutting of the stream banks within this section of the creek.

Many of the culvert outlets mentioned above have been installed such that they are perched as high as 2 m above the stream, creating an upstream barrier to fish migration. Additionally, with culvert lengths varying from 4 to 475 m within the Smith Creek watershed, fish habitat values are further impaired. Obstructions are discussed further in Section 12.3.

In terms of water quality parameters, there was also a notable decline in water quality as the flow travels from the upper watersheds through the areas of urban influence and ultimately into Okanagan Lake. A detailed discussion of the water quality parameters and sampling results is presented in Section 13.0. The nitrate levels within Smith Creek were very high due to the current and past agricultural activities which contribute to enriched algae growth around the mouth of the creek. Chloride concentrations were generally found to increase in the downstream reaches, particularly below the influence of Highway 97. E Coli concentrations varied widely along the creek and were found to be extremely high in samples obtained near Bering Road.

5.3 EXISTING SYSTEM DEFICIENCIES

Creek Restoration – Witt Road to Okanagan Lake

As noted above, the rapid runoff and steep channel gradients along Smith Creek have resulted in severe channel erosion within the section between Witt Road and Okanagan Lake. In some locations, it appears as though the down cutting is approaching depths of 6 to 8ft. As a result, the adjacent banks are experiencing stability problems as evidenced with the sloughing and movement cracks in Gellatly Road. Channel restoration options such as pool and riffle stream re-construction and slope reinforcement should be considered to implement more natural stream conditions. In some channel segments, more traditional armoring restoration may be required however; the preferred alternatives would include a reinstatement to natural channel conditions as much as possible. Considering the overall impact on the adjacent roadways and nearby houses, plus the water quality concerns as Smith Creek outlets into Okanagan Lake, this project should be considered as a High Priority project.

Drainage easement – Doucette Drive

Overland flow along Doucette Drive will travel towards the south west limit of Doucette Drive. Excess flow will travel across private property, to the south of Doucette Drive, towards Elliot Road. Since this route will receive runoff from municipal facilities, a drainage easement should be established. Project 5.2 recommends establishment of a protected drainage easement for overland flow.

Stream Stabilization – Smith Creek

The steep grades and peak flows in the upper sections of the creek yield erosive velocities over much of the creek corridor. A comprehensive creek stabilization plan is recommended within the creek to stabilize the outlet locations, and stream banks. The stream stabilization project has been identified as Project 5.3. Wherever possible pool and riffle stream re-construction, and natural back stabilization techniques such as live staking, boulder cross-vanes res-vegetating. The work should be completed in phases to minimize the amount of disturbance at any one time, and to allow for vegetation to become established prior to exposing additional areas.

Considering the extent of the creek corridor and magnitude of the potential stabilization works, it is recommended that the District complete a detailed assessment and stabilization plan that can be implemented over a longer period of time. Local community groups and residents can prove to be valuable team members and an excellent resource for implementing low cost stream stabilization and restoration plans. The long term watershed and stream restoration plan should involve local residents and community organizations to strengthen project support and fully utilize the resources within these organizations.

Drainage Easement – Bridlehill Road

In review of the existing topography and drainage routes, a significant portion of the existing roadways and developed areas will drain towards the south end of Bridlehill Road. There is an existing 600 mm pipe in this area to convey the flow towards Smith Creek. Flows in excess of the pipe capacity will travel overland, across the existing agricultural areas. It is not known if a drainage easement exists across this property. If an easement is not in place, then it is recommended that the District seek to obtain an easement for the overland flow route. This easement is presented as Project 5.4.

Storm Sewer Upgrades – Bridlehill Road

Based on the modeled 1 in 5 year design storm, the existing 250 mm pipes on Wildhorse Drive and Bridlehill Road do not have capacity to convey the design flow rates. Although the existing condition does not meet the desired standards for conveying the 5 year design flow rate, the depth of surcharge is not expected to reach the ground surface. This deficiency has been noted as Project 5.5.

Detention Area – Rubican Road

Based upon the available as-built information and hydrologic modeling, the peak flow rates within the storm drainage system at the discharge point near Rubican Road are in the range of 800 L/S and 2100 L/S for the 5 year and 100 year return periods,

respectively. The contributing area of the single family development is approximately 60 ha. In comparison to undeveloped areas, the single family urban development results in significant increases in the peak flow rate for the downstream reaches. The peak flow rates increase from the upstream flows of 77 L/s and 417 L/s for the same recurrence intervals as estimated at the upstream end of Smith Creek Road. Based on preliminary reviews, the provision of approximately 4000 m^3 of detention storage would permit a reduction in peak flow rates to approximately 100 L/s for the 100 year recurrence interval and 20 L/s for the 5 year.

To mitigate the rapid runoff rate from the developed areas, it is recommended that a stormwater detention facility be constructed in the vicinity of Rubican Road, prior to outletting the flow into Smith Creek. The proposed detention facility has been presented as Project 5.6.

In addition to the constructed detention area, we also suggest that the District introduce some Low Impact Development retro-fits within this single family neighbourhood. These LID initiatives may include items such as rainwater barrels and rain gardens that capture the runoff closer to the source, rather than collecting and storing it in the downstream areas.

5.4 FUTURE DEVELOPMENT AREAS

Upper Smith Creek

As shown on Figures 5.11 through 5.13, there is a substantial amount of future development area situated above the existing Smith Creek developments. Considering the potential downstream impacts, and current downstream channel stability problems, it is imperative that future developments incorporate the latest technologies for reducing the impacts of urban developments. Staged release rates are recommended within new development areas to make the most effective use of available storage and provide maximum benefit for the downstream areas. The estimate pre-development flow rates have been shown within Figures 5.11 to 5.13, based on the cursory review. A detailed and comprehensive storm water management plan is recommended to service this large developed area.

Brown Road

As indicated on Figure 5.14, there is a future development area shown to the east of Brown Road, south of Ingram Road. According to the District of West Kelowna, Official Community Plan, this area is designated as Core Center Multi-family. The downstream drainage network within this area is not well defined and generally includes overland

flow within the shallow roadside swales and shoulder areas. Based on existing conditions, the pre-development flow is estimated to be in the range of 5L/s for a 1 in 5 year storm.

Majoros Road

As shown on Figure 5.14, there is a future development area to the south of Majoros Road. This development area is immediately adjacent to Smith Creek and as such should maximize the potential to provide water quality improvements. If possible, direct discharge into Smith Creek should be avoided, and Low Impact Development techniques should be employed in as much as possible.

5.5 RECOMMENDED IMPROVEMENTS

Based on the review of the existing drainage network and estimated flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 5.1.

Table 5.1 – Improvement Projects for Existing Deficiencies
Smith Creek Drainage Basin

Project	Priority	Description	Cost Estimate
5.1	High	Creek Restoration	$647,500
5.2	Low	Drainage Easement – Doucette Drive to Elliot Road	-
5.3	Medium	Stream Stabilization	$668,250
5.4	Low	Drainage Easement – Bridlehill Road to Rubicon Road	-
5.5	Low	Storm Sewer – Copper Ridge to Wild Horse Drive	$46,600
5.6	High	Construct detention storage- Rubicon Road	$359,500

Table 5.2
Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
1	SCJ-11	370.8	Trapezoidal	300		185	619
SCD-1	SCJ-159	52.3	Circular	300	6%	0	73
SCD-1	SCJ-159	53.2	Circular	250	6%	99	187
SCJ-1	SCJ-5	165.3	Trapezoidal	600	4%	893	**1720**
SCJ-10	SCO-10	237.5	Trapezoidal	300	7%	66	66
SCJ-101	SCJ-102	91.7	Circular	900	1%	496	563
SCJ-102	SCJ-94	46.5	Circular	900	4%	496	563
SCJ-105	SCO-6	16.9	Circular	250	3%	19	47
SCJ-106	SCJ-105	46.0	Circular	250	4%	19	47
SCJ-11	SCJ-19	456.4	Trapezoidal	300	6%	46	154
SCJ-114	SCJ-115	36.9	Circular	250	3%	24	**82**
SCJ-115	SCJ-116	60.6	Circular	250	6%	82	**191**
SCJ-116	SCJ-117	52.4	Circular	250	7%	82	**188**
SCJ-117	SCJ-186	61.9	Circular	250	7%	89	**211**
SCJ-12	SCJ-27	586.9	Trapezoidal	300	8%	7	14
SCJ-121	SCJ-123	19.3	Circular	450	2%	29	108
SCJ-123	SCJ-124	38.3	Circular	450	10%	29	108
SCJ-124	SCJ-125	13.9	Circular	450	49%	29	108
SCJ-125	SCJ-126	31.9	Circular	450	7%	29	108
SCJ-126	SCJ-127	25.5	Circular	450	6%	29	108
SCJ-127	SCJ-128	57.3	Circular	450	9%	29	108
SCJ-128	SCJ-188	66.0	Circular	450	7%	29	108
SCJ-13	SCJ-18	395.3	Trapezoidal	300	7%	43	83
SCJ-133	SCJ-135	9.4	Circular	250	3%	19	54
SCJ-135	SCJ-137	55.8	Circular	250	7%	19	54
SCJ-137	SCJ-139	21.0	Circular	1000	18%	19	54
SCJ-139	SCJ-188	31.6	Circular	250	11%	19	54
SCJ-14	SCJ-15	207.4	Trapezoidal	300	5%	90	324
SCJ-148	SCJ-149	2.7	Circular	250	1%	23	59
SCJ-149	SCJ-168	48.2	Circular	200	9%	23	59
SCJ-15	SCO-2	2.6	Trapezoidal	300	20%	206	**1036**
SCJ-153	SCJ-148	73.3	Circular	250	6%	24	60
SCJ-159	SCJ-160	102.6	Circular	600	4%	264	751
SCJ-16	SCJ-33	119.1	Trapezoidal	300	1%	117	**196**
SCJ-160	SCJ-161	90.9	Circular	1000	1%	263	751
SCJ-161	SCJ-182	5.0	Circular	600	2%	262	751
SCJ-162	SCJ-163	13.4	Circular	900	3%	564	1336
SCJ-163	SCJ-1	262.0	Trapezoidal	600	5%	797	2062
SCJ-168	SCJ-115	48.8	Circular	250	6%	40	**119**
SCJ-169	SCJ-176	56.8	Circular	1000	14%	49	133
SCJ-176	SCJ-187	47.6	Circular	250	18%	49	133

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SCJ-179	SCJ-159	78.5	Circular	450	1%	85	270
SCJ-18	SCJ-28	18.5	Circular	600	3%	64	387
SCJ-182	SCJ-163	4.6	Trapezoidal	300	14%	262	751
SCJ-185	SCJ-187	15.2	Circular	250	12%	0	27
SCJ-186	SCJ-201	52.8	Circular	250	7%	89	**203**
SCJ-187	SCD-1	110.1	Circular	250	11%	100	**251**
SCJ-188	SCJ-189	6.9	Circular	450	2%	75	**226**
SCJ-189	SCJ-192	40.1	Circular	250	4%	75	226
SCJ-19	SCO-3	12.2	Trapezoidal	300	21%	380	**898**
SCJ-192	SCJ-193	22.0	Circular	450	15%	74	226
SCJ-193	SCJ-194	34.4	Circular	450	4%	75	226
SCJ-194	SCJ-195	41.2	Circular	450	4%	74	226
SCJ-195	SCJ-198	35.0	Circular	450	3%	86	270
SCJ-198	SCJ-199	51.3	Circular	450	1%	86	270
SCJ-199	SCJ-179	30.5	Circular	450	0%	86	270
SCJ-20	SCJ-21	18.4	Circular	900	12%	77	374
SCJ-201	SCJ-202	19.3	Circular	250	8%	89	**199**
SCJ-202	SCJ-204	49.3	Circular	250	7%	89	**196**
SCJ-204	SCJ-205	54.2	Circular	250	7%	89	**195**
SCJ-205	SCJ-159	38.8	Circular	250	7%	94	**233**
SCJ-206	SCJ-207	45.5	Circular	250	5%	24	61
SCJ-207	SCJ-153	106.6	Circular	250	1%	24	60
SCJ-21	SCJ-211	257.1	Trapezoidal	300	12%	76	374
SCJ-211	SCJ-217	8.8	Circular	900	1%	78	376
SCJ-212	SCJ-89	45.9	Trapezoidal	300	10%	105	523
SCJ-213	SCJ-215	27.4	Circular	250	5%	49	**161**
SCJ-214	SCJ-225	28.2	Circular	250	6%	0	0
SCJ-215	SCJ-216	52.0	Circular	250	2%	49	**161**
SCJ-216	SCJ-217	7.0	Circular	250	1%	49	161
SCJ-217	SCJ-212	6.3	Circular	900	1%	105	523
SCJ-22	SCJ-23	21.7	Circular	800	9%	564	1337
SCJ-222	SCJ-187	43.7	Circular	250	1%	0	**87**
SCJ-224	SCJ-169	33.4	Circular	250	5%	14	35
SCJ-23	SCJ-162	108.6	Trapezoidal	500	9%	564	1337
SCJ-230	SCJ-231	55.3	Circular	250	3%	14	35
SCJ-231	SCJ-232	60.5	Circular	250	7%	14	35
SCJ-232	SCJ-233	57.5	Circular	250	7%	14	35
SCJ-233	SCJ-234	17.4	Circular	250	0%	14	35
SCJ-234	SCJ-224	45.6	Circular	250	30%	14	35
SCJ-24	SCJ-75	153.2	Trapezoidal	300	5%	**496**	**496**
SCJ-248	SCJ-213	20.6	Circular	250	13%	49	**212**
SCJ-25	SCJ-24	22.7	Circular	900	5%	505	505
SCJ-253	SCJ-254	11.0	Circular	400	19%	65	319
SCJ-254	SCJ-255	53.5	Circular	450	11%	65	319

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SCJ-255	SCJ-256	71.3	Circular	450	10%	65	319
SCJ-256	SCJ-257	25.1	Circular	450	8%	65	319
SCJ-257	SCJ-260	69.8	Circular	450	7%	155	550
SCJ-26	SCJ-15	223.3	Trapezoidal	300	4%	60	386
SCJ-260	SCJ-261	5.7	Circular	450	3%	155	550
SCJ-261	SCJ-267	5.4	Trapezoidal	300	1%	155	**358**
SCJ-266	SCJ-85	17.7	Circular	450	1%	284	423
SCJ-267	SCJ-268	47.2	Circular	500	9%	155	300
SCJ-268	SCJ-88	11.3	Circular	1000	32%	155	300
SCJ-27	SCJ-18	382.5	Trapezoidal	300	8%	26	55
SCJ-278	SCJ-288	113.0	Circular	375	6%	153	466
SCJ-28	SCJ-26	213.1	Trapezoidal	300	3%	65	388
SCJ-285	SCJ-286	23.4	Circular	250	1%	0	44
SCJ-286	SCJ-287	25.8	Circular	375	2%	180	447
SCJ-287	SCJ-76	40.1	Circular	375	5%	180	451
SCJ-288	SCJ-286	111.6	Circular	375	2%	153	**371**
SCJ-29	SCJ-30	286.4	Trapezoidal	300	5%	57	105
SCJ-299	SCJ-78	20.8	Circular	375	27%	180	450
SCJ-3	SCJ-4	498.1	Trapezoidal	300	3%	88	**337**
SCJ-300	SCJ-302	117.3	Circular	250	1%	30	**80**
SCJ-301	SCJ-308	26.9	Circular	1000	1%	0	5
SCJ-302	SCJ-303	88.6	Circular	250	1%	29	**80**
SCJ-303	SCJ-304	99.9	Circular	250	4%	29	80
SCJ-304	SCJ-80	9.0	Circular	450	3%	284	766
SCJ-308	SCJ-309	10.6	Circular	300	10%	97	284
SCJ-309	SCJ-310	37.1	Circular	300	5%	97	284
SCJ-31	SCJ-32	188.2	Trapezoidal	300	3%	174	417
SCJ-310	SCJ-311	86.8	Circular	450	2%	97	284
SCJ-311	SCJ-312	58.4	Circular	300	22%	94	281
SCJ-312	SCJ-313	15.4	Circular	300	30%	91	278
SCJ-313	SCO-1	153.1	Trapezoidal	300	19%	91	278
SCJ-32	SCJ-33	161.5	Trapezoidal	300	1%	172	411
SCJ-33	SCO9	7.2	Trapezoidal	300	7%	248	607
SCJ-34	SCSU-1	10.2	Trapezoidal	300	5%	15	**283**
SCJ-4	SCJ-5	423.9	Trapezoidal	300	6%	84	396
SCJ-48	SCJ-92	445.7	Trapezoidal	300	4%	45	93
SCJ-49	SCJ-20	36.7	Trapezoidal	300	12%	77	374
SCJ-5	SCJ-6	61.8	Circular	900	6%	972	2253
SCJ-55	SCJ-70	137.7	Circular	675	6%	135	347
SCJ-57	SCJ-55	33.7	Circular	1000	7%	136	352
SCJ-58	SCJ-57	72.1	Circular	1000	2%	136	352
SCJ-59	SCJ-58	31.9	Circular	1000	5%	136	352
SCJ-6	SCJ-25	212.1	Trapezoidal	300	5%	**505**	**510**
SCJ-61	SCJ-11	30.7	Trapezoidal	300	6%	134	346

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SCJ-68	SCJ-69	30.6	Circular	1000	1%	134	347
SCJ-69	SCJ-61	19.5	Circular	1000	3%	134	347
SCJ-7	SCJ-10	36.2	Circular	300	1%	**66**	**66**
SCJ-70	SCJ-68	132.8	Circular	675	7%	134	346
SCJ-73	SCJ-97	97.4	Trapezoidal	300	11%	496	563
SCJ-74	SCJ-73	9.2	Circular	900	5%	496	564
SCJ-75	SCJ-74	21.9	Circular	900	9%	496	496
SCJ-76	SCJ-299	40.6	Circular	375	13%	180	450
SCJ-78	SCJ-79	28.0	Circular	375	12%	180	449
SCJ-79	SCJ-304	18.2	Circular	450	2%	180	452
SCJ-8	SCJ-9	63.1	Trapezoidal	300	5%	7	26
SCJ-80	SCJ-81	55.0	Circular	450	4%	284	**766**
SCJ-81	SCJ-82	22.8	Circular	450	6%	284	766
SCJ-82	SCJ-84	43.0	Circular	450	6%	284	**634**
SCJ-83	SCJ-19	690.2	Trapezoidal	300	9%	149	368
SCJ-84	SCJ-266	108.4	Circular	450	1%	284	**484**
SCJ-85	SCJ-86	124.2	Circular	450	1%	284	423
SCJ-86	SCJ-87	56.2	Circular	450	2%	284	423
SCJ-87	SCJ-88	15.2	Circular	450	3%	284	423
SCJ-88	SCJ-89	31.3	Circular	450	8%	436	722
SCJ-89	SCJ-22	298.9	Trapezoidal	500	9%	565	1339
SCJ-9	SCO-11	342.2	Trapezoidal	300	5%	50	191
SCJ-92	SCJ-93	37.6	Circular	250	1%	22	50
SCJ-93	SCJ-106	3.3	Circular	250	17%	19	47
SCJ-94	SCJ-95	100.9	Circular	900	2%	496	563
SCJ-95	SCO-4	62.4	Circular	900	5%	628	1062
SCJ-97	SCJ-98	28.0	Circular	900	4%	496	563
SCJ-98	SCJ-101	5.2	Circular	900	10%	496	563

Project 5.1 Creek Restoration – Smith Creek above Boucherie Road

Proposed Works:	Install erosion protection and stream bank stabilization along Smith Creek.
Implementation:	This work is considered a High priority, since the risk of property damage is high. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Highly erosive conditions in the open channel sections will continue and will further the risk of slope failure along Gellatly Road and the slopes below the residential area of Wetton Road.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	450	$1000	$450,000
Contingency (25%)				$112,500
Engineering (15%)				$85,000
Total Project Cost				**$647,500**

RSB ENGINEERING

Project 5.2 Obtain Drainage Easement – Doucette Drive to Elliot Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Doucette Drive to Elliot Road.
Implementation:	
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 5.3 Stream Stabilization – Smith Creek

Proposed Works:	Install erosion protection and stream bank stabilization along steeper sections of Smith Creek.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	

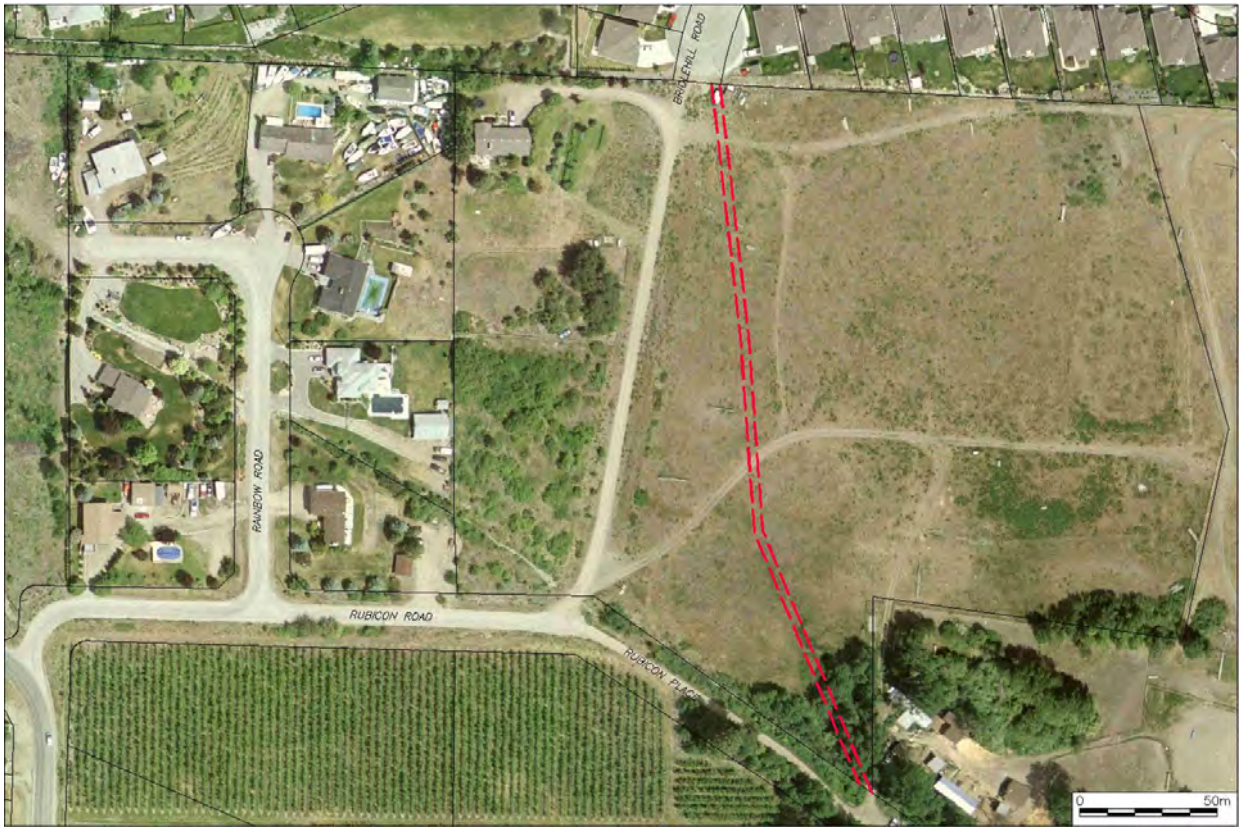


Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	1550	$300	$465,000
Contingency (25%)				$116,250
Engineering (15%)				$87,000
Total Project Cost				**$668,250**

RSB ENGINEERING

Project 5.4 Obtain Drainage Easement – Bridlehill Road to Rubicon Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Bridlehill Road to Rubicon Road.
Implementation:	Runoff from the upstream development areas flows overland enroute to Rubicon Road. The existence of a protected drainage easement or Right-of-Way is not known. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



Project 5.5 Storm Pipe Installation – Copper Ridge Drive to Wild Horse Drive

Proposed Works:	Install a short section of storm sewer pipe to interconnect Copper Ridge Drive and Wild Horse Drive.
Implementation:	This work is considered a Low priority, since the risk of flooding and property damage is low. The storm sewer pipes near the intersection of Wildhorse Drive and Bridlehill Road are near their hydraulic capacity.
Consequences if not completed:	The pipes along Bridlehill Road are at their hydraulic capacity and flow will surcharge above the pipe. Although the surcharge pipe conditions are not in conformance with District design criteria, it is not expected to reach the ground surface.
Priority:	3
Location:	



Description	Unit	Quantity	Unit Price	Total
600mm PVC	Lm	60	$375	$22,500
Boulevard Restoration	Lm	60	$100	$6,000
Break into Existing MH's	Ls	2	$2000	$4,000
Contingency (25%)				$8,100
Engineering (15%)				$6,000
Total Project Cost				**$46,600**

RSB ENGINEERING

Project 5.6 Construct Detention Storage – Rubicon Road

Proposed Works: Construct a storm water detention pond at Rubicon Road.

Implementation: Runoff from the upstream development areas flows unattenuated into the Smith Creek system. The increased flow rates from the urban development are contributing to increased peak flows in the creek, with a corresponding increase in creek erosion, and detrimental effects on water quality. This work is considered a High priority, since there is an increased risk of property and environmental damage downstream. .

Consequences if not completed: High runoff rates from the upstream urban development will contribute to erosive conditions in the downstream channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.

Priority: 1

Location:



Description	Unit	Quantity	Unit Price	Total
Storm Water Detention	LS	1	$250,000	$250,000
Contingency (25%)				$62,500
Engineering (15%)				$47,000
Total Project Cost				**$359,500**

RSB ENGINEERING

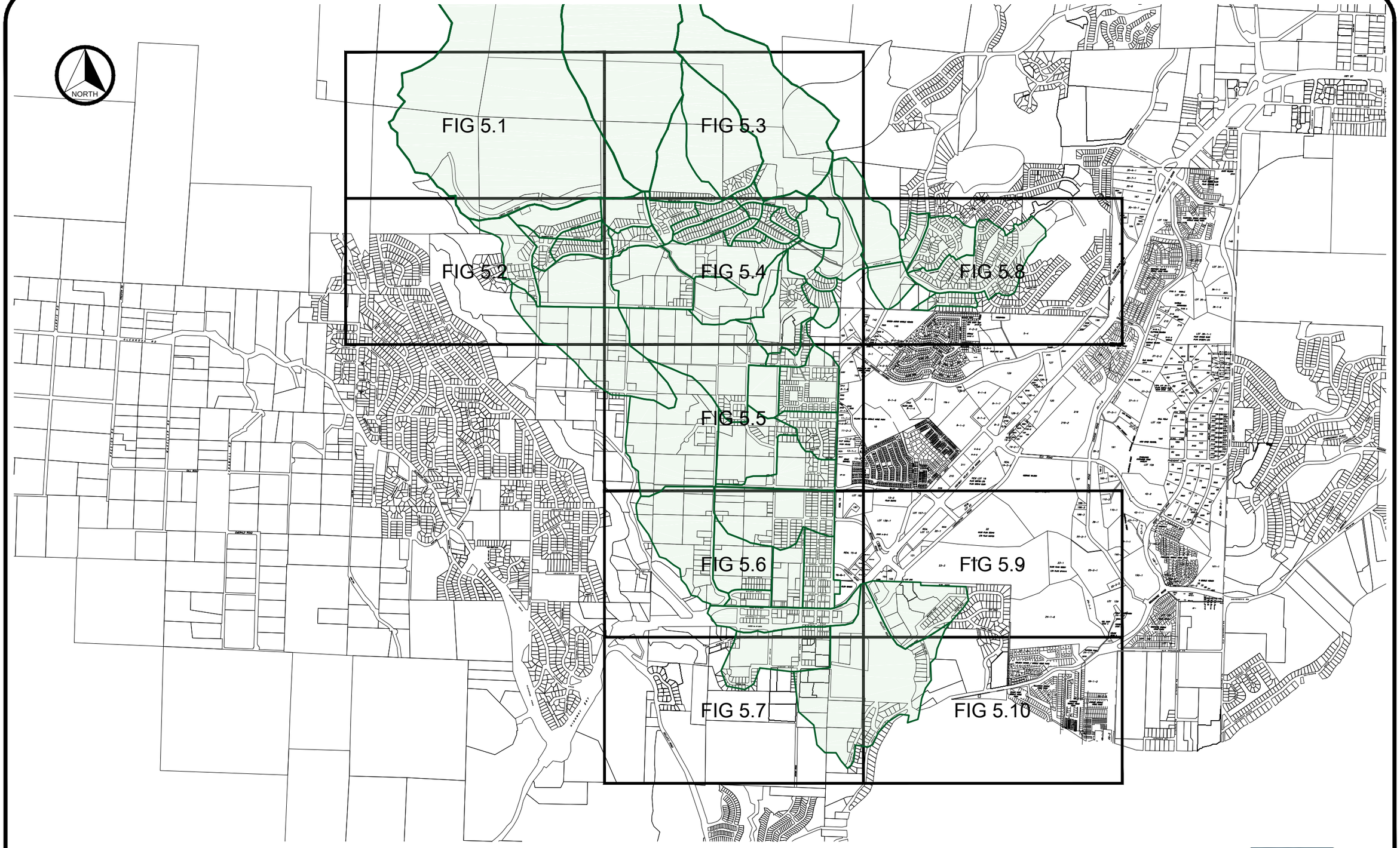
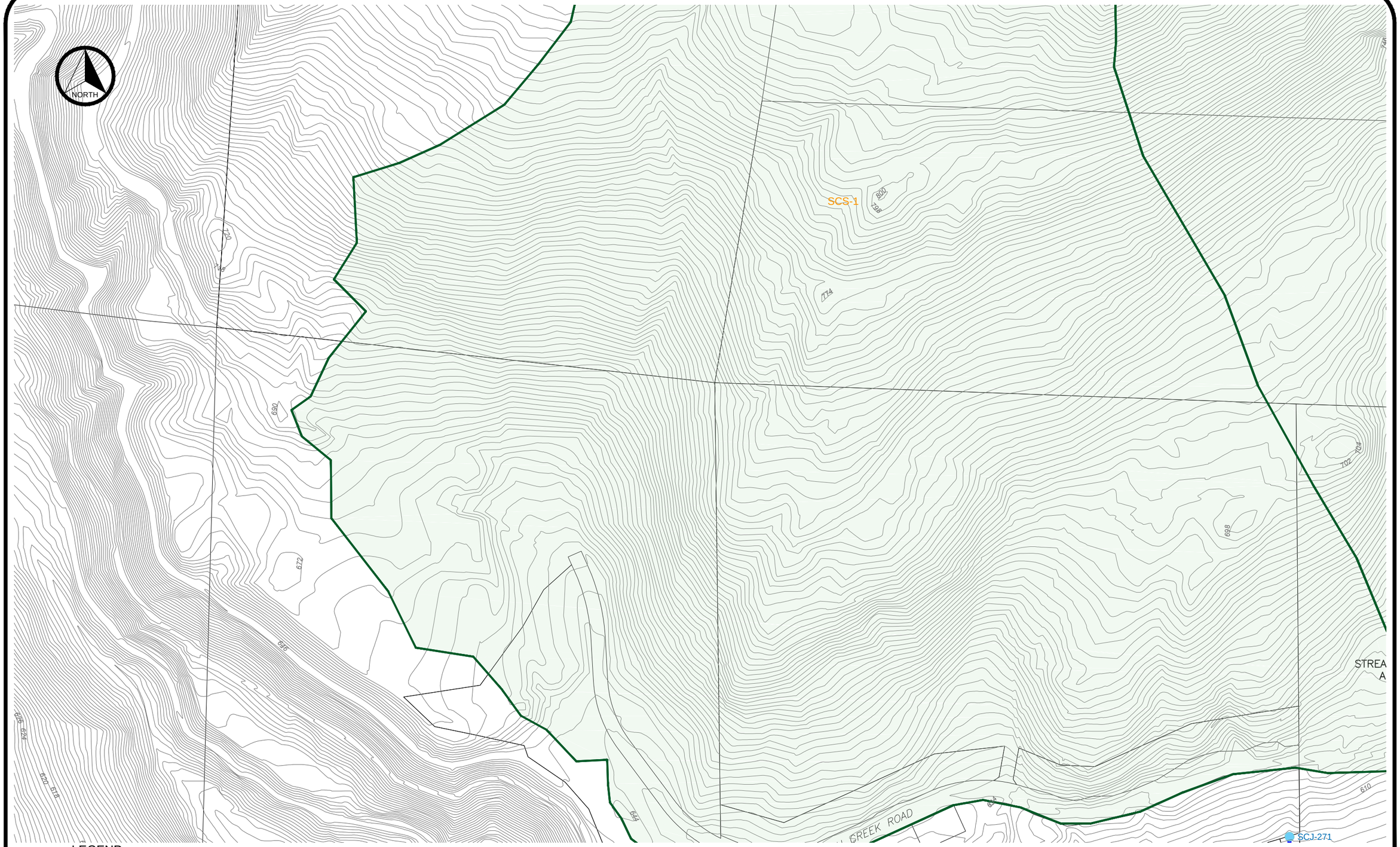


FIGURE 5.0
SMITH CREEK BASIN
KEY MAP
N.T.S.

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	5.1	5.3
	5.2	5.4

FIGURE 5.1
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

NO AS-CONSTRUCTED INFORMATION

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT 5.2

SMITH CREEK ROAD

SCS-34_2

SCS-4

SCS-16

SCJ-271 SCD-2 SCJ-281 SCJ-280 SCJ-273 SCJ-284 SCJ-283 SCJ-272 SCJ-285 SCJ-287 SCJ-76 SCJ-298 SCJ-299 SCJ-79 SCJ-82 SCJ-80 SCJ-304 SCJ-303 SCJ-302 SCJ-300 SCJ-291 SCJ-289 SCJ-292 SCJ-276 SCJ-274 SCJ-282 SCJ-294 SCJ-277 SCJ-293 SCJ-278 SCJ-288 SCJ-295 SCJ-286 SCJ-296 SCJ-297 SCJ-78 SCJ-2

DOUCETTE AVENUE
SUMMERVIEW COURT
SUMMERVIEW PLACE
DOUCETTE DRIVE
HAROLD ROAD
SANDBERG ROAD
TWIN PLACE
TELCOR PLACE
WEBBER ROAD
McIVER ROAD
COVENTRY CRES.
CANARY DRIVE
BLUE JAY DRIVE
McLEOD ROAD
McNAIR RD
McCLEOD ROAD
McCOY ROAD
McGEE ROAD
McMAHON ROAD
McGREGOR
STONEGATE RD
CORRAL RD
McMURCHIE

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	5.1	5.3
	5.2	5.4
		5.5

FIGURE 5.2
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

STREAM STABILIZATION AS PER PROJECT

5.3

EX. FENCE AROUND STORM INFRASTRUCTURE

STREAM STABILIZATION AS PER PROJECT

5.3

INTERCONNECT STORM SEWER AS PER PROJECT

5.5

POTENTIAL OVERLAND FLOW THROUGH PRIVATE PROPERTY (MAJOR STORM EVENT)

PIPE UNDER-CAPACITY FOR 1ME 1:5yr STORM CAPACITY IMPROVED BY PROPOSED PROJECT

5.5

SCS-6

SCS-8_1

SCS-35_3

SCJ-271 SCJ-253 SCJ-254 SCJ-226 SCJ-249 SCJ-255 SCJ-49 SCJ-20 SCJ-21 SCJ-227 SCJ-228 SCJ-229 SCJ-230 SCJ-281 SCJ-252 SCJ-232 SCJ-233 SCJ-210 SCJ-238 SCJ-239 SCJ-240 SCJ-241 SCJ-242 SCJ-243 SCJ-234 SCJ-237 SCJ-175 SCJ-224 SCJ-171 SCJ-173 SCJ-172 SCJ-207 SCJ-208 SCD-3 SCJ-209 SCJ-158 SCJ-146 SCJ-150 SCJ-151 SCJ-152 SCJ-147 SCJ-148 SCJ-149 SCJ-168 SCJ-115 SCJ-114 SCJ-113 SCJ-112 SCJ-116

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

5.1	5.3	
5.2	5.4	5.8

FIGURE 5.3
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

STREAM STABILIZATION AS PER PROJECT

5.3

POTENTIAL OVERLAND FLOW THROUGH PRIVATE PROPERTY (MAJOR STORM EVENT)

PIPE UNDER-CAPACITY FOR THE 1:5yr STORM CAPACITY IMPROVED BY PROPOSED PROJECT

5.5

SHOWN ORANGE PIPES SURCHARGE DURING THE 1:5yr STORM BUT MHs DO NOT OVERFLOW

PIPE UNDER-CAPACITY FOR THE 1:5yr STORM CAPACITY IMPROVED BY PROPOSED PROJECT

5.5

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT

5.4

INSTALL DETENTION POND AS PER PROJECT

5.6

STREAM STABILIZATION AS PER PROJECT

5.3

NO AS-CONSTRUCTED INFORMATION

DETENTION FACILITY NO AS-CONSTRUCTED INFORMATION

STREAM STABILIZATION

NORTH

RUBICON ROAD

ELLIOT ROAD

HAROLD ROAD

DEER RIDGE COURT

SHANNON LAKE ROAD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

5.1	5.3	
5.2	5.4	5.8
	5.5	

FIGURE 5.4
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

NO AS-CONSTRUCTED INFORMATION

DETENTION FACILITY NO AS-CONSTRUCTED INFORMATION

STREAM STABILIZATION AS PER PROJECT

NO AS-CONSTRUCTED INFORMATION

WETLANDS

NO AS-CONSTRUCTED INFORMATION

SCS-17 SCS-5_1 SCS-5_2 SCS-5_3 SCS-3_2 SCS-19

SCJ-166 SCJ-167 SCJ-25 SCJ-24 SCJ-324 SCJ-34 SCJ-325 SCJ-75 SCJ-72 SCJ-74 SCJ-73 SCJ-99 SCJ-100 SCJ-97 SCJ-98 SCJ-101 SCJ-107 SCJ-103 SCJ-102 SCJ-95 SCJ-96 SCJ-108 SCJ-48 SCJ-104 SCJ-94 SCJ-109 SCJ-12 SCJ-13 SCJ-92 SCJ-93 SCJ-106 SCJ-105 SCJ-27 SCJ-18 SCJ-28 SCJ-14 SCJ-26 SCJ-15

SCO-4 SCO-5 SCO-6 SCO-2

5.3

SCHARF ROAD · RUFLI ROAD · REECE ROAD · BROADVIEW ROAD · ELLIOTT ROAD · DEER RIDGE CRT. · SHANNON LAKE ROAD · OLD OKANAGAN HWY · ORLIN ROAD · CHIEFTAN ROAD · SMID ROAD · LOGAN CRT. · MARGARET ROAD · QUINCE ROAD · EVELYN RD · 25 MILE INDUSTRIAL

OLD OKANAGAN HWY MOBILE HOME PARK · VILLAGE GREEN MOBILE HOM · 3427 MOBILE · 3429 HOUSE · ERNIE MICHELL · LOT 220 · LOT 182

185 · 143 · 3255 B · 3255 C · 3255 A · 3255 D · 3–1 · 3301 · 3307 · 140 · 141 · 8–1–8 · 3313 · 3325 · 3345 · 3349 · 3355 · 11–1–1 · 11–2–3 · 11–2–5 · 11–2–6 · 11–2–7 · 11–2–8 · 3434 · 3436 · 13–1–1 · 81 · 3441 · 13–2 · 2330 · 10 · EM. 15

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	5.4	5.8
	5.5	
	5.6	5.9

FIGURE 5.5
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

SCS-20

SCS-21_1

SCS-21_2

NO AS-CONSTRUCTED INFORMATION

SCS-21_3

SCS-21_4

SCS-21_5

NO AS-CONSTRUCTED INFORMATION

SCS-22

SCJ-26

SCJ-15

SCO-2

SCJ-16

SCJ-33

SCO9

SCJ-31

SCJ-32

SCJ-30

SCJ-29

SCJ-90

SCJ-91

SCJ-54

SCJ-53

SCJ-59

SCJ-58

SCJ-56

SCJ-60

SCJ-55

SCJ-50

SCJ-52

SCJ-62

LOT 182

181

REM. 15

REM. 15-6

15-5-1

CLSR 69523

BERING ROAD

BROWN ROAD

BRENDALEE ROAD

GOSSET ROAD

DULKAY ROAD

DROUGHT ROAD

SOLAR ROAD

CHURCHILL ROAD

HIGHWAY No. 97 SOUTH

HIGHWAY No. 97 NORTH

DOBBIN ROAD

LAST ROAD

HEBERT ROAD

WINDT RD

ELLIS ROAD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	5.5	
	5.6	5.9
	5.7	5.10

FIGURE 5.6
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

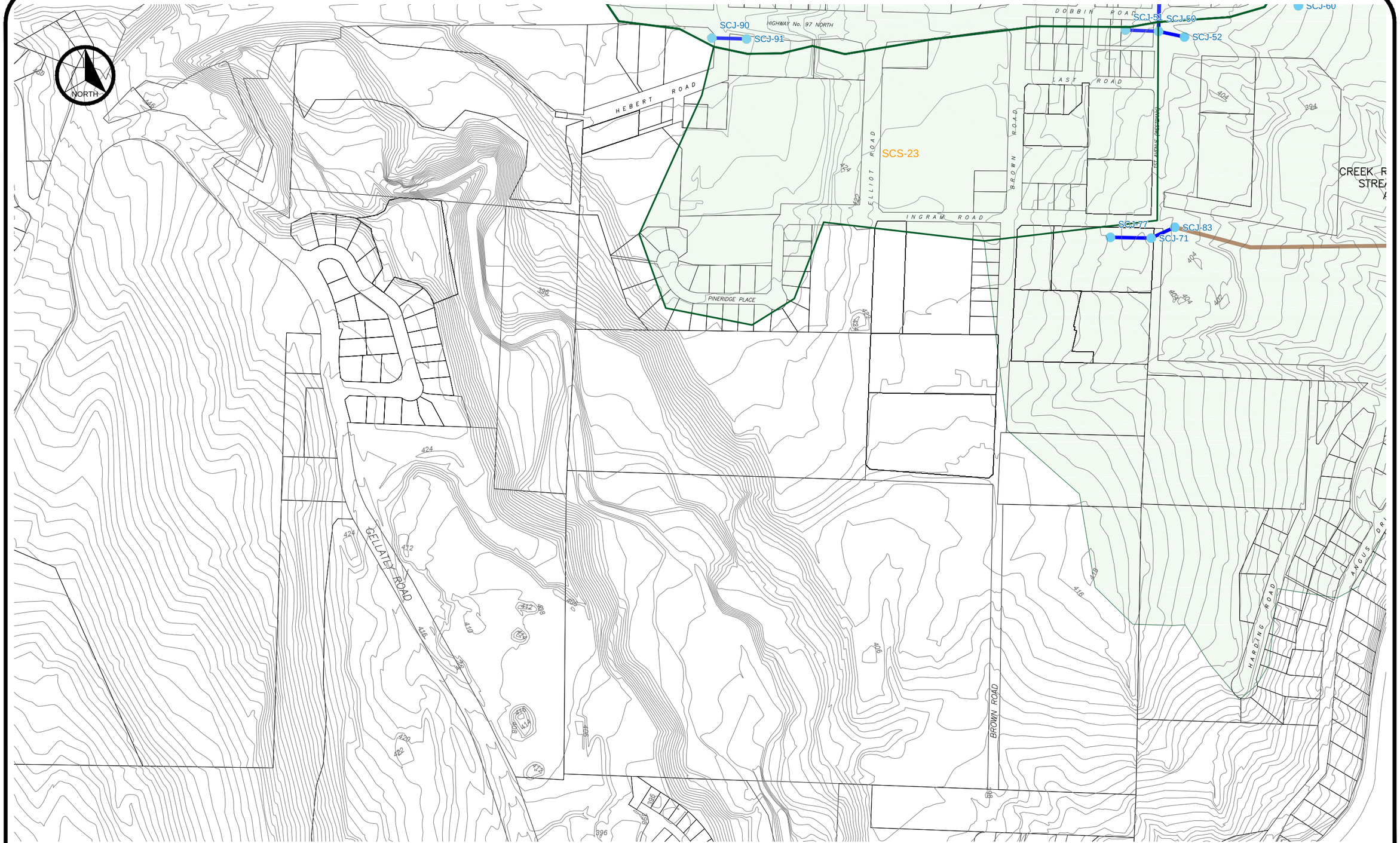
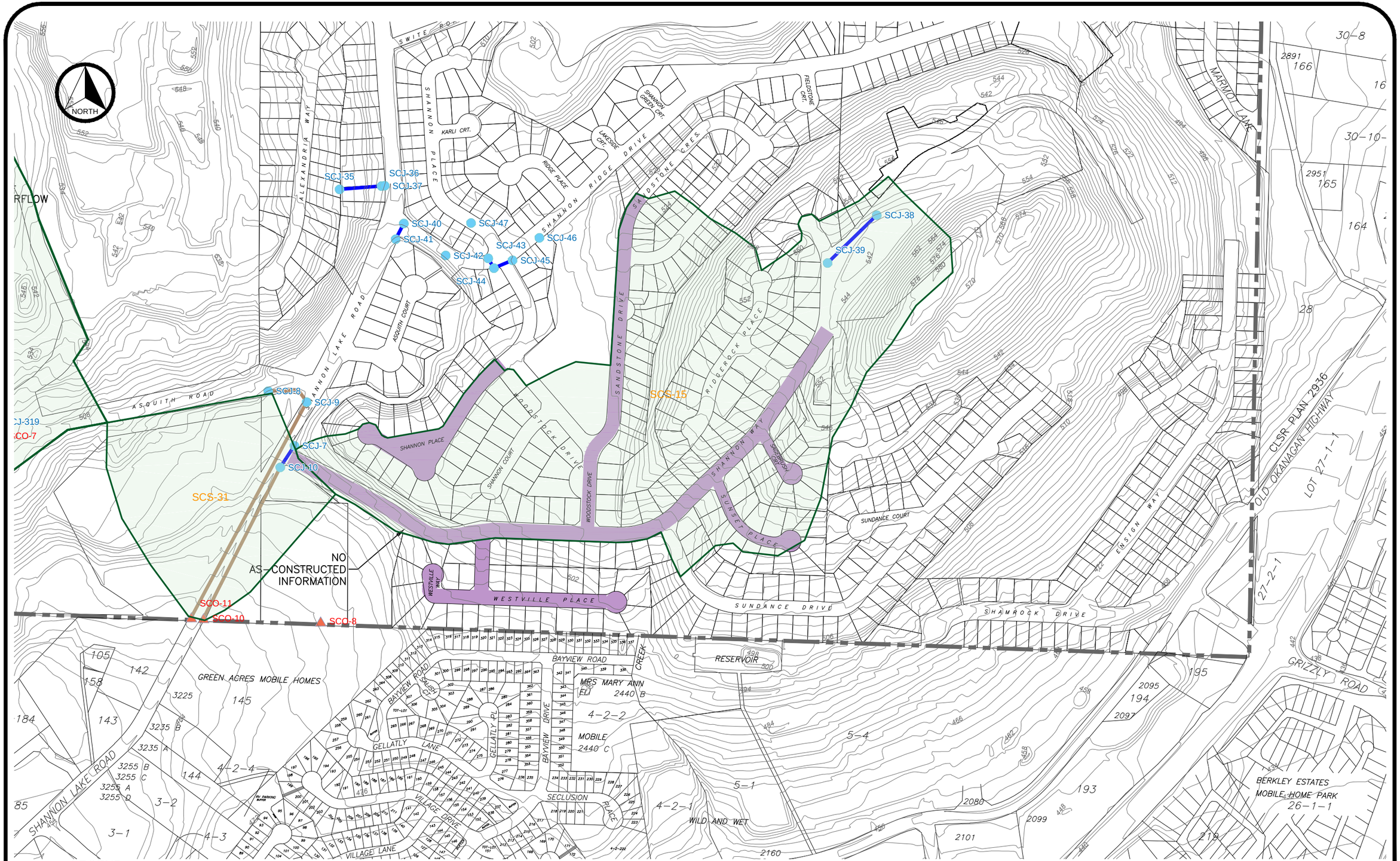


FIGURE 5.7
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



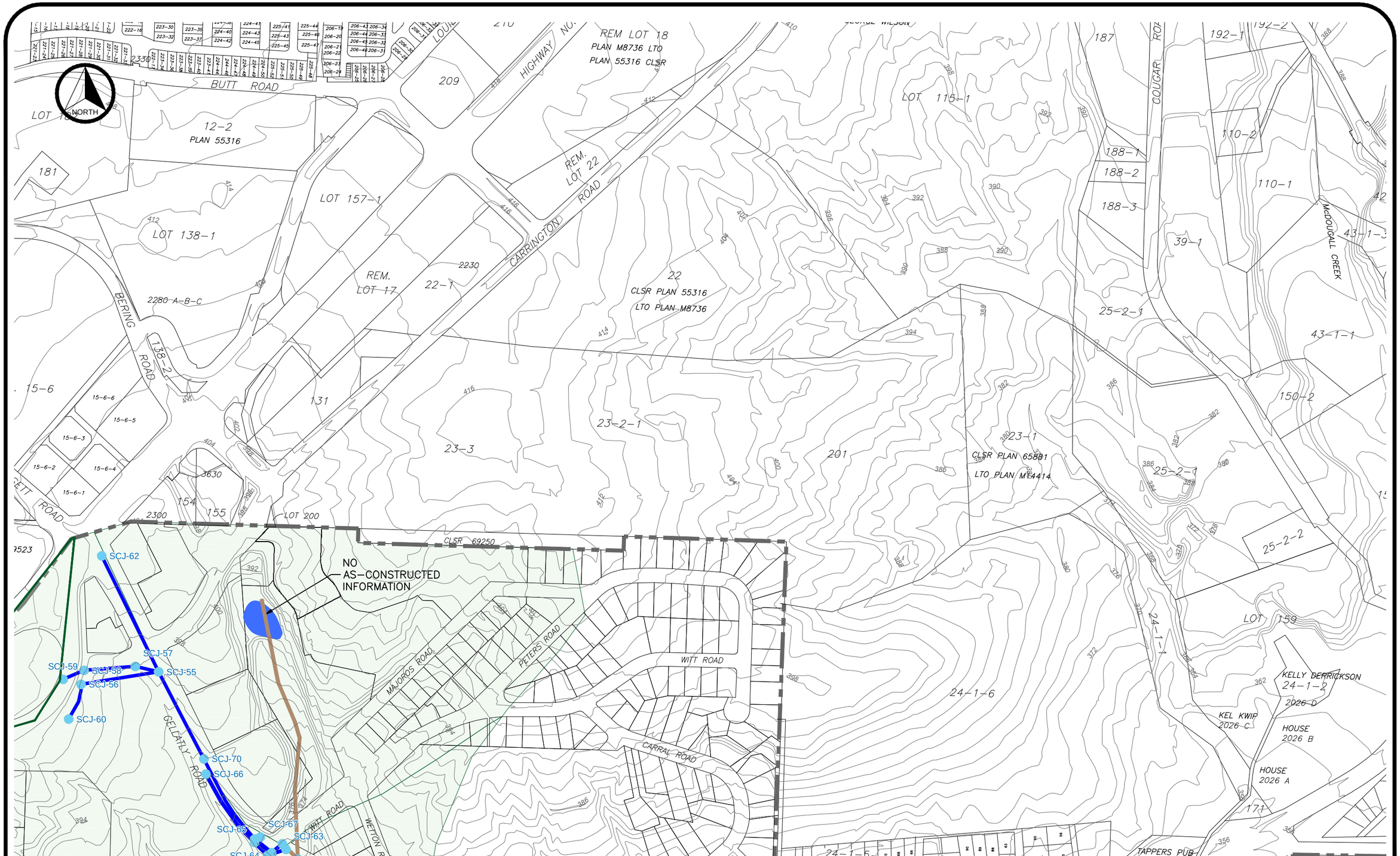
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

5.3		
5.4	5.8	
5.5		

FIGURE 5.8
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



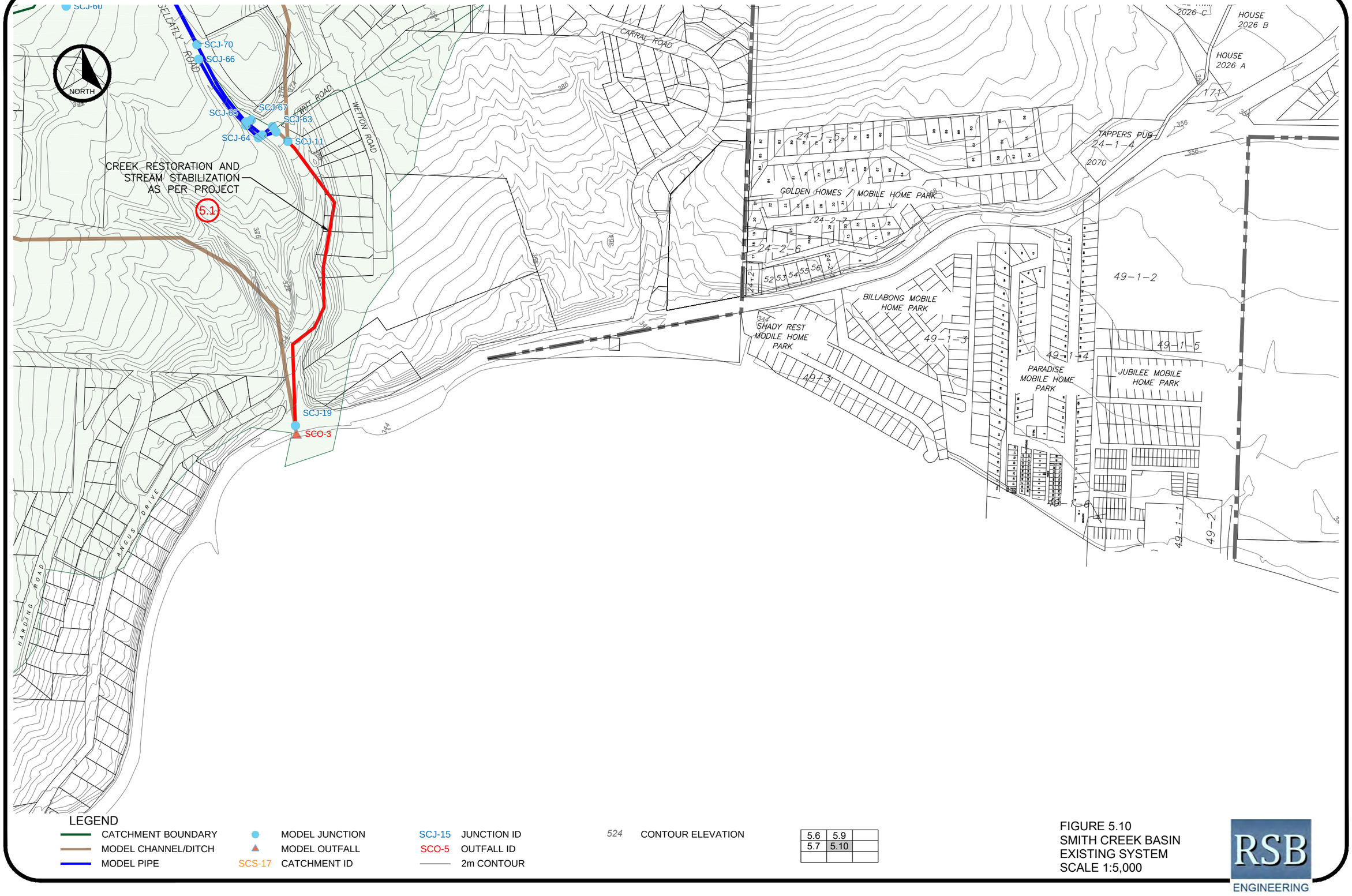
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

5.5		
5.6	5.9	
5.7	5.10	

FIGURE 5.9
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

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LEGEND

CATCHMENT BOUNDARY	MODEL JUNCTION	SCJ-15	JUNCTION ID	*524*	CONTOUR ELEVATION
MODEL CHANNEL/DITCH	MODEL OUTFALL	SCO-5	OUTFALL ID		
MODEL PIPE	SCS-17 CATCHMENT ID		2m CONTOUR		

5.6	5.9	
5.7	5.10	

FIGURE 5.10
SMITH CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 58.33 ha
Pre-development flow
Q_5=175 L/s
Post-development flows
Q_5=2803 L/s
Q_{100}=5371 L/s
Approx. Estimated
Required Storage: 9050m³

Area 37.09 ha
Pre-development flow
Q_5=111 L/s
Post-development flows
Q_5=1782 L/s
Q_{100}=3415 L/s
Approx. Estimated
Required Storage: 5755m³

Area 16.44 ha
Pre-development flow
Q_5=49 L/s
Post-development flows
Q_5=790 L/s
Q_{100}=1514 L/s
Approx. Estimated
Required Storage: 2551m³

Area 18.92 ha
Pre-development flow
Q_5=57 L/s
Post-development flows
Q_5=909 L/s
Q_{100}=1742 L/s
Approx. Estimated
Required Storage: 2934m³

Area 7.16 ha
Pre-development flow
Q_5=21 L/s
Post-development flows
Q_5=344 L/s
Q_{100}=659 L/s
Approx. Estimated
Required Storage: 1112m³

Area 2.75 ha
Pre-development flow
Q_5=9 L/s
Post-development flows
Q_5=132 L/s

SMITH CREEK ROAD

SCJ-271 SCJ-19 SCJ-20 SCJ-21 SCJ-226 SCJ-227 SCJ-228 SCJ-229 SCJ-230 SCJ-231 SCJ-232 SCJ-233 SCJ-234 SCJ-235 SCJ-237 SCJ-238 SCJ-239 SCJ-240 SCJ-241 SCJ-242 SCJ-243 SCJ-244 SCJ-245 SCJ-249 SCJ-250 SCJ-252 SCJ-253 SCJ-254 SCJ-255 SCJ-150 SCJ-151 SCJ-152 SCJ-148 SCJ-149 SCJ-153 SCJ-168 SCJ-207 SCJ-209 SCJ-210 SCJ-224 SCJ-169 SCJ-170 SCJ-171 SCJ-172 SCJ-173 SCD-208 SCD-3

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 5.11
SMITH CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

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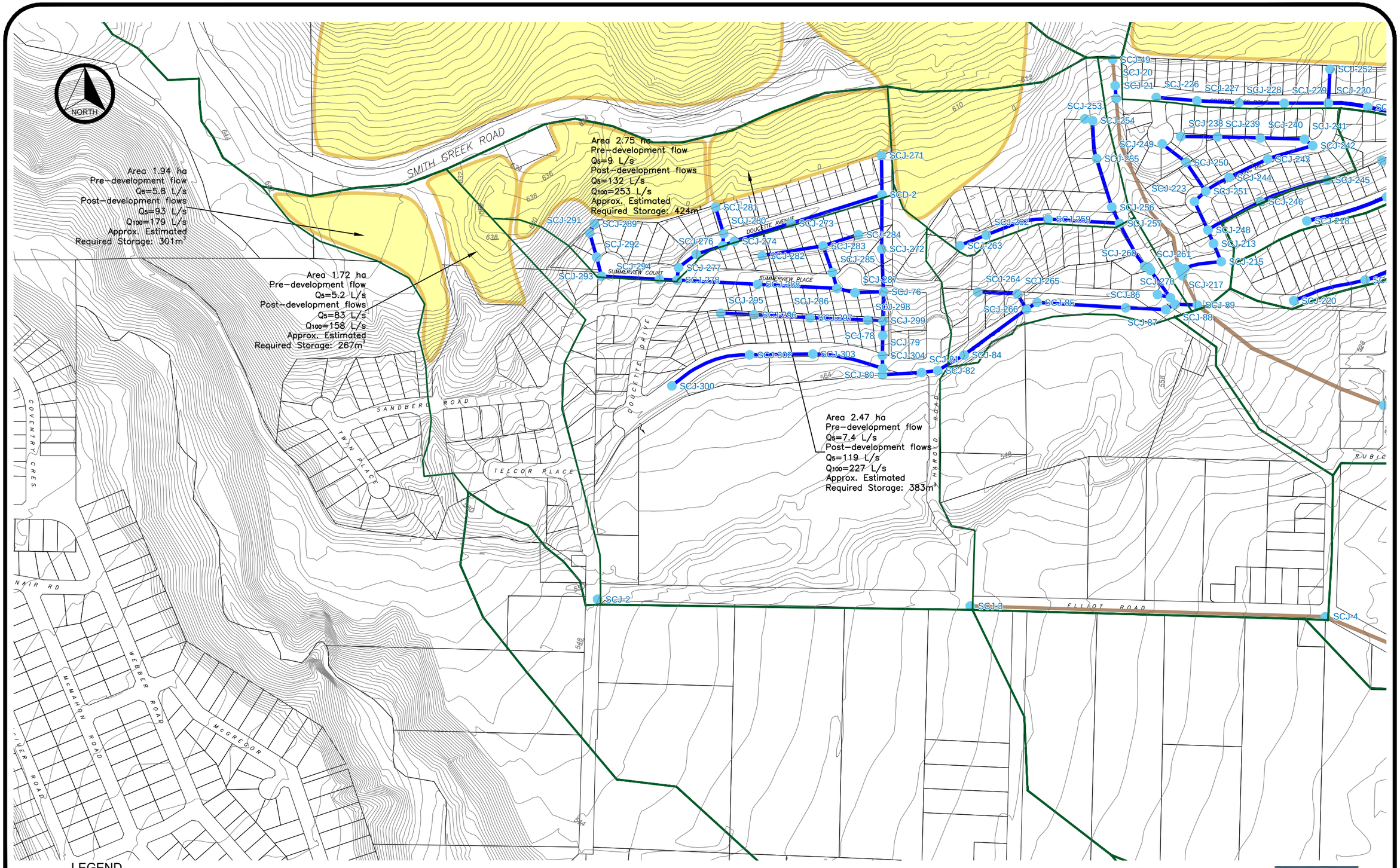


FIGURE 5.12
SMITH CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 7.16 ha
Pre-development flow
Q_5=21 L/s
Post-development flows
Q_5=344 L/s
Q_{100}=659 L/s
Approx. Estimated
Required Storage: 1112m³

Area 1.23 ha
Pre-development flow
Q_5=3.7 L/s
Post-development flows
Q_5=59 L/s
Q_{100}=113 L/s
Approx. Estimated
Required Storage: 191m³

Area 1.28 ha
Pre-development flow
Q_5=3.8 L/s
Post-development flows
Q_5=62 L/s
Q_{100}=118 L/s
Approx. Estimated
Required Storage: 199m³

Area 2.48 ha
Pre-development flow
Q_5=7.5 L/s
Post-development flows
Q_5=119 L/s
Q_{100}=228 L/s
Approx. Estimated
Required Storage: 385m³

Area 14.05 ha
Pre-development flow
Q_5=42 L/s
Post-development flows
Q_5=675 L/s
Q_{100}=1294 L/s
Approx. Estimated
Required Storage: 2180m³

Area 2.27 ha
Pre-dev. flow
Q_5=6.8 L/s
Post-dev. flows
Q_5=109 L/s
Q_{100}=209 L/s
Approx. Estimated
Required Storage: 352m³

Area 2.46 ha
Pre-dev. flow
Q_5=7.4 L/s
Post-dev. flows
Q_5=118 L/s
Q_{100}=227 L/s
Approx. Estimated
Required Storage: 382m³

Area 2.15 ha
Pre-dev. flow
Q_5=6.5 L/s
Post-dev. flows
Q_5=103 L/s
Q_{100}=198 L/s
Approx. Estimated
Required Storage: 333m³

Area 17.39 ha
Pre-development flow
Q_5=52 L/s
Post-development flows
Q_5=836 L/s
Q_{100}=1601 L/s
Approx. Estimated
Required Storage: 2698m³

SCJ-146 SCJ-150 SCJ-151 SCJ-147 SCJ-152 SCJ-208 SCD-3 SCJ-148 SCJ-209 SCJ-153 SCJ-149 SCJ-233 SCJ-210 SCJ-168 SCJ-232 SCJ-207 SCJ-234 SCJ-115 SCJ-114 SCJ-113 SCJ-112 SCJ-237 SCJ-224 SCJ-179 SCJ-116 SCJ-235 SCJ-169 SCJ-171 SCJ-172 SCJ-170 SCJ-183 SCJ-117 SCJ-132 SCJ-131 SCJ-111 SCJ-145 SCJ-136 SCJ-130 SCJ-118 SCJ-219 SCJ-176 SCJ-178 SCJ-144 SCJ-135 SCJ-133 SCJ-177 SCJ-184 SCJ-143 SCJ-129 SCJ-187 SCJ-186 SCJ-142 SCJ-185 SCJ-202 SCJ-190 SCJ-141 SCJ-134 SCJ-222 SCJ-201 SCJ-189 SCJ-120 SCJ-204 SCJ-188 SCJ-121 SCJ-221 SCJ-196 SCJ-193 SCJ-125 SCJ-122 SCJ-205 SCJ-198 SCJ-192 SCJ-128 SCJ-158 SCJ-200 SCJ-195 SCJ-194 SCJ-127 SCJ-126 SCJ-157 SCD-1 SCJ-159 SCJ-179 SCJ-199 SCJ-203 SCJ-212 SCJ-180 SCJ-225 SCJ-191 SCJ-236 SCJ-174 SCJ-247 SCJ-258 SCJ-269 SCJ-279 SCJ-317 SCJ-319 SCO-7 SCJ-305 SCJ-306 SCJ-290 SCJ-301 SCJ-318 SCJ-22 SCJ-23 SCJ-160 SCJ-162 SCJ-163 SCJ-182 SCJ-161

SCJ-35 SCJ-36 SCJ-37 SCJ-40 SCJ-41 SCJ-47 SCJ-43 SCJ-46 SCJ-42 SCJ-45 SCJ-44 SCJ-8 SCJ-9 SCJ-7 SCJ-10

SWITE ROAD
ALEXANDRIA WAY
SHANNON PLACE
KARLI CRT.
SHANNON GREEN CRT.
LAKESIDE CRT.
RIDGE PLACE
DRIVE
SHANNON RIDGE
SANDSTONE
SHANNON LAKE ROAD
ASQUITH COURT
ASQUITH ROAD
SHANNON PLACE
SHANNON COURT
SANDSTOCK DRIVE
RUBICON ROAD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SCS-17 CATCHMENT ID
- SCJ-15 JUNCTION ID
- SCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 5.13
SMITH CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

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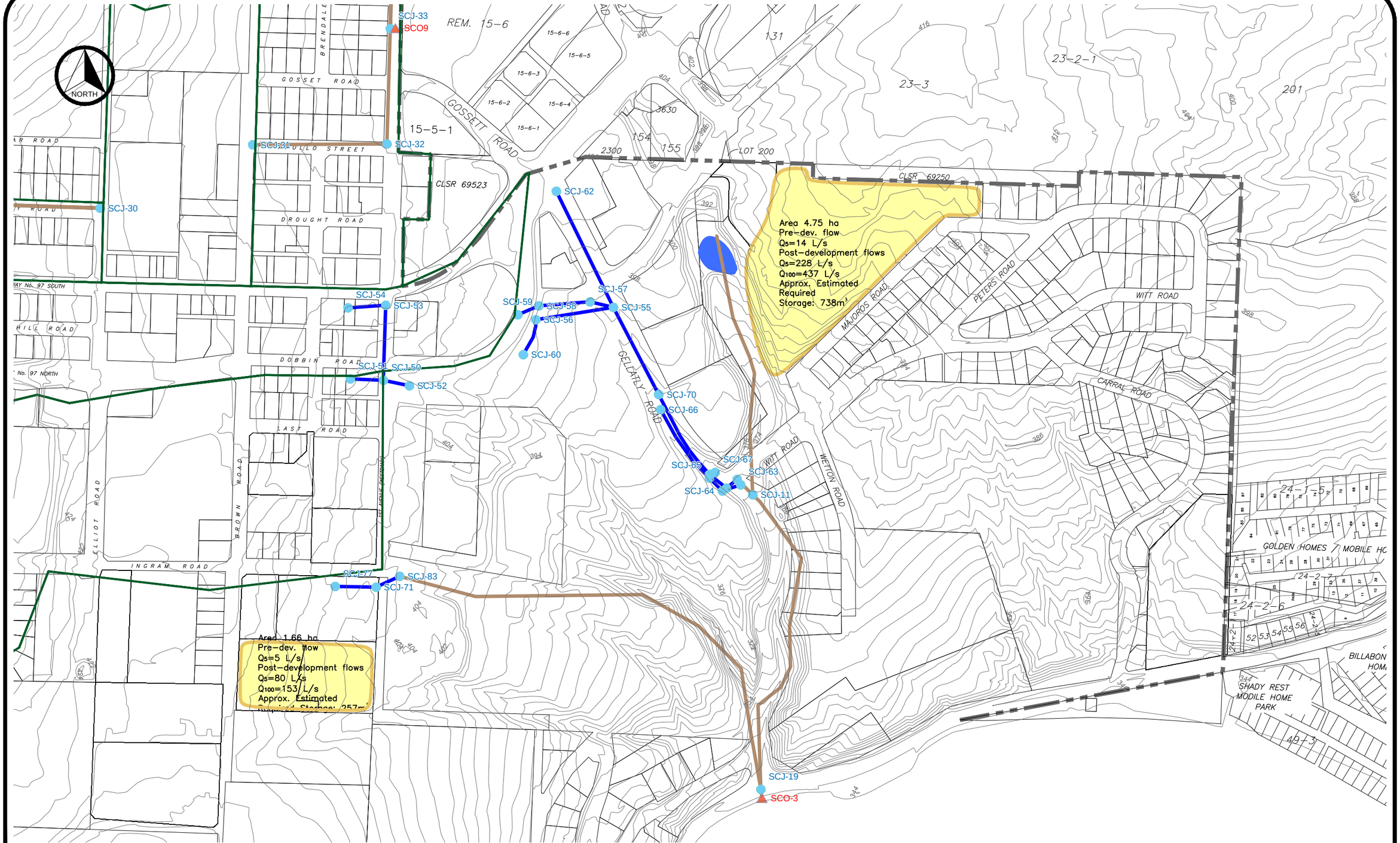


FIGURE 5.14
SMITH CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 6
SHANNON LAKE BASIN PLAN

6.1 BASIN DESCRIPTION

Shannon Lake is a small lake in central West Kelowna. The lake has a water level of elevation 502m, a surface area of 15 ha, and a depth up to 36m. This lake acts as a major "sink" as there is no gravity outlet (i.e. no pipe, watercourse or overland discharge). Normal water levels are controlled by the groundwater level and runoff into the lake is retained before it eventually evaporates or infiltrates.

Steep, forested hillsides to the north make up over 75% of the watershed. These steep slopes form the upper portion of the basin, which originates at the 1,403m elevation and slopes steeply at 25% until the 620m contour (approximate District Limits).

Between the 620m (+/-) contour and the lake, the basin's slope becomes moderate and in the range of 5-7%. Land-use in the lower catchment includes single-family residential lots and an 18-hole golf course that surround the lake. Community residents commonly use the lake for recreational fishing.

6.2 EXISTING SYSTEM ANALYSIS

The Shannon Lake catchment area contains a mix of single and multi-family developments, golf course property and undeveloped, forested areas within the upper reaches. The single-family development areas to the south of Shannon Lake are largely serviced with a series of non-interconnected drywells. As shown on the enclosed mapping of the existing system, the drywells are dispersed along the roadways and are intended to store and infiltrate the runoff from localized drainage areas. There are five known outlet locations on the south side of the lake and these have been shown on Figure 6.3. Within the residential areas to the north of Shannon Lake, the storm drainage system intercepts flow in Davidson Creek and conveys it through a piped system along Shannon Hills Place and discharges it overland east of Shannon Woods Way. This flow then re-enters the piped network on Shannon Woods Drive and is conveyed towards the outlet with the golf course, on the south side of Shannon Lake Road.

A stormwater detention facility was constructed in the north-west quadrant at the intersection of Shannon Lake Road and Shannon Woods Drive. This facility was constructed as a joint-use facility and also functions as a soccer/play field. The flow control/diversion structure was constructed to the north of the play field and consists of a 450 mm diversion pipe north of the detention area.

Flow in excess of the 250 mm pipe on Shannon Woods Drive would be directed to the detention area. Based upon the available as-built drawings, it appears as though the under-drain system is intended to serve as the primary disposal route during periods of inundation. The under-drain collection system is then connected to the downstream storm sewer at Shannon Lake Road.

A stormwater detention facility was recently constructed west of Shannon Lake Road, south of Lorne Road. This facility consists of a below-grade concrete tank and flow control structure to restrict the downstream flow rates to 61 L/s.

PCSWMM was used to estimate the stormwater runoff. The model nodes for the system are presented in Figures 6.1 through to 6.3. Runoff was estimated by simulating the 1 in 5 year and 1 in 100 year storms, with a 1 hour duration. The peak flow in the system is presented in Table 6.2. The peak flow rates have taken into consideration the anticipated drywell losses and infiltration. Note, the flows shown within Table 6.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

6.3 EXISTING SYSTEM DEFICIENCIES

Modify Existing Diversion Structure – Shannon Woods Crescent

As noted on Figure 6.1 the existing 250 mm pipes on Shannon Woods Way are subject to flows that exceed their hydraulic capacity. These pipes are connected to the Davidson Creek diversion system through the diversion structure situated between Shannon Woods Crescent and Shannon Hills Place. The diversion structure diverts the base flows from the 450 mm storm sewer into the existing 250 mm. Flows that exceed the capacity of the 250 mm diversion pipe would then overflow the weir and travel through the parallel 450 mm pipe and cross Shannon Woods Way to the east.

The storm sewer system on Shannon Woods Way has limited capacity due to the flatter grades. To alleviate this condition, it is recommended that the diversion structure be modified to restrict the flow within the 250 mm piped system, and utilize the capacity in the 450 mm pipes more frequently. This has been presented as Project 6.1.

Drainage Easement – Shannon Lake Golf Course

The existing storm drainage system is along Shannon Lake Road outlets on the south side of Shannon Lake Road, west of Golf Course Drive. Based on the available cadastral information, it is not apparent if the existing drainage corridor between the existing outlet and Shannon Lake is protected in a drainage easement. Project 6.2 recommends that the District ensure that the existing drainage route is protected within a drainage easement.

Drainage Easement – South of Shannon Lake

The existing drainage system contains four (4) outlet locations on the south side of Shannon Lake. Based on the available cadastral information, it is not apparent if these drainage outlets are protected in drainage easements. Project 6.3 recommends that the District confirm that these corridors are protected within drainage easements.

6.4 FUTURE DEVELOPMENT AREAS

West of Tallus Ridge Road

As shown on Figure 6.4, there is a substantial area of land intended for development within the slopes above and to the west of Tallus Ridge Drive and Tuscany Drive. The approximate development areas, as obtained from the Official Community Plan have been shown, although it is likely that the steep slopes may limit the overall developable areas. Within Figure 6.4, we have shown the estimated flow rates under existing and post-development conditions, based on a cursory review. Detailed stormwater management plans should be prepared for each area, and it is recommended that a broader, overall stormwater management plan be prepared to service these areas on a larger scale.

In considering the impacts to the downstream system, including Shannon Lake, it is recommended that Low Impact Development options be utilized where suitable to mitigate the increased flow rates and water quality concerns for inflow into Shannon Lake. Based on anecdotal reports, groundwater seepage problems and complainants tend to increase when water levels within Shannon Lake are at high levels. To minimize the overall increase in runoff, with the development of new impervious surfaces, it is recommended that new development areas incorporate methods such as rain gardens, infiltration strips and pervious surfaces.

Shannon View Drive

As shown on Figure 6.5, a future development area has been identified to the south of Shannon View Drive. This development area encompassed approximately 6 ha, although

the actual development area may be restricted due to rock or steep slopes. Runoff from the existing area is expected to flow to the north in the order of 18L/s for the 5 year storm. To reduce flows and impacts on downstream areas, a stormwater detention facility with a volume in the order of 935m^3 may be expected.

As with the remaining development parcels, it is recommended that Low Impact Development initiatives be used wherever possible to reduce the downstream impacts and sediment/nutrient loadings on Shannon Lake.

6.5 RECOMMENDED IMPROVEMENTS

Based on the review of existing drainage routes, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the associated costs are summarized in Table 6.1.

Table 6.1 –Improvement Projects for Existing Deficiencies
Shannon Lake Drainage Basin

Project	Priority	Description	Cost Estimate
6.1	Low	Modify Diversion Structure	$2,800
6.2	Low	Drainage Easement – Shannon Lake Golf Course	-
6.3	Low	Drainage Easement – South of Shannon Lake	-

Table 6.2
Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SLD-1	SLO-3	119.4	Circular	450	12%	0	125
SLD-1	SLJ-139	3.0	Circular	250	9%	70	206
SLD-2	SLJ-108	46.4	Circular	250	2%	89	96
SLD-2	SLJ-124	75.2	Circular	450	0%	151	404
SLJ-1	SLO-1	24.2	Circular	1000	4%	19	105
SLJ-100	SLJ-101	76.6	Circular	600	1%	238	741
SLJ-101	SLJ-102	71.1	Circular	600	3%	288	881
SLJ-102	SLO-2	33.3	Circular	600	5%	288	881
SLJ-104	SLJ-100	14.7	Circular	450	1%	109	430
SLJ-105	SLJ-93	18.4	Circular	250	5%	104	139
SLJ-106	SLJ-105	23.2	Circular	250	2%	6	38
SLJ-107	SLJ-105	118.4	Circular	250	2%	**102**	**124**
SLJ-108	SLJ-107	68.7	Circular	250	2%	112	**124**
SLJ-110	SLD-2	102.1	Circular	450	11%	219	432
SLJ-111	SLJ-110	58.3	Circular	450	10%	219	432
SLJ-112	SLJ-111	63.6	Circular	450	11%	219	432
SLJ-113	SLJ-112	52.5	Circular	300	2%	29	85
SLJ-117	SLJ-112	52.6	Circular	450	9%	193	350
SLJ-118	SLJ-117	63.6	Circular	450	14%	37	111
SLJ-119	SLJ-118	86.5	Circular	375	12%	37	111
SLJ-12	SLJ-3	51.7	Circular	250	11%	0	0
SLJ-120	SLJ-117	52.6	Circular	300	0%	134	**174**
SLJ-121	SLJ-108	71.2	Circular	250	3%	1	24
SLJ-124	SLSU-3	67.5	Trapezoidal	100	2%	200	553
SLJ-126	SLJ-119	97.4	Circular	375	11%	37	111
SLJ-128	SLJ-120	58.2	Circular	250	1%	**111**	**114**
SLJ-129	SLJ-128	78.9	Circular	250	1%	**96**	**106**
SLJ-135	SLJ-120	65.2	Circular	250	12%	23	68
SLJ-136	SLJ-135	54.3	Circular	250	11%	23	69
SLJ-139	SLJ-129	64.0	Circular	250	12%	81	236
SLJ-146	SLJ-150	39.3	Circular	450	12%	70	331
SLJ-148	SLJ-146	145.8	Circular	450	9%	70	331
SLJ-150	SLD-1	41.0	Circular	450	29%	70	331
SLJ-152	SLJ-139	35.2	Circular	250	20%	14	43
SLJ-155	SLJ-126	55.6	Circular	375	3%	38	111
SLJ-157	SLJ-148	76.2	Circular	450	8%	70	331
SLJ-161	SLJ-157	115.3	Circular	450	10%	70	331
SLJ-181	SLJ-182	28.8	Circular	250	2%	29	**145**
SLJ-182	SLJ-183	43.1	Circular	250	2%	29	**145**

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SLJ-183	SLJ-184	72.1	Circular	250	8%	29	145
SLJ-184	SLJ-185	50.3	Circular	250	7%	29	145
SLJ-185	SLJ-186	64.2	Circular	300	4%	29	146
SLJ-186	SLJ-187	68.5	Circular	300	2%	29	**155**
SLJ-187	SLJ-188	48.9	Circular	300	9%	95	**368**
SLJ-188	SLJ-192	35.4	Circular	300	21%	95	368
SLJ-190	SLJ-181	119.7	Circular	250	1%	0	**28**
SLJ-191	SLJ-190	76.1	Circular	250	1%	0	12
SLJ-192	SLJ-193	10.3	Circular	300	14%	95	**334**
SLJ-193	SLJ-194	25.9	Circular	300	3%	95	334
SLJ-194	SLSU-2	21.0	Circular	400	14%	95	334
SLJ-195	SLJ-196	119.2	Circular	375	1%	128	163
SLJ-196	SLJ-197	40.4	Circular	375	1%	129	**163**
SLJ-197	SLJ-198	72.6	Circular	375	0%	200	**315**
SLJ-198	SLJ-199	30.6	Circular	375	8%	198	315
SLJ-199	SLJ-200	11.4	Circular	375	5%	198	315
SLJ-200	SLJ-213	73.7	Circular	375	6%	198	315
SLJ-201	SLJ-204	18.1	Circular	400	5%	41	176
SLJ-202	SLJ-201	96.6	Circular	250	11%	41	176
SLJ-203	SLJ-202	105.8	Circular	250	11%	19	59
SLJ-204	SLJ-205	46.2	Circular	600	3%	79	292
SLJ-205	SLJ-104	150.9	Circular	600	1%	109	436
SLJ-211	SLJ-218	51.5	Circular	450	1%	197	334
SLJ-212	SLJ-211	81.0	Circular	375	2%	196	**334**
SLJ-213	SLJ-212	90.3	Circular	375	8%	198	336
SLJ-214	SLJ-195	20.3	Circular	300	0%	128	**162**
SLJ-215	SLJ-214	88.4	Trapezoidal	600	3%	131	465
SLJ-218	SLJ-219	6.1	Circular	450	1%	202	334
SLJ-219	SLJ-220	35.6	Circular	450	0%	209	334
SLJ-220	SLO-4	64.5	Circular	450	3%	200	334
SLJ-223	SLJ-224	22.6	Circular	375	2%	48	79
SLJ-224	SLJ-225	30.6	Circular	375	6%	48	79
SLJ-225	SLJ-197	15.4	Circular	450	7%	48	82
SLJ-226	SLJ-227	89.7	Circular	250	1%	0	**23**
SLJ-227	SLJ-228	58.5	Circular	250	1%	0	**36**
SLJ-228	SLJ-230	54.5	Circular	250	11%	85	**254**
SLJ-229	SLJ-228	62.2	Circular	250	3%	0	**27**
SLJ-230	SLJ-231	96.2	Circular	250	11%	85	**241**
SLJ-231	SLJ-215	79.7	Circular	300	3%	85	**241**
SLJ-240	SLJ-243	20.7	Circular	250	10%	51	165
SLJ-241	SLJ-240	7.2	Circular	250	160%	51	165
SLJ-242	SLJ-241	41.6	Circular	250	30%	51	165
SLJ-243	SLJ-101	15.4	Circular	250	16%	51	165

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
SLJ-5	SLJ-6	15.2	Circular	250	3%	2	15
SLJ-6	SLJ-211	35.5	Trapezoidal	300	7%	0	10
SLJ-66	SLJ-67	37.1	Circular	250	0%	1	7
SLJ-67	SLO-5	64.3	Circular	250	1%	10	66
SLJ-71	SLO-6	31.5	Circular	250	0%	47	136
SLJ-78	SLJ-79	61.8	Circular	250	0%	9	14
SLJ-79	SLO-7	44.6	Circular	250	4%	5	64
SLJ-93	SLJ-94	78.5	Circular	450	1%	104	250
SLJ-94	SLJ-95	46.4	Circular	450	1%	104	250
SLJ-95	SLJ-99	112.7	Circular	450	2%	104	250
SLJ-98	SLJ-100	98.4	Circular	450	3%	104	250
SLJ-99	SLJ-98	125.8	Circular	450	2%	104	250
SLO-3	SLJ-93	804.9	Trapezoidal	300	4%	0	119

Project 6.1 Modifications to Existing Diversion Structure – Shannon Hills Way

Proposed Works: Modify the existing diversion structure above Shannon Woods Way.

Implementation: The existing diversion structure allows for excess flow to enter the 250mm storm pipe on Shannon Woods Way. The surplus flow results in surcharging the existing storm pipe on Shannon Woods Way.

Consequences if not completed: Minor surcharging of the pipe system will occur.

Priority: 3

Location:



Description	Unit	Quantity	Unit Price	Total
Diversion Modifications	LS	1		$2,000.00
Contingency (25%)				$500.00
Engineering (15%)				$300.00
Total Project Cost				**$2,800.00**

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Project 6.2 Obtain Drainage Easement – Shannon Lake Golf Course

Proposed Works:	Establish a drainage easement or Right-of-Way over watercourse through Shannon Lake Golf Course.
Implementation:	An open watercourse flows through Shannon Lake Golf Course to Shannon Lake. It is not known if a registered easement or Right-of-Way exists for the drainage infrastructure and overland flow rate. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



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Project 6.3 Obtain Drainage Easement – Ridge Place to Shannon Lake

Proposed Works:	Establish a drainage easement or Right-of-Way from Ridge Place to Shannon Lake
Implementation:	Runoff discharges from Ridge Place and travels overland across private property to Shannon Lake. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



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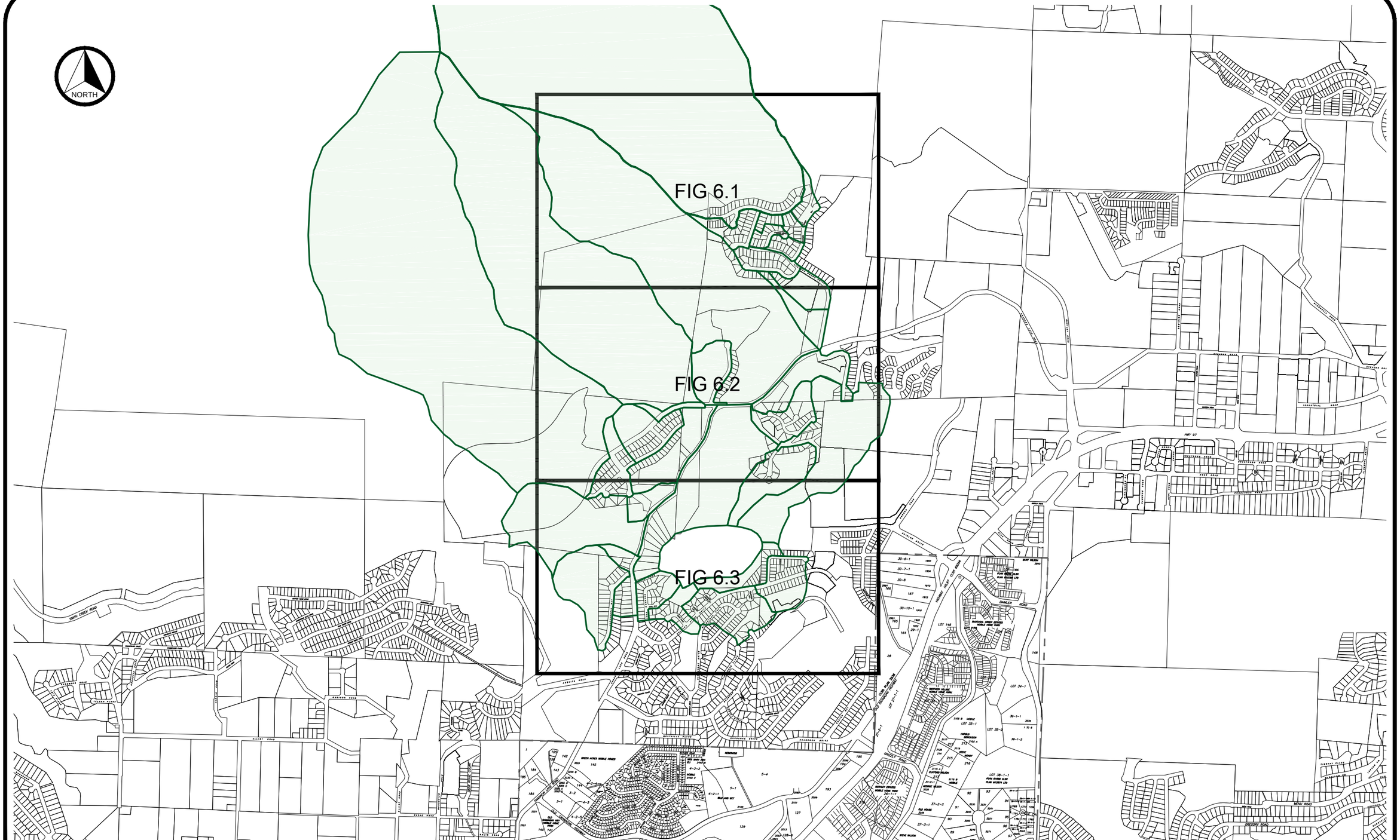


FIGURE 6.0
SHANNON LAKE BASIN
KEY MAP
N.T.S.

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NORTH

DAVIDSON CREEK

DAVIDSON CREEK INTAKE

MODIFY EX. DIVERSION AS PER PROJECT 6.1

DIVERSION STRUCTURE

ORANGE PIPES ARE UNDER-CAPACITY FOR THE 1:5yr STORM PROJECT 6.1 WILL CORRECT THIS DEFICIENCY

SLS-1 SLS-2 SLS-3 SLS-4 SLS-5 SLS-6 SLS-7 SLS-8 SLS-9 SLS-10 SLS-11 SLS-12 SLS-13 SLS-14

SLJ-166 SLJ-165 SLJ-164 SLJ-170 SLJ-160 SLJ-163 SLJ-161 SLJ-158 SLJ-159 SLJ-162 SLJ-169 SLJ-168 SLJ-157 SLJ-149 SLJ-148 SLJ-147 SLJ-154 SLJ-151 SLJ-156 SLJ-153 SLJ-167 SLJ-155 SLJ-125 SLJ-126 SLJ-119 SLJ-118 SLJ-116 SLJ-115 SLJ-114 SLJ-117 SLJ-112 SLJ-113 SLJ-111 SLJ-110 SLJ-144 SLJ-145 SLJ-146 SLJ-140 SLJ-150 SLJ-152 SLJ-143 SLJ-142 SLJ-136 SLJ-141 SLJ-135 SLJ-120 SLJ-132 SLJ-131 SLJ-130 SLJ-129 SLJ-128 SLJ-123 SLJ-127

SLD-1 SLD-2 SLO-3

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SLS-3 CATCHMENT ID
- SLJ-15 JUNCTION ID
- SLO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	6.1	
	6.2	

FIGURE 6.1
SHANNON LAKE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

SLJ-116
SLJ-115
SLJ-112
SLJ-114
SLJ-113
SLJ-111
SLJ-110
SLS-13
SLJ-123
SLD-2
SLJ-122
SLJ-127
SLJ-121
SLJ-108
SLJ-124
SLS-14
SLJ-107
SHOWN ORANGE PIPES SURCHARGE BUT MHs DO NOT OVERFLOW
SLJ-96
DETENTION FACILITY
SLJ-106
SLJ-105
SLJ-93
SLJ-83
SLJ-85
SLJ-86
SLJ-233
SLJ-94
SLJ-84
SLJ-235
SLJ-87
SLJ-232
SLJ-95
SLJ-88
SLJ-89
SLS-16
SLJ-99
SLJ-90
SLJ-97
SLJ-91
SLJ-234
SLJ-244
SLJ-98
SLJ-204
SLJ-92
SLJ-201
SLJ-205
SLJ-104
SLJ-202
SLJ-100
SLJ-209
SLJ-207
SLJ-101
SLJ-243
SLJ-242
SLS-17
SLJ-206
SLJ-241
NO AS-CONTRUCTED INFORMATION
SLJ-229
SLJ-208
SLJ-240
SLJ-228
SLJ-102
SLJ-209
SLJ-230
SLO-2
SLJ-227
SLJ-226
SLS-20
SLS-18
SLJ-231
SLJ-210
SLJ-191
SLS-21
SHOWN ORANGE PIPES SURCHARGE BUT MHs DO NOT OVERFLOW
SLJ-190
SLJ-189
SLJ-185
SLJ-215
SLJ-184
SLJ-186
SLS-24
SLS-23
OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT
SLJ-181
SLJ-183
SLJ-214
SLJ-182
SLJ-195
SLJ-187
6.2

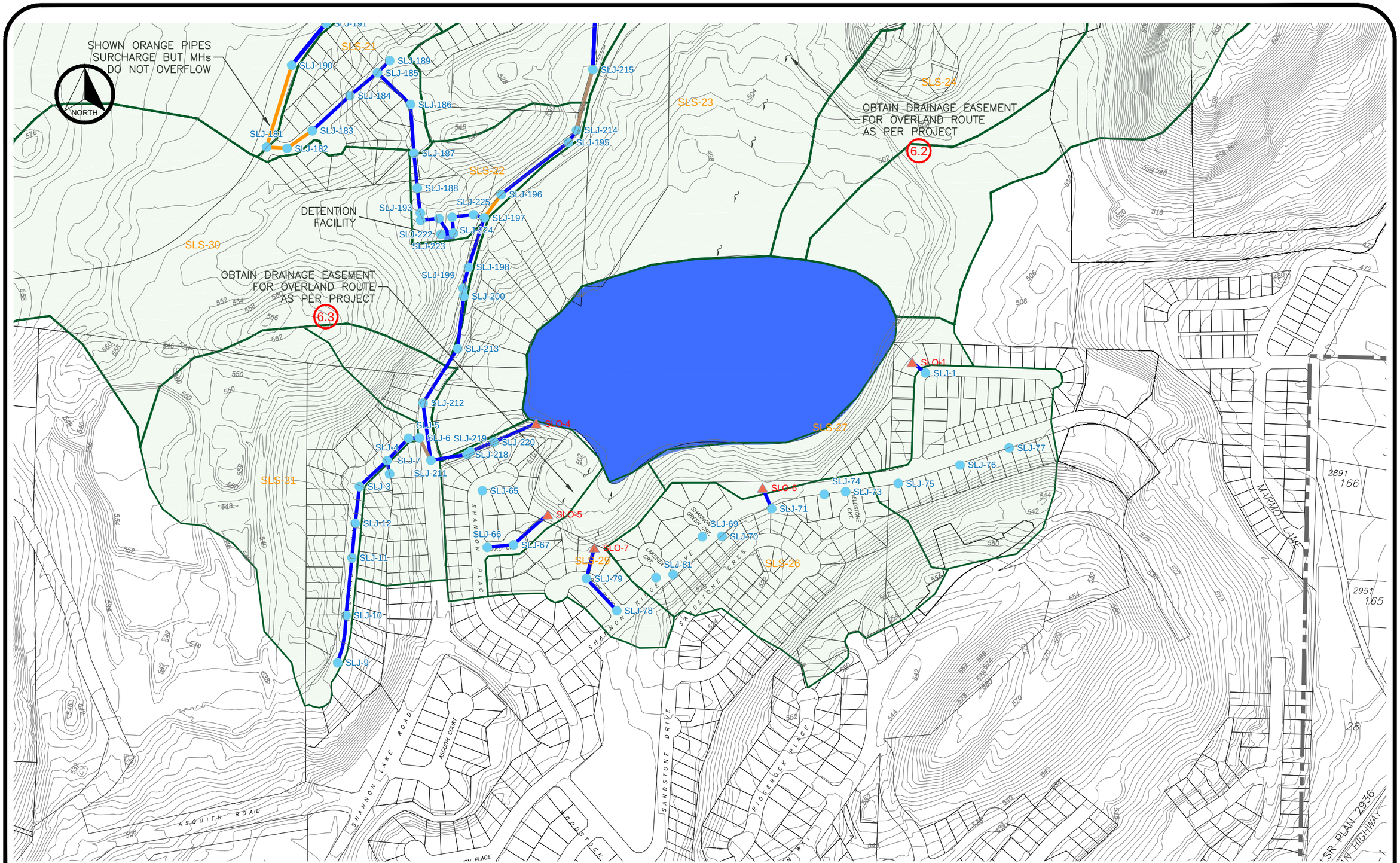
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SLS-3 CATCHMENT ID
- SLJ-15 JUNCTION ID
- SLO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	6.1	
	6.2	
	6.3	

FIGURE 6.2
SHANNON LAKE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SLS-3 CATCHMENT ID
- SLJ-15 JUNCTION ID
- SLO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	6.2	
	6.3	

FIGURE 6.3
SHANNON LAKE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 6.99 ha
Pre-development flow
Q_5=21 L/s
Post-development flows
Q_5=336 L/s
Q_{100}=644 L/s
Approx. Estimated
Required Storage: 1084m³

Area 6.50 ha
Pre-development flow
Q_5=20 L/s
Post-development flows
Q_5=312 L/s
Q_{100}=599 L/s
Approx. Estimated
Required Storage: 1007m³

Area 0.18 ha
Pre-development flow
Q_5=0.6 L/s
Post-development flows
Q_5=9 L/s
Q_{100}=17 L/s
Approx. Estimated
Required Storage: 28m³

Area 1.33 ha
Pre-development flow
Q_5=4 L/s
Post-development flows
Q_5=64 L/s
Q_{100}=122 L/s
Approx. Estimated
Required Storage: 207m³

Area 6.44 ha
Pre-dev. flow
Q_5=20 L/s
Post-dev. flows
Q_5=309 L/s
Q_{100}=593 L/s
Approx. Estimated
Required Storage: 997m³

Area 3.45 ha
Pre-development flow
Q_5=11 L/s
Post-development flows
Q_5=166 L/s
Q_{100}=318 L/s
Approx. Estimated
Required Storage:

Area 13.46 ha
Pre-development flow
Q_5=40 L/s
Post-development flows
Q_5=647 L/s
Q_{100}=1239 L/s
Approx. Estimated
Required Storage: 2089m³

SLJ-156
SLJ-167
SLJ-155
SLJ-125
SLJ-126
SLJ-116
SLJ-244
SLJ-204
SLJ-205
SLJ-104
SLJ-202
SLJ-201
SLJ-100
SLJ-208
SLJ-207
SLJ-229
SLJ-208
SLJ-228
SLJ-243
SLJ-240
SLJ-102
SLJ-209
SLJ-227
SLJ-230
SLO-2
SLJ-226
SLJ-210
SLJ-231

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SLS-3 CATCHMENT ID
- SLJ-15 JUNCTION ID
- SLO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 6.4
SHANNON LAKE BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

NORTH

Area 13.46 ha
Pre-development flow
Q5=40 L/s
Post-development flows
Q5=647 L/s
Q100=1239 L/s
Approx. Estimated
Required Storage: 2089m³

Area 3.45 ha
Pre-development flow
Q5=11 L/s
Post-development flows
Q5=166 L/s
Q100=318 L/s
Approx. Estimated
Required Storage: 533m³

Area 9.2 ha
Pre-development flow
Q5=28 L/s
Post-development flows
Q5=442 L/s
Q100=847 L/s
Approx. Estimated
Required Storage: 1426m³

Area 6.03 ha
Pre-development flow
Q5=18 L/s
Post-development flows
Q5=290 L/s
Q100=555 L/s
Approx. Estimated
Required Storage: 935m³

SLJ-90 SLJ-97 SLJ-234 SLJ-91 SLJ-92 SLJ-98 SLJ-244 SLJ-204 SLJ-201 SLJ-202 SLJ-205 SLJ-104 SLJ-100 SLJ-101 SLJ-243 SLJ-242 SLJ-241 SLJ-240 SLJ-102 SLO-2 SLJ-208 SLJ-207 SLJ-206 SLJ-229 SLJ-228 SLJ-209 SLJ-227 SLJ-230 SLJ-226 SLJ-231 SLJ-210 SLJ-191 SLJ-190 SLJ-189 SLJ-185 SLJ-215 SLJ-184 SLJ-186 SLJ-181 SLJ-183 SLJ-214 SLJ-195 SLJ-182 SLJ-187 SLJ-188 SLJ-193 SLJ-225 SLJ-196 SLJ-222 SLJ-224 SLJ-197 SLJ-223 SLJ-199 SLJ-198 SLJ-200 SLJ-213 SLJ-212 SLJ-6 SLJ-5 SLO-4 SLJ-219 SLJ-220 SLJ-211 SLJ-218 SLJ-4 SLJ-7 SLJ-3 SLJ-65 SLJ-12 SLJ-66 SLJ-67 SLO-5 SLO-7 SLO-6 SLJ-74 SLJ-73 SLJ-75 SLJ-71 SLJ-69 SLJ-70 SLJ-76 SLJ-77 SLO-1 SLJ-1

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- SLS-3 CATCHMENT ID
- SLJ-15 JUNCTION ID
- SLO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 6.5
SHANNON LAKE BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 7
MCDOUGALL CREEK BASIN PLAN

7.1 BASIN DESCRIPTION

With a watershed area of 4,770 ha, McDougall Creek has the second largest basin in the study area. Headwaters of the creek are derived from surface runoff from Carrot Mountain, Mount Hayman and Mount Swite. Summit elevations of all three mountains range from 1,420 m – 1,540 m with Carrot Mountain having the highest peak.

Over 80% of the watershed resides upstream (north) of the District Limits. The upper watershed has characteristics of a hanging valley – the watercourse centers a narrow, v-shaped ravine with multiple transverse gullies that contribute runoff. Topography is steep, rugged mountainside terrain with dense forest cover.

As McDougall Creek enters District Limits it parallels Bartley Road before crossing Shannon Lake Road, Byland Road, Highway 97 and entering Westbank First Nations land. The creek re-enters DWK property near Old Boucherie Road and Hitchner Road before its outfall to Okanagan Lake.

The watershed's lower reach, through DWK land, ranges in elevation from 342m to 600m. Stormwater contributing to the creek is from a mixture of residential, mobile home parks, and light commercial/industrial properties along Byland Road and Highway 97. McDougall Creek crosses multiple roadways in the District, all of which are bridge crossings.

7.2 EXISTING SYSTEM ANALYSIS

The McDougall Creek Basin contains a wide mix of piped drainage networks, roadside ditches and culverts. The more recent development areas to the east of Shannon Lake and within the Vineyard Drive developments contain piped systems and storm water detention facilities. The majority of these facilities include the use of large diameter pipes to provide underground detention storage, with a controlled release into the downstream systems.

The older development areas, such as those on the north side of Mount Boucherie, rely on overland flow routes, with undefined flow paths. Localized depression areas appear to capture much of the surface runoff during heavy rainfall events. It is anticipated that this would result in ponding of runoff within private property, especially during major storm or high runoff events.

Much of McDougall Creek traverses privately owned lands and the channel has been modified over much of its length. Modifications such as channelization, bank armouring and riparian vegetation removal is also extensive in lower stream sections.As noted within Section 12.3, five of the privately owned culverts along McDougall Creek were collapsed, and largely plugged with fines.

PC SWMM was used to estimate the stormwater runoff. The model nodes for the system are presented within Figures 7.1 through 7.10. Runoff was estimated by simulating the 1 in 5 year and 1 in 100 year storm events, with a 1 hour duration. The peak flow rates are presented in Table 7.2 at the end of this section. Note, the flows shown within Table 7.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

7.3 EXISTING SYSTEM DEFICIENCIES

During both the minor and the major storm events, localized ponding and depression storage will occur at a number of locations, particularly in the older developed areas. A number of driveways were originally constructed without positive drainage and/or flooding protection from on-site or adjacent lot grading patterns.

For the purposes of the Master Drainage Plan, we have focused primarily on the locations that are expected to receive flow contributions from off-site or roadway areas.

Bank Stabilization – Shannon Lake Road to Pike Road

Based on the results of modeling and creek analysis, the existing creek sections, from Shannon Lake Road to Pike Road are subject to erosive velocities. To protect and enhance the creek channel, a stream stabilization program is recommended for this section of the creek. These works may include features such as rock placement, riparian plantings, willow wattles to establish a root matrix and cover above the rock armouring. These improvements have been identified as Project 7.1.

Erosion Protection – Darroch Park to East Boundary Road

Runoff from the Pike Road area, including the Mount Boucherie Recreation complex and the secondary school, is directed towards a 600 mm storm outfall located to the east of Darroch Park. Runoff from these developed and highly impervious areas appears to flow

unattenuated into the downstream channels. These peak flow rates result in erosive velocities within the open channels downstream. To reduce the impact of the impervious surfaces within the upstream urban developments, Project 7.2 recommends the installation of a detention and/or infiltration facility downstream of the school playfields. Depending upon the soil parameters this may include an underground detention facility or an above grade dry detention/infiltration basin to promote groundwater recharge. The linear, downstream channels, enroute to East Boundary Road, also provide opportunities to implement channel improvements such as vegetated filter strips to assist in sediment transport and nutrient removal.

Localized Depression Areas – Ponderosa Road

As noted on the existing system figures. The existing topography in the vicinity of Ponderosa Road, east of Hewl Road results in localized depression areas, and runoff directed into private property. Based on the rainfall intensity and ground conditions at the time of rainfall occurrence, it is anticipated that minor ponding and/or flooding may occur within private property. To alleviate the flooding potential, particularly during large events, a perforated storm drainage conveyance system has been prepared within Project 7.3. These improvements would include a storm detention facility or perforated collection system to reduce the peak flow rates and a deep storm sewer installation to provide a positive drainage outlet. As an additional element for limiting downstream impact, a rain garden or infiltration basin may also be considered, provided the soil conditions prove suitable for infiltration to ground.

Boucherie Road/Old Boucherie Road

As noted on Figure 7.11 and within Section 12.3, surface ponding was observed in the area of Boucherie Road and Old Boucherie Road intersection. Frequent ponding and poor surface drainage was evident within this area during the course of the field reviews. Development in the upstream WFN lands is likely contributing to the increasing runoff within this location. It is suggested that discussions continue with WFN to review options within the upstream areas that would reduce the amount and frequency of overland flow events.

Auburn Road

As noted on Figure 7.3, the existing storm sewer system along Auburn Road/Daimler Drive was found to be slightly surcharged during the 5 year design storm; however it is not expected that surcharging would reach the ground surface.

Hichner Road

As outlined on Figure 7.11 and noted within Section 12.3, the McDougall Creek section from Old Boucherie Road through to Jennens Road is contained with earth berms along Hichner Road and the privately owned agricultural areas. The existing creek is extremely shallow and in some locations is elevated above the adjacent roadway. The earth berms are showing signs of erosion and are contributing to sediment concerns in the creek. Flooding of Hichner Road and the agricultural areas are of concern within this floodplain area.

For the short term improvements, it is recommended that the District proceed with interim berm improvements to provide a stable bank, and maximize the hydraulic capacity within the available space limitations. This project has been identified as Project 7.4.

For longer term improvements, it is recommended that the District pursue environmental approvals for channel modifications that may result in reducing flooding risk while at the same time enhancing residual pool habitat, spawning habitat and structure for fish. A comprehensive environmental assessment of the creek, accompanied by the channel engineering assessment would be required in support of the anticipated approvals process. The prescription would need to incorporate in-stream and riparian habitat enhancement components to realize a net gain production.

7.4 FUTURE DEVELOPMENT AREAS

Auburn Road

As outlined, in Figure 7.12, future development sites are anticipated to the west of Auburn Road, north of Daimler Drive. The expected development areas encompass approximately 11.5 ha, although the steep terrain may result in reduced developable area. Based on the cursory review, it is anticipated that the pre-development runoff for the 5 year event would be in the order of 35L/s. A staged release rate is recommended to mitigate impacts on the downstream receiving waters of McDougall Creek, and detention volumes in the order of 1770m^3 may be expected.

Sundance Road

As shown on Figure 7.13, a future development site of approximately 2 ha is anticipated in the area east of Sundance Drive. This is likely to include future extensions of Shamrock Drive. Pre-development runoff within this area is expected to be in the range of 6L/s with an anticipated detention volume of 312 m^3.

As shown on Figure 7.13, future development areas are expected to the east of East Boundary Road, north of Vineyard Drive. The parcels on East Boundary Road are situated tightly against the steep hillside, and encompass approximately 4.1 ha. These areas will likely discharge into the downstream network on East Boundary Road, and stormwater management initiations should be included to protect the downstream system. The peak flow rates are estimated to be in the order of 10.3 L/s, with an accompanying detention volume of approximately 650m^3.

Malbec Crescent

The areas to the east of Malbec Crescent include approximately 8.3 ha and are situated above the steep slopes of Vineyard Drive. In considering the steep gradients and downstream properties, careful attention to site grading and overland flow routes is critical in this area. Based on the cursory review, the peak flow rates are anticipated to be in the range of 24L/s, with a detention volume of 1240m^3.

7.5 RECOMMENDED IMPROVEMENTS

Based on the review of the existing drainage system, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 7.1.

Table 7.1 Improvement Projects for Existing Deficiencies
McDougall Creek Drainage Basin

Project	Priority	Description	Cost Estimate
7.1	Medium	Bank stabilization – Shannon Lake Road to Pike Road	$258,000
7.2	Medium	Detention storage and Erosion protection	$46,000
7.3	High	Drainage Improvements on Ponderosa Road	$275,000
7.4	High	Channel Improvements – Hitchner Road	$46.500

Table 7.2 Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MCD-1	MCJ-1	298.2	Trapezoidal	600	2%	33	**79**
MCD-1	MCJ-76	13.3	Circular	0.5	6%	64	139
MCJ-1	MCJ-2	35.6	Circular	0.6	1%	228	449
MCJ-10	MCO-5	268.6	Trapezoidal	0.6	2%	3	55
MCJ-103	MCJ-104	25.2	Circular	0.375	0%	0	1
MCJ-104	MCJ-105	4.0	Circular	0.375	9%	0	2
MCJ-105	MCJ-110	46.5	Trapezoidal	2	1%	393	1785
MCJ-107	MCJ-108	60.6	Circular	0.2	1%	26	48
MCJ-108	MCJ-109	65.3	Circular	0.3	0%	26	48
MCJ-109	MCJ-110	4.4	Circular	0.3	5%	26	57
MCJ-11	MCO-4	381.7	Trapezoidal	0.3	3%	8	20
MCJ-110	MCJ-29	55.0	Trapezoidal	2	5%	394	1797
MCJ-111	MCJ-112	43.0	Circular	0.15	8%	29	**60**
MCJ-112	MCJ-115	52.8	Circular	0.25	12%	47	119
MCJ-113	MCJ-112	10.5	Circular	0.25	12%	18	59
MCJ-114	MCJ-113	23.6	Circular	0.25	34%	18	59
MCJ-115	MCJ-116	34.3	Circular	0.3	4%	96	279
MCJ-116	MCJ-117	54.1	Circular	0.45	3%	96	279
MCJ-117	MCJ-118	17.3	Circular	3	2%	104	1185
MCJ-119	MCO-1	35.7	Circular	0.375	4%	103	302
MCJ-12	MCO-17	417.4	Trapezoidal	0.6	0%	77	**169**
MCJ-120	MCJ-121	18.1	Circular	0.25	4%	28	92
MCJ-121	MCJ-122	45.0	Circular	0.25	8%	28	92
MCJ-122	MCJ-115	95.4	Circular	0.25	3%	27	92
MCJ-123	MCJ-118	24.7	Circular	2.6	3%	0	293
MCJ-124	MCJ-120	14.9	Circular	0.25	92%	28	92
MCJ-125	MCJ-114	43.3	Circular	1	24%	18	59
MCJ-126	MCJ-124	25.3	Circular	0.25	19%	28	92
MCJ-130	MCJ-131	29.5	Circular	1	-99900%	18	45
MCJ-136	MCJ-170	38.4	Circular	0.2	4%	24	71
MCJ-137	MCJ-111	79.0	Circular	0.2	17%	2	6
MCJ-138	MCJ-137	18.9	Circular	0.2	-99900%	**22**	**66**
MCJ-14	MCJ-15	88.2	Circular	0.25	2%	23	60
MCJ-141	MCJ-142	19.1	Circular	0.25	3%	35	103
MCJ-142	MCJ-143	79.2	Circular	0.25	9%	64	189
MCJ-143	MCJ-144	64.3	Circular	0.25	12%	64	189
MCJ-144	MCJ-145	24.1	Circular	0.25	12%	64	189
MCJ-145	MCJ-153	94.8	Circular	0.45	3%	175	559
MCJ-146	MCJ-141	105.2	Circular	0.25	3%	35	103
MCJ-148	MCJ-149	65.1	Circular	0.3	8%	67	233
MCJ-149	MCJ-150	96.2	Circular	0.375	7%	91	307

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MCJ-15	MCJ-16	114.3	Circular	0.375	1%	64	**139**
MCJ-150	MCJ-151	91.0	Circular	0.375	7%	91	307
MCJ-151	MCJ-145	94.1	Circular	0.375	6%	91	307
MCJ-152	MCJ-148	11.7	Circular	0.3	14%	67	233
MCJ-153	MCJ-154	94.8	Circular	0.45	5%	175	559
MCJ-154	MCJ-155	65.3	Circular	0.45	4%	244	**723**
MCJ-155	MCJ-156	18.2	Circular	0.6	1%	244	723
MCJ-156	MCO-2	29.6	Circular	0.6	4%	244	724
MCJ-157	MCJ-149	20.8	Circular	0.3	2%	16	50
MCJ-158	MCJ-157	80.4	Circular	0.3	7%	16	50
MCJ-159	MCJ-158	86.1	Circular	0.3	6%	16	50
MCJ-16	MCJ-17	104.8	Circular	0.375	0%	119	**250**
MCJ-160	MCJ-159	102.3	Circular	0.3	1%	16	50
MCJ-161	MCJ-160	106.9	Circular	0.3	1%	8	27
MCJ-162	MCJ-161	89.1	Circular	0.25	9%	8	27
MCJ-165	MCJ-12	359.5	Trapezoidal	0.6	8%	40	126
MCJ-166	MCO-9	29.1	Circular	0.6	0%	158	**455**
MCJ-17	MCJ-23	108.4	Circular	0.45	2%	206	398
MCJ-170	MCJ-137	45.0	Circular	0.2	20%	24	71
MCJ-18	MCJ-19	74.1	Trapezoidal	0.5	3%	203	392
MCJ-19	MCJ-20	62.4	Circular	0.6	1%	206	401
MCJ-2	MCJ-3	179.5	Trapezoidal	0.6	11%	228	448
MCJ-20	MCJ-21	54.3	Trapezoidal	0.6	1%	205	403
MCJ-21	MCJ-166	362.8	Trapezoidal	0.6	3%	191	391
MCJ-22	MCO-10	349.4	Trapezoidal	0.6	3%	394	**1147**
MCJ-23	MCJ-18	70.6	Circular	0.6	3%	206	396
MCJ-24	MCJ-25	194.4	Circular	0.25	6%	5	6
MCJ-25	MCJ-26	162.7	Circular	0.25	14%	5	6
MCJ-26	MCJ-27	94.2	Circular	0.25	17%	5	6
MCJ-27	MCJ-28	366.6	Trapezoidal	0.6	4%	5	6
MCJ-28	MCJ-105	323.6	Trapezoidal	2	4%	397	1788
MCJ-29	MCJ-22	76.7	Trapezoidal	2	5%	397	1795
MCJ-3	MCJ-4	20.1	Circular	0.5	5%	325	**475**
MCJ-30	MCJ-31	37.5	Trapezoidal	2	3%	288	1355
MCJ-31	MCJ-28	412.2	Trapezoidal	2	4%	286	1353
MCJ-32	MCJ-33	428.4	Trapezoidal	0.6	3%	28	119
MCJ-33	MCJ-30	537.0	Trapezoidal	0.6	3%	40	146
MCJ-35	MCJ-36	35.6	Circular	0.25	5%	0	10
MCJ-36	MCJ-37	88.3	Circular	0.25	1%	0	**27**
MCJ-37	MCJ-38	17.1	Circular	0.25	3%	0	**34**
MCJ-38	MCJ-39	48.0	Circular	0.25	1%	0	**34**
MCJ-39	MCJ-40	33.9	Circular	0.25	1%	5	**44**
MCJ-4	MCO-3	118.9	Trapezoidal	0.6	3%	325	472

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MCJ-40	MCJ-46	75.2	Circular	0.375	1%	94	**244**
MCJ-41	MCJ-40	50.8	Circular	0.25	2%	0	**34**
MCJ-43	MCJ-44	70.6	Circular	0.25	3%	113	**164**
MCJ-44	MCJ-45	119.0	Circular	0.25	3%	**111**	**125**
MCJ-45	MCJ-46	120.0	Circular	0.25	1%	**110**	**115**
MCJ-46	MCJ-47	33.0	Circular	0.45	1%	**228**	**399**
MCJ-47	MCJ-51	55.4	Circular	0.45	0%	**221**	**399**
MCJ-48	MCO-12	16.3	Circular	0.6	1%	60	225
MCJ-49	MCJ-50	21.9	Circular	0.25	0%	8	**21**
MCJ-5	MCJ-3	87.5	Trapezoidal	0.6	1%	64	139
MCJ-50	MCJ-55	90.9	Circular	0.9	0%	213	**399**
MCJ-51	MCJ-50	57.3	Circular	0.525	0%	217	**399**
MCJ-52	MCJ-40	70.0	Circular	0.25	3%	0	5
MCJ-53	MCJ-54	26.4	Circular	0.6	1%	60	225
MCJ-54	MCJ-48	62.7	Trapezoidal	0.6	4%	60	225
MCJ-58	MCJ-59	69.4	Circular	0.25	7%	81	195
MCJ-59	MCJ-60	82.5	Circular	0.25	4%	78	**153**
MCJ-6	MCJ-61	64.3	Circular	0.25	1%	78	**118**
MCJ-60	MCJ-62	43.9	Circular	0.25	19%	114	286
MCJ-61	MCJ-58	116.2	Circular	0.25	3%	58	115
MCJ-62	MCJ-63	118.1	Circular	0.25	12%	111	**267**
MCJ-63	MCJ-64	13.7	Circular	0.25	2%	110	**109**
MCJ-64	MCJ-1	222.3	Trapezoidal	0.6	8%	109	105
MCJ-65	MCJ-86	12.1	Circular	0.25	1%	52	**137**
MCJ-66	MCJ-65	82.4	Circular	0.75	0%	52	**137**
MCJ-67	MCJ-73	12.3	Circular	0.25	4%	73	**150**
MCJ-68	MCJ-66	43.5	Circular	0.75	1%	55	123
MCJ-69	MCD-1	91.0	Trapezoidal	0.6	8%	73	143
MCJ-7	MCJ-53	114.1	Trapezoidal	0.6	3%	61	226
MCJ-73	MCJ-69	15.6	Circular	0.525	1%	73	147
MCJ-76	MCJ-78	9.1	Circular	0.3	58%	64	139
MCJ-77	MCJ-80	48.4	Circular	0.3	17%	64	139
MCJ-78	MCJ-77	56.9	Circular	0.3	23%	64	139
MCJ-8	MCJ-7	14.8	Circular	0.6	3%	61	226
MCJ-80	MCJ-5	13.5	Circular	0.4	5%	64	139
MCJ-83	MCJ-84	31.0	Circular	0.25	20%	29	90
MCJ-84	MCJ-85	39.4	Circular	0.25	15%	29	90
MCJ-85	MCJ-86	7.7	Circular	0.25	0%	29	**75**
MCJ-86	MCJ-6	1.0	Circular	0.25	-99900%	74	117
MCJ-87	MCJ-83	18.3	Circular	0.25	1%	3	5
MCJ-9	MCJ-10	236.9	Trapezoidal	0.05	3%	11	28
MCJ-93	MCJ-95	10.5	Circular	0.25	1%	58	184
MCJ-94	MCJ-93	47.6	Circular	1.05	0%	3	23

Project 7.1 Bank Stabilization – Shannon Lake Road to Pike Road

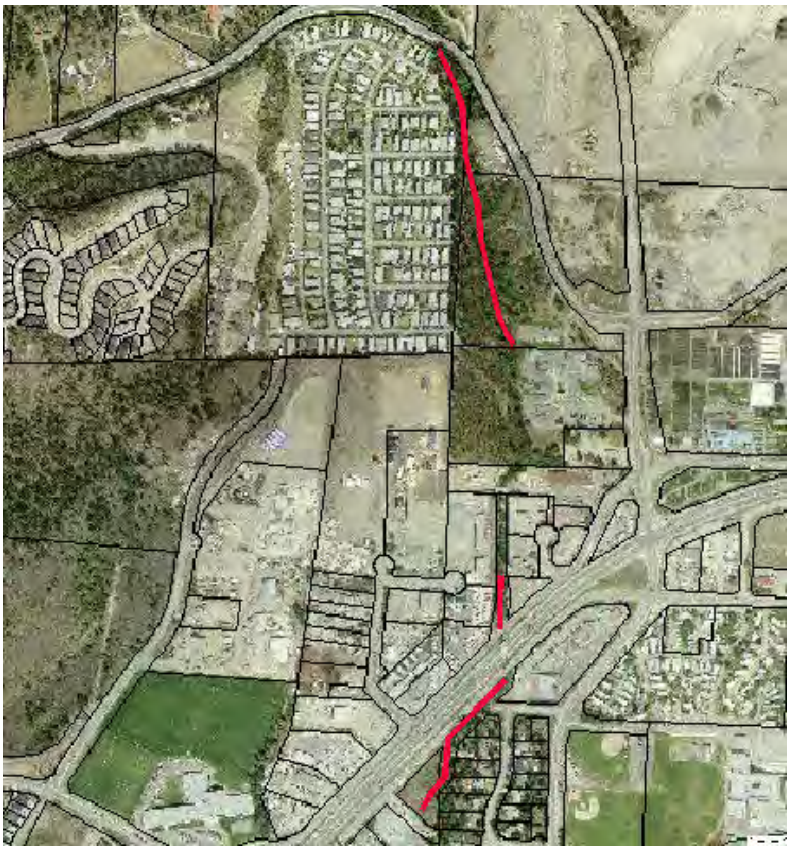
Proposed Works: Install erosion protection and stream bank stabilization along McDougall Creek, from Shannon Lake Road to Pike Road.

Implementation: This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.

Consequences if not completed: Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.

Priority: 2

Location:



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	800	$225	$180,000
Contingency (25%)				$45,000
Engineering (15%)				$33,000
Total Project Cost				**$258,000**

RSB ENGINEERING

Project 7.2 Detention Storage and Erosion Protection – Darrock Park to East Boundary Road

Proposed Works:	Provide rainwater detention and erosion protection within the storm sewer system upstream of Darrock Park.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	High runoff rates from the impervious surfaces within the Mount Boucherie complex that contribute to erosive conditions in the downstream channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Vegetative Filter Strip	Lm	120	$100	$12,000
Detention Area	Ls	1	$20,000	$20,000
Contingency (25%)				$8,000
Engineering (15%)				$6,000
Total Project Cost				**$46,000**

RSB ENGINEERING

Project 7.3 Drainage Improvements on Ponderosa Road

Proposed Works:	Provide rainwater infiltration and storm conveyance system on Ponderosa Road.
Implementation:	The localized depression area on Ponderosa Road will collect runoff from the nearby properties and roadway. This work is considered a High priority, since there is a risk of flooding and/or property damage.
Consequences if not completed:	Since there is no overland flow route runoff will collect in this low-lying area, and there is a risk of flooding on private property.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Drywells	ea	6	$5,000	$30,000
Catch basins	ea	12	$2,500	$30,000
300mm Perf storm pipe	Lm	400	$250	$100,000
Road Restoration	m^2	1200	$30	$36,000
Contingency (25%)				$49,000
Engineering (15%)				$30,000
Total Project Cost				**$275,000**

RSB ENGINEERING

Project 7.4 Channel Improvements – Hitchner Road to Jenner Road

Proposed Works:	Complete channel improvements on Hitchner Road and Jenner Road from Old Boucherie Road to Okanagan Lake.
Implementation:	The existing flow rate exceeds the channel capacity. This work is considered a High priority, due the environmental concerns and impact on the agricultural operations.
Consequences if not completed:	Erosive conditions in the open channel sections will present environmental concerns and potential flooding may resulting in operational concerns for active agricultural land-use.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Channel Improvements	Lm	540	$60	$32,400
Contingency (25%)				$8,100
Engineering (15%)				$6000
Total Project Cost				**$46,500**

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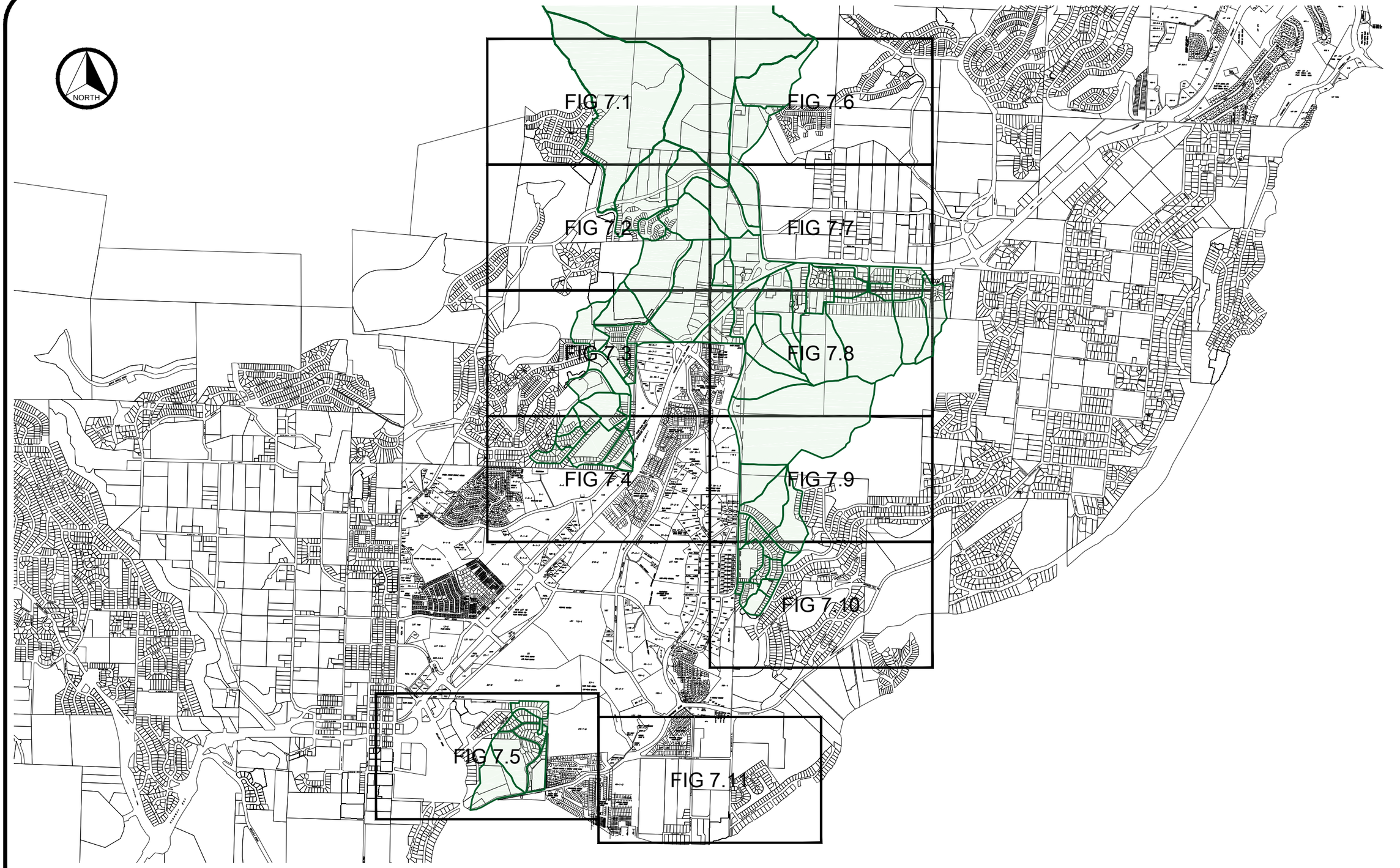


FIGURE 7.0
McDOUGALL CREEK BASIN
KEY MAP
N.T.S.

RSB ENGINEERING

NORTH

MCS-19_4

MCS-17_2

SHANNON WOODS WAY

SHANNON WOODS CRESCENT

SHANNON WOODS DRIVE

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	7.1	7.6
	7.2	7.7

FIGURE 7.1
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

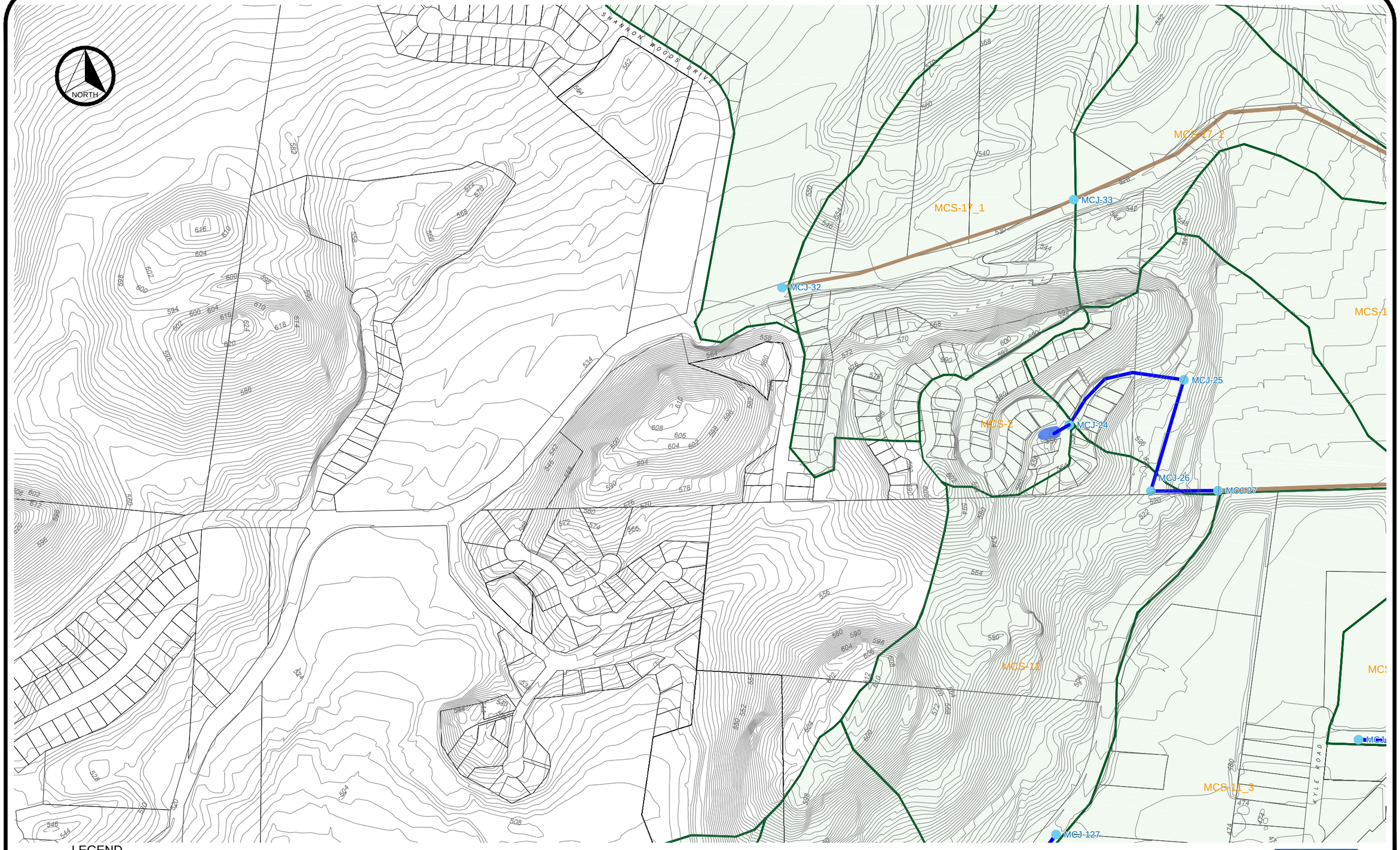


FIGURE 7.2
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

SHOWN ORANGE PIPES SURCHARGE BUT MHs DO NOT OVERFLOW

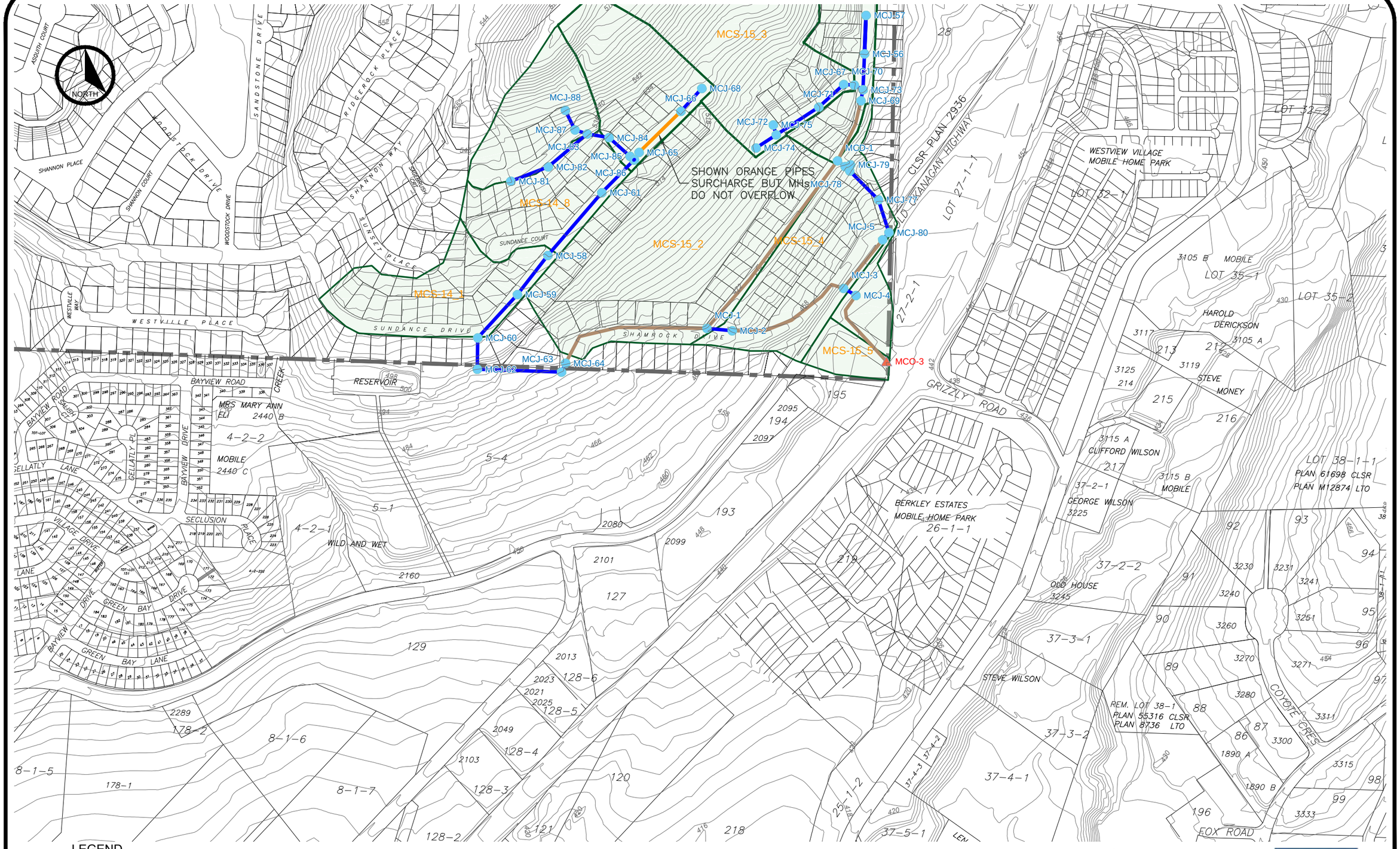
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 524 CONTOUR ELEVATION
- 2m CONTOUR

	7.2	7.7
	7.3	7.8
	7.4	7.9

FIGURE 7.3
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 524 CONTOUR ELEVATION
- 2m CONTOUR

	7.3	7.8
	7.4	7.9
		7.10

FIGURE 7.4
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

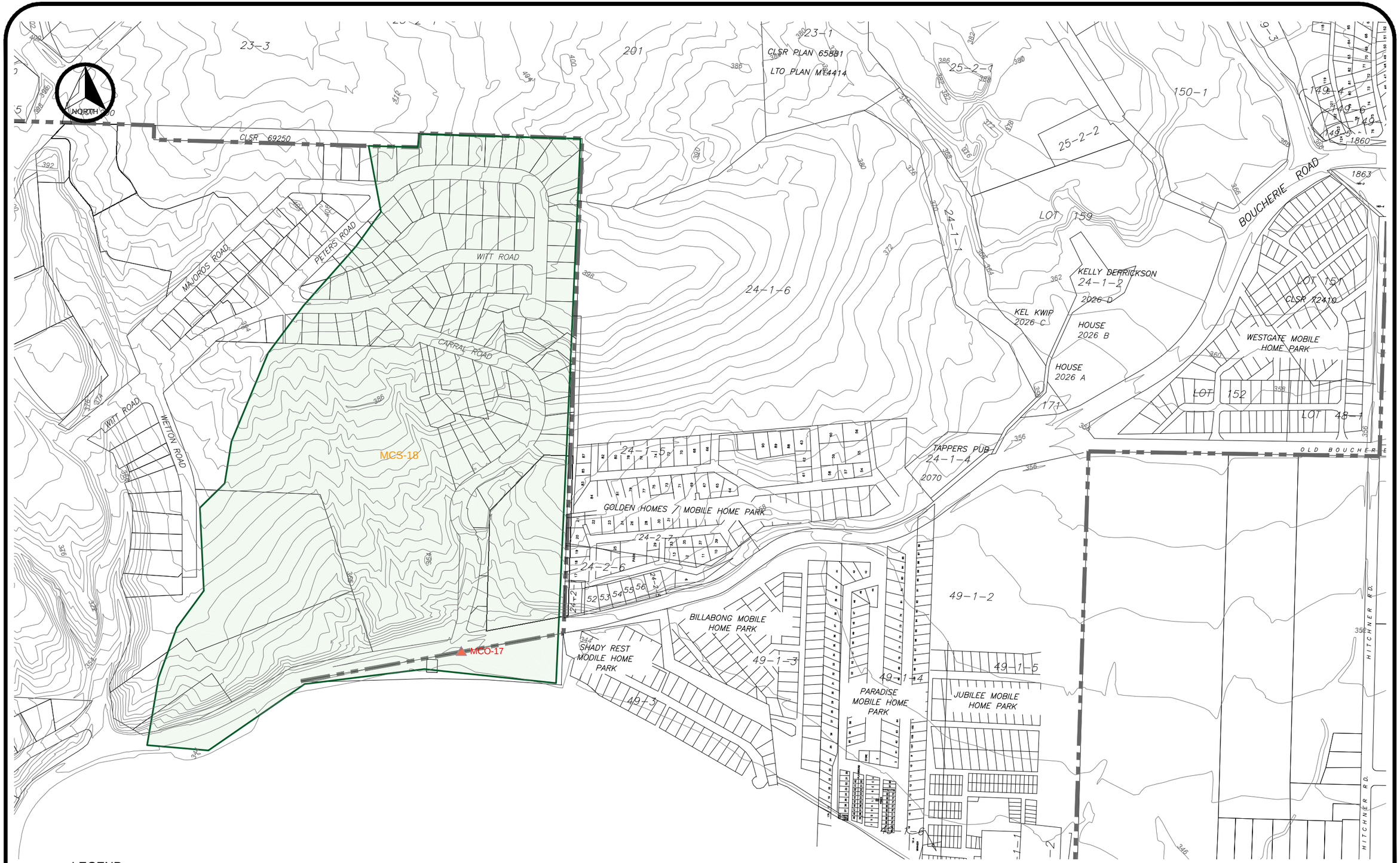
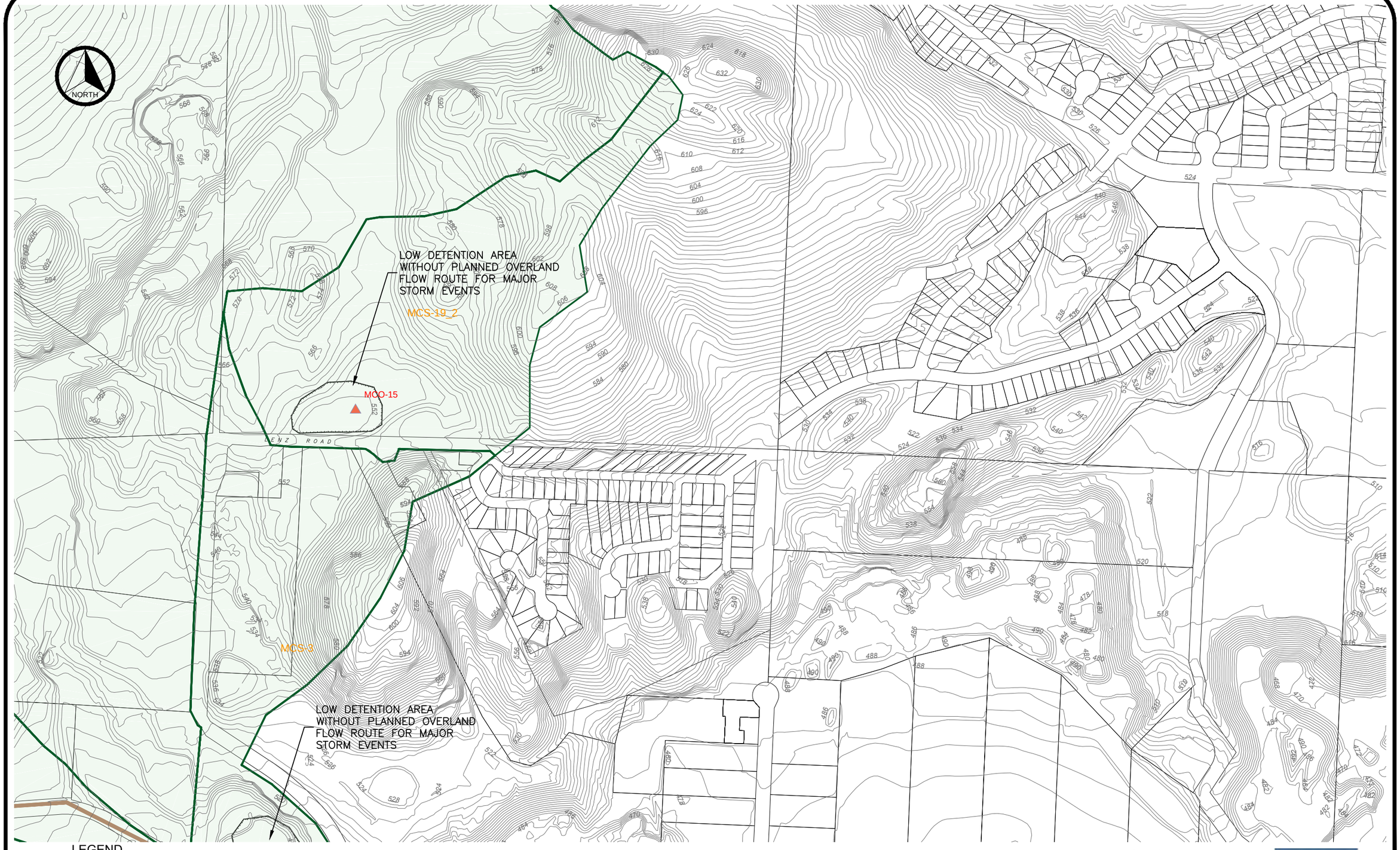


FIGURE 7.5
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

7.1	7.6	
7.2	7.7	

FIGURE 7.6
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

LOW DETENTION AREA WITHOUT PLANNED OVERLAND FLOW ROUTE FOR MAJOR STORM EVENTS

STREAM STABILIZATION AS PER PROJECT 7.1

STREAM STABILIZATION AS PER PROJECT 7.1

NORTH

MCJ-30
MCJ-31
MCO-13
MCS-10_1
MCJ-28
MCS-10_2
MCS-11_2
MCJ-104
MCJ-105
MCJ-106
MCJ-107
MCJ-108
MCJ-109
MCJ-102
MCJ-110
MCJ-29
MCJ-22
MCO-6
MCO-5
MCS-7_5
MCJ-10
MCS-7_4
MCJ-9
MCS-7_9
MCS7_10
MCO-7
MCO-8
MCS-7_7
MCJ-11

DOMINION ROAD
STEVENS ROAD
JULIANN ROAD
ROSS ROAD
WESTERN ROAD
INDUSTRIAL ROAD
McDOUGALL ROAD
HWY 97
BRENTWOOD ROAD
GREEN APPLE COURT
BROOKWOOD CRT
PONDEROSA CRT
DENNY CRT
MARILYN CRT
VISTA WAY
KYLE ROAD
CANNON LAKE ROAD
COMPASS CRT

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

7.1	7.6	
7.2	7.7	
7.3	7.8	

FIGURE 7.7
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

STREAM STABILIZATION AS PER PROJECT

7.1

SHOWN ORANGE PIPES SURCHARGE BUT MHs DO NOT OVERFLOW

LOW DETENTION AREAS WITHOUT PLANNED OVERLAND FLOW ROUTE FOR MAJOR STORM EVENTS IMPROVEMENTS AS PER PROJECT

7.3

CONNECT TO PIKE ROAD STORM SEWER AS PER PROJECT

NO AS-CONTRUCTED INFORMATION

INSTALL DETENTION FACILITY AND COMPLETE CHANNEL IMPROVEMENTS AS PER PROJECT

7.2

CONSTRUCT VEGETATED FILTER STRIP AS PER PROJECT

7.2

LOT 186
PLAN 58366 CLSR
PLAN M10780 LTO

McDOUGAL CREEK ESTATES MOBILE HOME PARK

LOT 147

LOT 32

LOT 34

BARTLEY ROAD

BURT WILSON

DAIMLER ROAD

PIKE ROAD

CAPRI ROAD

CAMERON ROAD

RIFFINGTON PL

HEWLETT ROAD

BRENTWOOD ROAD

ROSS ROAD

VISTA WAY

BRENTWOOD CRT

PONDEROSA PL

DENNY CRT

MARLIN CRT

NORTH

MCJ-98 MCJ-101 MCJ-99 MCJ-169 MCJ-100 MCJ-107 MCJ-108 MCJ-109 MCJ-110 MCJ-106 MCJ-102 MCJ-29 MCJ-22 MCJ-17 MCJ-16 MCJ-15 MCJ-14 MCJ-13 MCJ-23 MCJ-18 MCJ-19 MCJ-20 MCJ-21 MCJ-166 MCJ-10 MCJ-9 MCJ-11

MCO-14 MCO-10 MCO-7 MCO-8 MCO-4 MCO-9

MCS-8 MCS-9 MCS-7_11 MCS-7_7 MCS-7_10 MCS-7_9 MCS-7_4 MCS-7_1 MCS-7_13 MCS-7_6 MCS-7_12 MCS-6 MCS-5

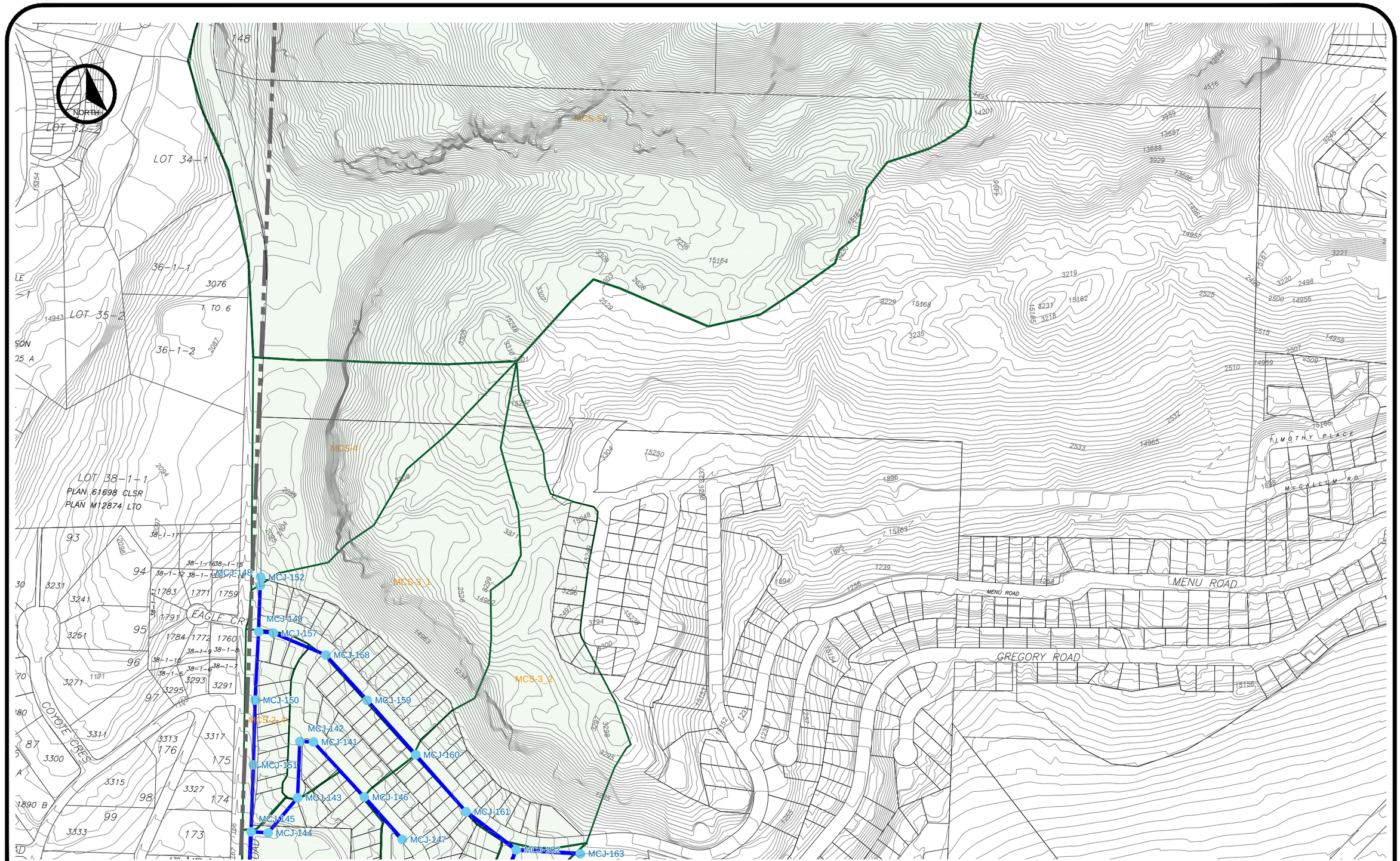
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

7.2	7.7	
7.3	7.8	
7.4	7.9	

FIGURE 7.8
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



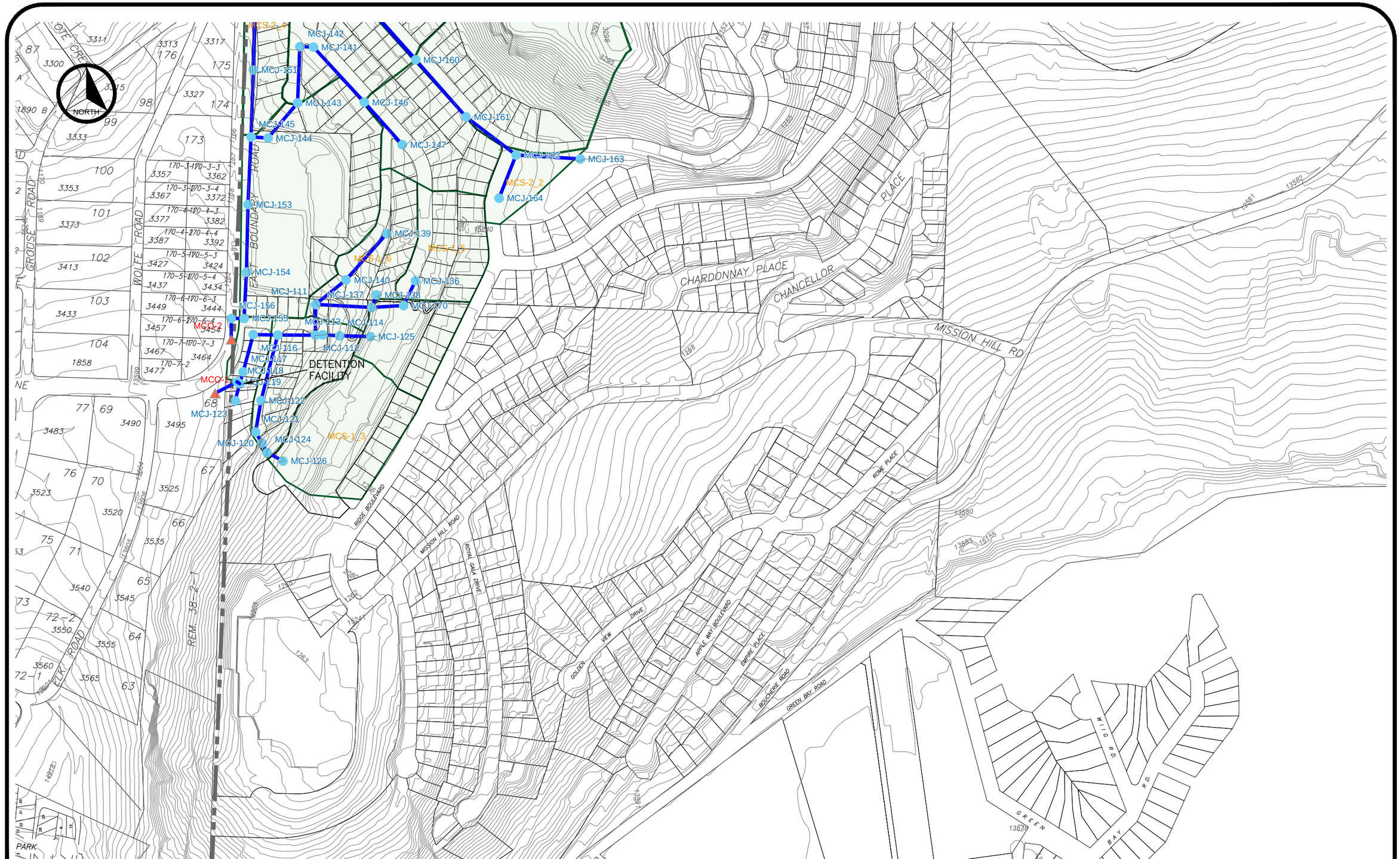
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 524 CONTOUR ELEVATION
- 2m CONTOUR

7.3	7.8	
7.4	7.9	
	7.10	

FIGURE 7.9
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

7.4	7.9	
	7.10	

FIGURE 7.10
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

BOUCHERIE ROAD

LOT 159

24-1-1

KELLY DERRICKSON
24-1-2
2026 D

KEL KWIP
2026 C

HOUSE
2026 B

HOUSE
2026 A

171

TAPPERS PUB
24-1-4
2070

WESTGATE MOBILE HOME PARK

LOT 151
CLSR 72410

LOT 152

LOT 48-1

LOT 1

1863

1835
160-2-3

1815

1803 1781 1773 1763
05 85 75 1-2
07 87 77
09 89 79

46-2-52
46-2-1

BOUCHERIE RD.

OLD BOUCHERIE RD.

MCJ-167

MCJ-168

OLD BOUCHERIE RD.

MCJ-171

EXISTING SURFACE
PONDING AT INTERSECTION

CHANNEL IMPROVEMENTS
AS PER PROJECT

7.4

HITCHNIER RD.

PRITCHARD RD.

NEWPORT DRIVE

CAMANO CAY

MILFORD CRES.

PRITCHARD DRIVE

49-1-2

49-1-3

49-1-4

49-1-5

49-1-6

49-1-1

49-2

PARADISE MOBILE HOME PARK

JUBILEE MOBILE HOME PARK

MCJ-172

JENNENS RD.

MCJ-173

MCO-23

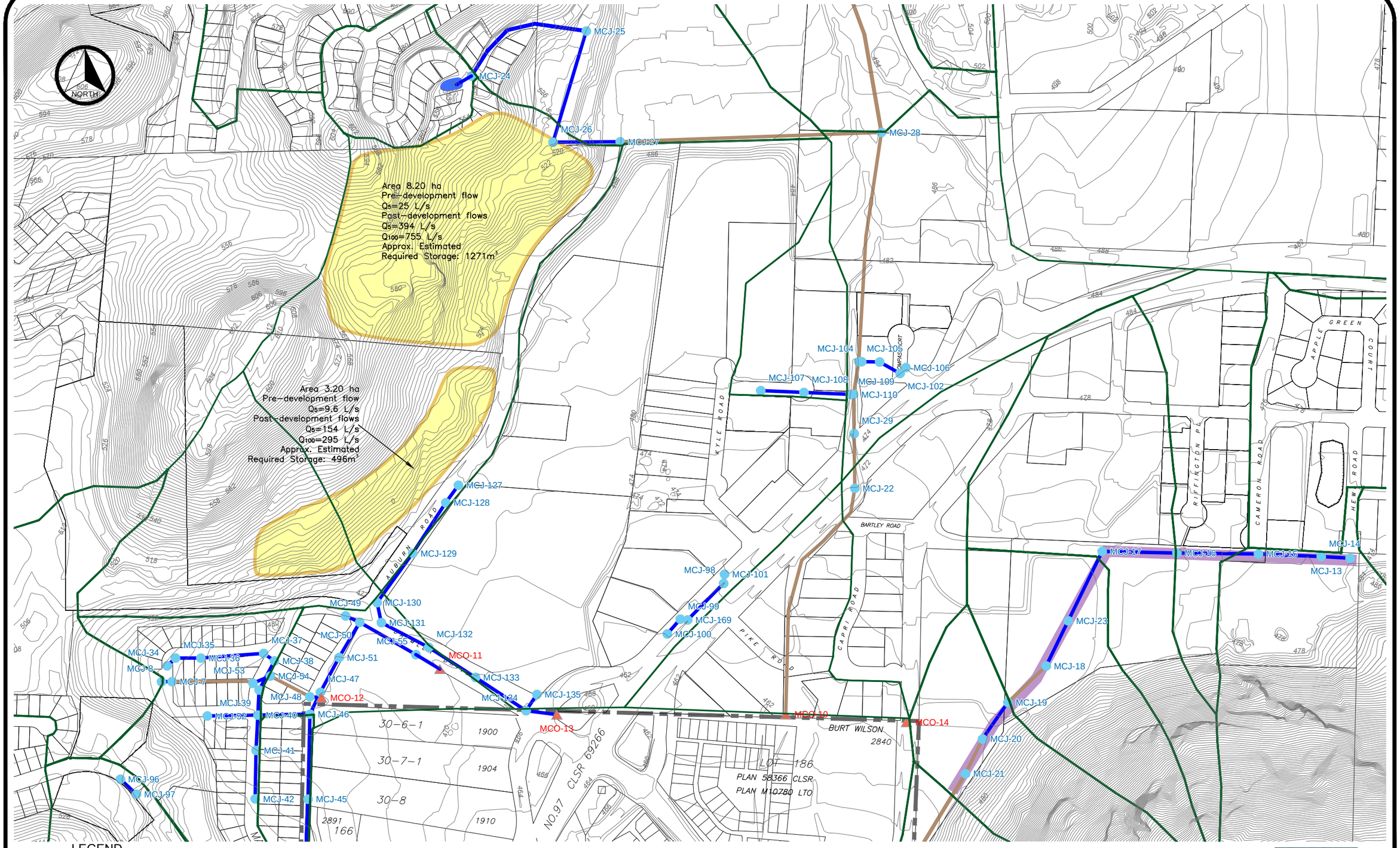
LEGEND

CATCHMENT BOUNDARY	MODEL JUNCTION	MCJ-15	JUNCTION ID	524	CONTOUR ELEVATION
MODEL CHANNEL/DITCH	MODEL OUTFALL	MCO-5	OUTFALL ID		
MODEL PIPE	MCS-3 CATCHMENT ID		2m CONTOUR		

7.5	7.11	

FIGURE 7.11
McDOUGALL CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MCS-3 CATCHMENT ID
- MCJ-15 JUNCTION ID
- MCO-5 OUTFALL ID
- 524 CONTOUR ELEVATION
- 2m CONTOUR

FIGURE 7.12
McDOUGALL CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

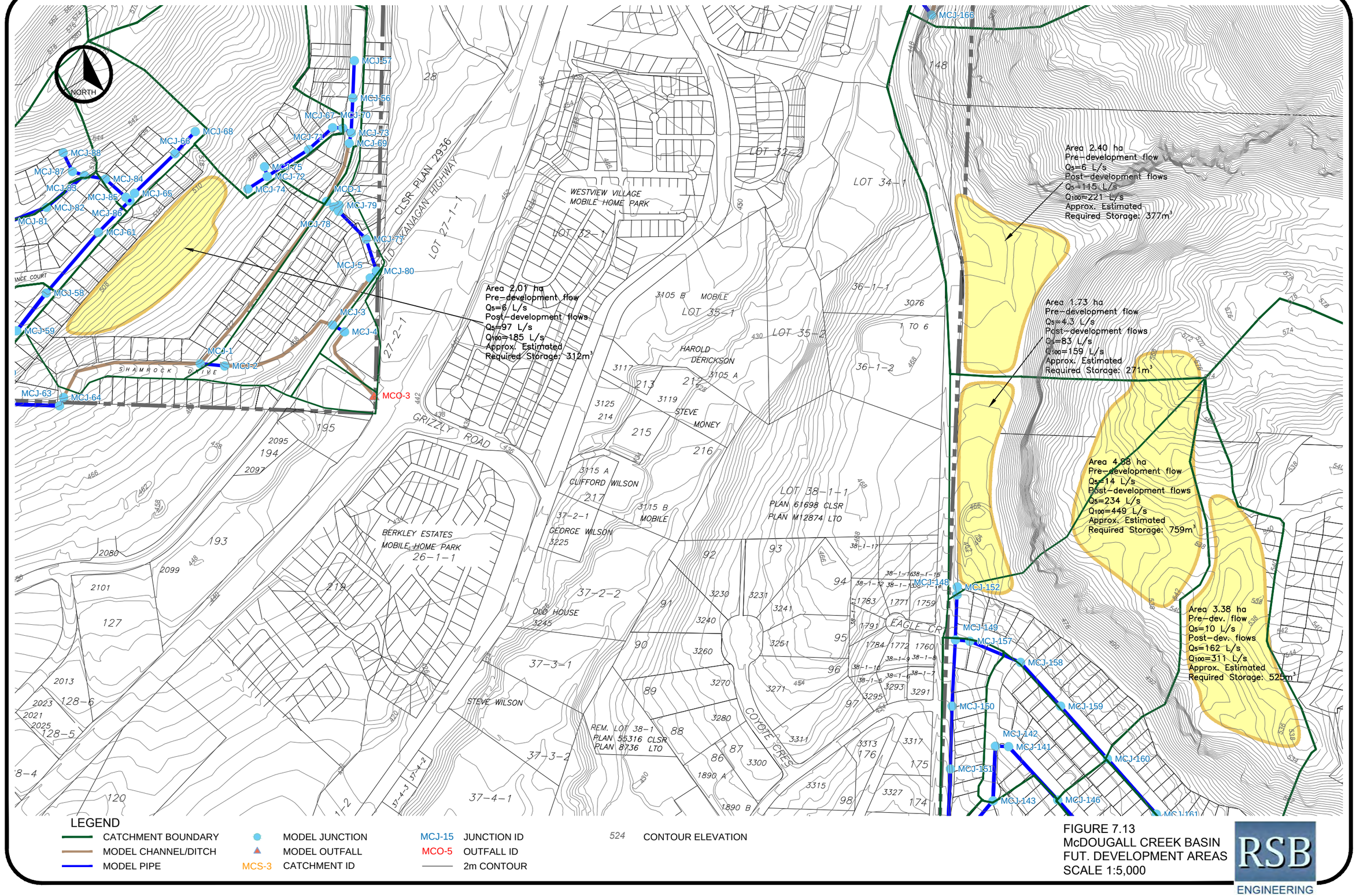


FIGURE 7.13
McDOUGALL CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 8
MOUNT BOUCHERIE BASIN PLAN

8.1 BASIN DESCRIPTION

Mount Boucherie is the highest landmark in the District. With a top elevation of 758m, the summit stands over 417m above the lake level. The Mountain is comprised of volcanic rock which has formed cliff faces, ridge lines and steep slopes. Rock outcrops are prominent over most of the mountain, with little to no surficial soil layer present. There is a thicker surface soil layer over the northeastern slope which has resulted in denser tree coverage.

Runoff from the mountain flows into District Limits, with exception to the westerly slopes which drain into Westbank First Nations (IR 9). This basin comprises the eastern and southern slopes of Mount Boucherie, extending east to Thacker Drive, south to Green Bay and to Mission Hill Winery in the southwest.

8.2 EXISTING SYSTEM ANALYSIS

The Mount Boucherie drainage basin consists of a mix of land uses and drainage infrastructure. Land use ranges from undeveloped steep slopes along the east face of Mount Boucherie to residential development areas within the lower reaches of the basin.

The more recent single-family developments consist of standard curb and gutter roadway sections, with a piped storm sewer network, while the earlier development areas, in the vicinity of Thacker Road and Sunnyside consist of open ditches and culverts.

Runoff from the Vineyard Drive vicinity drains into two stormwater detention facilities located near Menu Road, at Chasselas Road. Based on the available as-built drawings, these ponds have a detention volume of 1400 m^3, with a release rate of approximately 44 L/s.

The areas below Menu Road, including Gregory Road and Mission Hill Place and Apple Way Boulevard drain towards the south and outlet within the trunk storm sewer on Green Bay Road. In review of the available drawings, we have noted no stormwater detention facilities within this area, from Gregory Road through to Green Bay Road.

Runoff from the Trevor Drive area is split, with the southern sections contributing to the storm sewer system on Topham Road and Boucherie Road culvert near Quail’s Gate Vineyard.

The northern portions of Trevor Drive drain to the east towards Ourtoland Road, prior to entering the roadside ditch along Boucherie Road. Runoff along this route also connects to the existing culvert crossing Boucherie Road near the Quail's Gate Vineyard.

Runoff from the eastern portions of Menu Road and Gregory Road drains through a series of piped connections and overland flow channels enroute to the same culvert crossing near Quail's Gate Vineyard. These areas contribute to the Bowen Creek system, which as noted in Section 12.3 is a spring fed system.

In review of the available drawings, there were no stormwater detention facilities or water quality enhancement facilities located within the developed areas of these sub-basins.

The existing 600 mm culvert near Quail's Gate Vineyard connects to a small diameter storm sewer system that traverses the vineyard and discharges upstream of the existing wetlands on the west shores of Green Bay.

The majority of the Mount Boucherie drainage basin is conveyed through the trunk storm sewer along Green Bay Road. The existing trunk sewer consists of 1,200 mm concrete pipe that outlets into Okanagan Lake. The outfall consists of a perforated, submerged pipe, extending approximately 125 m into Okanagan Lake.

Also within this same area is an existing lake pump station, situated along the shoreline. This station pumps water from Okanagan Lake over to the east shore of Green Bay. The approximate route has been shown on Figure 8.3 although no drawings for the station or the piping system could be located.

The eastern limits of the Mount Boucherie basin, including the areas generally bounded by Boucherie Road and Thacker Drive, drain towards the south. These residential neighbourhoods were developed prior to the current curb and gutter standards and include roadside swales/ditches along with roadway culverts. Based upon field reviews and topographical information, runoff within this area follows an overland flow route through a series of valleys and roadside swales. This area ultimately discharges into Bowen creek south of Montigny Road and then into Okanagan Lake.

The Sunnyside neighbourhood consists primarily of overland flow and roadside swales. There is a section of piped storm sewer along Holmes Road, that discharges into Bowen Creek, north-east of Allison Place.

The model nodes for the Mount Boucherie system are presented within Figures 8.1 to 8.6. The corresponding flow rates for the 1 in 5 year and 1 in 100 year storm events are

presented in Table 8.2. Note, the flows shown within Table 8.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

8.3 EXISTING SYSTEM DEFICIENCIES

Within the Mount Boucherie drainage basin, a number of deficiencies have been noted and are presented within Figures 8.1 to 8.6. The noted deficiencies include largely surface ponding issues and right-of-way or easement establishment. The deficiencies are noted below and outlined on the project sheets attached at the end of this section.

Drainage Easement – Braeburn Court to Mission Hill Road

Runoff from the end of Breaeburn Court is directed towards Mission Hill Road. It is not known if a registered easement exists on the lots between these roads. Project 8.1 has been presented for District staff to confirm if is a registered easement exists, and if not, it is recommended that a drainage easement be established.

Erosion Protection – Menu Road to Gregory Road

Runoff from the low point on Menu Road flows overland towards Gregory road, and to the south of Gregory Road. The flow velocities are considered high and have the potential to generate erosive conditions if the channels are not adequately protected. The channel flows through privately owned lands and it is not known if a drainage easement has been established. Project 8.2 recommends that an easement be established if one is not currently present. Further, if a channel within the lots is not adequately protected, it is recommended that improvements be completed to ensure channel stability.

Erosion Protection - Gregory Road to Mission Hill Road

Much of the overland flow from the developed areas of Gregory Road, Menu Road and Trevor Road, flows south toward Boucherie Road along the route of Bowen Creek. As noted in Section 12.3, much of the stream accepts storm water runoff from impervious surfaces. During the larger storm events, the velocities within this route are considered high and will result in erosive conditions. Erosive protection measures as well as establishment of a drainage easement are recommended within Project 8.3.

Conveyance Improvements - Boucherie Road to Okanagan Lake

The initial alignment of Bowen Creek has been significantly modified and contains a mix of overland flow and pipes of various sizes. The hydraulic capacity is much lower than the anticipated design flows. Excess flow is expected to cause surface ponding and erosion problems along the undefined route to Okanagan Lake. Project 8.4 recommends the establishment of a drainage easement as well as construction of a conveyance system that will safely carry the 100 year flow rate of 1500 L/s to the lake. It is recommended that an infiltration system, with disposal to ground, be installed to promote groundwater recharge above the existing wetlands during the less severe and more frequent event. To encourage sediment and floatable removal, a oil/grit separator is recommended near Boucherie Road that will allow for easier access and maintenance of the chamber.

Storm Sewer – Sunnyview Road

Sections of the existing storm sewer on Sunnyview Road are undersized and unable to convey the design flow rate. The excess flow will travel overland and will increase the risk of erosion in the downstream agricultural areas. Project 8.5 recommends replacement of the existing storm sewer. It is not known if a drainage easement has been registered in this area, however, it s recommended that an easement be established if one is not already present.

Drainage Easement – Stevenson Road to Douglas Road

Runoff from the areas of Stevenson Road and Anders Road flows overland through the agricultural areas north of Douglas road. It is not known if a registered easement exists for this route, to convey the runoff from the upstream urban areas. Project 8.6 recommends the establishment of a drainage easement within this area.

Drainage Easement – Douglas Road to Ogden Road

Similar to the above noted deficiency, Project 8.7 has been presented for district staff to confirm if a drainage easement has been established for this route from Douglas Road through to Ogden Road.

Drainage Easement – Lakeview Cove to Ourtoland Road

Runoff from the urban development on Trevor Road flows overland from Trevor road to Ourtoland Road. During heavy rainfall events, overland flow will travel to the east of Trevor Road, across privately owned lands. It is not known if a registered drainage easement has been established for this route. In addition, these are steep slopes in this area and are subject to erosion. Project 8.8 has been presented for District staff to confirm the presence of a registered easement.

Drainage Easement – Ogden Road to Westbrook Road

Runoff in the low point of Ogden Road will flow overland to the south, towards Westbrook Road. This route will traverse privately owned lands and it is not known if a drainage easement has been registered through these lots. Project 8.9 has been presented for the District staff to confirm if a drainage easement has been registered, and if not, it is recommended that an easement be established.

Drainage Easement – McCartney Road to Montigny Road

Runoff from McCartney Road will flow overland across privately owned lands, enroute to Montigny Road. It is not known if a registered easement has been established for drainage purposes. Project 8.10 has been presented for District staff to confirm if an easement has been registered.

Drainage Easement – Bazett Road to Sunnyside Road

Bazett Road is a downhill gradient cul-de-sac, and surface runoff from the roadway will travel across privately owned lands enroute to Sunnyside Road. It is not known if a registered easement has been established over this route and, Project 8.11 has been presented for district staff to confirm and/or establish a drainage easement along the overland route.

Inspect/Clean Outfall Pipe – Green Bay Road

The existing 1200 mm diameter storm sewer along Green Bay Road provides the only outfall for the upstream drainage network. The pipe and lake outfall are largely in a submerged condition, with very flat grades. The Green Bay storm system has been known to surcharge up to the roadway surface under larger runoff events. This may be contributed to the large upstream catchment area and may also be influenced by sediment accumulation within the lower sections of the trunk sewer. Project 8.12 recommends that the existing pipe be inspected and cleaned as may be required, to re-instate the initial hydraulic capacity. Due to the proximity of the lake outfall, it is recommended that an environmental monitoring and mitigation plan be implemented prior to initiating the inspection and cleaning works. Based on the Record Drawings, the outfall pipe is a perforated metal pipe, placed at the lake bottom. The condition of the pipe should be reviewed with divers to confirm the structural integrity and ensure that the pipe openings are still exposed and functional.

Storm Sewer Overflow – Green Bay Road

Increasing runoff from the upstream areas surcharges the existing 1200 mm diameter storm sewer on Green Bay Road during heavy rainfall events. To provide additional

outlet capacity, Project 8.13 recommends the installation of a high level overflow route on Green Bay Road. This pipe would serve as an emergency overflow route, and would receive flow only when the 1200 mm trunk sewer approaches a pipe full condition. The objective is to provide a safe and predictable overflow route under high runoff events only. The pipe would outlet to a vegetated channel north of Green Bay Road. A storm drainage easement would be required to allow a positive outlet towards the existing wetlands on Green Bay.

Relocate Catchbasin Leads – Green Bay Road

The existing catchbasins along Green Bay Road collect roadway runoff and discharge it into the private canal on the south side of Green Bay Road. It is not known if there is an easement in place over the existing canal to permit discharge from the municipal system. Project 8.14 recommends that the existing catchbasins leads be re-directed into the existing 1200 mm storm pipe on Green Bay Road.

8.4 FUTURE DEVELOPMENT AREAS

Figures 8.7 and 8.8 depict the future development areas with the Mount Boucherie Basin, as obtained from the official community plan of Figure 2.1.

North Pinot Noir Drive

As shown on Figure 8.7, the areas above Pinot Noir Drive and Vineyard Drive are anticipated to develop as residential properties. Runoff from these future development areas will cascade down to the existing developed areas. In considering the steep gradients below these hillside developments, careful attention to site grading and overland flow routes is critical. Based on a cursory review, the peak flow rates and approximate detention volumes have been shown as Figure 8.7.

South of Gregory Road

As shown on figure 8.7, a development site of approximately 2 ha is anticipated to the south of Gregory road. Pre-development runoff within this area is expected to be in the range of 6L/s with an anticipated detention volume of 323m^3. Prior to additional runoff being discharged into the overland system of Bowen Creek, it is recommended that a drainage easement be established within the downstream areas,

South of Royal Gala Drive

As shown on Figure 8.8, a future development area is anticipated to the west f the Mission Ridge development. This development area is situated above Boucherie Rod and would contribute directly into the Green Bay Road trunk sewer system. To minimize

impacts on the downstream system, careful storm water management practices will be required. The preliminary runoff rates under existing conditions is estimated to be in the range of 23L/s, with an estimated detention volume in the order of 1180m^3.

8.5 RECOMMENDED IMPROVEMENTS

Based on the review of existing drainage systems, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 8.1.

Table 8.1 – Improvement Projects for Existing Deficiencies
Mount Boucherie Creek Basin

Project	Priority	Description	Cost Estimate
8.1	Low	Drainage Easement – Braeburn Court to Mission Hill Road	-
8.2	Low	Erosion Protection – Menu Road to Gregory Road	$55,075
8.3	Low	Erosion Protection – Gregory Road to Mission Hill Road	$113,150
8.4	High	Conveyance improvements – Boucherie Road to Okanagan Lake	$738,000
8.5	Low	Storm sewer Upgrades – Sunnyview Road	$275,600
8.6	Low	Drainage Easement – Stevenson Road to Douglas Road	-
8.7	Low	Drainage Easement – Douglas Road to Ogden Road	-
8.8	Low	Drainage Easement – Lakeview Cove Rd to Ourtoland Rd.	-
8.9	Low	Drainage Easement – Ogden Rd. to Westbrook Rd.	-
8.10	Low	Drainage Easement – McCartney Rd. to Montigny Rd.	-
8.11	Low	Drainage Easement – Bazett Rd. to Sunnyside Rd.	-
8.12	High	Inspect/clean Outfall pipe – Green Bay Road	$21,600
8.13	High	Install Storm overflow pipe – Green Bay Road	$67,500
8.14	Medium	Relocate Catchbasin Leads- Green Bay Road	$17,000

Table 8.2
Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MB128	MB478	57.3	Circular	600	1%	278	468
MB158	MBJ-6	605.9	Trapezoidal	600	4%	161	412
MB196	MB198	40.2	Circular	250	15%	18	54
MB198	MB200	118.6	Circular	250	1%	18	52
MB200	MB202	86.5	Circular	1000	6%	18	52
MB202	MB240	90.6	Circular	250	5%	125	**202**
MB204	MB202	42.1	Circular	250	39%	107	211
MB208	MB204	30.4	Circular	250	2%	56	56
MB218	MB226	33.1	Circular	250	5%	28	84
MB220	MB218	6.5	Circular	1000	12%	28	85
MB222	MB220	19.8	Circular	200	39%	28	85
MB224	MB222	10.0	Circular	200	26%	28	85
MB226	MB228	52.1	Circular	1000	5%	28	84
MB228	MB236	62.2	Circular	250	19%	60	183
MB236	MB246	33.3	Circular	1000	1%	60	183
MB240	MB242	20.0	Circular	1000	1%	125	774
MB242	MB258	72.7	Circular	250	5%	125	**157**
MB246	MB248	48.8	Circular	1000	1%	60	618
MB248	MB250	29.0	Circular	300	10%	122	304
MB250	MB252	42.1	Circular	300	5%	122	**251**
MB252	MB254	44.3	Circular	300	5%	122	251
MB254	MB256	34.8	Circular	300	4%	122	**229**
MB256	MB260	9.6	Circular	300	19%	237	332
MB258	MBJ-17	320.9	Trapezoidal	100	12%	8	50
MB258	MB256	72.5	Circular	250	4%	118	137
MB260	MBJ-17	261.8	Trapezoidal	100	14%	40	134
MB260	MB270	107.6	Circular	300	0%	197	198
MB262	MB248	13.1	Circular	1000	5%	64	839
MB264	MB248	62.3	Circular	1000	1%	0	320
MB270	MB272	35.4	Trapezoidal	600	2%	197	198
MB272	MBJ-17	223.0	Trapezoidal	600	15%	197	198
MB292	MB304	47.7	Circular	250	4%	167	**233**
MB294	MB292	31.6	Circular	200	0%	14	**78**
MB296	MB294	30.5	Circular	200	1%	12	**48**
MB298	MB296	30.5	Circular	200	0%	11	**48**
MB304	MB306	18.3	Circular	250	44%	167	233
MB306	MB308	47.6	Circular	250	13%	164	234
MB308	MB310	100.3	Circular	250	15%	164	233
MB310	MB312	32.5	Circular	250	12%	163	233

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MB312	MB314	34.9	Circular	250	12%	163	233
MB314	MB316	88.7	Circular	250	8%	163	**214**
MB316	MB318	85.7	Circular	250	8%	163	**200**
MB318	MBJ-45	10.9	Trapezoidal	100	9%	38	74
MB318	MB320	36.3	Circular	250	1%	125	129
MB320	MBJ-13	307.9	Trapezoidal	100	4%	54	55
MB320	MB322	89.6	Circular	250	1%	71	78
MB322	MB324	47.8	Circular	250	1%	71	**71**
MB324	MB328	92.4	Circular	250	1%	**71**	**71**
MB326	MB328	8.9	Circular	500	1%	2	6
MB328	MB330	12.4	Circular	500	1%	71	71
MB330	MB332	5.9	Circular	250	2%	71	71
MB332	MB334	42.2	Circular	250	41%	71	71
MB334	MB208	30.0	Circular	300	1%	**56**	**56**
MB358	MB224	46.2	Circular	200	23%	28	85
MB372	MB374	18.4	Circular	250	2%	0	20
MB374	MB376	33.6	Circular	250	3%	82	**227**
MB376	MB380	57.7	Circular	250	50%	82	227
MB378	MB376	19.9	Circular	250	1%	0	0
MB380	MB398	27.2	Circular	250	17%	82	227
MB398	MB490	51.8	Circular	250	54%	82	227
MB400	MB486	70.7	Circular	525	2%	215	322
MB430	MB436	7.9	Circular	1000	1%	2	22
MB432	MB436	23.1	Circular	450	14%	81	263
MB434	MB466	271.8	Trapezoidal	600	3%	80	257
MB436	MB434	15.6	Circular	450	10%	81	258
MB440	MB442	103.8	Circular	600	3%	408	1153
MB442	MB546	98.9	Circular	600	4%	408	1153
MB464	MB466	46.2	Circular	250	18%	39	120
MB466	MB468	108.8	Circular	250	8%	147	**209**
MB468	MB470	100.0	Circular	250	8%	147	**206**
MB470	MB472	80.4	Circular	250	8%	147	**196**
MB472	MB474	77.9	Circular	250	6%	147	**196**
MB474	MB476	20.6	Circular	250	9%	176	**279**
MB476	MB494	130.3	Circular	1200	0%	1091	2501
MB478	MB476	78.1	Circular	1200	0%	919	2230
MB480	MB128	16.9	Circular	600	0%	242	389
MB482	MB478	34.7	Circular	600	16%	627	1803
MB484	MB480	75.4	Circular	600	1%	243	**389**
MB486	MB484	44.4	Circular	525	2%	215	322
MB488	MB490	70.7	Circular	250	3%	31	**93**
MB490	MB400	25.4	Circular	300	2%	215	**319**
MB492	MB488	92.7	Circular	250	8%	31	93

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MB494	MB496	127.0	Circular	1200	0%	1088	2498
MB496	MB498	93.2	Circular	1200	3%	1114	2590
MB498	MB500	102.2	Circular	1200	0%	1114	**1192**
MB500	MB502	102.0	Circular	1200	0%	1114	1192
MB502	MB504	177.1	Circular	1200	0%	1114	1192
MB504	MB506	29.8	Circular	1200	1%	1114	1193
MB506	MB508A	124.8	Circular	1200	3%	1114	1192
MB510	MB482	24.1	Circular	600	10%	627	1803
MB512	MB510	26.9	Circular	600	26%	597	1715
MB514	MB512	20.5	Circular	600	35%	597	1715
MB520	MB522	48.4	Circular	1000	8%	31	94
MB522	MB510	51.5	Circular	250	7%	31	92
MB524	MB536	27.1	Circular	250	7%	0	4
MB534	MB540	69.1	Circular	250	18%	31	93
MB536	MB538	29.7	Circular	250	2%	0	**80**
MB538	MB548	120.1	Circular	600	7%	551	**1578**
MB540	MB542	11.4	Circular	250	23%	31	93
MB542	MB544	48.7	Circular	250	28%	31	93
MB544	MB492	44.8	Circular	1000	40%	31	93
MB546	MB538	104.0	Circular	600	5%	407	1153
MB548	MB550	97.6	Circular	1000	7%	550	1578
MB550	MB514	95.3	Circular	600	8%	550	1576
MB572	MB576	55.1	Circular	375	2%	57	120
MB574	MB572	10.4	Circular	250	6%	57	120
MB576	MB578	13.6	Circular	375	4%	57	120
MB578	MB580	68.0	Circular	375	6%	57	120
MB580	MB582	41.9	Circular	375	4%	57	120
MB582	MB584	60.4	Circular	375	7%	57	120
MB584	MB586	59.2	Circular	375	21%	57	120
MB586	MB588	17.6	Circular	375	24%	57	120
MB588	MB906	61.9	Circular	525	8%	57	120
MB592	MB574	58.6	Circular	250	11%	57	120
MB694	MB704	32.5	Circular	375	2%	0	61
MB702	MB694	27.9	Circular	375	8%	0	61
MB704	UPLANDS_POND_2	29.6	Circular	375	30%	0	61
MB726	MB702	10.1	Circular	300	2%	0	61
MB728	MB726	16.4	Circular	250	88%	0	61
MB742	MB744	44.8	Circular	300	9%	193	330
MB744	MB746	19.9	Circular	250	8%	193	**290**
MB746	MBJ-28	171.0	Trapezoidal	1000	9%	455	885
MB748	MB744	28.9	Circular	1000	1%	0	36
MB750	MB742	7.6	Circular	250	4%	0	**262**
MB766	MB262	186.6	Trapezoidal	600	21%	64	155

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MB846	MB848	116.2	Circular	250	1%	6	28
MB848	MB850	58.6	Circular	250	9%	6	28
MB850	MB852	105.0	Circular	250	11%	9	46
MB852	MB854	11.5	Circular	250	7%	9	46
MB854	MB856	37.7	Circular	300	17%	9	46
MB856	MB858	22.6	Circular	1000	2%	9	46
MB858	MB860	19.1	Circular	375	3%	9	46
MB860	UT	45.7	Circular	375	25%	33	104
MB864	MB866	5.8	Circular	250	8%	42	52
MB866	MB766	18.0	Circular	600	17%	42	52
MB868	MB870	90.0	Circular	250	3%	26	79
MB870	MB872	95.7	Circular	250	8%	26	78
MB872	MB860	63.1	Circular	250	7%	26	78
MB886	MB916	31.0	Circular	375	5%	149	426
MB896	MB898	13.0	Circular	525	3%	309	866
MB898	MB440	8.6	Circular	525	3%	309	867
MB900	MB896	48.9	Circular	375	12%	148	426
MB906	MB908	67.6	Circular	525	5%	133	334
MB908	MB910	75.0	Circular	525	15%	133	334
MB910	MB912	25.0	Circular	525	13%	133	334
MB912	MB914	62.4	Circular	525	2%	133	334
MB914	MB896	68.2	Circular	600	1%	133	334
MB916	MB900	61.1	Circular	375	1%	148	426
MBJ-1	MBJ-30	25.1	Circular	300	8%	55	145
MBJ-10	MBJ-40	11.8	Circular	500	7%	159	476
MBJ-11	MBJ-42	19.9	Circular	600	15%	92	328
MBJ-12	MBJ-15	57.8	Trapezoidal	600	3%	550	**1170**
MBJ-13	MBJ-7	98.6	Trapezoidal	600	14%	339	826
MBJ-14	MBJ-22	57.4	Circular	150	27%	**97**	**97**
MBJ-15	MBJ-39	32.2	Circular	450	3%	**333**	**332**
MBJ-16	MBJ-17	532.3	Trapezoidal	600	4%	397	521
MBJ-17	MBJ-14	19.0	Circular	600	5%	**294**	**294**
MBJ-19	MBJ-26	41.6	Trapezoidal	600	2%	273	598
MBJ-2	3	418.3	Trapezoidal	600	7%	59	176
MBJ-20	MBJ-41	141.9	Trapezoidal	600	2%	371	540
MBJ-21	MBJ-15	202.6	Trapezoidal	600	7%	339	814
MBJ-22	MBJ-23	40.2	Circular	150	10%	**60**	**60**
MBJ-23	MBJ-24	97.6	Circular	150	16%	60	60
MBJ-24	MBJ-25	150.1	Circular	150	7%	**50**	**50**
MBJ-25	1	18.8	Trapezoidal	600	5%	49	49
MBJ-26	MBJ-27	50.2	Circular	900	1%	273	598
MBJ-27	MB746	278.6	Trapezoidal	1000	8%	272	597
MBJ-28	2	50.6	Circular	900	2%	455	885

Up Node	Down Node	Length (m)	Cross-Section	Existing Diameter (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
MBJ-29	MB864	54.3	Circular	250	17%	42	52
MBJ-3	MBJ-4	441.7	Trapezoidal	600	3%	81	755
MBJ-30	MBJ-31	119.8	Trapezoidal	600	8%	53	143
MBJ-31	MBJ-32	16.0	Circular	300	8%	51	142
MBJ-32	MBJ-33	149.9	Trapezoidal	600	8%	50	142
MBJ-33	MBJ-34	14.9	Circular	500	8%	50	142
MBJ-34	3	227.5	Trapezoidal	600	9%	47	142
MBJ-35	MBJ-20	406.5	Trapezoidal	600	6%	373	540
MBJ-36	MBJ-5	12.2	Circular	450	5%	183	297
MBJ-37	MBJ-36	51.5	Trapezoidal	600	4%	161	232
MBJ-38	MBJ-37	17.4	Circular	300	4%	**124**	**125**
MBJ-39	MBJ-16	505.0	Trapezoidal	600	3%	339	334
MBJ-4	MBJ-43	493.3	Trapezoidal	600	2%	149	**1064**
MBJ-40	MBJ-6	223.7	Trapezoidal	600	7%	159	476
MBJ-41	MBJ-12	186.1	Trapezoidal	600	2%	512	1077
MBJ-42	MBJ-41	198.6	Trapezoidal	600	15%	91	327
MBJ-43	MBJ-38	236.5	Trapezoidal	600	3%	274	**1246**
MBJ-44	MBJ-37	126.5	Trapezoidal	50	7%	40	116
MBJ-45	MBJ-46	272.0	Trapezoidal	600	4%	118	381
MBJ-46	MBJ-13	11.6	Circular	600	4%	286	**776**
MBJ-5	MBJ-19	414.1	Trapezoidal	600	7%	183	296
MBJ-6	MBJ-35	11.7	Circular	500	6%	374	**540**
MBJ-7	MBJ-21	152.3	Trapezoidal	600	5%	339	823
MBJ-8	MBJ-10	307.6	Trapezoidal	600	7%	43	125
MBJ-9	MBJ-10	233.8	Trapezoidal	600	12%	62	190

Project 8.1 Obtain Drainage Easement – Braeburn Court to Mission Hill Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Braeburn Road to Mission Hill Road.
Implementation:	Access to the storm drainage infrastructure is limited due to the topography and fencing. It is not known if a registered easement or Right-of-Way exists for the drainage infrastructure and overland flow rate. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



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Project 8.2 Erosion Protection – Menu Road to Gregory Road

Proposed Works: Install erosion protection measures along the storm outfall route from Menu Road to south of Gregory Road.

Implementation: Runoff velocity in this channel section is high and results in erosive conditions along the channel. This work is considered a Low priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.

Consequences if not completed: Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.

Priority: 3

Location:



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	175	$225.00	$39,375
Contingency (25%)				$9,800
Engineering (15%)				$5,900
Total Project Cost				**$55,075**

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Project 8.3 Erosion Protection/ Drainage Easement – Gregory Road to Mission Hill Road

Proposed Works:	Install erosion protection measures and establish a drainage easement along the storm outfall route from south of Gregory Road to Mission Hill Road.
Implementation:	Runoff velocity in this channel section is high and results in erosive conditions along the channel. This work is considered a Low priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	3
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	350	$225.00	$78,750
Contingency (25%)				$19,700
Engineering (15%)				$14,700
Total Project Cost				**$113,150**

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Project 8.4 Conveyance Improvements – Boucherie Road to Okanagan Lake

Proposed Works: Complete ditching improvements and storm sewer installation from Boucherie Road to Okanagan Lake, north of Green Bay Road.

Implementation: The existing flow rate significantly exceeds the pipe capacity, and the overland flow results in erosion problems and sediment concerns within Green Bay. This work is considered a High priority, due the environmental concerns and impact on the agricultural operations. Environmental benefits can be achieved with the implementation of the erosion protection measures.

Consequences if not completed: Erosive conditions in the open channel sections will continue to present environmental concerns and related to sediment deposit within Green Bay, and operational concerns for the active agricultural land-use.

Priority: 1

Location:



Description	Unit	Quantity	Unit Price	Total
750mm PVC	Lm	325	$600	$195,000
Manholes	ea	12	$4,000	$48,000
Oil/Grit Separator	LS	1		$270,000
Contingency (25%)				$129,000
Engineering (15%)				$96,000
Total Project Cost				**$738,000**

RSB ENGINEERING

Project 8.5 Storm Sewer Upgrades – Sunnyview Road

Proposed Works:	Replace the existing storm sewer near the south end of Sunnyview Road.
Implementation:	The existing flow rate within the storm sewer at the south end of Sunnyview Road exceeds the hydraulic capacity of the pipe. As a result, the flow will surcharge to the ground surface, and flow overland through the downstream agricultural area. This work is considered a Low priority since the risk of flooding and property damage is considered low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	The pipe will surcharge to the ground surface, may result in erosive conditions in the downstream areas.
Priority:	3
Location:	



Description	Unit	Quantity	Unit Price	Total
600mm PVC	Lm	455	$375	$170,625
Manholes	ea	7	$3,000	$21,000
Contingency (25%)				$48,000
Engineering (15%)				$36,000
Total Project Cost				**$275,600**

RSB ENGINEERING

Project 8.6 Obtain Drainage Easement – Stevenson Road to Douglas Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Stevenson Road to Douglas Road.
Implementation:	Overland flow travels across private property enroute to a localized depression area within the agricultural fields. This flow route and depression area is not within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 8.7 Obtain Drainage Easement – Douglas Road to Ogden Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Douglas Road to Ogden Road.
Implementation:	Overland flow travels across private property through a well defined gulley, towards Odgen Road. This flow route is not within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 8.8 Obtain Drainage Easement – Lakeview Cove Road to Ourtoland Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Lakeview Cove Road to Ourtoland Road.
Implementation:	During large rainfall events, overland flow travels across private property enroute to the north end of Ourtoland Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. The steep slopes may also be prone to erosion during a significant rainfall event. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 8.9 Obtain Drainage Easement – Ogden Road to Westbrook Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Ogden Road to Westbrook Road.
Implementation:	Overland flow from the Ogden Road area travels overland across private property enroute to Westbrook Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 8.10 Obtain Drainage Easement – McCartney Road to Montigny Road

Proposed Works:	Establish a drainage easement or Right-of-Way from McCartney Road to Montigny Road.
Implementation:	Overland flow from the Ogden Road area travels overland across private property enroute to Westbrook Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



Project 8.11 Obtain Drainage Easement – Bazett Road to Sunnyside Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Bazett Road to Sunnyside Road.
Implementation:	Overland flow from the west end of Bazett Road travels overland across private property enroute to Sunnyside Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 8.12 Inspect/Clean Outfall Pipe – Green Bay Road

Proposed Works:	Carry out a camera and diving inspection of the existing 1200mm storm outfall pipe at Okanagan Lake.
Implementation:	The condition, and potential sediment accumulation within the existing outfall pipe is not known. This work is considered a High priority, since the risk of flooding and/or property damage on Green Bay Road is considered moderate to high.
Consequences if not completed:	Reduced capacity within the pipe may contribute to pipe surcharging problems within the Green Bay drainage system. Sediment accumulation, or blocked outlet holes will restrict the pipe discharge capacity and can result in surcharging in the upstream areas.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Inspection	LS	1		$15,000
Contingency (25%)				$3,800
Engineering (15%)				$2,800
Total Project Cost				**$21,600**

RSB ENGINEERING

Project 8.13 Install Storm Overflow Pipe – Green Bay Road

Proposed Works: Install a 600mm overflow pipe on Green Bay Road.

Implementation: To help alleviate the pipe surcharging in the Green Bay storm sewer system, a high level overflow pipe has been proposed, to connect into the proposed outfall, north of Green Bay Road. This work is dependent upon prior completion of the new storm sewer pipe as outlined in Project 8.4. The high level overflow can divert approximately 200L/s from the Green Bay system, into the new outfall during major runoff events. This work is considered a High priority, since the risk of flooding and/or property damage in the Green Bay area is high.

Consequences if not completed: The Green Bay storm sewer system will continue to surcharge, increasing the risk of flooding and property damage during large runoff events.

Priority: 1

Location:



Description	Unit	Quantity	Unit Price	Total
600mm PVC	Lm	80	$375	$30,000
Manholes	ea	3	$4,000	$12,000
Dewatering	LS	1		$5,000
Road Restoration	m^2	100	$30	$3,000
Contingency (25%)				$12,500
Engineering (15%)				$5,000
Total Project Cost				**$67,500**

RSB ENGINEERING

Project 8.14 Relocate Catch basin Leads – Green Bay Road

Proposed Works:	Remove the existing catch basin leads, and connect them to the existing 1200mm storm sewer pipe.
Implementation:	The existing catch basins along Green Bay Road currently discharge into the privately owned canal on the south side of Green Bay Road. There is no easement or Right-of-Way permitting the discharge of the municipal stormwater into the private canal. This work is considered a Moderate priority.
Consequences if not completed:	Runoff from the urban areas along Green Bay road will continue to discharge into the privately owned canal.
Priority:	2

Location:



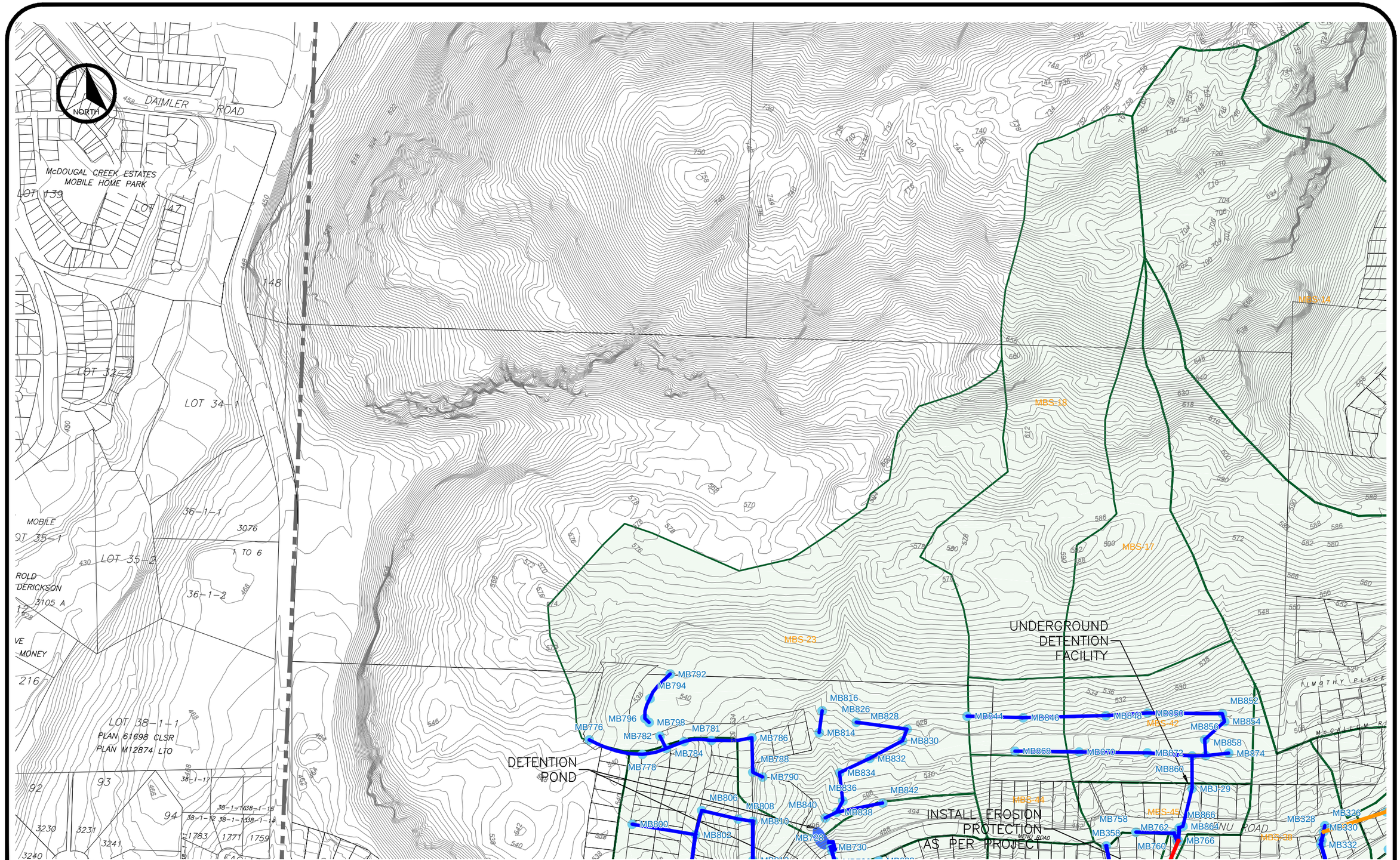
Description	Unit	Quantity	Unit Price	Total
Catch basins	ea	6	$2000	$12,000
Contingency (25%)				$3,000
Engineering (15%)				$2,000
Total Project Cost				**$17,000**

RSB ENGINEERING



FIGURE 8.0
MOUNT BOUCHERIE BASIN
KEY MAP
N.T.S.

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MBS-23 CATCHMENT ID
- MB800 JUNCTION ID
- MB754 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

		8.4
	8.1	8.5
	8.2	8.6

FIGURE 8.1
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

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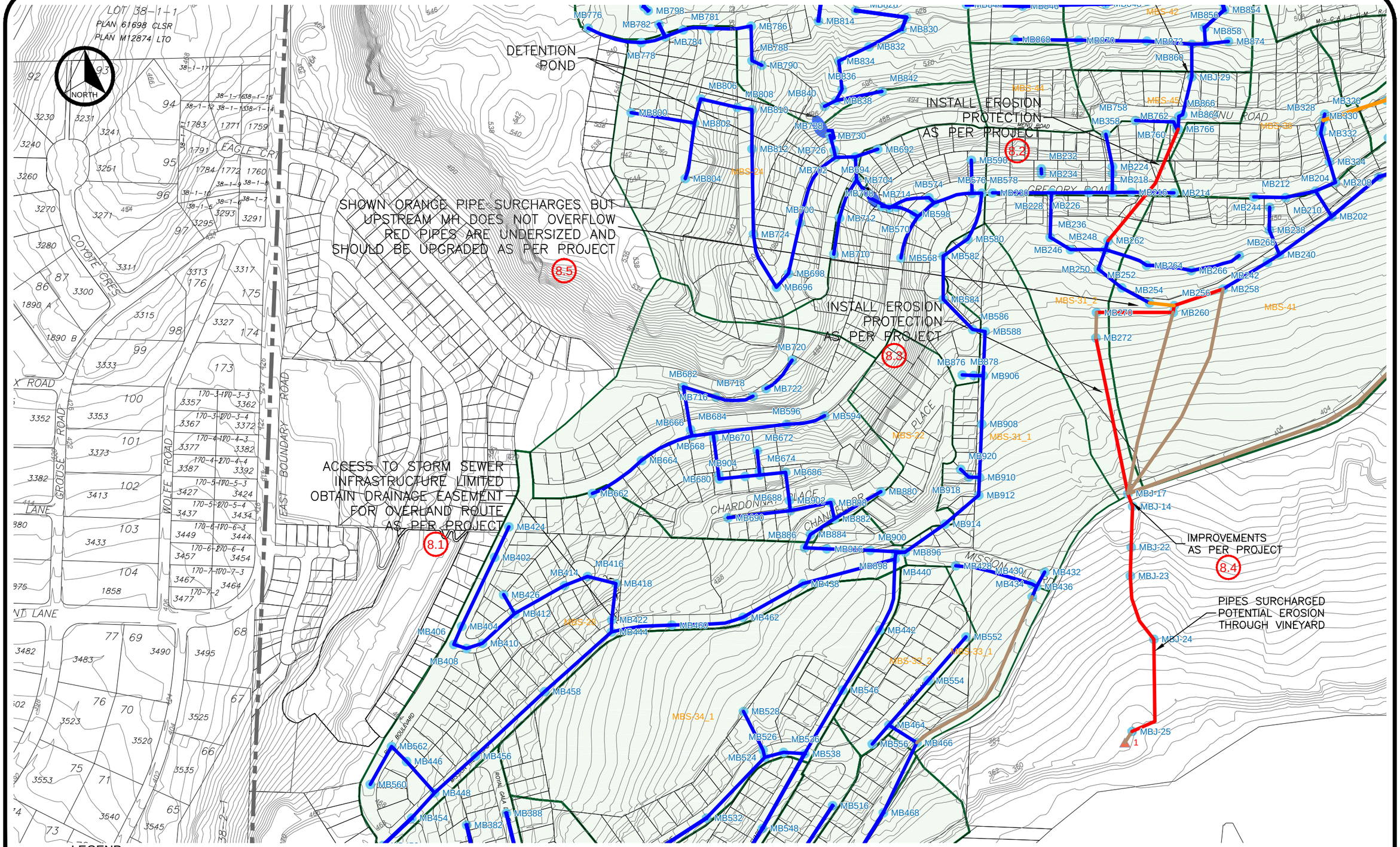


FIGURE 8.2
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

INSTALL HIGH-LEVEL OVERFLOW AND VEGETATED CHANNEL AS PER PROJECT

8.13

SUBMERGED PIPES DUE TO OKANAGAN LAKE WATER LEVEL DRAINAGE IMPROVEMENTS AS PER PROJECT

8.4

PROBABLE SEDIMENT ACCUMULATION IN PIPES INSPECT PIPES AND OUTFALL AS PER PROJECT

8.12

RELOCATE CATCHBASIN LEADS TO EXISTING 1200mm STORM SEWER AS PER PROJECT

8.14

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MBS-23 CATCHMENT ID
- MB800 JUNCTION ID
- MB754 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	8.2	8.6
	8.3	

FIGURE 8.3
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

INDUSTRIAL ROAD

COMBE DRD ROAD

THOMAS ROAD

COLLEEN ROAD

HUDSON ROAD

PONDEROSA CRT

DENNY CRT

MARILYN CRT

ALHAMBRA DRIVE

LYNDEN ROAD

MICHAEL DRIVE

PAULA ROAD

GUIDI ROAD

JOYCE ROAD

TREVOR DRIVE

CORDOVA WAY

ARLINGTON PLACE

STEVENSON ROAD

WINNIPEG ROAD

HARMON R

STUART ROAD

RUNNEY ROAD

CAYLINE ROAD

LINDSAY COURT

GANT CR

WELLINGTON ROAD

ANDERS ROAD

OLALLA AVE.

HAWTHORN ROAD

DOUGLAS ROAD

HACKER DRIVE

MBS-1

MBS-2

MBS-3

MBS-4

MBS-5

MBS-6

MBS-7

MBS-8

MBS-9

MBS-10

MBS-11

MB130

MB132

MB134

MB136

MB138

MB150

MB152

MB154

MB156

MB158

MBJ-1

MBJ-2

MBJ-3

MBJ-8

MBJ-9

MBJ-30

MBJ-31

MBJ-32

MBJ-33

MBJ-34

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT 8.6

LOCAL DEPRESSION

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MBS-23 CATCHMENT ID
- MB800 JUNCTION ID
- MB754 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	8.4	
8.1	8.5	

FIGURE 8.4
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

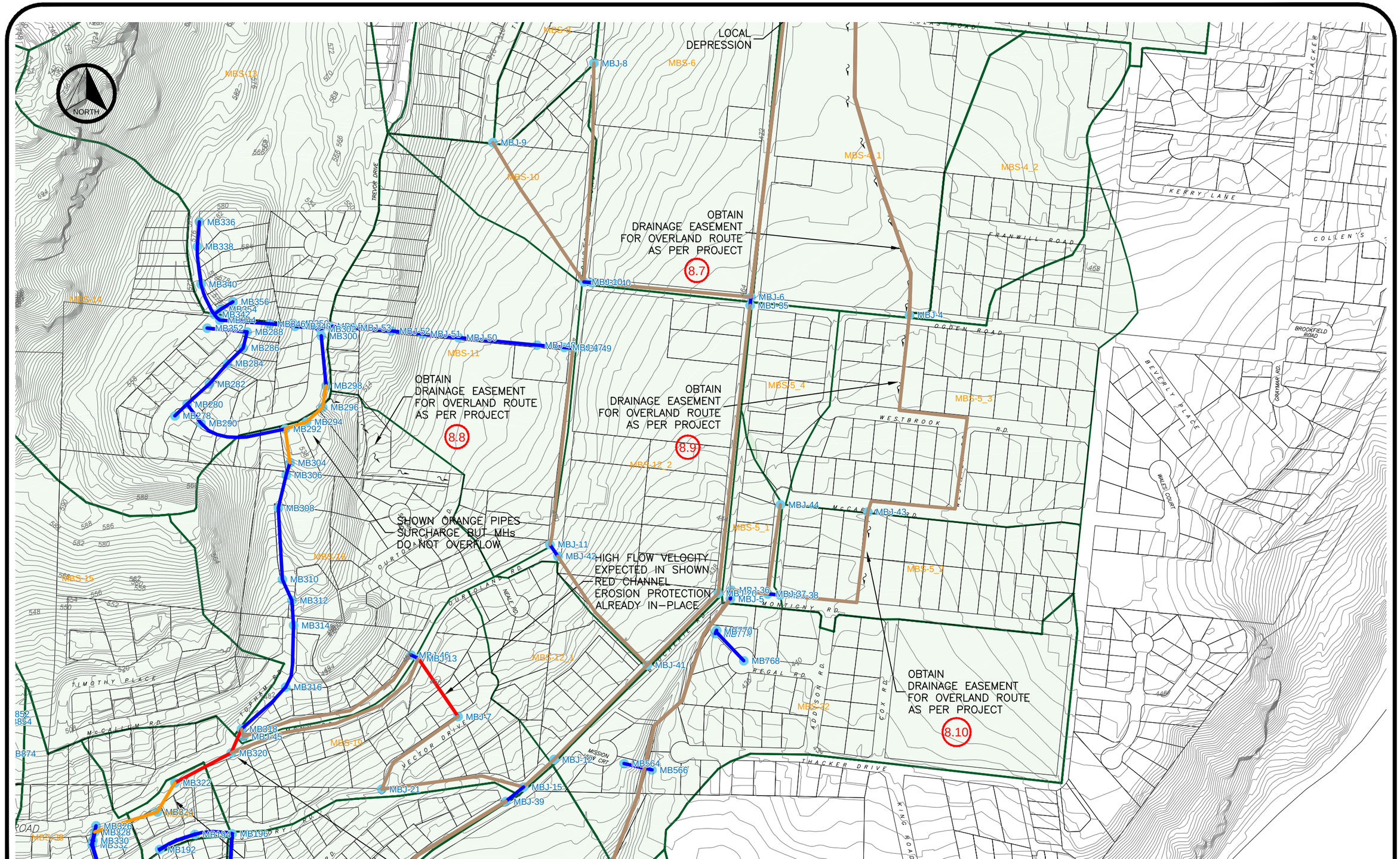


FIGURE 8.5
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

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SHOWN RED PIPES
OVERFLOW TO DITCHES
TO THE EAST
NO IMPROVEMENT
REQUIRED

SHOWN ORANGE PIPES
SURCHARGE BUT MHs
DO NOT OVERFLOW

OBTAIN
DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT

8.11

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MBS-23 CATCHMENT ID
- MB800 JUNCTION ID
- MB754 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

8.1	8.5	
8.2	8.6	
8.3		

FIGURE 8.6
MOUNT BOUCHERIE BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

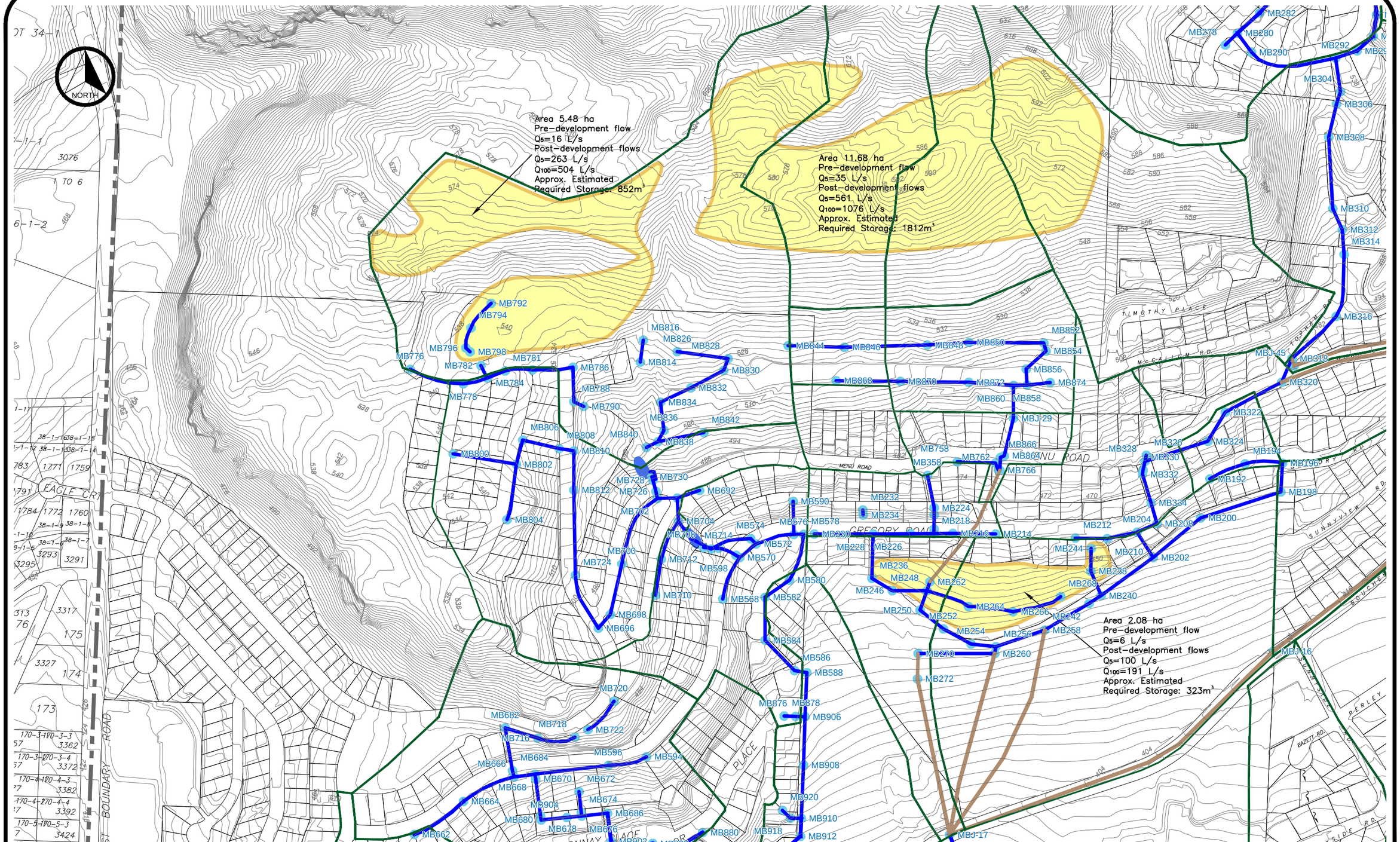
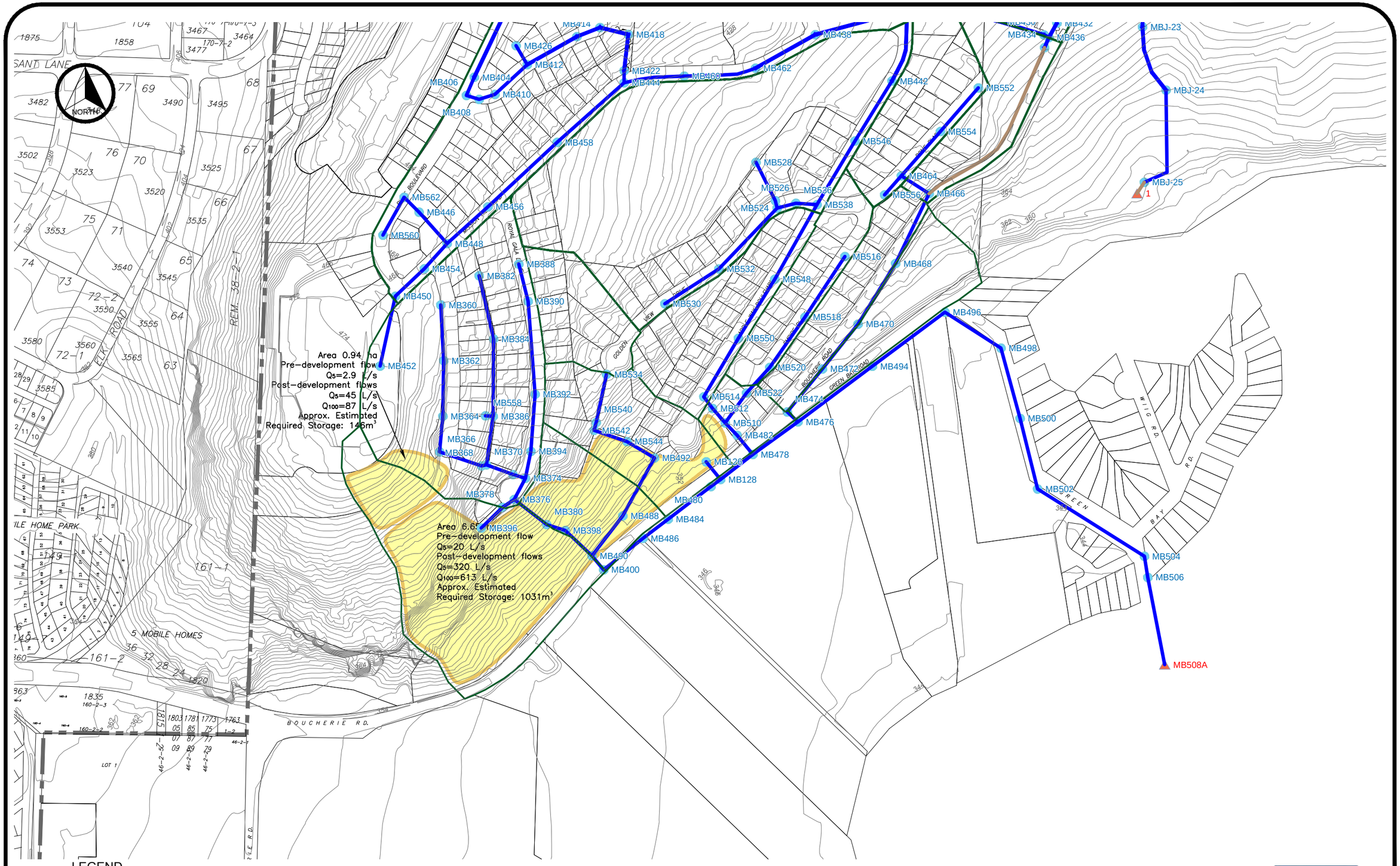


FIGURE 8.7
MOUNT BOUCHERIE BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- MBS-23 CATCHMENT ID
- MB800 JUNCTION ID
- MB754 OUTFALL ID
- 524 CONTOUR ELEVATION
- 2m CONTOUR

FIGURE 8.8
MOUNT BOUCHERIE BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

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SECTION 9
KEEFE CREEK BASIN PLAN

9.1 BASIN DESCRIPTION

Keefe Creek is a large watershed located east of McDougall Creek. Although the watershed boundaries extend to Mount Hayman (elev. 1415m) the creek originates from the outfall of Rose Valley Lake (elev. 600m). From the discharge dam on Rose Valley Lake, the creek flows south before switching to an easterly direction across Westlake Road, then northwards through First Nations land (IR 10) and into Okanagan Lake.

The watershed has an approximate drainage area of 2,008 ha which includes Rose Valley Lake, West Kelowna Estates and the industrial area near Stevens Road. Lakeview Irrigation District (LID) uses Rose Valley Lake as a potable water supply source, with a dam to control water levels and provide storage. The dam acts as a regulator for flows in Keefe Creek.

Aside from the main channel of Keefe Creek, there are two important areas in the basin that contain DWK drainage infrastructure and are sources of urban stormwater runoff. These areas are:

1) West Kelowna Estates – a series of residential subdivisions along upper Westlake Drive and Horizon Drive. These neighbourhoods have a combination of storm sewers, culverts, ditches and curb-gutter road sections.

2) Large industrial area between Stevens Road and Highway 97, from Bartley to Westlake Road.

9.2 EXISTING SYSTEM ANALYSIS

The Keefe Creek drainage basin contains a mix of undeveloped hillside areas, residential development and industrial areas. The older single-family development areas are typically serviced with roadside ditches and culverts, while the newer development areas incorporate the newer standards of curb/gutter and storm sewer systems. The recently developed areas around Rose Valley and Sunview Drive consist of a piped storm sewer system that discharges into Faulkner Creek, west of Westlake Road.

As outlined in Section 12.3, there has been significant development pressure on the Keefe Creek system with a resulting degradation of creek stability and loss of riparian habitats. Creek down-cutting and sediment deposits within the channel have yielded a lack of gravel substrates and loss of habitat in the downstream sections. In addition, several tile

drains were noted during the watercourse evaluation, one of which was noted to have a strong odour of septic effluent.

A joint-use stormwater detention facility and park was recently constructed south of Rose Meadow Drive which serves to collect excess flow from the low-point on Rose Meadows Drive. A private (strata) detention tank was constructed to service the bare-land strata development north of Calendonia Way, and is intended to restrict flows from the storm sewer system on Calendonia Way.

The developed areas in the vicinity of Sunview Drive and Caledonia Way did not appear to contain any stormwater detention facilities that would reduce the peak flow rates in the downstream areas.

The storm drainage network within this area was largely interconnected with piped and overland channels to convey the runoff directly to Faulkner Creek. This results in rapid run-off, low infiltration potential and high velocities within the creek channel.

A private (strata) storm detention facility was constructed east of Scott Road, south of McNaughton Road. According to the available Record Drawings, it appears as though this facility was constructed as part of the adjacent strata development. Based on the field reconnaissance however, it appears that this facility also receives runoff contributions from areas upstream of the strata development.

The industrial areas rely entirely on overland flow routes and infiltration for stormwater drainage as there are no piped systems within this developed area. The large parcels, flat grades and permeable soils combine to produce relatively low runoff rates. Some minor surface ponding however has been noted in the vicinity of Stevens Road and Ross Road. As such, drainage within this area has not presented notable flooding concerns. Considering the potential pollutant risks associated with industrial development however, it is recommended that the District work closely with the Fire Department to maintain an up-to-date inventory of the industrial uses, chemicals and potential contaminants that may be discharged into the environment as either overland flow or through the subsurface soils which may lead to groundwater contamination.

PCSWMM was used to estimate the stormwater runoff. The model nodes for the system are presented within Figures 9.1 through 9.9. Runoff was estimated by simulating the 1 in 5 year and 1 in 100 year storms with 1 hour duration. The peak flow in the system is presented in Table 9.2 at the end of this section. Note, the flows shown within Table 9.2 are presented for comparative purposes only and should not be used for detailed design of infrastructure works. Sections shown in bold indicate surcharged conditions, in which the inflow exceeds the modeled capacity. Segments downstream of surcharged node do

not include the flow rate that exceeds the downstream conveyance capacity. Detailed analysis and further dynamic modeling iterations should be completed as a part of future improvement works or changes to the existing drainage system to determine the downstream impacts.

9.3 EXISTING SYSTEM DEFICIENCIES

During both the minor and major storm events, localized ponding and depression storage will occur at a number of locations. As with most hillside development areas, a number of driveways have been constructed without positive drainage away from the buildings. This may present nuisance drainage and/or flooding problems from on-site drainage areas. For the purposes of the Master Drainage Plan, we have focused primarily on these locations that may receive runoff contributions from other, offside drainage areas.

Industrial Area Inventory – Stevens Road Industrial Development

Considering the potential pollutant risks associated with industrial operations, and the wide variation in products or chemicals used on site, it is important that the District maintain an up-to-date inventory and identification of potential risks. The risks are not only limited to liquid stored on-site but should also consider the potential contaminants and downstream impacts due to fire-fighting operations that may carry contaminants into the downstream areas. This may include, but not necessarily limited to overland flow routes and groundwater contamination risks. This project has been recommended as Project 9.1.

Ditch Erosion along Westlake Road

The existing ditch along the west side of Westlake Road is subject to high flow rates and erosive velocities. The ditch section from Rosewood Drive to Caledonia Way has an estimated velocity of 1.8 m/s. Erosion protection measures such as riprap, check dams or geo-fabric lining should be installed to minimize the erosion potential and resulting sedimentation downstream. The recommended improvements have been presented as Project 9.2.

Erosion Protection and Drainage Easement – Parkinson Road to Scott Crescent

Due to the steep grades in the overland flow route from Parkinson Road through to Scott Crescent, this section is subject to erosive velocities. In addition, it is not apparent if this drainage route is protected with an existing drainage easement. Project 9.3 recommends that the District confirm that this route is protected by a drainage easement and that additional erosion protection measures such a vegetated geotextile lining be used, or riprap lining in isolated locations to minimize the erosion potential.

Erosion Protection – Bear Creek Road

Due to the steep grades the roadside ditch on the west side of Bear Creek Road is subject to erosive velocities. Erosion protection measures such as a vegetated geotextile lining and check dams are recommended within Project 9.4 to reduce the erosion potential along this route.

Drainage Easement – Parkinson Road to Vancouver Road

Drainage from the undeveloped areas north of Guest Road and also along Parkinson Road drain through a system of piped sections as well as overland flow channels enroute to Vancouver Road and then ultimately to Bear Creek Road. Based on the available cadastral information, it is not apparent if a drainage easement exists through these properties. In addition, the steep grades result in potentially erosive velocities in the overland flow sections. Project 9.5 recommends the establishment of protected drainage easements as well as the inclusion of erosion protection measures.

Culvert outlet Improvements – Horizon Drive

The existing culvert outlet is situated several feet above the existing ground. This results in an erosive, condition at the outlet. Project 9.6 recommends cutting the existing culvert and installing a riprap lined discharge apron to prevent further erosion at the outlet.

Drainage Easement – Bear Creek Road to Westside Road

Overland flow in the vicinity of the Bear Creek Road/Scott Crescent intersection travels eastward towards Westside Road. This flow path should be protected within a drainage easement to ensure that future construction or development is not within the existing drainage routes. These recommendations are provided within Project 9.7.

Channel Erosion – Spyglass Way to Westview Way

The existing channel, from Spyglass Way to Westview Way is subject to very high flow rates and high velocity as the flow travels down the steep bank to Westview Way. Based on the available Record Drawings information, it appears that this channel receives flow from the earlier developments such as Covington Court and Pinewood Place, as well as the recently completed strata development in Diamond View Estates. There does not appear to be any stormwater detention facilities within Diamond View Estates strata development, and as such, the contributing watershed area and impervious surfaces result in rapid runoff potential, with high peak flow rates.

The existing channel is lined with polymer and riprap protection, however, the velocity and steep grades result in velocities that exceed the riprap stability and the channel is

showing signs of overtopping and failure. The recommended channel improvements are identified in Project 9.8.

Repair/Expand Detention Facility – Westview Way

A stormwater detention facility was constructed to the east of Westview Way, north of Horizon Drive. This facility accepts runoff from the up-stream developments on Westview Way and Diamond View Estates, plus runoff from the strata development in Horizon Village. Field review of the detention facility has indicated that the earth berms utilized to form the detention area have eroded, and the detention facility does not function as intended. Flow through this detention basin will continue to cause erosion within the existing bermed areas.

In addition, the basin volume appears to be quite low in comparison to the contributing watershed area. As outlined in Project 9.9, it is recommended that the detention facility be expanded and the earth berms re-constructed to safely contain the desired volume.

Erosion Protection, Keefe Creek – Horizon Drive to WFN

The incremental runoff increases from the residential developments has resulted in higher flow rates and increase erosion potential within Keefe Creek. Based on the modeling results, the velocity in the channel sections below Horizon Drive are expected to be in the range of 2.0 to 3.7 m/s. Channel velocities in this range are considered erosive and result in down-cutting of the stream channel, particularly during heavy rainfall events. Project 9.10 recommends an integrated channel stabilization plan.

Erosion Protection and Drainage Easement – Horizon Drive to Spyglass Way

Runoff from the areas above Horizon Drive including Olympus Way and Pinewood Place is conveyed through a combination of channels, culverts and piped system enroute to Spyglass Way. The peak flow rates and steep grades results in erosive velocities within the open channel sections. Based on the available cadastral information, it is not apparent if the existing drainage route is protected within a drainage easement. Project 9.11 recommends that the District confirm if a drainage easement exists and that erosion protection measures be in place to minimize the impact of the high velocity.

Infiltration System – Stevens road to Ross Road

The existing surface drainage system along Stevens Road is undulating, with poorly defined drainage routes. Some surface ponding has been noted in the vicinity of Stevens Road and Ross Road. To minimize the extent of surface ponding, an infiltration system is recommended as Project 9.12. As noted in Section 19, the soils within this area are categorized as well suited for infiltration to ground. To allow for a staged approach in

infrastructure construction, Project 9.12 includes the installation of 5 drywells and 200m of a perforated pipe system to promote infiltration along the Stevens Road corridor. This system can be expanded in incremental units along Stevens Road, with an ultimate conveyance system towards Keefe Creek, for larger events that may exceed the natural infiltration capacity.

Erosion Protection – Westview way Outfalls to Keefe Creek

Runoff from the urban developments along Westview Way, and above, discharge into Keefe Creek along the steep banks to the north of the creek. The discharge rates result in overland flow rates that are considered erosive, and are expected to result in erosion along these banks, especially during larger runoff events. Project 9.13 recommends that erosion protection measures, such as geotextile lining, check dams or riprap linings be implemented to reduce the erosion potential along the banks.

Erosion Protection – Horizon Drive

Runoff from Horizon Drive, west of Horizon Village discharges into Keefe Creek along a steep bank. During large runoff events, this will result in erosive velocities along the steep bank above the creek. Project 9.14 recommends the installation of erosion protection measures to reduce this erosion potential.

Drainage Easement and Erosion Protection – Aurora Drive to Covington Court

Runoff from Horizon Drive discharges into privately owned lands east of Aurora Drive, and then through to Covington Court. It is not known if a registered drainage easement has been established along this corridor. In addition, the flow velocities along this channel are considered erosive along the steeper sections of this reach. Project 9.15 includes the recommendation for erosion protection measures, as well as the confirmation of a registered storm drainage easement.

Culvert Modifications – Horizon Drive

The outlet of the existing culvert on Horizon Drive at Keefe Creek is perched several meters above the creek. The vertical drop creates erosive conditions, at the ground surface below. Project 9.16 recommends modifications to the existing outlet, and riprap installation to safely convey the flow to the channel bottom.

9.4 FUTURE DEVELOPMENT AREAS

The anticipated development areas within the Keefe Creek Basin have been indicated on Figures 9.10 through 9.12. These development areas have been extracted from the available Official Community Plan information, as included in Figure 2.1.

Westlake Road – South of Rosewood Drive

As shown on Figure 9.10, future development areas are expected south of Rosewood Drive, encompassing approximately 11 ha. The anticipated developments are expected to include a mix of residential and institutional zoning.

The development sites will contribute into the existing Faulkner/Keefe Creek system which is already experiencing heavy influence from residential developments. These areas are situated with areas that potentially moderately to well suited for disposal to ground, and these options should be explored as much as possible to promote low impact development options. As a minimum, storm water management practices should utilize a staged release rate to protect the downstream areas. Based on the cursory review, the estimated runoff rate under existing conditions is estimated to be in the range of 11L/s, with a detention volume in the order of 1780m^3. These development parcels are also within the flow path of the discharge channel from the Rose Valley Dam. Special consideration for flooding protection is required in the design for this route to ensure public safety.

North of Rosalee Lane

As shown on Figure 9.10, the future development areas above Rosalee Lane encompass approximately 12 ha of steeply sloping terrain. The hydrogeological review indicates that this areas is not considered suitable for storm water disposed to ground. Although this option may not be suitable, other low impact development options such as rain barrels, and on-site detention facilities should be examined. As noted on Figure 9.10, the estimated runoff rate under existing conditions is estimated at 36L/s and the accompanying detention volume for the 100 year recurrence interval is estimated at 1888m^3.

North of Rose Meadow Drive

As indicated on Figure 9.10, there is an anticipated development parcel of approximately 4.5 ha situated north of Rose Meadow Drive and west of Rosalee Lane. It is anticipated that this area will discharge into the storm drainage system along Rosalee Lane. Based on the cursory review, the anticipated runoff rate under existing conditions is 12L/s and the storm water detention volume is expected to be in the range of 690m^3.

North of McPhail Court

Figure 9.11 indicates the anticipated development area within the valley north of McPhail Court. To limit the impacts on downstream sections of McPhail Court and West Kelowna Road, storm water management initiatives should be implemented as part of the development. As noted on Figure 9.11, the peak flow rate under pre-development

conditions is estimated at 2.5L/s, with a storm water detention volume estimated at 130m^3 for the 1 in 100 year recurrence interval.

North of Westview Way

As shown on Figure 9.12, the future development area of approximately 1.3 ha is anticipated north of Westview Way. The steep slopes and limited access may restrict the developable areas however; the peak runoff rate under existing conditions is estimated to be 3.4L/s, with a detention volume estimated at 210m^3

9.5 RECOMMENDED IMPROVEMENTS

Based on the review of existing drainage systems, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 9.1.

Table 9.1 – Improvement Projects for Existing Deficiencies
Keefe Creek Drainage Basin

Project	Priority	Description	Cost Estimate
9.1	Medium	Industrial Area Inventory – Stevens Road Industrial Area	-
9.2	Medium	Channel Improvements/Easement – Rosewood Dr. to Westlake Road	$200,400
9.3	Medium	Erosion Protection/Easement – Griffiths Place to McNaughton Rd.	$152,725
9.4	Medium	Erosion Protection – Bear Creek Rd	$113,150
9.5	Medium	Erosion Protection/Easement – Parkinson Rd. to Bear Creek Rd.	$46,825
9.6	Medium	Culvert Outlet Improvements – Horizon Drive	$3,650
9.7	Low	Drainage Easement – Bear Creek Rd. to Westside Rd.	-
9.8	High	Erosion Protection/Easement – Spyglass Way to Westview Way	$23,250
9.9	High	Repair Detention Basin – Northeast of Westview Way	$21,550
9.10	Medium	Creek Improvements – Horizon Dr. and Spyglass Way	$259,000
9.11	Medium	Erosion Protection – Horizon Dr. to Spyglass Way	$46,925
9.12	High	Infiltration System – Stevens Road and Ross Road	$164,750
9.13	Medium	Erosion Protection – Spyglass Way to Keefe Creek	$38,750
9.14	Medium	Erosion Protection – Horizon Dr. to WFN Boundary	$13,000
9.15	Medium	Erosion Protection/Easement – Horizon Dr. to Covington Ct.	$32,300
9.16	Medium	Erosion Protection – Westlake R. to Devon Court	$38,800

Table 9.2
Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
9	KCJ-69	362.9	Trapezoidal	4000	3%	52	410
KC100	KC102	15.2	Circular	1000	7%	19	169
KC102	KCJ-13	36.1	Trapezoidal	600	39%	19	170
KC14	KC16	34.0	Circular	250	13%	143	287
KC152	KC186	85.3	Circular	450	7%	4	13
KC16	KC18	80.7	Circular	450	2%	143	289
KC162	KC164	52.8	Circular	250	2%	12	46
KC164	KC166	18.4	Circular	250	3%	12	46
KC166	KC168	9.5	Circular	250	5%	12	46
KC168	KCJ-39	220.7	Trapezoidal	1000	6%	12	46
KC176	KC178	88.2	Circular	1000	11%	37	113
KC178	KC180	45.8	Circular	1000	1%	37	113
KC18	KC20	45.1	Circular	450	2%	137	282
KC180	KC182	13.0	Circular	1000	8%	90	269
KC182	KC184	16.2	Circular	1000	3%	90	269
KC184	KC364	70.0	Circular	1000	1%	90	269
KC186	KC190	114.2	Circular	1000	7%	3	13
KC190	KC192	115.7	Circular	450	2%	3	13
KC192	KC194	21.8	Circular	500	1%	3	13
KC194	KCJ-37	308.5	Trapezoidal	600	8%	30	88
KC196	KC220	51.1	Circular	900	1%	341	1124
KC198	KC196	109.2	Circular	900	0%	290	930
KC20	KC22	32.5	Circular	450	1%	176	388
KC200	KC198	51.0	Circular	900	1%	290	930
KC202	KC200	24.2	Circular	900	0%	290	930
KC204	KC202	93.6	Circular	900	0%	256	826
KC206	KC202	11.4	Circular	300	0%	17	62
KC208	KC206	36.0	Circular	250	5%	17	62
KC210	KC208	95.0	Circular	250	7%	17	62
KC212	KC210	61.6	Circular	250	8%	23	68
KC218	KC222	88.6	Circular	500	7%	3	15
KC22	KC26	26.5	Circular	900	2%	198	442
KC220	KCJ-8	463.2	Trapezoidal	600	8%	362	1175
KC222	KC196	9.3	Circular	500	14%	53	190
KC224	KC222	29.1	Circular	375	1%	50	176
KC226	KC224	29.3	Circular	250	32%	50	176
KC228	KC226	27.5	Circular	250	8%	50	176
KC230	KC228	50.3	Circular	250	8%	22	106
KC232	KC230	56.1	Circular	250	11%	22	106

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
KC234	KC204	88.8	Circular	900	1%	223	715
KC236	KC234	137.1	Circular	600	1%	28	148
KC238	KC234	67.3	Circular	750	0%	195	567
KC254	KC238	60.4	Circular	750	1%	195	567
KC256	KC254	33.0	Circular	525	2%	164	438
KC258	KC256	93.6	Circular	525	1%	167	441
KC26	KC30	18.3	Circular	900	3%	247	589
KC260	KC258	134.4	Circular	525	1%	170	444
KC262	KC260	164.5	Circular	525	1%	134	316
KC264	KC254	75.8	Circular	450	0%	42	130
KC268	KC262	51.1	Circular	375	3%	137	320
KC274	KC268	31.5	Circular	300	5%	100	175
KC276	KC274	45.5	Circular	250	11%	100	173
KC28	KC26	34.1	Circular	500	1%	36	119
KC280	KC236	35.7	Circular	450	1%	31	127
KC282	KC280	49.7	Circular	300	10%	22	90
KC284	KC282	70.6	Circular	300	7%	22	90
KC292	KC236	88.8	Circular	450	1%	0	6
KC294	KC292	97.2	Circular	300	3%	0	6
KC296	KC294	115.8	Circular	300	5%	3	15
KC30	KC32	11.5	Circular	900	4%	247	589
KC32	KC34	20.5	Circular	1000	2%	247	590
KC324	KC330	60.7	Circular	250	3%	100	**173**
KC326	KC324	48.0	Circular	375	31%	100	317
KC330	KC276	15.5	Circular	250	28%	100	173
KC34	KC366	113.5	Triangular	600	15%	247	589
KC348	KC350	16.8	Circular	450	6%	49	168
KC350	KC352	45.6	Circular	450	28%	49	168
KC352	KC354	4.6	Circular	450	11%	49	168
KC354	KC356	99.6	Trapezoidal	600	6%	49	168
KC356	KC358	9.1	Circular	1000	6%	95	313
KC358	KC360	17.8	Circular	1000	3%	95	313
KC360	KC14	89.8	Trapezoidal	600	26%	95	313
KC362	KCJ-21	157.4	Trapezoidal	600	1%	199	594
KC364	KC362	86.1	Circular	1000	16%	90	269
KC366	KC368	34.5	Circular	900	27%	247	589
KC368	KC522	40.1	Trapezoidal	600	31%	247	589
KC370	KC372	25.7	Circular	1000	33%	24	80
KC372	KCJ-70	28.6	Trapezoidal	600	21%	24	80
KC396	KC418	130.7	Circular	300	10%	37	125
KC418	KC420	121.7	Circular	375	10%	37	125
KC420	KC422	89.8	Circular	450	3%	37	125
KC422	KC436	65.9	Circular	525	5%	147	481

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
KC424	KC426	77.4	Circular	450	3%	72	231
KC426	KC428	82.3	Circular	450	2%	72	231
KC428	KC422	74.7	Circular	450	3%	72	231
KC430	KC424	90.1	Circular	375	8%	33	103
KC432	KC430	89.6	Circular	375	8%	33	103
KC434	KC432	74.0	Circular	375	4%	33	103
KC436	KC438	73.2	Circular	525	6%	147	481
KC438	KC440	35.0	Circular	450	10%	147	481
KC440	KC442	16.8	Circular	450	26%	147	481
KC442	KC444	46.3	Circular	450	10%	147	481
KC444	KC446	9.0	Circular	450	23%	147	481
KC446	KC448	31.1	Circular	450	39%	147	481
KC448	KC450	23.4	Circular	525	6%	147	481
KC450	KC452	45.1	Circular	600	3%	147	481
KC452	KC468	73.3	Circular	600	3%	186	611
KC46	KCJ-58	61.3	Trapezoidal	700	32%	247	589
KC460	KC466	44.9	Circular	250	9%	33	117
KC466	KC480	49.9	Circular	250	7%	182	182
KC468	KC470	88.3	Circular	600	7%	186	611
KC470	KC472	27.6	Circular	600	7%	186	611
KC472	KC474	76.0	Circular	600	4%	186	611
KC474	KC482	76.6	Circular	600	9%	258	854
KC478	KC474	44.7	Circular	250	8%	113	117
KC48	KCJ-57	88.8	Trapezoidal	1000	25%	294	778
KC480	KC478	37.2	Circular	250	3%	120	120
KC482	KC484	8.9	Circular	600	6%	258	854
KC484	KC486	29.1	Circular	600	35%	258	854
KC486	KC488	10.1	Circular	675	4%	258	854
KC488	KCJ-11	71.7	Circular	900	1%	631	1303
KC494	KC498	44.8	Circular	300	11%	43	143
KC498	KCJ-59	74.8	Trapezoidal	600	33%	43	142
KC50	3	65.6	Circular	250	76%	57	211
KC502	KC504	45.8	Circular	250	18%	33	98
KC504	KCJ-34	135.6	Trapezoidal	600	20%	33	98
KC508	KC510	13.2	Circular	250	25%	15	48
KC510	KC542	23.7	Circular	250	72%	15	48
KC522	KC524	28.7	Circular	900	3%	247	589
KC524	KC46	11.1	Trapezoidal	1000	9%	247	589
KC534	KC536	43.6	Circular	375	18%	75	337
KC536	KCJ-60	52.4	Trapezoidal	600	36%	75	338
KC538	KC540	21.8	Circular	900	5%	779	1883
KC540	KCJ-12	38.6	Trapezoidal	4000	1%	779	1811
KC542	KC544	46.2	Circular	250	21%	15	48

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
KC544	2	29.0	Circular	300	3%	24	**51**
KC68	KC70	20.2	Circular	611	18%	16	52
KC70	KCJ-46	81.2	Trapezoidal	600	23%	16	52
KC72	KC74	106.4	Circular	300	7%	34	108
KC74	KC75	37.0	Circular	300	18%	34	108
KC75	KCJ-56	4.6	Trapezoidal	600	24%	34	108
KC76	KC78	7.1	Circular	300	6%	46	253
KC78	KC80	41.5	Circular	300	16%	46	253
KC80	KC534	61.4	Circular	300	13%	46	253
KCJ-1	KCJ-2	157.7	Circular	1200	4%	59	288
KCJ-10	KCJ-70	179.7	Trapezoidal	600	12%	299	902
KCJ-11	KCJ-56	24.9	Trapezoidal	4000	6%	631	1303
KCJ-12	KCJ-13	54.8	Circular	900	1%	793	1667
KCJ-13	KCJ-34	83.1	Trapezoidal	4000	4%	793	1667
KCJ-14	KCJ-15	37.2	Circular	600	5%	96	**559**
KCJ-15	KCJ-19	275.2	Trapezoidal	600	1%	104	558
KCJ-16	KCJ-17	28.0	Circular	600	7%	61	367
KCJ-17	KCJ-20	150.8	Trapezoidal	600	3%	61	365
KCJ-18	9	169.7	Trapezoidal	600	6%	103	440
KCJ-19	8	341.7	Trapezoidal	600	7%	126	599
KCJ-2	KCJ-3	79.4	Trapezoidal	2000	10%	59	288
KCJ-20	KCJ-63	20.1	Circular	600	7%	61	365
KCJ-21	KCJ-22	37.1	Circular	600	8%	199	593
KCJ-22	KCJ-23	85.8	Trapezoidal	600	13%	199	593
KCJ-23	KCJ-24	25.0	Circular	600	4%	199	593
KCJ-24	KCJ-25	41.3	Trapezoidal	600	22%	241	711
KCJ-25	KCJ-26	28.3	Circular	600	7%	241	711
KCJ-26	KCJ-27	215.3	Trapezoidal	600	30%	241	711
KCJ-27	KCJ-10	85.4	Circular	900	14%	299	903
KCJ-28	KC50	35.3	Circular	600	4%	57	211
KCJ-3	KCJ-4	229.6	Trapezoidal	2000	1%	58	284
KCJ-33	4	15.6	Trapezoidal	4000	-	1022	2561
KCJ-34	KCJ-33	130.8	Trapezoidal	4000	4%	809	1681
KCJ-35	KCJ-9	75.6	Trapezoidal	600	8%	57	162
KCJ-36	KCJ-35	21.5	Circular	600	8%	56	162
KCJ-37	KCJ-36	351.6	Trapezoidal	600	8%	56	163
KCJ-38	KC538	114.1	Trapezoidal	4000	6%	773	1872
KCJ-39	KCJ-40	28.0	Circular	600	4%	17	70
KCJ-4	KCJ-5	26.5	Circular	1200	2%	90	413
KCJ-40	KCJ-41	271.7	Trapezoidal	1000	6%	17	70
KCJ-41	KCJ-42	219.3	Trapezoidal	1000	6%	21	89
KCJ-42	KC362	59.0	Trapezoidal	1000	6%	72	262

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
KCJ-44	KCJ-31	409.6	Trapezoidal	600	27%	36	126
KCJ-45	KCJ-49	260.5	Trapezoidal	600	6%	65	222
KCJ-46	KCJ-47	25.3	Circular	600	23%	16	52
KCJ-47	KCJ-48	68.3	Trapezoidal	600	23%	16	52
KCJ-48	KCJ-45	45.9	Circular	250	23%	16	52
KCJ-49	KCJ-50	35.9	Circular	450	23%	65	222
KCJ-5	KCJ-6	116.6	Trapezoidal	2000	7%	90	412
KCJ-50	KCJ-30	93.5	Trapezoidal	600	9%	65	222
KCJ-52	KCJ-53	28.4	Circular	500	4%	40	124
KCJ-53	KCJ-54	31.8	Trapezoidal	600	2%	40	124
KCJ-54	KCJ-55	26.7	Circular	500	2%	40	124
KCJ-55	KC20	263.8	Trapezoidal	600	6%	40	124
KCJ-56	KCJ-60	259.3	Trapezoidal	4000	6%	657	1352
KCJ-57	2	10.9	Circular	900	25%	294	778
KCJ-58	KC48	38.0	Circular	900	32%	294	778
KCJ-59	KCJ-38	110.2	Trapezoidal	4000	6%	730	1650
KCJ-6	KCJ-7	29.9	Circular	1200	2%	103	448
KCJ-60	KCJ-59	77.7	Trapezoidal	4000	6%	697	1517
KCJ-61	KC28	146.8	Circular	500	6%	36	119
KCJ-62	KCJ-33	61.6	Trapezoidal	4000	11%	308	815
KCJ-63	KCJ-18	172.7	Trapezoidal	600	7%	60	364
KCJ-64	KCJ-66	140.4	Trapezoidal	600	27%	129	395
KCJ-65	1	405.3	Trapezoidal	600	14%	27	92
KCJ-66	6	297.2	Trapezoidal	50	2%	**4**	**4**
KCJ-67	KCJ-68	348.8	Trapezoidal	4000	3%	60	429
KCJ-68	KCJ-12	273.6	Trapezoidal	4000	3%	58	419
KCJ-69	KCJ-67	340.1	Trapezoidal	4000	3%	50	402
KCJ-7	8	1205.7	Trapezoidal	600	5%	94	433
KCJ-70	19	20.9	Trapezoidal	600	139%	320	960
KCJ-8	KCJ-9	54.2	Circular	600	7%	358	**803**
KCJ-9	KC488	375.1	Trapezoidal	4000	7%	443	1028

Project 9.1 Industrial Area Inventory – Stevens Road Industrial Development

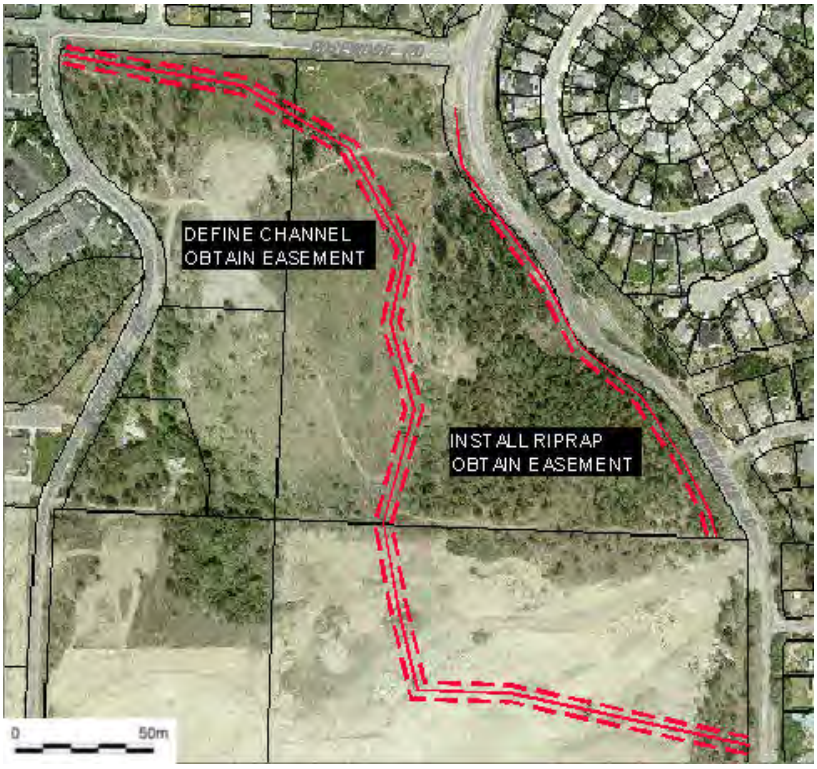
Proposed Works:	Conduct field review and inventory of existing storm infrastructure and drainage courses within Industrial areas.
Implementation:	Industrial properties are required to detain runoff. An on-site inventory of existing storm components is required to determine the level of service presently available and the risk of flooding. This work is considered a Medium priority, since the risk of flooding and/or property damage is undetermined.
Consequences if not completed:	Due to the magnitude of impervious surface in industrial areas and the age of the existing drainage components, runoff could potentially cause localized flooding or excess downstream impact.
Priority:	2
Location:	



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Project 9.2 Channel Improvements/Drainage Easement – Rosewood Dr to Westlake Rd

Proposed Works:	Channel grading from McDougall Road and Rosewood Road to Westlake Road. Install erosion protection along Westlake Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Inadequate channel capacity and erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Channel Construction	Lm	430	$225.00	$96,750
Erosion Protection	Lm	190	$225.00	$42,750
Contingency (25%)				$34,900
Engineering (15%)				$26,000
Total Project Cost				**$200,400**

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Project 9.3 Erosion Protection/Drainage Easement – Griffiths Place to McNaughton Rd

Proposed Works:	Install erosion protection measures and establish a drainage easement or Right-of-Way along watercourse from Griffiths Place to the I.R. boundary south of McNaughton Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	485	$225.00	$109,125
Contingency (25%)				$27,300
Engineering (15%)				$16.300
Total Project Cost				**$152,725**

RSB ENGINEERING

Project 9.4 Erosion Protection – Bear Creek Rd from Vancouver Road to I.R. boundary

Proposed Works:	Install erosion protection measures along watercourse from Griffiths Place to Scott Crescent.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	350	$225.00	$78,750
Contingency (25%)				$19,700
Engineering (15%)				$14,700
Total Project Cost				**$113,150**

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Project 9.5 Erosion Protection/Drainage Easement – Parkinson Rd to Bear Creek Rd

Proposed Works:	Install erosion protection measures and establish drainage easements along watercourse from Parkinson Road to Bear Creek Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	145	$225.00	$32,625
Contingency (25%)				$8,100
Engineering (15%)				$6,100
Total Project Cost				**$46,825**

RSB ENGINEERING

Project 9.6 Culvert Outlet Improvements – Horizon Drive

Proposed Works: Cut existing culvert and install riprap apron at outfall.

Implementation: This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.

Consequences if not completed: Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.

Priority: 2

Location:



Description	Unit	Quantity	Unit Price	Total
Culvert Modification	LS	1		$500
Erosion Protection	LS	1		$2,000
Contingency (25%)				$650
Engineering (15%)				$500
Total Project Cost				**$3,650**

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Project 9.7 Obtain Drainage Easement – Bear Creek Rd to Westside Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Bear Creek Road to Westside Road.
Implementation:	
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 9.8 Erosion Protection/Drainage Easement – Spyglass Way to Westview Way

Proposed Works:	Install erosion protection measures and establish drainage easements along watercourse from Spyglass Way to Westview Way.
Implementation:	This work is considered a High priority, since the risk of flooding and property damage is high, and the existing channel is showing signs of failure. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Channel Improvements	Lm	65	$250	$16,250
Contingency (25%)				$4,000
Engineering (15%)				$3,000
Total Project Cost				**$23,250**

RSB ENGINEERING

Project 9.9 Repair Detention Basin – Northeast of Westview Way

Proposed Works:	Perform improvements to existing detention basin and review the potential to increase the active volume of the basin.
Implementation:	Runoff from the upstream development areas flows into a small detention area below Westview Way. The downstream berm has been eroded, resulting in a loss of detention storage and the detention facility is no longer functioning. The berm material will continue to erode, and will result in sediment deposits downstream. This work is considered a High priority, since there is an increased risk of property and environmental damage downstream.
Consequences if not completed:	Erosive conditions will continue and will resulting higher flow rates in the downstream areas of Keefe Creek.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
Repair Detention Pond	LS	1		$15,000
Contingency (25%)				$3,750
Engineering (15%)				$2,800
Total Project Cost				**$21,550**

RSB ENGINEERING

Project 9.10 Creek Improvements – Keefe Creek between Horizon Dr and Spyglass Way

Proposed Works:	Install erosion protection and stream bank stabilization along Keefe Creek.
Implementation:	This work is considered a Medium priority, since the risk of property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	

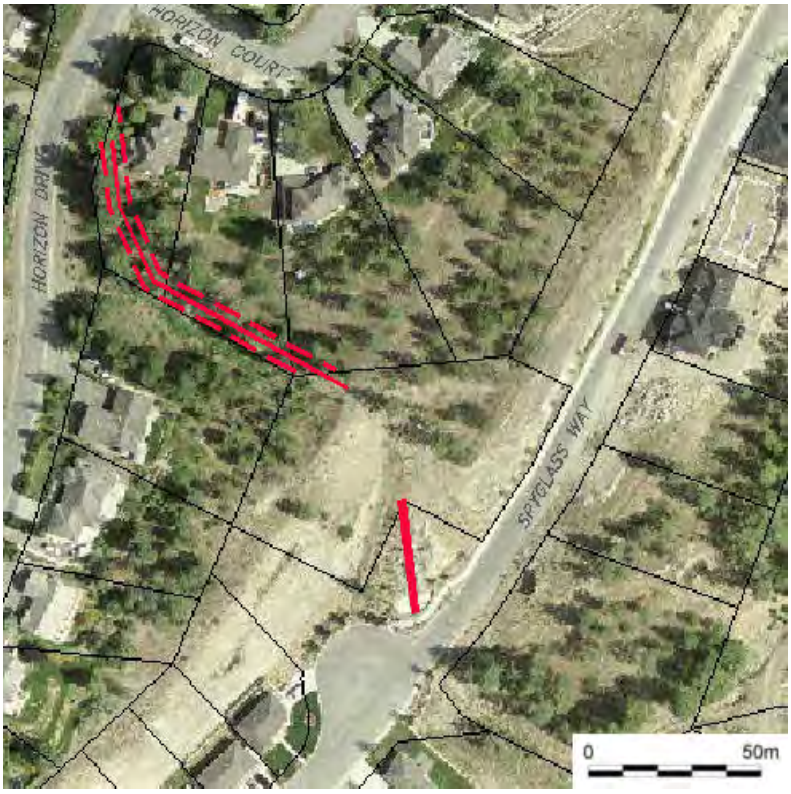


Description	Unit	Quantity	Unit Price	Total
Creek Restoration	Lm	600	$300	$180,000
Contingency (25%)				$45,000
Engineering (15%)				$34,000
Total Project Cost				**$259,000**

RSB ENGINEERING

Project 9.11 Erosion Protection/Drainage Easement – Horizon Dr to Spyglass Way

Proposed Works:	Install erosion protection measures and establish drainage easements along watercourse from Horizon Drive to Spyglass Way.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Creek Restoration	Lm	145	$225	$32,625
Contingency (25%)				$8,200
Engineering (15%)				$6,100
Total Project Cost				**$46,925**

RSB ENGINEERING

Project 9.12 Install Infiltration System – Stevens Road and Ross Road

Proposed Works:	Construction of a storm drainage collection system, and below grade storage/infiltration system to reduce the flooding risks and promote groundwater recharge.
Implementation:	The localized depression area along Stevens Road will collect runoff from the nearby properties and roadway. This work is considered a High priority, since there is a risk of flooding and/or property damage. Environmental benefits can also be achieved with the implementation of the infiltration facilities.
Consequences if not completed:	Since there is no overland flow route runoff will collect in this low-lying area, and there is a risk of flooding on private property.
Priority:	1
Location:	



Description	Unit	Quantity	Unit Price	Total
450mm PVC Perf	Lm	200	$300	$60,000
Drywells	ea	5	$5000	$25,000
Road Restoration	Lm	200	$150	$30,000
Contingency (25%)				$28750
Engineering (15%)				$21,000
Total Project Cost				**$164,750**

RSB ENGINEERING

Project 9.13 Erosion Protection – Spyglass Way to Keefe Creek

Proposed Works:	Install erosion protection measures along two watercourses from Spyglass Way to Keefe Creek.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	120	$225	$27,000
Contingency (25%)				$6,750
Engineering (15%)				$5,000
Total Project Cost				**$38,750**

RSB ENGINEERING

Project 9.14 Erosion Protection – Horizon Drive west of I.R. boundary near Hwy 97

Proposed Works:	Install erosion protection measures along watercourse next to Horizon Road.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	40	$225	$9,000
Contingency (25%)				$2,300
Engineering (15%)				$1700
Total Project Cost				**$13,000**

RSB ENGINEERING

Project 9.15 Erosion Protection/Drainage Easement – Horizon Drive to Covington Court

Proposed Works:	Install erosion protection measures and establish a drainage easement along watercourse from the intersection of Aurora Heights and Horizon Road to Covington Court.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	100	$225	$22,500
Contingency (25%)				$5,600
Engineering (15%)				$4,200
Total Project Cost				**$32,300**

RSB ENGINEERING

Project 9.16 Erosion Protection – Westlake Road southwest of Devon Court

Proposed Works:	Install erosion protection measures along watercourse from Westlake Road to Creek.
Implementation:	This work is considered a Medium priority, since the risk of flooding and property damage is low. Environmental benefits can be achieved with the implementation of the erosion protection measures.
Consequences if not completed:	Erosive conditions in the open channel sections will continue and may lead to channel instability and sediment deposition in the downstream sections.
Priority:	2
Location:	



Description	Unit	Quantity	Unit Price	Total
Erosion Protection	Lm	180	$225	$27,000
Contingency(25%)				$6,800
Engineering(15%)				$5,000
Total Project Cost				**$38,800**

RSB ENGINEERING

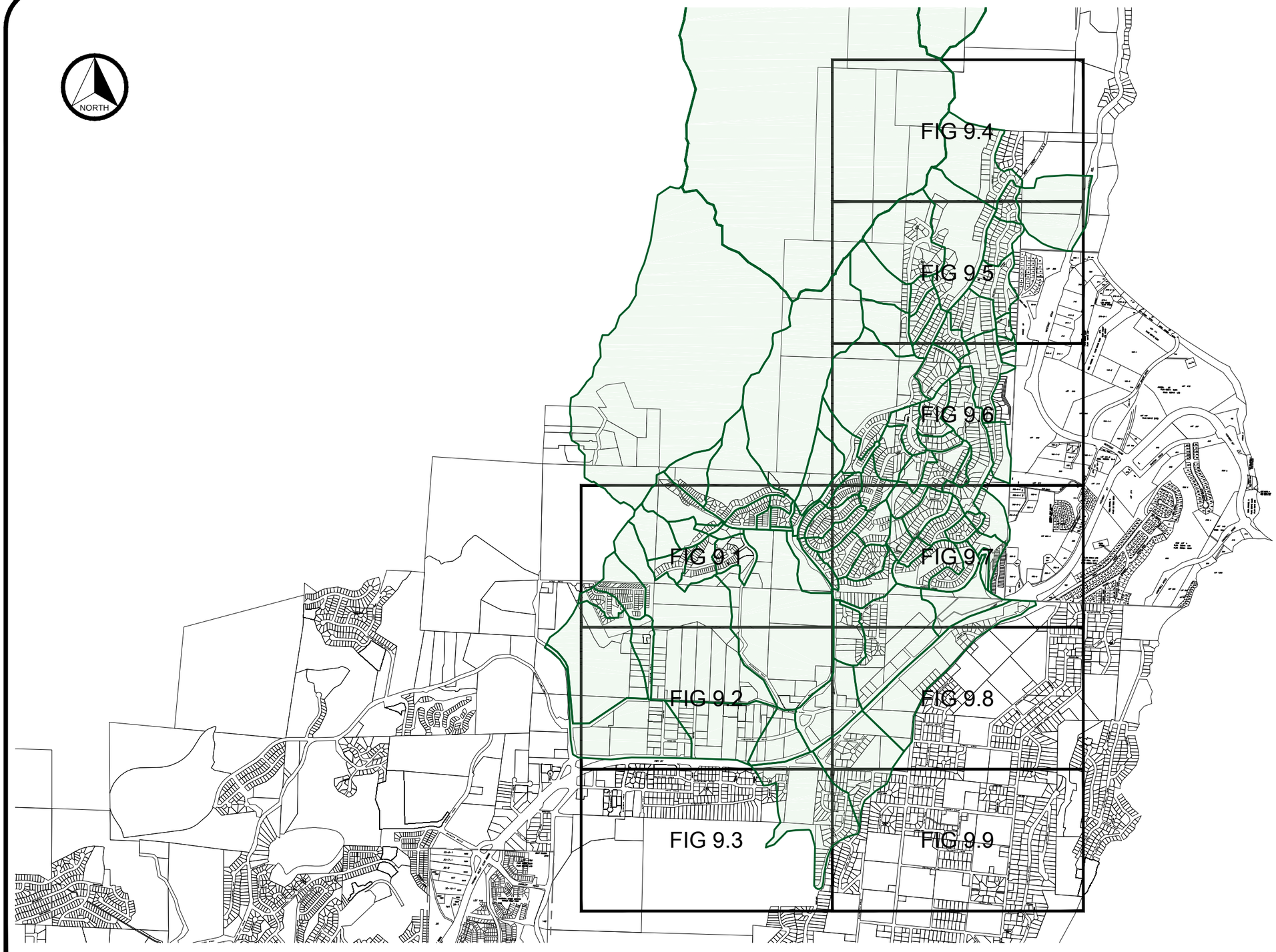


FIGURE 9.0
KEEFE CREEK BASIN
KEY MAP
N.T.S.

RSB ENGINEERING

NORTH

SHOWN ORANGE PIPES
SURCHARGE FOR THE 1:5yr STORM
PUT MHs DO NOT OVERFLOW

INSTALL RIP–RAP
FOR EROSION PROTECTION
AS PER PROJECT
9.2

DEFINE CHANNEL AND
OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
9.2

KCJ-1 KC300 KC298 KC296 KCJ-2 KCJ-3 KC294 KC308 KC310 KC306 KC304 KC292 KC302 KC242 KC240 KC236 KCJ-4 KCJ-5 KC280 KC282 KC334 KC320 KC322 KC318 KC284 KC314 KC316 KC312 KC286 KC336 KC328 KC326 KC330 KC276 KC278 KC332 KC324 KC274 KC268 KC290 KC270 KC262 KC272 KC260 KC258 KC254 KC256 KC264 KC252 KC238 KCJ-6 KCJ-7 KC234 KC204 KC202 KC200 KC266 KC338 KC248 KC250 KC246 KC244 KC210 KC212 KC216 KC208 KC206 KC198 KC224 KC232 KC230 KC228 KC226 KC222 KC218 KC196 KC220 KCJ-37 KC424 KC414 KC416 KC412 KC190 KC374 KC192 KC390 KC194 KC392 KC434 KC432 KC430 KC408 KC406 KC410 KC426 KC428 KC422 KC436 KC438 KC440 KC442 KC446 KC444 KC448 KC450 KCJ-36 KCJ-35 KCJ-8 KCJ-9

KCS-24 KCS-28 KCS-32 KCS-34 KCS-35 KCS-37 KCS-42_1 KCS-42_2 KCS-40 KCS-38 KCS-43 KCS-46_2 KCS-45 KCS-54 KCS-56 KCS-59 KCS-60_1 KCS-60_2 KCS-61 KCS-61_1

KCJ-65 KCJ-64 KCJ-66

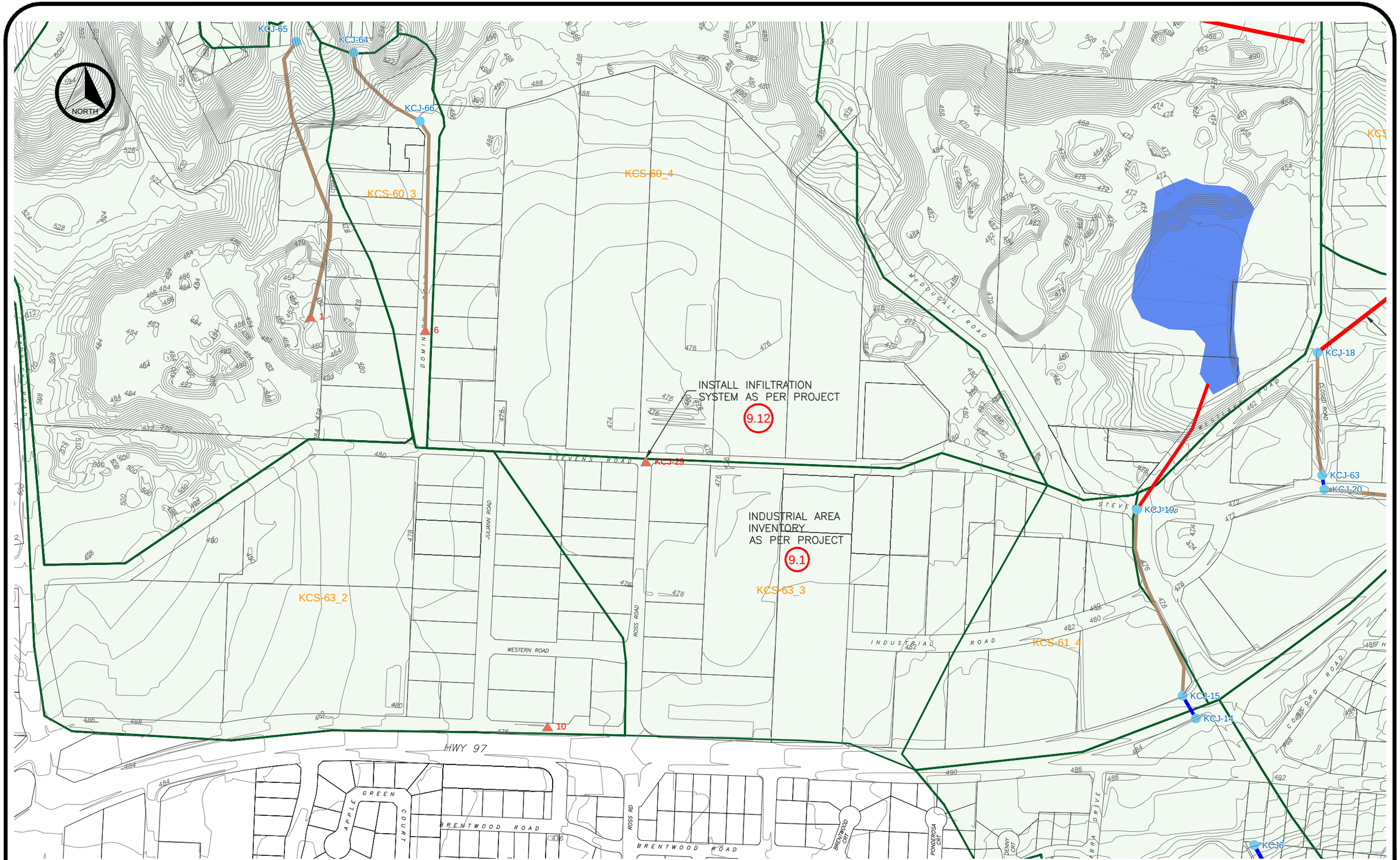
	9.1	9.7
	9.2	9.8

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

FIGURE 9.1
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	9.1	9.7
	9.2	9.8
	9.3	9.9

FIGURE 9.2
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



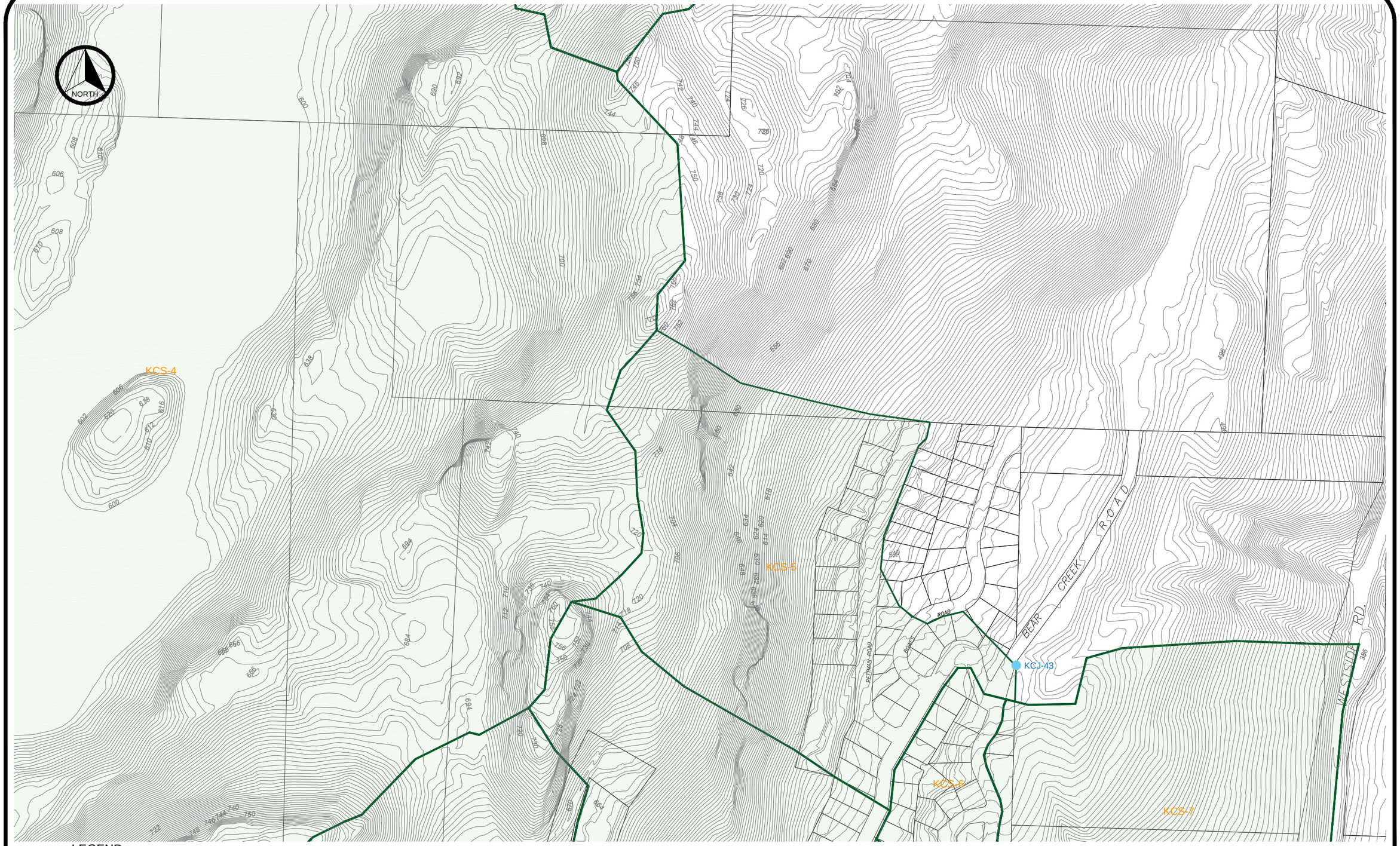
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	9.2	9.8
	9.3	9.9

FIGURE 9.3
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	9.4	
	9.5	

FIGURE 9.4
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

KCS-6
KCS-7
KCS-9
KCS-10
KCS-11
KCS-12
KCS-13
KCS-14
KCS-15
KCS-16
KCS-17
KCS-18
KCS-19
KCS-20
KCS-32

KC62
KC60
KC64
KC54
KC56
KC58
KC162
KC166
KC168
KC164
KC172
KC174
KC176
KC178
KC180
KC182
KC184
KC364
KC362
KC66
KC68
KC70
KCJ-44
KCJ-46
KCJ-47
KCJ-48
KCJ-45
KCJ-49
KCJ-50
KCJ-30
KCJ-31
KCJ-39
KCJ-40
KCJ-41
KCJ-42
KCJ-21
KCJ-22
KCJ-23
KCJ-24
KCJ-25
KCJ-26
KCJ-27
KCJ-10
KC370
KC372
KCJ-70
19

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION AS PER PROJECT 9.5

INSTALL EROSION PROTECTION AS PER PROJECT 9.4

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT 9.7

INSTALL EROSION PROTECTION AS PER PROJECT 9.4

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION AS PER PROJECT 9.10

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION AS PER PROJECT 9.3

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION AS PER PROJECT 9.13 9.3

LOT 208
PARCEL D PLAN 53610 CLSR PLAN M8116 LTO
PARCEL GP

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	9.4	
	9.5	
	9.6	

FIGURE 9.5
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

KCS-25
KCS-23
KCS-22_1
KCS-22_2
KCS-20
KCS-27_4
KCS-27_1
KCS-27_5
KCS-27_10
KCS-26
KCS-27_3
KCS-28

KC364
KC362
KCJ-42
KCJ-41
KCJ-26
KC370
KC372
KCJ-70
19
KCJ-28
KC50
5
KC136
KC138
KC134
KC132
KC124
KC122
KC128
KC126
KC130
KC140
KC152
KC188
KC142
KC148
KC150
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KC186
KC190
KC377
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KC400
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KC398
KC390
KC380
KC384
KC382
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KC346
KC342
KC344
KC340
KC352
KC354
KC348
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KC156
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KC160
KC154
KC356
KC358
KC360
KC10
KC14
KC12
KC16
KC18
KC20
KC24
KC28
KC32
KC30
KC34
KCJ-61
KCJ-51
KCJ-52
KCJ-53
KCJ-54
KCJ-55
KC366
KC40
KC42
KC36
KC38
KC44

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION
9.15

CUT CULVERT OUTLET AND INSTALL RIP-RAP PROTECTION AS PER PROJECT
9.16
9.6

OBTAIN DRAINAGE EASEMENT AND IMPROVE EXISTING CHANNEL TO AVOID OVERFLOWING ON PRIVATE PROPERTY AS PER PROJECT

LLOYD JONES DRIVE
PINEWOOD PLACE
KELOWA PLACE
COVINGTON COURT
HORIZON DRIVE
SHALEROCK RIDGE
SPLAND ROAD
VANCEE RD

PARCEL D PLAN 53510 CLSR PLAN M8116 LTO
REM. PARCEL E PLAN 53...
316
315-2
315-1
LOT 210
LOT 304
LOT 209
192-3
192-1-4
192-1-50
192-1-3
192-2
192-1-1
335
336
LOT 311
LOT 2
302-6-5
590A
PARCEL
WE

LEGEND

CATCHMENT BOUNDARY	MODEL JUNCTION	KCJ-66	JUNCTION ID	524	CONTOUR ELEVATION
MODEL CHANNEL/DITCH	MODEL OUTFALL	KCC44	OUTFALL ID		
MODEL PIPE	KCS-60_4 CATCHMENT ID		2m CONTOUR		

	9.5	
	9.6	
9.1	9.7	

FIGURE 9.6
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AND INSTALL EROSION PROTECTION AS PER PROJECT

OBTAIN DRAINAGE EASEMENT AND IMPROVE EXISTING CHANNEL TO AVOID OVERFLOWING ON PRIVATE PROPERTY AS PER PROJECT

REPAIR DETENTION POND AS PER PROJECT

INSTALL EROSION PROTECTION WITHIN CREEK SECTION AS PER PROJECT

INSTALL RIP-RAP FOR EROSION PROTECTION AS PER PROJECT

INSTALL EROSION PROTECTION WITHIN CREEK SECTION AS PER PROJECT

INSTALL EROSION PROTECTION WITHIN CREEK SECTION AS PER PROJECT

INSTALL EROSION PROTECTION WITHIN CREEK SECTION AS PER PROJECT

9.15 9.11 9.8 9.9 9.10 9.13 9.10 9.10 9.14

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	9.6	
9.1	9.7	
9.2	9.8	

FIGURE 9.7
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

NORTH

KCS-61_1

KCS-61_2

KCS-62

KCS-64

KCJ-67

KCJ-69

KCJ-18

KCJ-63

KCJ-20

KCJ-17

KCJ-16

KCJ146

KCJ148

KCJ144

KCJ140

KCJ142

KCJ6

INSTALL EROSION PROTECTION WITHIN CREEK SECTION AS PER PROJECT

9.16

HANTS ROAD

DEVON ROAD

DEVON COURT

SOMERSET CRT

PROSERPINE ROAD

KEEFE RD.

KELVIEW

SCANTLAND ROAD

THACKER DRIVE

BUENAVISTA RD.

HAXMAN DRIVE

CRESTVIEW ROAD

ISELER RD

COLLINGWOOD ROAD

McKAY ROAD

HARMON ROAD

STUART ROAD

WINNIPEG ROAD

RUMNEY ROAD

HILLSBOROUGH PLACE

HUDSON ROAD

COLLEEN ROAD

CLOSE ROAD

THOMAS RD

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

9.1	9.7	
9.2	9.8	
9.3	9.9	

FIGURE 9.8
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

KCS-64

NORTH

KCJ146
KCJ148
KCJ144
KCJ140
KCJ142
KCJ6
KCJ2
KCJ4
KCJ8
KCJ10
KCJ14
KCJ16
KCJ20
KCJ26
KCJ22
KCJ28
KCJ24

HUDSON ROAD
WINNIPEG
RUMNEY ROAD
SKYLINE ROAD
AVONDALE COURT
LINDSAY COURT
HILLSBOROUGH PLACE
GANT CRES.
WELLINGTON ROAD
ANDERS ROAD
CORDOVA WAY
ARLINGTON PLACE
TEAL ROAD
OLALLA AVE.
STEVENSON ROAD
LAKERIDGE ROAD
BENEDICK ROAD
CASA LOMA
HAWTHORN ROAD
DOUGLAS ROAD
THACKER DRIVE
LAKEVIEW DRIVE
KERRY LANE
WEATHERHILL CRESENT
COLLEN'S HILL
FRANWILL ROAD
COURTLAND ROAD
TREVOR DRIVE
JOYCE ROAD
PLAZA DRIVE

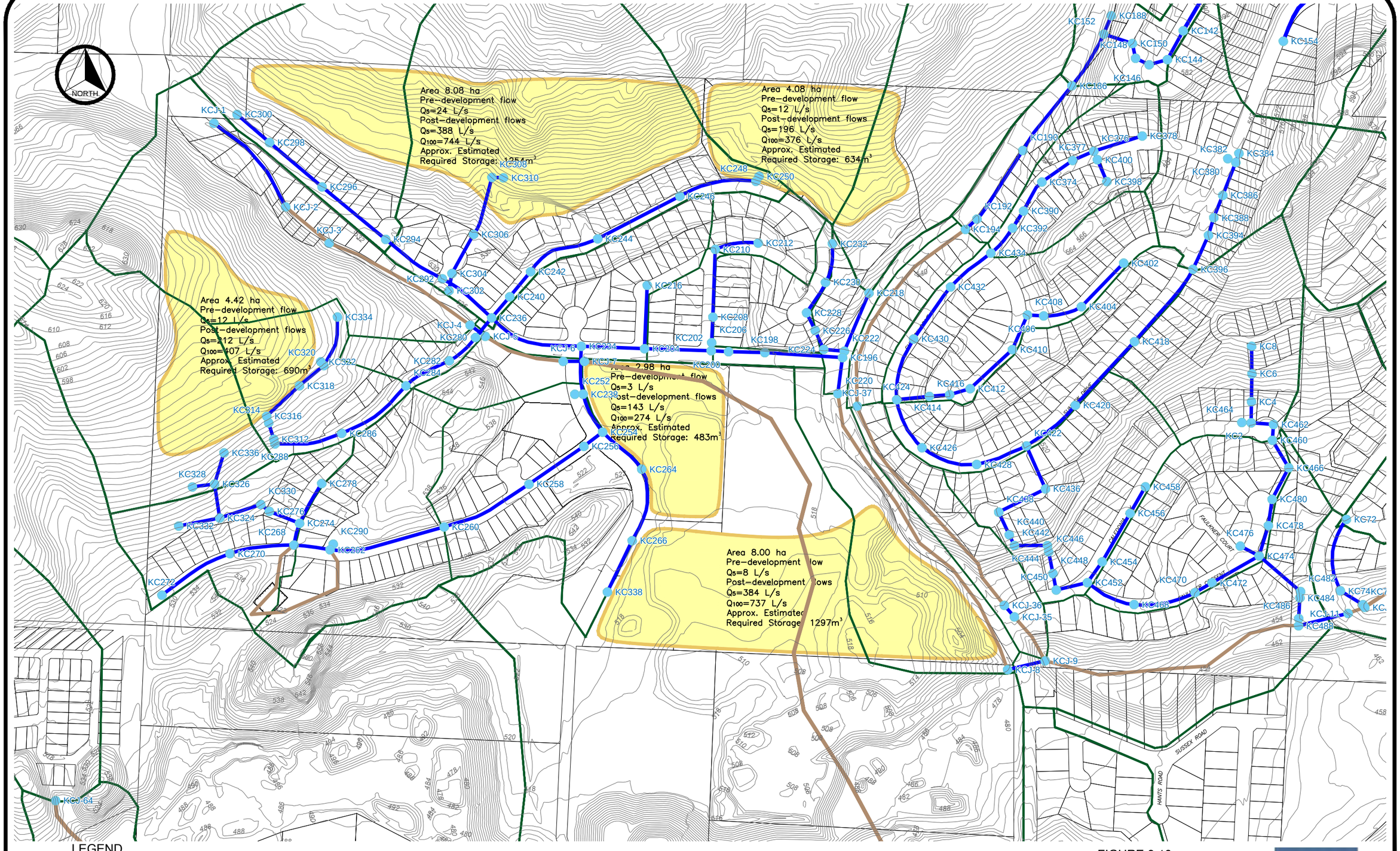
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

9.2	9.8	
9.3	9.9	

FIGURE 9.9
KEEFE CREEK BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- KCS-60_4 CATCHMENT ID
- KCJ-66 JUNCTION ID
- KCC44 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

FIGURE 9.10
KEEFE CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

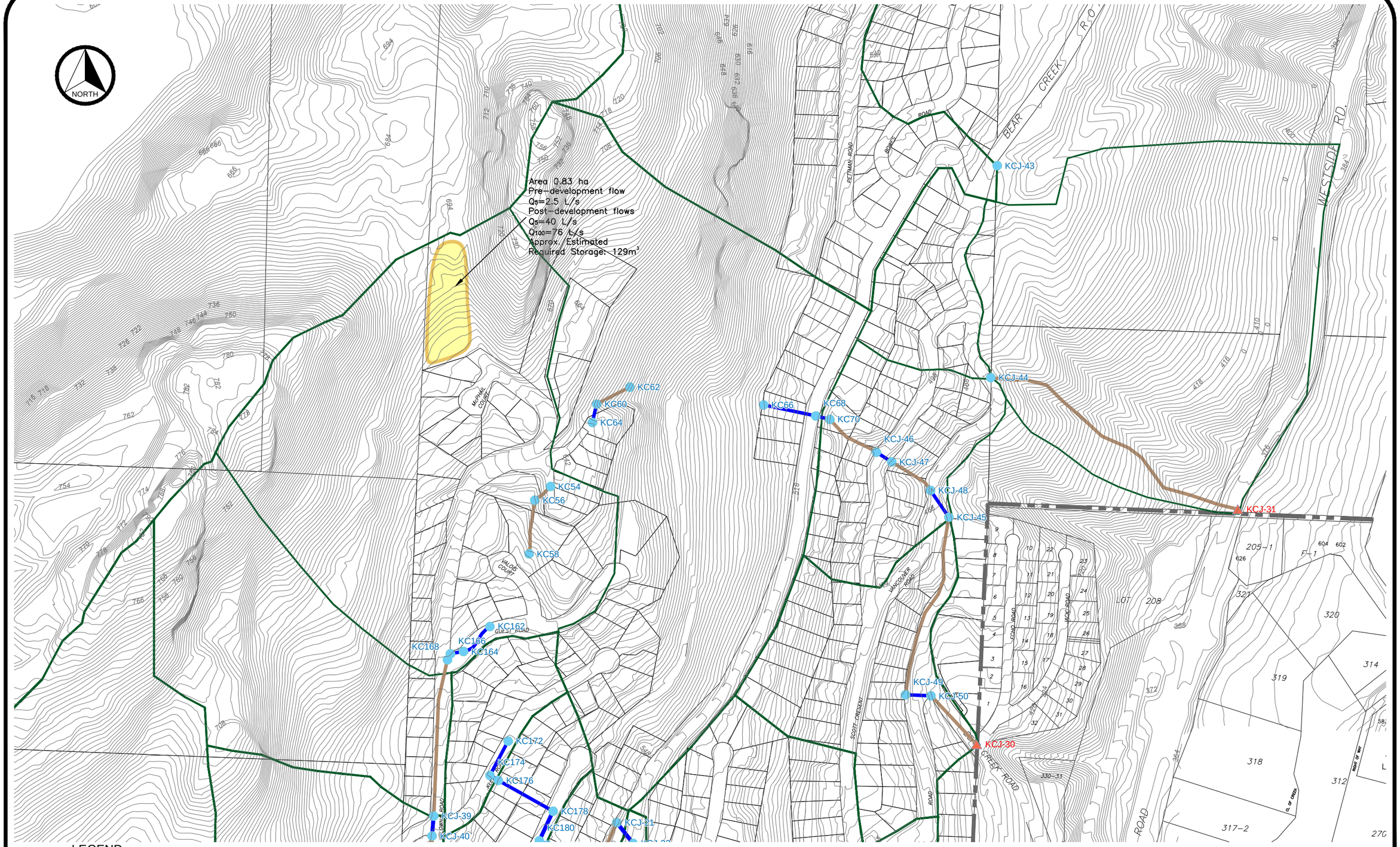


FIGURE 9.11
KEEFE CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

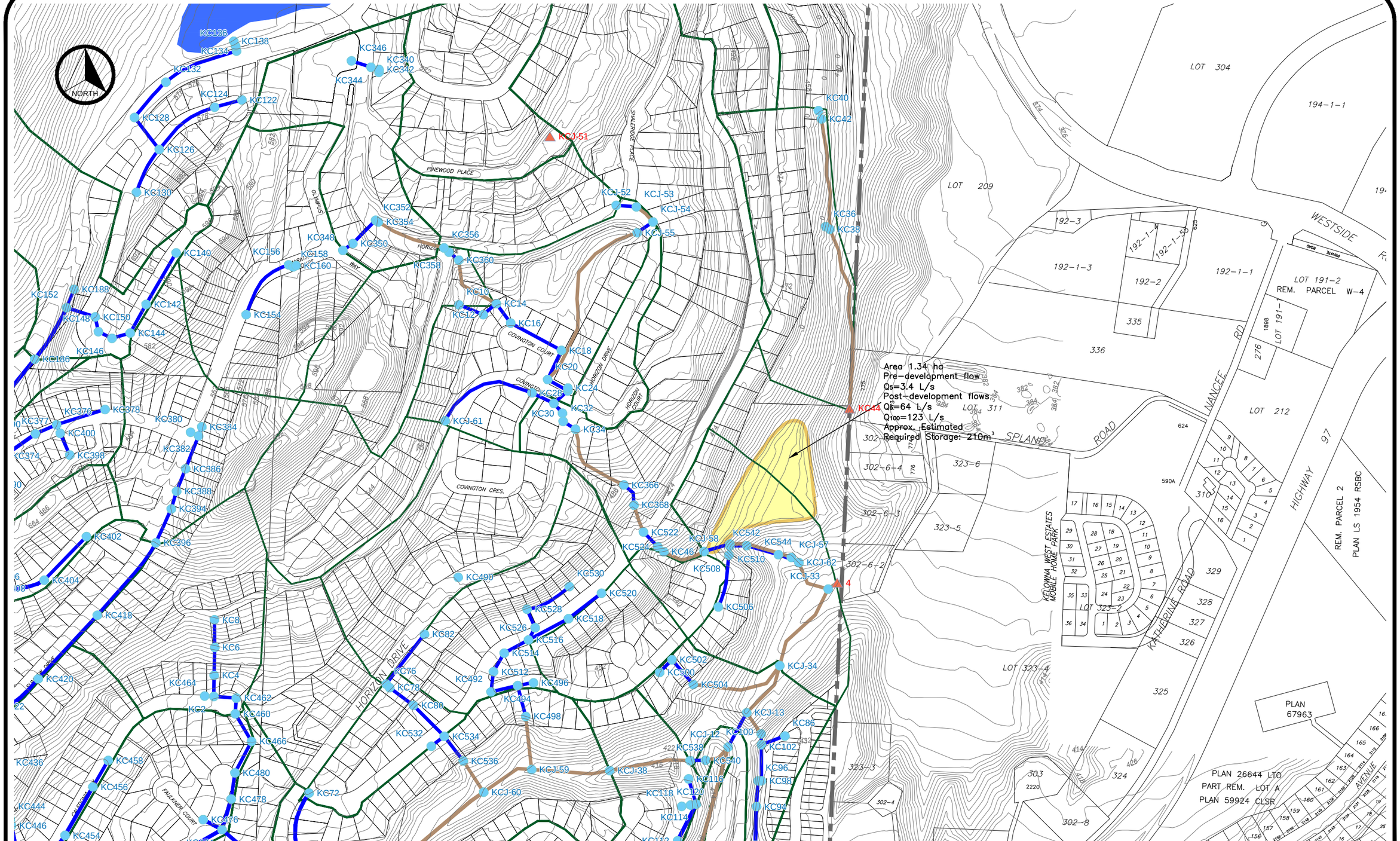


FIGURE 9.12
KEEFE CREEK BASIN
FUT. DEVELOPMENT AREAS
SCALE 1:5,000

RSB ENGINEERING

SECTION 10
LAKEVIEW HEIGHTS BASIN PLAN

10.1 BASIN DESCRIPTION

East of Mount Boucherie, the Lakeview Heights area is a mixture of residential and small agricultural properties. The basin encompassing approximately 330ha, is generally bounded to the west by Thacker Drive, the north by Highway 97 and by the lake to the east and south. Casa Loma neighbourhood is included within this basin.

Upper portions of this basin, near Thacker Drive, are located on a plateau situated 100 to 120m above lake level. The plateau slopes to the east at a gradient of 5% before the topography changes to steep slopes of 25%. The steep slopes (zoned P1-Park) are comprised of loose silt, limited surface cover and numerous small ravines.

Runoff from the upper plateau flows overland and infiltrates into the subsurface above the top of bank. Signs of seepage and groundwater discharge are evident in the ravines.

Development in the basin has historically been constrained due to the topography, sensitive silty slopes and lack of a defined downstream drainage route.

10.2 EXISTING SYSTEM ANALYSIS

The Lakeview Heights drainage basin is extensively rural in character, with open ditches and roadway culverts. With the exception of some bare-land strata developments, there are essentially no storm sewer pipes within this basin.

The drainage basin consists of a mix of agricultural and residential land use patterns. Runoff from the residential development areas generally travels in a west to east direction, towards Okanagan Lake.

Isolated local depression areas west of Thacker Drive collect drainage from the area between Anders Road and Stuart Road; however the runoff volume is expected to be low, due to the overall low percentage of impervious area.

The residential area in the vicinity of Ridgeview Road and Thacker Drive drains towards the east, above the steep banks and then ultimately into Okanagan Lake. No outlet or discharge pipes were noted in the field reviews and it is anticipated that the overland drainage routes will follow the natural topography.

The highways maintenance contractor has indicated that the existing 300 mm culvert at the north end of Ridgeview Road had been intentionally blocked. When opened, this

culvert permitted water to flow onto private property to the east, resulting in flooding problems for the home owners.

The Casa Loma development contains a mix of ditches, culverts and a piped storm sewer system; however no drawings could be located outlining the size, location or extent of the piped system. For the purposes of this report, the Casa Loma area was modeled without a piped storm sewer system and the drainage routes would follow the existing topography.

PCSWMM was used to estimate the stormwater runoff. The model nodes for the system are presented within Figures 10.1 through 10.5. Runoff was estimated by simulating the 1 in 5 year and 1 in 100 year storms with a1 hour duration. The peak flow in the system is presented in Table 10.2 at the end of this section.

10.3 EXISTING SYSTEM DEFICIENCIES

During both the minor and major storm events, localized ponding and depression storage may occur at a number of locations. A number of driveways were constructed without positive drainage away from the building and may present nuisance drainage and/or minor flooding from on-site drainage.

For the purposes of the Master Drainage Plan, we have focused primarily on these conditions that are expected to receive additional flow contributions from off-site or roadway areas.

Drainage Easement – Harmon Road to Boucherie Road

Drainage from the north end of Harmon Road travels overland, through private property enroute to Boucherie Road, near Proserpine Road. Based on available information, it does not appear as though there is a protected drainage easement along this route. Project 10.1 recommends that the District establish a registered drainage easement, north of Harmon Road.

Drainage Easement – Hayman Drive to Boucherie Road

Runoff from the areas near Hayman Drive and Crestview Road will flow overland from Hayman Drive to Boucherie Road, near the intersection with Highway 97. Based on the available mapping information, it is not apparent if a drainage easement exists along this property. Project 10.2 recommends that the District establish a protected easement for this overland flow route.

Drainage Easement – Bridgeview Road to Okanagan Lake

The north end of Bridgeview Road is situated within a localized low-point. As noted by highways maintenance staff, the existing culvert on Bridgeview Road was intentionally blocked to restrict the flow heading east. To improve drainage in this area, Project 10.3 recommends that the District establish a drainage easement to the east of Bridgeview Road. Minor surface drainage works may also be necessary within the residential lot to ensure adequate drainage along the route.

Drainage Easement – Kelview Crescent to Okanagan Lake

Runoff from the east end of Kelview Crescent travels overland, while enroute to Okanagan Lake. Based on the available mapping information, it is not apparent if a drainage easement exists within the down-slope properties. Project 10.4 recommends that the District establish a protected easement along this route for drainage purposes.

Drainage Easement – Thacker Drive to Okanagan Lake

Thacker Drive, south of Scantland Road contains a low-point that directs runoff to the east of Thacker Drive, towards Okanagan Lake. It is not apparent if this overland drainage route is protected within an easement. Project 10.5 recommends that the District establish a drainage easement along this route, to convey the overland flow.

Drainage Easement – Lakeridge Road to Okanagan Lake

As shown on Figure 10.4, runoff from the south end of Lakeridge Road travels across an adjacent resident lot, and then towards Okanagan Lake near the south end the resort. It is not known if this drainage route is protected within a registered drainage easement, and Project 10.6 has been presented for District staff to confirm, or establish a protected easement.

Drainage Easement –Weatherhill Cres to Okanagan Lake

Similar to the above, runoff from the south end of Weatherhill Cres. travels between two existing homes at the end of Weatherhill Cres. Any surface flow will then travel over the steep banks above Okanagan Lake. Project 10.7 has been presented to ensure that this drainage route is adequately protected within a registered easement.

Drainage Easement –Graymar Road to Okanagan Lake

As shown on Figure 10.4, runoff from the south end of Graymar Road travels across two existing residential lots, and then crosses Colleens Hill Road. Once on the east side of Colleens Hill Road, any surface flow then travel across the steep banks above Okanagan Lake. The flow rates are anticipated to be quite low, and are not expected to generate

erosive conditions. Project 10.8 has been presented to ensure that this flow route is protected within a registered drainage easement.

Drainage Easement –King Road Okanagan Lake

As indicated on Figure 10.5, surface runoff from west edge of King Road will follow the existing gulley that crosses two large residential properties and then over the steep banks above Okanagan Lake. It is not known if a drainage easement has been established over these properties. Project 10.9 has been presented for the District staff to confirm or establish an easement along this existing drainage corridor.

A number of catchbasins within the Casa Loma area, particularly near the end of Zoralek Cove and Casa Rio Drive. This may reduce the ability to convey the flow through the lake outfall pipes, and should be cleaned to reduce the risk of surcharging and sediment deposit in the lake.

10.4 FUTURE DEVELOPMENT AREAS

Based on the available Official Community Plan, there are no significant future development parcels indentified within this basin. It is anticipated however, that some areas may be re-developed at a higher density and minor infilling will occur over time. It is recommended that low impact development initiatives be utilized within any future development or re-development projects to minimize any impacts of urban runoff.

10.5 RECOMMENDED IMPROVEMENTS

Based on the review of existing drainage systems, hydraulic capacities and peak flow rates, the recommended improvements have been presented in the following project sheets. The recommended improvement projects and the estimated costs are summarized in Table 10.1.

Table 10.1 – Improvement Projects for Existing Deficiencies
Lakeview Heights Basin

Project	Priority	Description	Cost Estimate
10.1	Low	Drainage Easement – Harmon Road to Boucherie Road	-
10.2	Low	Drainage Easement – Hayman Drive to Boucherie Road	-
10.3	Low	Drainage Easement – Bridgeview Road to Okanagan Lake	-
10.4	Low	Drainage Easement – Kelview Crescent to Okanagan Lake	-
10.5	Low	Drainage Easement – Thacker Drive to Okanagan Lake	-
10.6	Low	Drainage Easement – Lakeridge Road to Okanagan Lake	-
10.7	Low	Drainage Easement –Weatherhill Cres to Okanagan Lake	-
10.8	Low	Drainage Easement –Graymar Road to Okanagan Lake	-
10.9	Low	Drainage Easement –King Road Okanagan Lake	-

Table 10.2
Existing System – Summary Table

Up Node	Down Node	Length (m)	Cross-Section	Existing Size (mm)	Slope of Conduit (%)	Q5 Maximum Flow (L/s)	Q100 Maximum Flow (L/s)
LHJ-10	LHJ-9	179.3	Trapezoidal	600	9%	68	157
LHJ-11	LHJ-10	20.7	Circular	500	2%	68	**157**
LHJ-16	LHJ-17	152.9	Trapezoidal	600	1%	248	**321**
LHJ-21	LHJ-25	189.2	Trapezoidal	600	4%	218	733
LHJ-22	LHJ-23	363.3	Trapezoidal	600	7%	85	249
LHJ-23	LHJ-21	203.3	Trapezoidal	600	7%	171	551
LHJ-24	LHJ-23	562.7	Trapezoidal	600	10%	25	77
LHJ-25	LHJ-20	231.6	Trapezoidal	600	4%	557	**1454**
LHJ-26	LHJ-25	668.8	Trapezoidal	600	7%	133	429
LHJ-6	LHJ-5	204.1	Trapezoidal	600	8%	48	48
LHJ-7	LHJ-6	19.1	Circular	300	3%	**48**	**48**
LHJ-8	LHJ-7	53.3	Trapezoidal	600	10%	68	157
LHJ-9	LHJ-8	15.0	Circular	500	3%	68	157

Project 10.1 Obtain Drainage Easement – Harmon Road to Boucherie Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Harmon Road to Boucherie Road.
Implementation:	Overland flow from the west end of Harmon Road travels overland across private property enroute to Boucherie Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



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Project 10.2 Obtain Drainage Easement – Hayman Drive to Boucherie Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Hayman Drive to Boucherie Road.
Implementation:	Overland flow from Hayman Drive near Issler Road travels overland across private property enroute to Boucherie Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



Project 10.3 Obtain Drainage Easement – Bridgeview Road to Campbell Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Bridgeview Road to Campbell Road.
Implementation:	Overland flow from the north end of Bridgeview Road near Essen Road travels overland across private property enroute to Campbell Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3

Location:



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Project 10.4 Obtain Drainage Easement – Kelview Crescent to Campbell Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Kelview Crescent to Campbell Road.
Implementation:	Overland flow from the east end of Kelview Crescent travels overland across private property enroute to Campbell Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 10.5 Obtain Drainage Easement – Thacker Drive to Campbell Road

Proposed Works:	Establish a drainage easement or Right-of-Way from Thacker Drive to Campbell Road.
Implementation:	Overland flow from Thacker Drive travels overland across private property enroute to Campbell Road. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 10.6 Obtain Drainage Easement – Lakeridge Road to Okanagan Lake

Proposed Works:	Establish a drainage easement or Right-of-Way from Lakeridge Road to Okanagan Lake.
Implementation:	Overland flow from Lakeridge Road travels overland across private property enroute to Okanagan Lake. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



Project 10.7 Obtain Drainage Easement – Weatherhill Crescent to Okanagan Lake

Proposed Works:	Establish a drainage easement or Right-of-Way from Weatherhill Crescent to Okanagan Lake.
Implementation:	Overland flow from Weatherhill Crescent travels overland across private property enroute to Okanagan Lake. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 10.8 Obtain Drainage Easement – Graymar Road to Okanagan Lake

Proposed Works:	Establish a drainage easement or Right-of-Way from Graymar Road to Okanagan Lake.
Implementation:	Overland flow from Graymar Road travels overland across private property enroute to Okanagan Lake. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



RSB ENGINEERING

Project 10.9 Obtain Drainage Easement – King Road to Okanagan Lake

Proposed Works:	Establish a drainage easement or Right-of-Way from King Road to Okanagan Lake.
Implementation:	Overland flow from King Road travels overland across private property enroute to Okanagan Lake. It is not known if this flow route is within a protected drainage easement or Right-of-Way. This work is considered a Low priority, since the risk of flooding and/or property damage is considered low.
Consequences if not completed:	Without an established easement or Right-of-Way, the District will not have the authority to enter onto the property and to install, repair, maintain or replace the drainage works.
Priority:	3
Location:	



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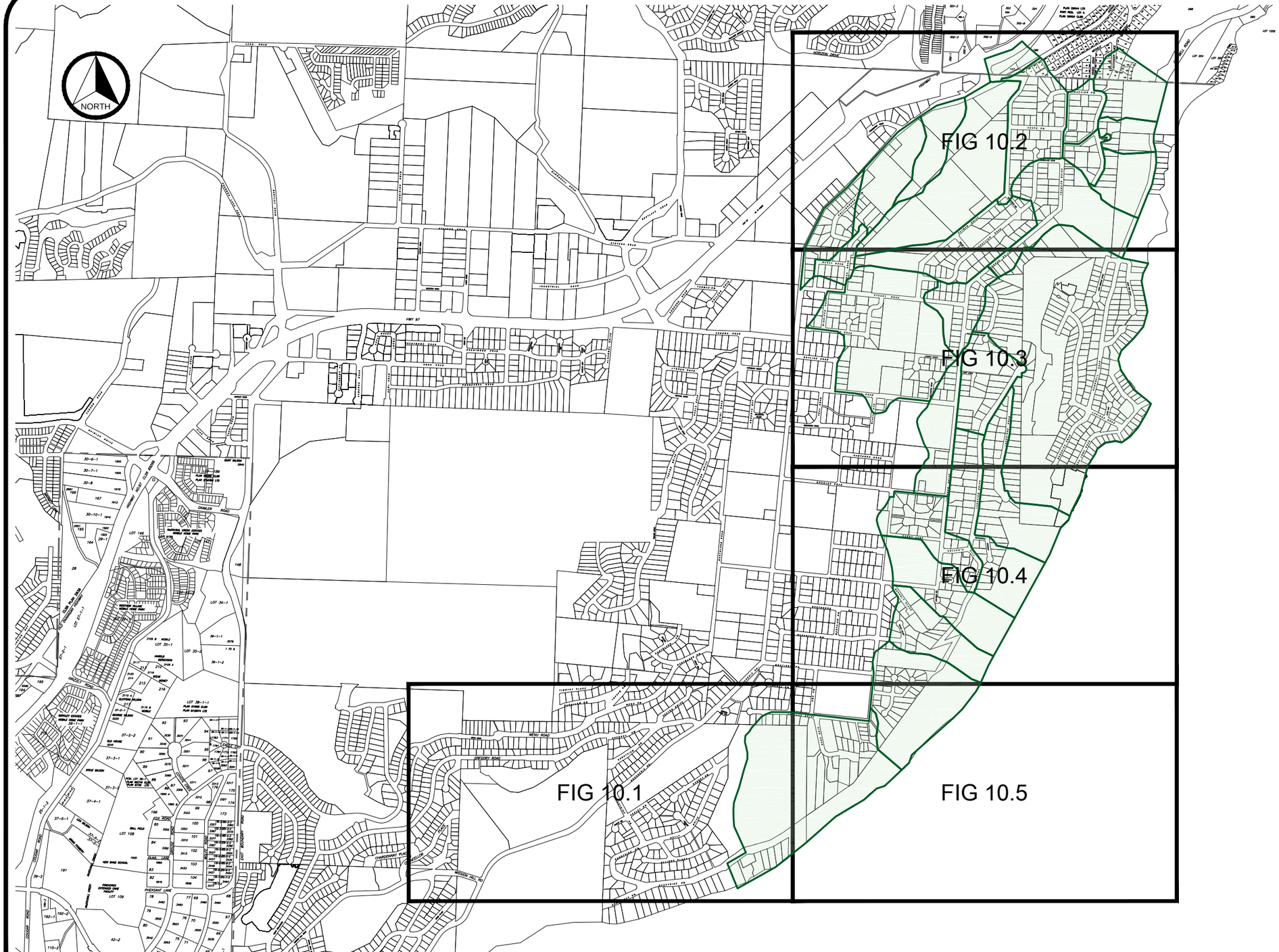


FIGURE 10.0
LAKEVIEW HEIGHTS BASIN
KEY MAP
N.T.S.

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- LHS-16 CATCHMENT ID
- LHJ-21 JUNCTION ID
- LHJ-2 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

		10.4
	10.1	10.5

FIGURE 10.1
LAKEVIEW HEIGHTS BASIN
EXISTING SYSTEM
SCALE 1:5,000

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NORTH

PART REM. LOT A
PLAN 59924 CLSR

HORIZON DRIVE

HIGHWAY

CAMPBELL ROAD

TOMAT CRESCENT

MICHELE PLACE

ALEXANDER PLACE

ESSEN ROAD

BRIDGEVIEW RD.

KELVIEW ROAD

KELVIEW CRES.

SCANTLAND ROAD

THACKER DRIVE

CRESTVIEW ROAD

HAYMAN DRIVE

BUNNAVISTA RD.

PROSERPINE ROAD

COLLINGWOOD ROAD

McKAY ROAD

LOT

OKANAGAN LAKE

LHJ-20

LHJ-25

LHJ-21

LHJ-23

LHJ-22

LHJ-24

LHJ-26

LHJ-19

LHJ-27

LHJ-28

LHJ-29

LHJ-30

LHJ-18

LHS-2_1

LHS-2_3

LHS-2_2

LHS-2_4

LHS-1_4

LHS-1_3

LHS-1_2

LHS-1_1

LHS-3_1

LHS-3_3

LHS-3_5

LHS-3_4

LHS-4

EXISTING 300mm CULVERT
BLOCKED

OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
10.1

OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
10.2

OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
10.3

OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
10.4

OBTAIN DRAINAGE EASEMENT
FOR OVERLAND ROUTE
AS PER PROJECT
10.5

LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- LHS-16 CATCHMENT ID
- LHJ-21 JUNCTION ID
- LHJ-2 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	10.2	
	10.3	

FIGURE 10.2
LAKEVIEW HEIGHTS BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

OBTAIN DRAINAGE EASEMENT FOR OVERLAND ROUTE AS PER PROJECT

AS PER PROJECT

NORTH

LHS-1_2

LHS-1_1

LHS-2_4

LHS-4

LHS-5

LHS-6

LHS-7

LHS-8

LHS-9

LHJ-14

LHJ-15

LHJ-16

LHJ-17

LHJ-18

LHJ-24

LHJ-26

LOCAL DEPRESSION

LOCAL DEPRESSION

LOCAL DEPRESSION

NO AS–CONSTRUCTED INFORMATION

NO AS–CONSTRUCTED INFORMATION

OKANAGAN LAKE

McKAY ROAD

STUART ROAD

WINNIPEG ROAD

LINE ROAD

LINDSAY COURT

GANT CRES.

ANDERS ROAD

HAWTHORN ROAD

TEAL ROAD

OLALL AVE.

WELLINGTON ROAD

LAKERIDGE ROAD

HILLSBOROUGH PLACE

HAXMAN DRIVE

CRESTVIEW ROAD

HACKER DRIVE

CASA GRANDE DRIVE

CASA RIO DRIVE

CAMPBELL ROAD

LUCINDE ROAD

ALICE CRT

BENEDICK ROAD

CASA LOMA ROAD

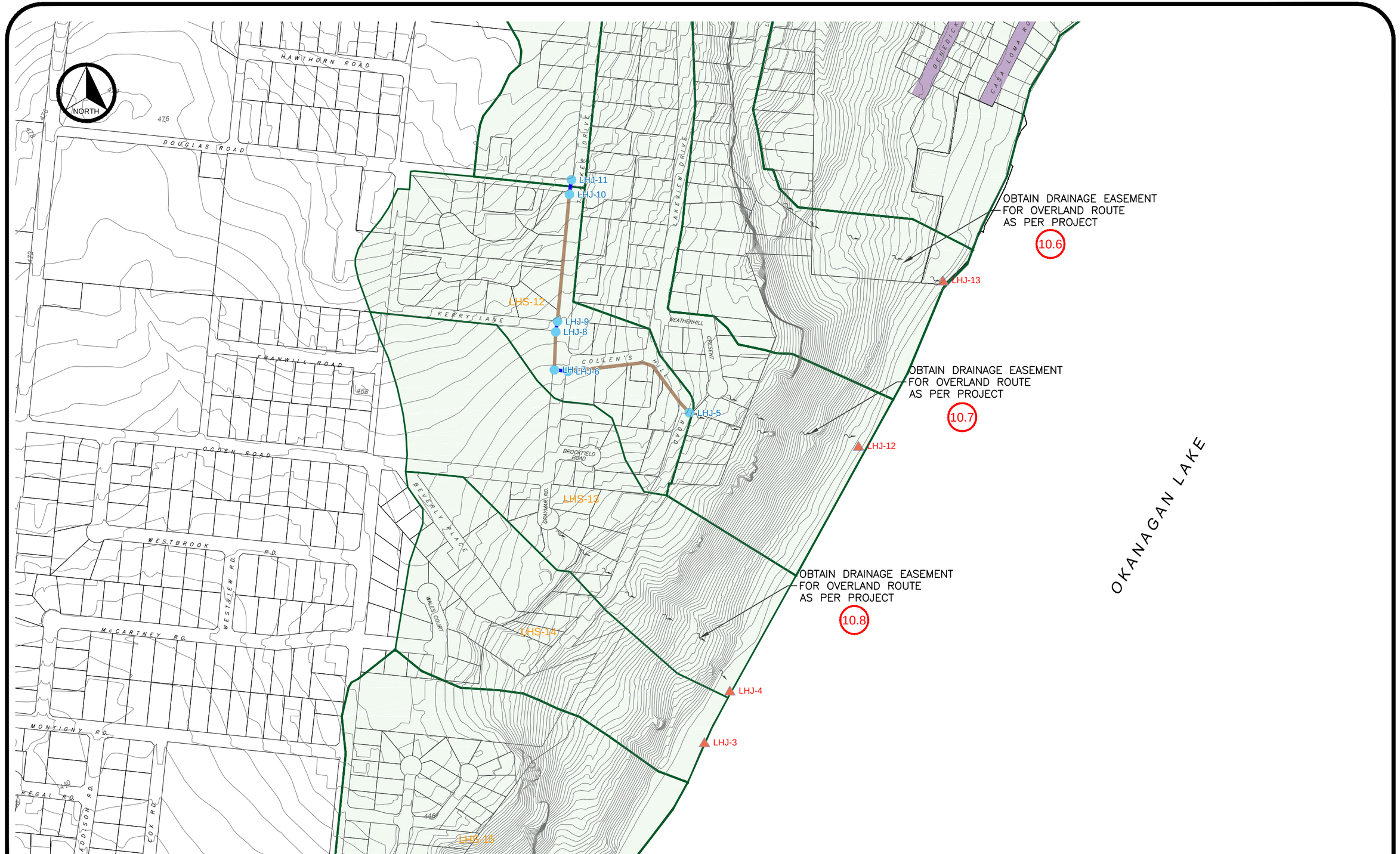
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- LHS-16 CATCHMENT ID
- LHJ-21 JUNCTION ID
- LHJ-2 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	10.2	
	10.3	
	10.4	

FIGURE 10.3
LAKEVIEW HEIGHTS BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



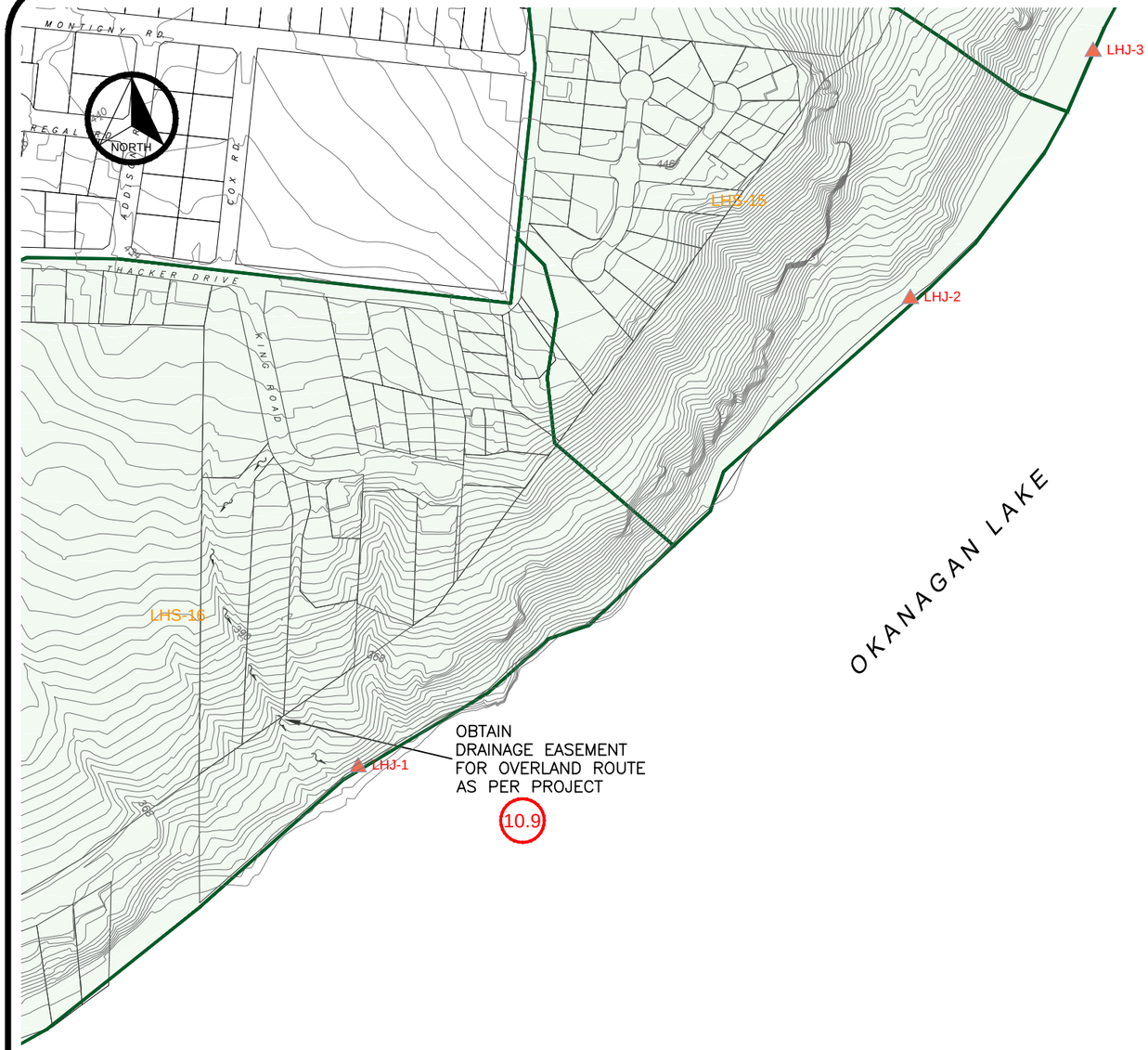
LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- LHS-16 CATCHMENT ID
- LHJ-21 JUNCTION ID
- LHJ-2 OUTFALL ID
- 2m CONTOUR
- 524 CONTOUR ELEVATION

	10.3	
	10.4	
10.1	10.5	

FIGURE 10.4
LAKEVIEW HEIGHTS BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING



LEGEND

- CATCHMENT BOUNDARY
- MODEL CHANNEL/DITCH
- MODEL PIPE
- MODEL JUNCTION
- MODEL OUTFALL
- LHS-16 CATCHMENT ID
- LHJ-21 JUNCTION ID
- LHJ-2 OUTFALL ID
- 2m CONTOUR
- *524* CONTOUR ELEVATION

	10.4	
10.1	10.5	

FIGURE 10.5
LAKEVIEW HEIGHTS BASIN
EXISTING SYSTEM
SCALE 1:5,000

RSB ENGINEERING

SECTION 11
HYDROGEOLOGICAL OVERVIEW

11.1 BACKGROUND

The traditional objectives of storm water management practice have been to remove water from the surface as quickly as possible, preferably to the nearest receiving water system (above or below ground), while assuring minimum inconvenience to human activities. The main advantage has been the reduction of flooding, particularly flooding generated by urbanization, including concentration of flow due to deforestation and construction of roads and buildings. The main disadvantages have been the impacts on water quality to the receiving environment (both chemical and sediment), erosion, groundwater mounding and slope instability due to daylighting seepage or up-gradient loading.

With respect to storm water disposal to ground, the major controlling factors influencing the feasibility are ground slope, infiltrative capacity of surficial soil and depth to groundwater, or a limiting condition.

Within the Okanagan Valley, storm water disposal to ground has been utilized for storm water management predominantly in areas where ground slope is relatively flat and where soils are granular in nature. This includes soak away pits and dry wells in the commercial and industrial areas within communities situated in the lower elevation areas of the Valley, as well as dry wells and infiltration lagoons to handle runoff in semi-rural subdivisions along the edges of the Valley. Historically, the design and implementation of storm water disposal to ground has been undertaken with a view to the minimization of infrastructure costs and has not addressed the potential influences on areas located at lower elevation, nor has it addressed potential cumulative impacts which could occur with further urbanization up-slope. With increasing development in the Valley, in particular semi-rural residential development on peripheral upland areas, cumulative impact areas where slope failures and problematic groundwater conditions have developed are increasing in number.

As part of the Master Drainage Plan, this assignment was commissioned to determine pre-development conditions, evaluate on a cursory level the suitability of specific development areas for storm water disposal to ground and to identify areas which would be prone to impacts from up-slope disposal to ground.

One of the major features of this Study is the concept of a "limiting condition", defined as a barrier restricting water from further vertical migration downwards. The depth to a limiting condition is defined as the depth at which groundwater, bedrock, glacial till or fine-grained silt/clay is encountered. Bedrock and low hydraulic conductivity soils, such as till, silt and clay will cause build-up, or mounding, of groundwater to occur. Groundwater is also considered a limiting condition, as water will mound on the water

table. As such, a relatively shallow depth to a limiting condition reduces the allowable height of mounding which can occur prior to seepage occurring at ground surface. Furthermore, where a shallow limiting condition is encountered, such as bedrock, till or groundwater, water may travel horizontally along the soil-bedrock interface and surface along slopes where the bedrock subcrops or where steep soil slopes occur at lower elevation.

Similar hydrogeological assessments relating to the infiltrative capacity of soils have been completed in the Okanagan Valley, including a study for the City of Kelowna (EBA, 1997) which looked at soil type, slope and depth to water in relation to storm water disposal. However, the EBA study did not look at potential down-gradient impacts due to groundwater loading resulting from storm water disposal to ground. Golder Associates Ltd. (2006, 2009) has completed studies relating to the feasibility of stormwater disposal to ground and the cumulative impacts of residential development in steeply-sloping settings, with the objective of identifying cumulative impacts of rising water levels.

All of these studies are based on a modification of DRASTIC, which is a standardized system developed by Aller et al (1987) to assess the relative influence of basic hydrogeological factors which affect the vulnerability of groundwater to contamination. The word DRASTIC is an acronym representing the hydrogeological factors, including D= Depth to Groundwater, R = Recharge (net), A = Aquifer media, S = Soil type, T = Topography (slope), I = Impact of vadose zone (unsaturated zone above groundwater) and C = Conductivity (hydraulic) of the aquifer. For the studies referenced above and this assignment, determination of infiltration capacity at surface, ie, the feasibility of storm water disposal to ground, is based on a modification of DRASTIC, which considers depth to groundwater, or limiting condition, as well as slope and soil type only.

11.2 METHODOLOGY

The scope of work for this assignment was to complete an assessment within the Study Area of the suitability of the subsurface to infiltrate storm water. The analysis was relative, not quantitative, as the quantity of data available was sparse and the quality of the data, in most cases, was not verifiable. The total area covered by the assessment is approximately 12,270 hectares. The Westbank First Nation Reserve #IR9, which is located within the DWK, was not included in this assessment.

The suitability for infiltration of stormwater to ground was completed using the spatial data storage and Multiple Criteria Analysis (MCA) capabilities of Geographic Information System (GIS) software. The Study Area was discretized into roughly 2,500 polygon elements, to which discrete values were assigned for the three dominant factors

influencing infiltration, including surface elevation (ground slope), soil type and depth to limiting condition. The relative influence of each of these factors was assigned in the form of an ordinal value, or ranking applied for each attribute for each polygon element in the Study Area.

Multiple Criteria Analysis (MCA) was used to subjectively rank polygon elements across the Study Area as being well suited, moderately suited or not suited for disposal of storm water to ground. This was based on a total scoring for all attributes at each element location. The total scores for all elements were then compared and a ranking order, or preliminary suitability rating determined, based on the highest suitability (with the highest score) to the lowest suitability (lowest score).

11.3 COMPILED INFORMATION

Surficial Geology and History of Glaciation

The review of geology in the area is based primarily on previous work completed by Nasmith (1962), Fulton (1976), Roed et al (1978) and Paradis (2009). The bedrock geology is based on field mapping and correlation with other bedrock exposures and unit sequences found in the Interior of British Columbia. The more recent Quaternary (surficial or alluvial) geology is based on mapping, relatively shallow borings and an understanding of the depositional environments and resulting landforms due to glacial advance and retreat.

Bedrock exposed at ground surface covers over 43.6% of DWK, predominantly in the higher elevation areas along the northern and western limits of the Study Area, surrounding Mt. Boucherie, and to the south of the Glenrosa Area. The remainder of West Kelowna is covered with tills (32.5%), clays (4.3%), glacially-deposited sand & gravel (16.6%) and 3% comprised primarily of alluvial fan sediments, fluvial floodplain sediments, organic sediments, and scree deposits. According to the British Columbia Geological Survey (BCGS) website, the bedrock geology in the area is dominated by 5 major rock types.

- undivided volcanics of the Penticton Group (Eocene) is the most dominant rock type. The volcanics include the Marron, Kettle River, Springbook, Marama and Skaha formations;
- mudstones, siltstone, shale, fine clastic sedimentary rocks from the Penticton Group, including the Kettle River and Springbook formations, dominate to the south, along Lake Okanagan
- volcaniclastic rocks of the Harper Ranch Group dominate to the north
- basaltic volcanic rocks from the Lambley Creek Basalt, dominate in the area of Mount Boucherie

Nasmith (1962) is by far the best source of information for surficial (alluvial) geology in the Study Area. The surficial geology for the entire Okanagan Valley is generally described as being dominated by glacial and post-glacial deposits, derived from the erosion of the bedrock in the Valley and adjacent upland areas, followed by various stages of deposition. The resultant landforms along the edges of and in the base of the Valley are complex and include alluvial fans, deltas and associated gullies and stream channels. The sediment types associated with the landforms include lacustrine silt and clay, glacial and glacial-fluvial deposits of till, clay, silty sand, sand and gravel and more recent fluvial and alluvial sediments.

The landforms, as well as sediment types, are described by Nasmith through a sequence of depositional events, divided into pre-glacial, glacial advance/occupation/ retreat and post-glacial events. Pre-glacial events in the Study Area include the deposition of sediments (the White Lake Formation) associated with a large river system which flowed through the main Okanagan Valley. The sediments buried a large portion of the existing volcanic terrain. This was subsequently followed by major tectonic activity including uplift and faulting, which created the Okanagan Fault and the complex bedrock geology of the area. Additional volcanic activity (basalt flows) occurred after the faulting and uplift. Dissection (downward erosion) of the dominant stream channels along the edge of the Valley also occurred during this period.

Glacial advance and occupation was characterized by the buildup of ice across a large area which completely engulfed the Province of British Columbia. The thickness of ice reached as much as 3000 m and the weight of the ice caused scouring of the underlying bedrock. Ice movement in the Valley was influenced by gravity, primarily away from accumulation areas, generally from north to south and from higher to lower elevations. Glacial retreat was characterized by "down-melting" within the upland areas first and subsequently in the Valley itself. Stagnant ice created blockages, both within the tributaries which drained into the Valley and within the Valley itself, which resulted in the creation of Glacial Lake Penticton.

Melt water from the glaciers, combined with runoff from creeks and streams draining the surrounding plateau (to the west of West Kelowna), flowed along the margin of the Valley, eroding the outwash channels and depositing gravels and sands, sometimes on the edge of the ice and sometimes in ponds blocked in the tributary valleys by the ice that occupied the base of the Okanagan Valley.

The resultant deposits associated with these major creeks are often referred to as fan deposits and are dominated by sand and gravel in proximal (higher elevation) areas. Fine sand and silt become more prominent in the distal areas of these fans, at lower elevations where Powers and McDougall creeks enter Lake Okanagan and opposite ends of Gellatly Bay. Lacustrine (lake bottom) deposits associated with Glacial Lake Boucherie predominate where the post-glacial down-cutting (erosion) by Powers and McDougall creeks did not occur. The approximately remaining extent of the clay/silt that was deposited by Lake Boucherie is 900 ha, bounded to the north by Old Okanagan Highway,

the south by Lake Okanagan (Gellatly Bay), the west by Elliot Road and the east by McDougall Creek. A good portion of the WestBank First Nation Reserve # IR9, is covered by the silt//clay. The approximate centroid of the clay/silt is 311920 E / 5523702N, which is the junction of Hwy 97 and Butt Rd, and the clay/silt is present between approximately 455 masl and 400 masl. This only infers that the clay/silt could be present between these elevations points, not necessarily that the thickness of the unit is 55 m. There are two other, smaller, areas where lacustrine silt/clay predominate including along the south flank of Mt. Boucherie and the silt bluff immediately north of the western approach to the Okanagan Floating Bridge (Siwash Point).

Extensive sand and gravel areas exist as fan and ice-contact deposits associated with Powers Creek and McDougall Creek. The gravel pits, which exist between Westlake Road and Dominion Road, were lain by glacier melt along McDougall Creek, which was diverted to the east when the Lake Boucherie area was occupied by ice. At the same time, a fan deposit was lain by Powers Creek along the western edge of the ice blockage. The Powers Creek Fan is predominantly on the east side of Powers Creek, where Glencoe Road and Scharf Road intersect.

Till deposits, both as extensive blanket coverage and as a relatively thin veneer above bedrock, exist in several areas, most notably around the flanks and to the northeast of Mt. Boucherie, to the west of Shannon Lake and to the west of Glenrosa.

The Geological Survey of Canada map of the Kelowna Area by Paradis (2009) is the most detailed mapping for the area.

Other Subsurface Information

The surficial geology was augmented by information from boreholes, test pits and other available data for discrete locations within the Study Area. This information was obtained from several sources including government databases, reports from the Regional District of Central Okanagan, DWK and files that had been accumulated over the years by the consultants.

The BC Ministry of Environment's (BCMoE) internet-based, Water Resources Atlas (WRA) and associated water well database (WELLS), was queried to provide information on known water wells, as well as the extent and properties of known aquifers in the Study Area. The majority of the water wells in the Study area are located in bedrock dominated upland areas, primarily where larger, semi-rural, lots require on site services. There are a few wells completed in the sand and gravel areas, including a few near McDougall Road that are used by the local nursery and in the gravel pits.

Selected reports containing subsurface information were also obtained from RDCO and DWK. These were generally limited to documents describing the results of shallow geotechnical or environmental drilling programs. The information from these sources was

useful for determining the depth to limiting condition, specifically the depth to bedrock, clay, till and water. The depth to water in many instances was not used, as the limiting condition was most often encountered at a shallower depth.

Several field surveys were completed in order to observe the geology, topography and bedrock exposures, as well as depths to limiting condition at locations where excavations were underway.

11.4 ASSIGNMENT OF INFILTRATION FACTORS

Groundwater Flow Direction

Prior to assigning attribute values for soil type, slope and depth to limiting condition, the depth to groundwater at discrete locations across the Study Area was used to produce a map of inferred groundwater flow direction. For the preparation of this map, it was assumed that the depth to groundwater was within 1 m at the bedrock-soil interface in the upland areas. The resultant map of groundwater flow direction in the Study Area is presented in Figure 11.1. This map was used along with the digital elevation data to determine depth to groundwater throughout the Study Area.

In general, the direction of groundwater flow is from the bedrock-dominated upland areas in the west, towards Lake Okanagan in the east and south. There is a drainage divide which extends from the northeast corner of Mount Boucherie to the junction of Westlake Road and Rosewood Drive. Groundwater flow to the east of this divide, reports to Lake Okanagan along a route which mimics the current alignment of Highway 97. Groundwater flow to the west of this divide generally follows the routing of McDougall Creek, which is to the east of the clays associated with the former Lake Boucherie. Subsurface flow, from the Shannon Lake Area and from the buried fan deposit, immediately east of Powers Creek, converges to the west of the clays in the approximate area where Elliot Road intersects Butt Road. Due to limited information on groundwater levels in this immediate area, it is unclear as to what direction the flow is subsequently directed – either towards Powers Creek, towards Lake Okanagan, or a combination of both.

Soil Type

Soil type directly relates to the hydraulic conductivity or permeability of the soil and in turn the ability to infiltrate storm water. The soil types considered in this study ranged from bedrock, with the relatively lowest capacity to infiltrate water, to sand and gravel with the highest capacity. Soil types were determined primarily using the digital surficial geology map prepared by Paradis (2009), along with interpretation based on geological relationships described by Naismith (1962) regarding the glacial history of the Westbank Area.

The conceptual geological model used for establishing spatial relationship and extent of soil types throughout the Study Area is based on the assumption that the lacustrine silts were relatively continuous up to the elevation (455 m asl) at which Glacial Lake Boucherie merged with the larger Glacial Lake Penticton (which occupied the entire Okanagan Valley).

Each soil type was assigned an attribute value reflecting the capacity to infiltrate water. Water itself (the water table) has the lowest capacity to infiltrate and thus was assigned the lowest value of 1. Bedrock was assumed to be massive and, with the exception of weathering that would provide for storage of some infiltrated water, was assigned a low value of 2. Clay, silt or till, which are cohesive soils with relatively low hydraulic conductivity, were assigned a value between 3 and 5. Increasingly granular materials were assigned relatively higher values ranging from 6 to 10. Due to the limited amount of information on gradational characteristics, not all values were used. Furthermore, some soil types as described by Paradis (2009) were grouped into larger categories and assigned the same attribute value. For example, all granular (glacio-fluvia, fan, terrace and floodplain) materials, including Gt, Gb, Go, Gx, Ap, Af, and At, were assigned a value of 8. Similarly, all till materials, including Tb and Tv, were assigned a value of 3. Lacustrine sediments including Lv, Lb, La and Ld, were assigned a value of 4. The remaining polygons designated as O, Ap, Af and At were also assigned a value of 4. A map which shows the distribution of the surficial geology in the Study Area is presented in Figure 11.1. The assigned attribute value for each soil type is presented in the following table:

Table 11.1 – Assigned Attribute Values for Each Soil Type

Soil Type	Assigned Soil Infiltration Value	Units Included	% of Study Area Occupied
Bedrock	2	All rock	43.6
Till	3	Tv, Tb, Tv/R	32.5
Lacustrine (silt/clay)	4	La, Lb, Lv, Ld	4.3
Granular (sand/gravel)	8	Go, Go/R, Gt, Gx	16.6
Other	4	O, Ap, Af, At	3.0
		Total =	100

Surface Topography (Slope)

Surface topography, or ground slope, directly relates to the ability of water to infiltrate and indirectly relates to the potential for soil erosion. In general, a relatively steep slope will promote runoff rather than infiltration. In areas where silt and/or clay is present in conjunction with a relatively steep slope, a higher potential for soil erosion exists. Alternately, where slope is relatively flat, water will tend to pond, which promotes infiltration, particularly where soil is more granular. GIS software was used to categorize the digital elevation data received from RDCO into slope categories. A map which shows the distribution of the slope categories in the Study Area is presented in Figure 11.2. The assigned attribute value for each slope category is presented in the following table. There are areas where slope exceeds 40%, but these account for less than 0.01% of the total area studied and therefore the value is reported as zero in Table 11.2.

Table 11.2 – Assigned Attribute Values for Each Slope

Slope Range %	Assigned Slope Category Value	% of Study Area Occupied
0 - 1	1	0.8
1 - 5	7	9.9
5 - 10	10	20.1
10 - 15	8	18.4
15 - 20	6	23.3
20 - 25	5	15.0
25 - 30	4	7.8
30 - 35	3	4.3
35 - 40	2	1.4
>40	1	0.0

Depth to Groundwater or Limiting Condition

Surficial soil type, along with observed groundwater conditions and known locations of bedrock exposure, were used to determine the depth to limiting condition as defined in

Section 11.1. A relatively shallow depth to limiting condition was assigned a lower value, reflecting a decreased capacity to receive infiltrated water without excessive mounding, or daylighting of seepage. Shallow depths to limiting condition occur where till, bedrock or clays were noted at or near surface. With increasing depth to limiting condition, a higher number was assigned. Greater depths for a limiting condition occur where sand and gravel deposits exist. Many instances were encountered where a shallow limiting condition was encountered, such as bedrock or till, that would cause water to travel horizontally along the top of the bedrock or till, surfacing along slopes where the bedrock or till subcrops at lower elevation. In such an instance, any groundwater encountered at greater depth would not be considered the limiting condition.

A depth to limiting condition of less than 1.5 m was considered to be prohibitive for disposal of storm water to ground. The depth was chosen to correspond roughly with the minimum depth of unsaturated soil required for a conventional sewage disposal field, which depends on evapotranspiration and the dissipation of mounding, to operate appropriately. In many cases the soil type in a polygon element and in turn the ability of the soil type to infiltrate water, was more critical than the actual depth to water. For example in bedrock polygon elements, the depth to limiting condition was assigned a default value of 2. Lacustrine clay/silt and both types of till were all assigned a value of 3.

Many of the polygon elements along the edges of lacustrine silt/clay areas were found to have very steep slope, which is a common feature as clay/silt tends to erode or fail in vertical pieces. As a result, especially for larger polygons, the GIS software would over-predict the average depth to groundwater in these polygons in steep areas. It was therefore necessary to limit the maximum depth to limiting condition in such areas to a maximum score of 4.

A map which shows the distribution of the depth to limiting condition in the Study Area is presented in Figure 11.3. The assigned attribute value for each category is presented in the following table:

Table 11.3 – Assigned Attribute Values for Each Category

Depth to Limiting Condition Range (m)	Assigned Category Value	% of Study Area Occupied
0 - 1	1	56.4
1 - 2	2	18.0
2 - 3	3	7.4
3 - 4	4	4.2
4 - 5	5	1.1
5 - 6	6	3.4
6 - 7	7	1.7
7 - 8	8	0.4
8 - 9	9	0.3
> 9	10	7.2

11.5 ASSESSMENT OF SUITABILITY FOR STORMWATER DISPOSAL

Using the GIS software, attribute values for each element were totalled (MCA analysis) and a comparison of total scores for all elements completed by dividing total scores into categories reflecting levels of suitability for storm water disposal to ground. Each category was colour-coded for plotting such that identification of spatial grouping of similar categorized elements was possible.

The categories of suitability of storm water disposal to ground are as follows:

- **NOT SUITABLE -** those locations where the total score of attributes is less than or equal to 18. These are typically locations where at least two of the three infiltration attributes were of low to very low value. For example those locations where infiltration is not feasible by default, including locations where the depth to limiting condition is less than 2 m, such as shallow bedrock, silt/clay and where depth to groundwater is basically at or near ground surface. Areas where slope is greater than 35 percent and areas within 100 m of slopes exceeding 35 percent were also considered not feasible, due to high potential for erosion.

- **POSSIBLY SUITABLE -** those locations where the total score is between 18 and 22, typically representative of average scoring for all three attributes, or better than average scoring for at least two attributes. These locations are not considered by default to be suitable, but would require investigation of both on-site and off-site (down-slope) subsurface conditions to allow for an appropriate assessment of feasibility and potential down slope impacts

- **WELL SUITED —** those locations where the total score is equal to or exceeds 22, representative of above average scoring on all three attributes. All of these locations had relatively coarse grained surface soils, flat topography and considerable depth to groundwater.

The results of the preliminary analysis (Figure 11.4) indicate that a large portion of the Study Area is not suited for storm water disposal to ground as summarized in Table 11.5. Strong spatial grouping, or correlation, exists in the higher elevation, bedrock-dominated areas, generally above approximately 525 masl, along with areas where till and/or silt/clay exist. Those locations where storm water disposal to ground appears feasible are generally located where the glacio-fluvial and alluvial fan deposits are present, as well as where ice contact deposits are present immediately down-gradient of bedrock exposures.

Table 11.5 – Results of Preliminary Ananylsis

Final Suitability Ranking	% of Study Area Occupied
Not Suitable	85.5
Possibly Suitable	7.2
Well Suited	7.4

11.6 CONCLUSIONS AND RECOMMENDATIONS

In terms of documenting baseline conditions throughout the Study Area, this assignment has collated and input into GIS format a substantial amount of information including topography, surficial soil, subsurface soil and groundwater conditions. The GIS files represent a substantial database, which could be used for other wide-area applications relating to water, such as quantification of irrigation return flow, water source protection planning and drought management.

Applying the concept of limiting condition to the available data, the majority of the Study Area is not considered to be well suited for disposal of storm water to ground. The areas where it is considered feasible are generally limited to glacio-fluvial and alluvial sediments associated with McDougall and Powers creeks. Disposal to ground in these areas could be accomplished via dry wells in close proximity to the creeks, however the potential water quality impacts of urban runoff on aquatic habitat in the creeks could be compromised. Further enhancement of infiltrative capacity could potentially be realized by incorporating a surface detention facility adjacent to a field of dry wells in order to realize a delay in time of concentration and removal of sediment, prior to charging the dry wells.

There is no information regarding what type of soils may be present underneath the clay/silt which dominates the Westbank First Nation reserve #IR9. It may be that the granular deposits associated with earlier glacial runoff along McDougall Creek may extend underneath the clay. Some deep drilling would be required to verify this.

The suitability analysis is considered preliminary only, as a limited number of discrete data points were available for review, specifically for soil and groundwater conditions below the surficial mapping by the GSC.

Comments regarding specific proposed development areas are provided below.

Based on the analysis and conclusions, the following recommendations are made:

- Further, more detailed analysis, including drilling to determine soil properties and water levels at greater depth, as well as hydraulic response testing to determine infiltrative capacity and mounding characteristics is recommended in any area being considered for storm water disposal

- Any development which occurs in the proposed development areas should incorporate xeriscape principles to limit the potential for irrigation return flow contributing additional water to the subsurface

Figure 11.1 - Groundwater Flow Direction and Surficial Deposits

District of West Kelowna Master Stormwater Management Plan

Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	November 3, 2009

Legend

- District of West Kelowna Boundary
- Major Highway
- Sensitive Habitat Inventory and Mapping (SHIM) Streams
- Lakes

Surficial Deposits

- Bedrock (B)
- Till (T)
- Lacustrine (L)
- Granualar (G)
- Other (O)

1,000 500 0 1,000 2,000

Meters

1 : 30,000

District of West Kelowna

RSB Engineering

Sustainable Subsurface Solutions

Ecoscape Environmental Consultants Ltd.

Figure 11.2 - Surface Topography Classification (Slope)

District of West Kelowna Master Stormwater Management Plan

Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	November 3, 2009

Legend

- District of West Kelowna Boundary
- Major Highway
- Sensitive Habitat Inventory and Mapping (SHIM) Streams
- Lakes

Slope Range (%) - Slope Category Value

- 0 to 1% - Slope Category Value 1
- 1 to 5% - Slope Category Value 7
- 6 to 10% - Slope Category Value 10
- 11 to 15% - Slope Category Value 8
- 16 to 20% - Slope Category Value 6
- 21 to 25% - Slope Category Value 5
- 26 to 30% - Slope Category Value 4
- 31 to 35% - Slope Category Value 3
- 36 to 40% - Slope Category Value 2
- Greater than 40% - Slope Category Value 1

Note: Tabloid (11in x 17in) printed map is not to scale. The print is intended to be printed on a 24in x 36in sheet to be properly portrayed at 1:30,000. However, the scale bar will be scaled down proportionally to allow for approximate measurements.

1,000 500 0 1,000 2,000

Meters

1 : 3 0 , 0 0 0

District of West Kelowna

RSB ENGINEERING

Sustainable Subsurface Solutions

ECOSCAPE Environmental Consultants Ltd.

Figure 11.3 - Depth to Limiting Condition

District of West Kelowna Master Stormwater Management Plan

Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	November 3, 2009

Legend

- District of West Kelowna Boundary
- Major Highway
- Sensitive Habitat Inventory and Mapping (SHIM) Streams
- Lakes

Depth to Limiting Condition

- 0.0 to 1.0 Metres (1)
- 1.1 to 2.0 Metres (2)
- 2.1 to 3.0 Metres (3)
- 3.1 to 4.0 Metres (4)
- 4.1 to 5.0 Metres (5)
- 5.1 to 6.0 Metres (6)
- 6.1 to 7.0 Metres (7)
- 7.1 to 8.0 Metres (8)
- 8.1 to 9.0 Metres (9)
- Greater than 9.0 Metres (10)

Note: Tabloid (11in x 17in) printed map is not t
is intended to be printed on a 24in x 36in sheet
portrayed at 1:30,000. However, the scale bar v
down proportionally to allow for approximate m

1,000 500 0 1,000 2,000

Meters

1 : 3 0 , 0 0 0

District of West Kelowna

RSB ENGINEERING

Sustainable Subsurface Solutions

ECOSCAPE Environmental Consultants Ltd.

Figure 11.4 - Multiple Criteria Analysis (MCA)

District of West Kelowna Master Stormwater Management Plan

Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	November 3, 2009

Legend

- District of West Kelowna Boundary
- Major Highway
- Sensitive Habitat Inventory and Mapping (SHIM) Streams
- Lakes

Stormwater Disposal to Ground Suitability Ranking

- Not Suitable
- Possible Suitable
- Well Suited

Note: Tabloid (11in x 17in) printed map is not to scale. The print is intended to be printed on a 24in x 36in sheet to be properly portrayed at 1:30,000. However, the scale bar will be scaled down proportionally to allow for approximate measurements.

1,000 500 0 1,000 2,000

Meters

1 : 3 0 , 0 0 0

RSB ENGINEERING

Sustainable Subsurface Solutions

ECOSCAPE Environmental Consultants Ltd.

SECTION 12
WATERCOURSE EVALUATION

12.1 INTRODUCTION

The following section presents information collected between 2003 and 2010 on all watercourses occurring within the District of West Kelowna. Information and watercourse evaluations presented herein, pertain to both the natural and anthropogenic charter of respective watercourses. The information has subsequently been used in developing the District of West Kelowna Stormwater Masterplan.

Project Background

As resource development and human populations increase in British Columbia, pressures for all resources and services have accelerated. Rapid growth has often overwhelmed the ability of local planners to manage land and preserve sensitive habitats (Mason and Knight, 2001). This has resulted in the loss or degradation of aquatic and riparian habitats that are critical for fish and a diverse wildlife assemblage. Accordingly, there is an urgent need to develop stronger tools and better methods to conserve, protect, and reclaim these habitats.

Sensitive Habitat Inventory and Mapping (SHIM) is a standard for fish and aquatic habitat mapping in urban and rural watersheds in British Columbia. SHIM attempts to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about local freshwater habitats, watercourses, and associated riparian communities.

SHIM is designed as a land-planning, computer-generated, interactive GIS tool that identifies sensitive aquatic and terrestrial habitats. It is intended to provide community, stewardship groups, individuals, regional districts and municipalities with an effective, low-cost delivery system for information on these local habitats and associated current land uses.

SHIM has numerous applications and can:

- Provide current information not previously available to urban planners, to allow more informed planning decisions and provide inventory information for integration into Official Community Plans;
- Identify and map areas of significant impairment (e.g., erosion, channelization, habitat degradation) and potential point sources of pollution;
- Assist in the design of stormwater/runoff management plans;
- Monitor for changes in habitat resulting from known disturbance;

- Help guide management decisions and priorities with respect to habitat restoration and enhancement projects;
- Assist in determining setbacks and fish/wildlife-sensitive zones;
- Identify sensitive habitats for fish and wildlife along watercourses;
- Provide a means of highlighting areas that may have problems with channel stability or water quality that require more detailed study;
- Provide baseline mapping data for future monitoring activities; and,
- Map and identify the extent of riparian vegetation available and used by wildlife and fisheries resources.

Objectives of Watercourse Evaluation

The objectives of the project were to:

- Develop a summary report for watercourses inventoried in 2001-2003 by the Regional District Central Okanagan (RDCO) using the SHIM methodology, intended to provide a baseline catalogue document for the District of West Kelowna. Attributes such as discharges, channel condition, erosion, obstructions, and anthropogenic modifications were reviewed, updated in 2010 field inspections and summarized.
- Append a Level of Impact Rating to each stream reach occurring within the 120 km of watercourses which flow within DWK and WFN lands, which will enable scoring of each watercourse in terms of its current level of impact, ecological condition and intrinsic habitat value. The simple rating system will help to facilitate prioritization of sites for improved management and enhancement opportunities.
- Identify habitat restoration and enhancement opportunities in important watercourses and areas throughout the Study Area. Ecoscape will provide general design guidelines and functional objectives for consideration in detailed design stages.
- Identify potential areas for infiltration, attenuation and detention, with the objective of developing a more innovative and sustainable stormwater management plan. Where possible, these elements will facilitate biofiltration, recharge of shallow groundwater, water conservation (capture for reuse and irrigation) and habitat enhancement initiatives which will provide aesthetic improvements to public corridors within DWK.
- Augment and potentially enhance local land use planning maps and/or specific site or detailed planning surveys.

12.2 METHODOLOGY

Field inventory, data processing and data deliverables conformed to the SHIM Standards (Mason and Knight, 2001), which can be reviewed in full at:

http://www.shim.bc.ca/methods/SHIM_Methods.html

Scope of Work

The project work scope included review and analysis of SHIM data collected within the DWK (formerly RDCO) municipal boundaries between 2001 and 2003, with 2010 inspections completed to document changes since the initial surveys were completed.

Field data collection, management and preliminary identification of management issues were completed between 2001 and 2003 by Brent Magnan (DWK Environmental Planner at the time of report completion). A summary report had not previously been generated for the extensive watercourse inventory. Therefore the scope of this project involved assembling previously collected information and updated knowledge[1] to generate a baseline catalogue for reference in stormwater management and landuse planning.

Centerline Survey

Within the previous RDCO report of 2001 to 2003 data, the stream centerline was mapped along the center of the bankfull (not floodplain) width. The creek was stratified into a series of successive sections (segments), each possessing and being characterized by different attributes or biophysical characteristics (i.e. hydraulic class, channel characteristics, substrates composition, and riparian class, etc.). The stream segmentation and associated attributes was the fundamental unit of the centerline survey with point features providing a more quantitative measure of relative disturbance/modification and aquatic habitat quality/complexity (i.e. area abundance of deep pools, spawning substrates, large woody debris, bank erosion, etc.).

Table 12.1 provides a complete list of features and corresponding attributes that were recorded using the Trimble Geo Explorer (GPS) and SHIM Data Dictionary (Module 3, Mason and Knight, 2001).

[1] Based on local knowledge of watercourse changes and development activity that has occurred since the original surveys were completed.

Table 12.1 – Overview of Watercourse and Habitat Attributes

Survey Component	Main Attribute	Detailed Feature Collected
Stream Centre Line	Stream Reference Information	Name; Watershed Code; Date; Time; Survey Conditions; Surveyors
	Stream Segment Points	Start; Stop; Reach Break; Elevation; Representative Photographs
	Stream Segment Class	Stream Section; State of Section (i.e. natural/modified/channelized); Dominant Hydraulic Type
	Segment Characteristics	Section Gradient; Fish Spawning; Canopy; Access; Gravel
	Segment Substrate Attributes	Dominant Substrate Type; Compaction
	Segment Channel Attributes	Widths (wetted, bankfull), Depths (wetted, bankfull)
	Segment Instream Cover	% Total Cover; % by Feature/Cover Type (large woody debris/deep pool/over stream vegetation etc.)
	Segment Riparian Attributes	Left and Right Bank Riparian Class (vegetation association; structural stage; bank slope; material etc.)
		Segment Summary Description
	Level of Impairment	Score 0 (Severely impaired) – 6 (Natural); Rationale
	Enhancement Opportunity Rating	0 (Nil) – 4 (Very High); Rationale
Watercourse and Habitat Features	Culvert Attributes	Type-Material; Condition; Barrier; Size; Baffles
	Obstruction Attributes	Type-Material; Barrier; Size; Photo
	Stream Discharge Attributes	Point of Discharge; Type-material; Size
	Erosion Feature	Type of Erosion; severity; exposure; material
	Fish Habitat Attributes	Type of Habitat (Spawning/rearing/cover); Size; Slope; Photo
	Enhancement Areas	Type of Enhancement; Potential or existing enhancement
	Wildlife Observations	Type of Observation; Wildlife species; Photo
	Wildlife Tree Attributes	Type of Tree; Size; Location
	Near Waterbody Attributes	Type of Waterbody (spring/side channel/pond etc.); Size
	Wetland Attributes (Polygon feature)	Wetland Type-Class; Photo
	Photograph Location	Location; Direction.

Top of Bank Survey

Watercourse (lake, pond, stream and wetland) location and extent are critical for providing information to help determine the degree of protection to which a watercourse should be entitled. Determining the correct location of a stream, functionally (hydrologically) connected watercourses and wetlands, and their associated top of banks (TOB) is a necessary prerequisite for delineating Fisheries Sensitive Zones (FSZ). FSZs are an essential planning component in defining the Streamside Protection and Enhancement Area for development adjacent to a stream.

The top of bank was defined using the following criteria, as recognized by the Ministry of Environment and Department of Fisheries and Oceans Canada:

i) The point closest to the boundary of the active floodplain of a stream where a break in the slope of the land occurs such that the grade beyond the break is flatter than 3:1 at any point for a minimum distance of 15 metres measured perpendicularly from the break;

ii) For a floodplain area not contained within a ravine, the edge of the active floodplain of a stream where the slope of the land beyond the edge is flatter than 3:1 at any point for a minimum distance of 15 metres measured perpendicularly from the edge; or,

iii) The first significant break in a ravine slope where the break occurs such that the grade beyond the break is flatter than 3:1 for a minimum distance of 15 metres measured perpendicularly from the break, and the break does not include a bench within the ravine that could be developed.

Data Logging and Processing

GPS settings were in accordance with Resource Inventory Committee Standards to ensure the collection of spatially accurate data. The coordinate system used was North American Datum 83, UTM Zone 11 North.

Field (GPS) data were post processed (differentially corrected) in the office using base stations situated both in Penticton (SOPAC, Dominion Radio Astrophysical Observatory), and Kettle Falls, Washington (USFS, Colville National Forest).

Data dictionary tools designed for ARC View 3.x were employed to process the data and to export the data into ESRI shapefiles. Final mapping deliverables were produced in ArcGIS 9.2.

Quality Assurance and Quality Control

The Resource Inventory Committee and SHIM Methodology (Mason and Knight, 2001) provide specific requirements for quality assurance and quality control. These standards such as GPS settings/precision, logging intervals, and data management and deliverables were followed throughout the project. For data collected by Ecoscape in 2009 and 2010, data review and quality assurance and control were provided by Kyle Hawes, R.P.Bio. – Senior resource inventory biologist.

Level of Impact/Condition Scoring

Ecoscape developed and appended a Level of Impact rating to each identified stream segment. This rating system was designed with the intent of providing a more measurable parameter in evaluating the watercourse condition and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities. Individual reach scores were assigned based on the criteria outlined in Table 12.2.

Table 12.2 – Level of Impact Criteria

Stream Impact Criteria[1]	Combined Segment Score
Nil-Nil (*Nil impacts on both banks*)	6
Nil-Low	5
Nil-Mod	4
Nil-High	3
Low-Low	4
Low-Mod	3
Low-High	2
Mod-Mod	2
Mod-High	1
High-High (*Impact on both banks is high*)	0

1. Numeric Bank Impact Scores: Nil=3 Low=2 Mod=1 High=0

The raw data and rationale for respective stream segment scores can be found in Appendix A within the Stream line data. Weighted scores for respective impact ratings were obtained by dividing the cumulative length of segments receiving the same SHIM impact rating by the total SHIM stream length to obtain a fractional abundance (% of SHIM stream length). This value was then multiplied by the respective SHIM Score (0-6) equaling the weighted score. A zero (0) to six (6) rating system was developed to evaluate respective stream segments in terms of their degree of disturbance, where a stream segment not being recently modified (natural) received a score of 6 (nil), and a stream segment being highly modified on both banks/channelized/ditched, etc. received a score of 0 (both banks high). The sum of weighted scores was then divided by the maximum attainable score (6)[2] and transformed into a percentage value to yield the stream condition score.

Subsequently, a habitat value score was assigned to each watercourse based on its intrinsic value. Factors such as fish habitat, riparian condition (natural, anthropogenic modifications), stream magnitude, level of impairment, and flows were used to assign a rating between 0 and 1, with Low Habitat Value receiving a 0 and Very High Habitat Value up to a 1. Habitat quality scores were assigned to each watercourse within the District of West Kelowna municipal boundaries. Respective habitat ratings were assigned based on information compiled during the various field surveys and analysis and data compilation. The following ratings were adapted from the fish passage protocol (BC MOE, 2008) to consider potential capability based on channel morphology and hydrology - also recognizing that many of the watercourses have been altered by anthropogenic factors:

- **Very High Habitat Rating (0.76 -1.0)** was assigned to streams where high-value spawning or rearing habitats were recorded or have the potential to occur with appropriate restoration (eg. Locations with abundance of suitably sized gravel, deep pools, undercut banks, stable large woody debris and well-vegetated, natural riparian area).

- **High Habitat Rating (0.51-0.75)** was assigned to watercourses with suitable spawning habitat and a moderate rearing potential for fish species present. These systems may also have higher gradients (limiting the availability of higher quality spawning and production capacity) in conjunction with smaller catchment areas.

[2] A combined weighted score of 6 would be attained if all segments were natural with no discernable human disturbance on either the right or left bank. Note this evaluation does not factor in impacts upstream of the District of West Kelowna municipal boundary limit, which could still impact on water quality and habitat values.

- **Moderate Habitat Rating (0.26-0.50)** was assigned to watercourses without suitable spawning habitat and having low rearing potential (eg. Locations with highly modified banks, lacking in fish habitat features). A moderate habitat rating may have been assigned to watercourses which remain in a relatively natural state with limited anthropogenic impacts, although fisheries value may be limited due to ephemeral drainage.

- **Low Habitat Rating (0-0.25)** was assigned to ephemeral, intermittent and discontinuous watercourses/drainages. A low rating may also be assigned to streams that have been intensively modified.

The above habitat ratings are based primarily on aquatic habitat values. However, while some watercourses may receive a relatively low habitat rating, their intrinsic value should not be overlooked. Many of the ephemeral riparian gullies support or have the potential to support high biodiversity values in an urban and sub-urban context. Recognizing this, efforts should continue to protect and restore associated riparian, transitional, and wetland sites along these watercourses regardless of aquatic habitat values.

12.3 RESULTS

The following section summarizes the morphological and biophysical character of each of the surveyed watercourses. Summary results and discussions for individual watercourses are commensurate with their overall magnitude, habitat rating, and level of impact. Refer to the corresponding figures (maps) for segment attributes. Representative photos have been embedded in the corresponding text. The processed data from the centreline survey (Stream_line) and feature data has been included in Appendix A. In addition, this data can be found in digital format accompanying the complete inventory catalogue, which includes all point features, attributes, and representative photos (intended for use in an ESRI GIS platform).

SMITH CREEK DRAINAGE

The Smith Creek Drainage was first surveyed in 2001 and included approximately 13.5 km between the upper municipal boundary and the confluence of Smith Creek and Okanagan Lake. In addition to Smith Creek, watercourses surveyed included Smith Creek Tributary 1, Smith Creek Tributary 2, Smith Creek Tributary 1A, Smith Creek Tributary 1B, Westbank Creek, Westbank Creek Tributaries 1, 2, and 3, Johnson Spring, Tomat Creek, and 14 small numbered tributaries to Tomat Creek.

Stream Primary Character

Smith Creek has been modified over approximately 3.1 km (49%) of the surveyed stream length, with approximately 3.3 km (51.2%) remaining natural at the time of the 2001 SHIM survey (Table 12.3 based on SHIM field inventory and anaylsis of 6.4 linear km of Smith Creek within the District of West Kelowna). Of the 3.1 km of modified stream length, about 2.4 km of stream had been ditched or culverted, including Segments 2, 6, 8, 9, 11, 12, 12.1, 13, 14, 15, 16, 19 and 20.1. Less severe anthropogenic impacts were documented in Segments 1, 5.1, 7, 18 and 21.

Table 12.3 – Smith Creek

Summary of Primary Stream Character

Segments	Primary Character	Length (m)	Percentage of stream length
5.1	Channelized	11.1	0.2%
6, 8, 11, 12.1, 14, 16, 19	Culvert	1264.0	19.8%
2, 9, 12, 13,15, 20.1	Ditch	1146.5	17.9%
1, 7, 18, 21	Modified	697.6	10.9%
3, 4, 5, 10, 17, 20, 22, 23, 24, 25, 26, 27	Natural	3268.47	51.2%

The main tributaries to Smith Creek include Tomat Creek, which is approximately 1.5 km long and Westbank Creek, which is approximately 2.1 km long. Approximately 79% of Tomat Creek was described as being modified to some extent, with 46% ditch and 33% modified. Only 317.5 m, or 21 % of Tomat Creek had a natural primary character at the time of survey. Tributaries to Tomat Creek accounted for 1.3 km of streamlength within the Smith Creek drainage. Approximately 51% of the small watercourses were modified, with 48% ditch, while 49% of the Tomat Creek tributaries were described as natural.

Westbank Creek is spring-fed and provides year-round base flows to Smith Creek, contributing to fisheries values; however, it has been highly modified; with 43% of the 2 km stream occurring within culverts, 42% ditched, 7% modified, and only 8% described

as natural. Westbank Creek's tributaries account for 0.95 km of stream and are 100% modified, with 19% culverted and 81% ditched.

In addition to documentation of entire stream segments, which have been placed in culverts, each culvert encountered during the SHIM survey was measured and recorded. Smith Creek and Smith Creek Tributaries 1, 1a, 1b and 2 accounted for approximately 7.5 km of stream. Of this 7.5 km, a total of 1.9 km, or 25%, of the watercourse has been culverted. Tomat Creek and its tributary springs include approximately 3 km of stream length. Culverts are not as prevalent in this watercourse, with 109 m, or 3.7% culverted at the time of the 2001 SHIM survey. Westbank Creek and its tributaries account for about 3 km of stream, 1.4 km or 46% of which occurs within culverts within the West Kelowna town centre.

Many of the culvert outlets mentioned above have been installed such that they are perched as high as 2 m above the stream, creating an upstream barrier to fish migration. Additionally, with culvert lengths varying from 4 to 475 m within the Smith Creek watershed, fish habitat values are further impaired. Obstructions are discussed further in Section 12.3.



Photo 12.1: Taken in January, 2010 representative of the estimated 81% of ditching that occurs along Westbank Creek tributaries.



Photo 12.2: Taken near Highway 97, representative of perched culverts which are barriers to fish passage.

Stream Channel and Hydraulic Character

Smith Creek exhibits a primarily riffle/pool and riffle morphology for approximately 74% of the 6.4 km SHIM stream length (Table 12.4 Values shown are based on SHIM field inventory and analysis of 6.4 linear km of Smith Creek within the District of West Kelowna). Approximately 5% exhibited run characteristics, while Segments 25, 26 and 27 occur at the upper limits of the municipal boundary where steeper gradients result in cascade/pool morphology for 21% of the surveyed stream length.

Table 12.4 – Smith Creek Summary of Hydraulic Stream Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
5.1, 13	Run	318.1	5.0%
6, 8, 9, 11, 12, 12.1, 14, 16, 18, 19, 20.1, 21	Riffle	2218.1	34.7%
1, 2, 3, 4, 5, 7, 10, 15, 17,20, 22, 23, 24	Riffle/Pool	2490.4	39.0%
25, 26, 27	Cascade/Pool	1360.6	21.3%

The average channel gradient throughout the surveyed portion of Smith Creek was around 4.9% (Table 12.5 Values shown are based on SHIM field inventory and analysis of 6.4 linear km of Smith Creek within the District of West Kelowna). The stream gradients averaged for each of the 29 segments varied from 0 to 40%. The mean bank full width recorded for Smith Creek was 1.8 m.

Table 12.5 – Smith Creek Channel Summary

Segments	Gradient (%)			Stream Channel		
	Average	Min	Max	Mean Bankfull Width (m)	Min (m)	Max (m)
1-27	4.9	0	40.0	1.8	0.0	3.0

Tributary streams within the Smith Creek watershed were generally consistent with Smith Creek, in that the hydraulic character of 40% of the stream length was riffle and 35% was riffle/pool. Approximately 18 % of tributary streams exhibited run

characteristics, while 1% was classified as standing water and 4% of the stream length was considered wetland. Hydraulic character information was missing for 2% of the inventoried stream length.

The average channel gradient for Tomat Creek was 2%, with a minimum gradient of 3% and a maximum of 15%. The mean bank full width of Tomat Creek was 2.3 m. Westbank Creek had an average stream gradient of 2.2%, with a minimum of 1% and maximum of 4%. Mean bank full width for Westbank Creek was approximately 1m.

Instream Habitat Cover/Complexity

Total and relative instream cover is a field estimate of the type and amount of in-channel cover available to fish. Total cover represents the total percentage of the wetted area of respective segments occupied by cover. The relative abundance (%) of cover types (e.g., deep pool, large woody debris, etc.) is an estimate of the distribution (of respective cover types) within the total cover estimate for the segment.

Approximately 44% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.6 Values shown are based on SHIM field inventory and analysis of 6.4 linear km of Smith Creek within the District of West Kelowna). A total of 12 segments were estimated to have a total percentage of the wetted area occupied by cover of less than 10%, accounting for 36% of the surveyed stream length. The type of cover available over this 2.3 km of stream length was limited to undercut banks. A total of 10 stream segments, totaling 1.9 km of stream length, did however contain instream cover greater than 75%.

Table 12.6 – Smith Creek Summary and Distribution of Instream Cover/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
1, 5.1, 7, 15, 17, 18, 20, 20.1, 21, 22, 23, 24	<10%	2316.1	36%	0%	0%	0%	0%	0%	0%	100%
2, 26, 27	11-20%	384.2	6%	21%	0%	10%	24%	37%	8%	0%
3	21-40%	163.2	3%	0%	0%	0%	0%	50%	40%	10%
4, 5, 10, 25	41-50%	1627.5	25%	12%	0%	0%	19%	39%	26%	4%
	51-75%	0.0	0%	0%	0%	0%	0%	0%	0%	0%
6, 8, 9, 11, 12, 12.1, 13, 14, 16, 19	>75% **	1896.2	30%	u/k**	u/k	33%	u/k	u/k	u/k	u/k

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

**U/k=unknown; data fields were incomplete for total cover by cover type for segments with >75% cover

Within Tomat Creek, 63% of the stream length had less than 10% cover, which equates to approximately 46 m of instream cover/habitat complexity. During the 2001 stream survey, 25% of the stream length exhibited instream habitat coverage between 21-40%, which was comprised of small woody debris and undercut banks. Only 12% of the 1.3 km stream length exhibited instream cover greater than 75%, which included both instream and overstream vegetation. Tributaries to Tomat Creek had 23% of the overall stream length with no cover, 46% had cover between 21-40%, 3% of the stream length had 50% cover, 10% of the stream had between 51-75% and 18% exhibited cover between 80 and 100%. The type of cover recorded within Tomat Creek tributaries consisted exclusively of instream and overstream vegetation and small woody debris.

Westbank Creek was recorded as having 0% cover over 29% of the 2.1 km watercourse, while 71% of the stream was recorded as having 100% instream cover. Instream vegetation was the only type of cover recorded for this stream and only allocated over 440 m. Given that Westbank Creek is largely comprised of culvert and ditch, it is not known whether the 100% cover was allocated to stream segments occurring within culverts, or if the remaining 1045 m of cover was also instream vegetation. Tributaries to Westbank Creek were similar to the main channel, with 17% of the 947 m of stream length exhibiting 0% cover, and 83% of the streams recorded as having 100% cover. Cover type was primarily instream vegetation.

There is a relative absence of important fish habitat features such as deep pools and large woody debris within the Smith Creek watershed.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications to the Smith Creek stream channel and riparian area were documented along the 6.4 km of stream length surveyed. Two wooden pedestrian bridges were recorded. A total of eight (8) water withdrawals were documented, along with associated infrastructure such as pump stations, as well as old dams and diversions for irrigation purposes. A trail was also noted to cross the creek at one water withdrawal site.

A total of three (3) modification features were recorded along Tomat Creek. These included one wooden bridge which had collapsed and two (2) water withdrawals. One additional water withdrawal was noted along Westbank Creek within the Smith Creek drainage and it was associated with a water well.



Photo 12.3: Looking downstream towards a wooden pedestrian bridge that crosses Smith Creek in Segment 16.

Discharges/Waterbodies

A discharge includes any substance that enters a watercourse via an artificial structure (i.e., pipe), whether it is a contribution of clean cold water from a spring, or pollution from a sewage outlet or storm drain.

A total of seven (7) discharges were identified along Smith Creek and its tributary streams during the 2001 SHIM survey (Table 12.7 Values shown are based on SHIM field inventory 2001 and analysis of 7.5 linear km of Smith Creek and tributaries within the District of West Kelowna). At this time, there were five (5) storm drains recorded, with an average diameter of 0.34 m and a maximum observed discharge pipe of 0.75 m. Data indicates that only one (1) discharge was flowing during the October survey. The other documented discharges were associated with an agricultural drainage ditch and a tile drain that runs approximately 216 m parallel to the road. It should be noted that significant discharges occur on Smith and Tomat Creeks through West Bank First Nations lands; draining extensive impervious areas from commercial developments. These features are not represented in the field data. However, their impact on the downstream receiving water course has been observed to be detrimental and significant.

Table 12.7 – Summary of Discharges Identified on Smith Creek and Tributaries

Type	Count	Mean Diameter (m)	Min Diameter (m)	Max diameter (m)	Number flowing during survey
Agricultural Runoff	1			0.5 m drainage ditch	0
Storm Drain	5	0.34	0.1	0.75	1
Tile Drain	1	0.2	0.20	0.2	0
Total	7				1

A total of 27 waterbody features were recorded within the Smith Creek drainage within the study boundary. Of the 27 waterbodies recorded, seven (7) were described as natural springs and 20 as tributary streams.



Photo 12.4: Looking towards one of a series of discharges recorded along the left bank of Smith Creek within Segment 6 during the 2010 SHIM review.

Bank Stability and Erosion

Stream bank erosion from livestock access to landslides was recorded along Smith Creek and its tributaries between 2001 and 2003. While Table 12.8 provides a summary of erosion recorded along the left and right banks, it should be noted that these numbers are conservative due to omission of some erosion data during data collection and the features and values shown are based on SHIM field inventory 2001 and analysis of 7.5 linear km of Smith Creek within the District of West Kelowna . During data analysis, it was found that there were two erosion points with missing length data, and five erosion points missing height information. From the data available, it was noted that the average height of erosion was 1.6 m along the left bank and approximately 1 m along the right bank. The average area of exposure was around 20.5 m^2 for the left bank and 12 m^2 for the right, while the recorded maximum exposure for a single continuous incident was 60m^2.

Table 12.8 – Summary of Bank Erosion Recorded Along Smith Creek and Tributaries

Left Bank						Right Bank				
Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length		Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length
130.00	1.63	245.50	20.46	1.74%		223.00	0.96	161.50	12.42	2.99%

Along Smith Creek, particularly downstream of Highway 97 along Gellatly Road, both banks exhibit severe down cutting. There is an overall lack of attenuation and retention capacity to deal with increased surface runoff from upstream impervious surfaces. The resulting down cutting of the banks has resulted in sedimentation of instream substrates and of potential spawning gravels near the confluence of Smith Creek and Okanagan Lake.



Photo 12.5: This photo was taken in 2010 of erosion and down-cutting along Smith Creek as it flows beside Gellatly Road.

Fish Habitat

Upstream migration of adfluvial fish species is limited to approximately 150 m upstream of the confluence of Smith Creek and Okanagan Lake. Resident rainbow trout have been documented further upstream and their presence has been assumed as default throughout the mainstem and lower tributaries. Kokanee have been observed to spawn within the lower reaches of Smith Creek downstream of the barrier to fish passage.

Obstructions / Barriers

Obstructions included all features that had the potential to prevent the normal passage of fish during all or part of the year. A summary of potential obstructions or barriers to upstream fish migration is summarized in Table 12.9 (Values shown are based on SHIM field inventory 2001 and analysis of 7.5 linear km of Smith Creek and tributaries within the District of West Kelowna.). Within 150 m of the confluence of Smith Creek and Okanagan Lake, the first barrier to fish passage is encountered. Spawning kokanee were documented below the culvert and cascade barriers during the 2001 field survey; the passage of adfluvial rainbow trout populations is also not possible.

In 2010, it was noted that the cascade barrier at approximately 155 m upstream of Okanagan Lake has been blown out due to high flows and additional down cutting of the stream channel.

Table 12.9 – Smith Creek and Tributaries Summary of Potential Obstruction/Barriers to Upstream Fish Migration

Distance from Okanagan Lake (km)	Stream Name	Type of Obstruction	Barrier
0.16	Smith Ck	Cascade	Yes*
0.3	Smith Ck	Cascade	Yes
0.76	Smith Ck	Cascade	unknown
0.15	Smith Ck	Culvert	Yes
5.6	Smith Ck	Falls	Yes
0.53	Smith Ck Trib 1	Culvert	Yes
2.2	Smith Ck Trib 2	Culvert	Potential
0.88	Smith Ck Trib 2	Culvert	Yes
1.7	Tomat Ck	Cascade	unknown
2.2	Tomat Ck	Culvert	Potential
2.4	Tomat Ck	Culvert	unknown
2.5	Tomat Ck	Falls	Potential
1.2	Westbank Ck	Culvert	Yes
1.4	Westbank Ck	Culvert	unknown
1.9	Westbank Ck	Culvert	Potential
1.1	Westbank Ck	Culvert	unknown

*This feature no longer persists as a barrier due to high flows and unraveling of the feature.

Stream Impact Summary

Ecoscape established a Level of Impact Rating for each stream segment, as well as an overall Habitat Condition score for the watercourse. The sum of weighted SHIM scores equaled 2.03 (out of 6), with Smith Creek receiving a stream grade of approximately 34% (Figure 12.1). A total of 17 segments received a score of 0, indicating that impacts were high along both banks over 48% of the stream length. There were only three (3) segments receiving an impact score of 6, meaning that impacts were considered to be nil along both banks.

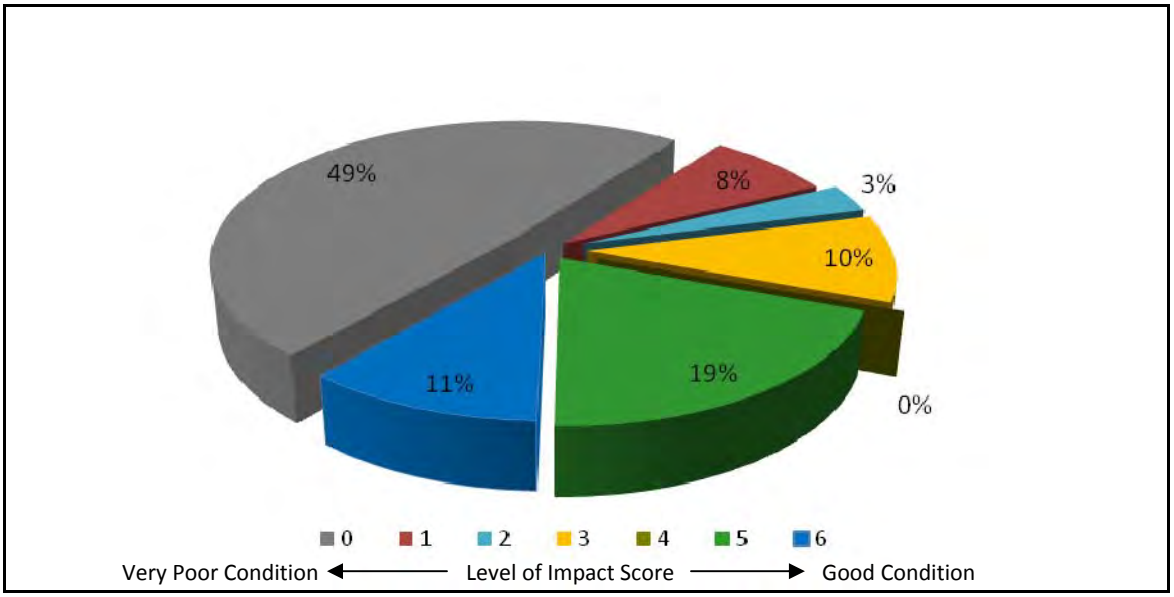


Figure 12.1. Relative distribution of impact scores on Smith Creek stream segments. Values shown above are based on SHIM field inventory and analysis of ~6.4 linear km of Smith Creek within the District of West Kelowna.

Table 12.10 outlines stream grades and scores for tributary streams within the Smith Creek drainage.

Table 12.10. Stream Impact Summary for watercourses within the Smith Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Smith Creek	33.9%	2.03	6387.2
Smith Creek Tributary 1	39.2%	2.35	405.2
Smith Creek Tributary 1A	33.3%	2	283.7
Smith Creek Tributary 1B	66.7%	4	58.2
Smith Creek Tributary 2	12.8%	0.77	325.3
Tomat Creek	26.7%	1.6	1513.6
Tomat Creek Overflow Channel	16.7%	1	40.9
Tomat Creek Tributary 1	100.0%	6	140.9
Tomat Creek Tributary 3	16.7%	1	86.3
Tomat Creek Tributary 4	0.0%	0	41.2
Tomat Creek Tributary 5	83.3%	5	47.6
Tomat Creek Tributary 6	100.0%	6	126.1
Tomat Creek Tributary 7	100.0%	6	169.4
Tomat Creek Tributary 9	0.0%	0	357.5
Tomat Creek Tributary 11	16.7%	1	23.5
Tomat Creek Tributary 12	16.7%	1	63.8
Tomat Creek Tributary 13	50.0%	3	111.4
Tomat Creek Tributary 14	0.0%	0	58.6
Tomat Creek Tributary 16	83.3%	5	45.2
Johnson Spring	16.7%	1	123.2
Westbank Creek	4.3%	0.26	2088.4
Westbank Creek Tributary 1	0.0%	0	211.8
Westbank Creek Tributary 2	0.0%	0	573.3
Westbank Creek Tributary 3	0.0%	0	161.4

Smith Creek Summary and Recommendations

Several management issues of concern have been identified along Smith Creek, and this is a priority watercourse for channel and riparian rehabilitation works, as well as improved stormwater Management. Key observations from the SHIM field inventory and potential enhancement opportunities are as follows:

- The channel of Smith Creek has downcut over 1-m in places, leaving the riparian/floodplain communities perched high and dry. In locations along Gellatly Rd, Smith Creek is down-cutting beneath the road fill, which over time could begin undermining the stability of the road.

- Barriers to upstream kokanee and rainbow trout migration occur approximately 150 m upstream from Okanagan Lake, with a cascade further prohibiting upstream migration 320 m from Okanagan Lake. However, in 2010 it was noted that high flows along Smith Creek had resulted in the removal of the cascade barrier at 150m, potentially permitting further upstream migration if the downstream perched culvert can be addressed.

- Need for increased recognition of Smith Creek as a fish stream with habitat value for rainbow trout and kokanee. Adherence to least risk fisheries work windows must be addressed, as well as recognition of localized impacts on system as a whole.

- Spring-fed tributary streams provide year-round base flows.

- Sedimentation of spawning substrates near the confluence of Okanagan Lake and Smith Creek.

- Mass erosion sites

- Perched culverts barring fish passage occur along Smith Creek, including within 150 m of Okanagan Lake.

- Livestock access in upper reaches, which would benefit from fencing.

- Ditches void of vegetation, whereas incorporation of vegetated swales and riparian areas would be beneficial for filtration and infiltration.

- Culverts/piping and overall channelization has occurred throughout the Smith Creek drainage. Daylighting of stream reaches that are piped would be a preferred option; however, unlikely in recently developed areas of the drainage.

- Overall lack of stormwater detention and attenuation throughout the Smith Creek drainage, which is compounded by the increased impervious surfaces throughout developed areas.

- Enhancement of lower reaches for spawning kokanee now that one lower barrier has been removed - address downcutting and erosion.

- Channel reconstruction and bioengineering is required in areas where severe downcutting has occurred; efforts should be focused downstream of Highway 97.

- Enhancement work has occurred within the RDCO Park downstream of Highway 97; however, flows are not moving through the enhanced channel as intended. There may be potential in this location for construction of off-channel habitat, wetland creation and increased attenuation of storm water generated upstream.

POWERS CREEK DRAINAGE

The Powers Creek Drainage was surveyed between 2001 and 2003 and included approximately 21.4 km between the upper municipal boundary and the confluence of Powers Creek and Okanagan Lake. In addition to the approximately 9 km main stem of Powers Creek, watercourses surveyed included Powers Creek numbered tributaries 2, 3, 3-1, 3-2, 3-2-1, 3-3, 4, 5, 6, 6-1, Glen Rosa Creek and McKellar Rd Creek.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

Powers Creek remains natural over approximately 89% of the surveyed main stem (Table 12.11 Values shown are based on SHIM field inventory and analysis of 9 linear km of Powers Creek and tributaries within the District of West Kelowna). Only 1% of the approximately 9 km surveyed has been culverted, occurring within Segment 15. Segments 6, 7 and 10 were described as modified, representing 10% of the stream length.

Table 12.11 – Powers Creek Summary of Primary Stream Character

Segments	Primary Character	Length (m)	Percentage of stream length
15	Culvert	110.0	1.2%
6, 7, 10	Modified	868.6	9.6%
1, 2, 3, 4, 5, 8, 9, 11, 12, 13, 14,16, 17, 18, 19, 20, 21, 22, 23, 24, 24.1, 25, 25.1	Natural	8028.88	89%

The total stream length surveyed of Powers Creek tributaries is approximately 12.3 km. In contrast to Powers Creek, its tributaries are modified to some extent over 79% of the stream length – largely within the Glenrosa neighbourhoods. While approximately 21% retains a natural primary character, 36% has been ditched, 19% culverted, 16% modified, 7% described as other, and 1.5% was described as channelized.

Culverts occurred over approximately 3136 m, or 15%, of the SHIM stream length of Powers Creek and its tributary streams. Culverts varied in length from 5 to 829 m, which occurred in Segment 5 of Powers Creek Tributary 3. The culvert under Highway 97 along the main stem is perched and poses a likely obstruction to fish passage.



Photo 12.6: Looking downstream towards the Powers Creek culvert inlet and Highway 97 and Glenrosa (flowing) discharges.

Stream Channel and Hydraulic Character

Powers Creek exhibits largely a cascade/pool morphology for approximately 68% of the 9 km SHIM stream length (Table 12.12 Values shown are based on SHIM field inventory and analysis of 9 linear km of Powers Creek and tributaries within the District of West Kelowna). Approximately 25% exhibited riffle/pool characteristics, 2.5% was described as a riffle, 4% displayed a run morphology, while 1% was described as standing water. The average channel gradient throughout the surveyed portion of Powers Creek was around 3% (Table 12.13 Values shown are based on SHIM field inventory and analysis of 9 linear km of Powers Creek and tributaries within the District of West Kelowna). The stream gradients averaged for each of the 27 segments varied from 0 to 13%. The mean bank full width recorded for Powers Creek was 9.1 m.

Table 12.12 – Powers Creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
2, 7	Run	344.0	3.8%
8, 15	Riffle	228.2	2.5%
1, 3, 4, 6, 9, 10, 11, 16, 17	Riffle/Pool	2219.3	24.6%
12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 24.1, 25, 25.1	Cascade/Pool	6121.1	68.0%
5	Standing Water	95.0	1.1%

Table 12.13 – Powers Creek Stream Channel Summary

Gradient (%)			Stream Channel		
Average	Min	Max	Mean Bankfull Width (m)	Min (m)	Max (m)
2.6	0.5	13.0	9.1	0.0	18.0

Over 6.7 km, or 55% of Powers Creek tributaries displayed riffle morphology. Approximately 9% of tributary streams exhibited riffle/pool characteristics, 5% were cascade/pool, 4% were classified as cascade, 3% pool, 3% run, 0.6% standing water,

0.4% wetland, 0.1% slough and 3% other. Hydraulic character information was missing for 18% of the inventoried stream length. The average stream gradient of Powers Creek tributaries was 5.6%, with the highest gradient being 32% in Powers Creek Tributary 6 and the lowest at 0%, occurring within several tributaries. Average bank full width of tributary watercourses to Powers Creek was documented to be 1.3 m.

Instream Habitat Cover/Complexity

Of all watercourses within the District of West Kelowna, Powers Creek supports the greatest habitat value and potential for fish and wildlife. Approximately 39% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.14 Values shown are based on SHIM field inventory and analysis of 9 linear km of Powers Creek and tributaries within the District of West Kelowna). Only five segments were estimated to have a total percentage of the wetted area occupied by cover of less than 10%, accounting for 11% of the surveyed stream length. There were five segments which had estimated total cover between 11-20%, accounting for only 4% of the SHIM stream length. Eleven segments had estimated total cover between 21% - 40% of the wetted area - accounting for a total of 5.6 km of stream. There were four segments with total cover estimated from 41% to 50%, accounting for 15% of the SHIM stream length. Segments 5, 6 and 18, occurred over approximately 662 m, and had total cover of 80%.

Table 12.14 – Powers Creek Summary and Distribution of Instream/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
1, 15, 16, 17, 25.1	<10%	984.5	10.9%	0%	0%	0%	0%	0%	0%	100%
4, 8, 24, 24.1	11-20%	346.4	3.8%	11%	8%	0%	43%	8%	7%	15%
2, 3, 7, 9, 10, 11, 12, 13, 14, 19, 25	21-40%	5633.2	62.5%	33%	23%	0%	29%	6%	5%	3%
20, 21, 22, 23	41-50%	1381.9	15.3%	40%	37%	0%	23%	0%	0%	0%
	51-75%	0.0	0.0%	0%	0%	0%	0%	0%	0%	0%
5, 6, 18	>75%	661.5	7.3%	14%	53%	0%	8%	16%	0%	4%

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications to the stream channel and riparian area were only documented along 373 m, or 2% of the 21.4 km of surveyed length of Powers Creek and its tributary streams. Modifications had a cumulative linear measurement of over 168 m along the left bank, 173 m along the right bank, and 33 m instream (Table 12.15 Values shown are based on SHIM field inventory 2001-2003and analysis of 21.4 linear km of Powers Creek and tributaries within the District of West Kelowna). Modifications such as water withdrawals, pipe crossings and fences are not effectively quantified by stream length. Eight (8) water withdrawals, one (1) fence, and three (3) pump stations were noted along Powers Creek.

While not necessarily quantified in terms of stream length, modifications of concern along Powers Creek and its tributaries noted within the RDCO report during the initial field survey included:

- Livestock access resulting in channel widening, erosion and water quality issues (Lower reaches of Powers Creek and Tributaries 3-3 and 4);
- Construction of residential units near the centre-line of Tributary 3-3, which is an ephemeral watercourse;
- Removal of riparian vegetation; and,

  Introduction of exotic fish species due to construction of an artificial spring-fed pond (Tributary 3).

Type	Left Bank				Right				Instream		
	Length (m)	% of total length of modifications	% of SHIM stream length		Length (m)	% of total length of modifications	% of SHIM stream length		Length (m)	% of total length of modifications	% of SHIM stream length
Bridge	87.50	23.46%	0.41%		87.50	23.46%	0.41%		0.00	0.00	0.00%
Dam	0.00	0.00%	0.00%		0.00	0.00%	0.00%		0.00	0.00	0.00%
Fences	0.00	0.00%	0.00%		0.00	0.00%	0.00%		0.00	0.00%	0.00%
Detention Pond	unknown				0.00	0.00%	0.00%		0.00	0.00	0.00%
Trail	0.00	0.00%	0.00%		0.00	0.00%	0.00%		0.00	0.00	0.00%
Livestock Crossing	unknown				0.00	0.00%	0.00%		0.00	0.00%	0.00%
Retaining Wall/Bank Stabilization	0.00	0.00%	0.00%		15.00	4.02%	0.07%		0.00	0.00%	0.00%
Road	0.00	0.00%	0.00%		0.00	0.00%	0.00%		22.00	5.90%	0.10%
Other	80	21.45%	0.37%		70.00	18.77%	0.33%		5.00	1.34%	0.02%
Pump Station	2 along left bank				1 along right bank				6.00	1.61%	0.03%
Water Withdrawal					2 along right bank				6 instream		
	167.50				172.50				33.00		

Table 12.15 – Powers Creek Summary of Modifications

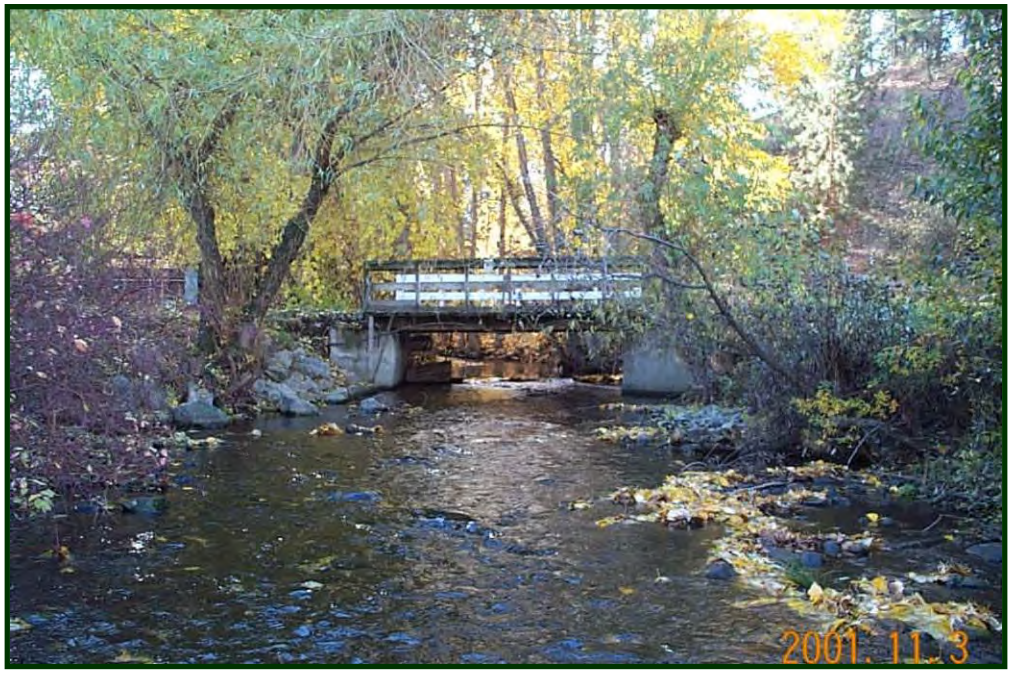


Photo 12.7: Looking towards one of the bridge crossings which occur along the length of Powers Creek.

Discharges/Waterbodies

A total of 14 discharges were documented along Powers Creek and its tributaries during the field inventory (Table 12.16 Values shown are based on SHIM field inventory 2009 and analysis of 21.4 linear km of Powers Creek and tributaries within the District of West Kelowna). A total of 9 storm drains were recorded, with an average diameter of 300 mm and a maximum observed discharge pipe diameter of 1000 mm. Three (3) of the 9 storm drains were observed to be flowing at the time of the field survey. There were two (2) tile drains recorded, as well as three (3) discharges recorded as other, two of which were runoff ditches that entered into watercourses. It was noted that severe siltation of stream channels and associated substrates was occurring due to the high amounts of impermeable surface runoff being diverted to stream channels via storm drains or ditching.

Table 12.16 – Summary of Discharges identified on Powers Creek and Tributaries

Type	Count	Mean Diameter (m)	Min Diameter (m)	Max diameter (m)	Number flowing during survey
Storm Drain	9	0.3	0.2	1	3
Tile Drain	2	0.10	0.1	0.1	0
Other	3	0.2	0.20	0.4 m wide ditch	2
Total	14				5

A total of 15 waterbody features were recorded along Powers Creek within the study boundary. Of the 15 waterbodies recorded, seven (7) were natural springs, seven (7) were tributary streams and one waterbody was identified as an irrigation outflow.



Photo 12.8: Looking towards flowing discharges documented within the Powers Creek drainage during the 2001-2003 field survey period.

Bank Stability and Erosion

Stream bank erosion along Powers Creek and its tributaries was documented along approximately 226 m of the left bank and 258 m along the right bank (Table 12.17 Values shown are based on SHIM field inventory 2001 and analysis of 21.4 linear km of Powers Creek and tributaries within the District of West Kelowna). The recorded area of exposure along the left bank was 227m^2, while larger scale landslides occurring along the

right bank in the upper reaches of Powers Creek resulted in a total area of exposure of approximately 2827 m^2. While Table 12-17 provides a summary of erosion recorded along the left and right banks, it should be noted that these numbers are conservative due to omission of some erosion data during data collection. During data analysis, it was found that there were three erosion points with missing length and or height data along the left bank, and four erosion points missing data along the right bank. Of those missing a component of data, two (2) features were described as landslides and one as mass sloughing, which could significantly increase the erosion measurements along the right bank.

Table 12.17 – Summary of Bank Erosion Recorded Along Powers Creek and Tributaries

Left Bank						Right Bank				
Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length		Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length
226.00	1.50	227.00	20.64	1.06%		258.00	11.35	2826.50	166.26	1.21%



Photo 12.9: looking towards an eroding bank documented along Powers Creek in 2001.

Fish Habitat

Both kokanee and rainbow trout inhabit portions of Powers Creek, with kokanee utilizing the lower 3.0 km of stream for migration, spawning and incubation. Resident rainbow trout occur throughout Powers Creek, utilizing the stream for all life stages. Deep pools located within the Glen Canyon area were noted to provide overwintering habitat for rainbow trout.

Sedimentation of stream substrates due to larger, active landslides and bank sloughing in upper reaches limits spawning habitat value. Additionally, increased sediment contributions from modified tributary streams and factors such as removal of riparian vegetation further contribute negatively to fisheries values of the watercourse.

Upstream migration of adfluvial fish species (both kokanee and rainbow trout) is limited to approximately 2.8 km upstream from the confluence with Okanagan Lake, due to the presence of a series of five falls/cascades of varying heights and lengths.

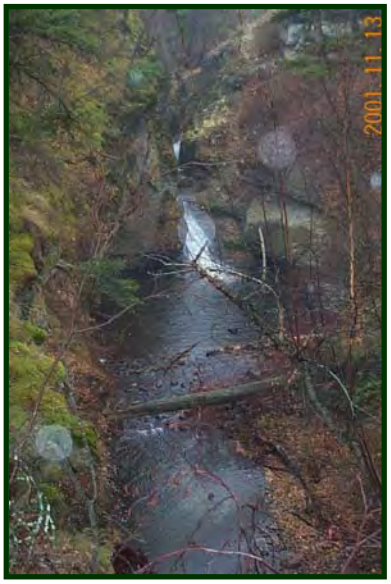


Photo 12.10: Looking towards the series of falls and cascades which poses a barrier to fish passage at approximately 2.8 km upstream of the confluence of Powers Creek and Okanagan Lake. Deep pools provide fish habitat value.

Obstructions / Barriers

Obstructions included all features that had the potential to prevent the normal passage of fish during all or part of the year. A summary of potential obstructions or barriers to upstream fish migration is summarized in Table 12.18. Values shown are based on SHIM field inventory (2001) and analysis of 21.4 linear km of Powers Creek and tributaries within the District of West Kelowna

A total of five (5) obstructions were documented as being confirmed barriers to upstream fish migration, with the first obstruction encountered being the set of falls at approximately 2.8 km upstream from Okanagan Lake. One (1) culvert was identified as a potential barrier to fish passage; however, this culvert is at the Powers Creek Highway 97 crossing and was measured to be perched 1.5 m, likely prohibiting any further upstream migration. A further set of falls at approximately 5.1 m upstream and a log jam at 6.4 km were identified as potential obstructions.

Table 12.18 – Powers Creek and Tributaries Summary of Potential Obstruction/Barriers to Upstream Fish Migration

Distance from Okanagan Lake (km)	Stream Name	Type of Obstruction	Barrier
2.8	Powers Creek	Falls	Yes
3.1	Powers Creek	Culvert	Potential
3.2	Powers Creek	Culvert	Yes
3.9	Powers Creek	Canyon	Yes
5.1	Powers Creek	Falls	Unknown
6.4	Powers Creek	Log Jam	Unknown
7.7	Powers Creek	Dam	Yes
8.1	Powers Creek	Cascade	Yes

Stream Impact Summary

The level of impact summary identified a sum of weighted SHIM scores equivalent to 5.28 (out of 6), resulting in a stream grade of 88% for Powers Creek (Figure 12.2). Only one segment received a score of 0, indicating high levels of impact along both banks. One segment accounting for 4% of the stream length received a score of 2, indicating that both banks exhibited moderate impacts or one bank was low and one high. Three segments received a score of 3 (1 bank nil and 1 bank high, or 1 bank low and 1 bank moderate) and accounted for 11% of the stream length. Three segments received a score of 4, having both banks exhibiting nil impacts, or 1 bank nil and 1 bank moderate. There were 6 segments allotted a score of 5, indicating that 1 bank had nil impacts and 1 low for 9% of the stream length. The majority of Powers Creek was scored a 6, representing nil impacts and natural conditions along both banks for over 6.4 km of the Powers Creek SHIM length.

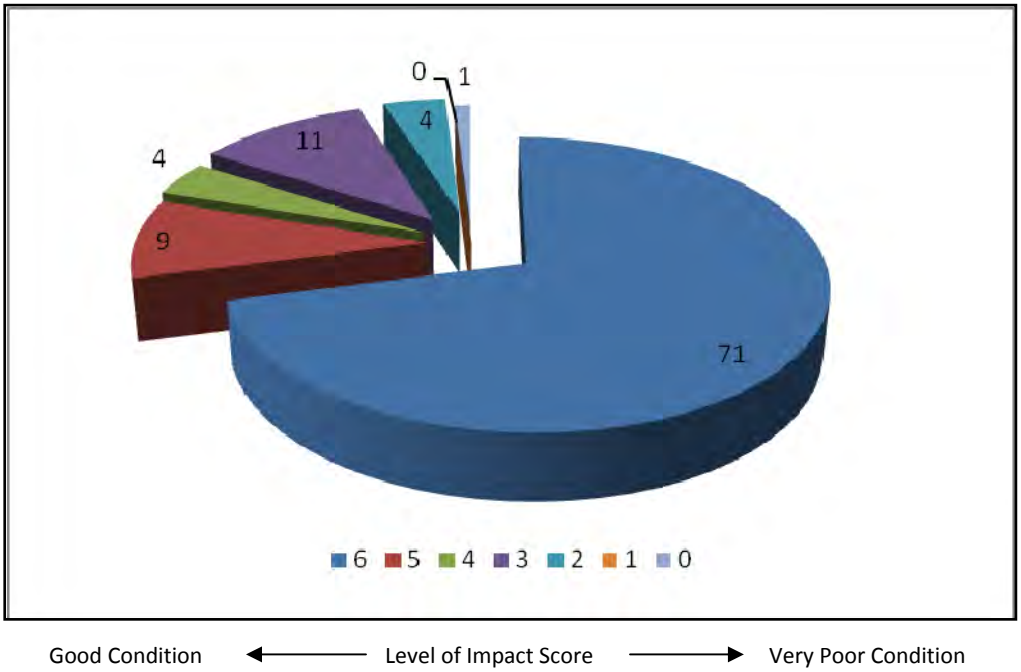


Figure 12.2. Powers Creek summary of Level of Impact.
Values shown above are based on SHIM field inventory and analysis of ~9 linear km of Powers Creek within the District of West Kelowna.

Table 12.19 outlines stream grades and scores for tributary streams within the Powers Creek drainage.

Table 12.19 – Stream Impact Summary

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Powers Creek	88.0%	5.28	9007.5
Powers Creek Tributary 2	30.0%	1.8	272.7
Powers Creek Tributary 3	10.2%	0.61	2202.2
Powers Creek Tributary 3-1	0.0%	0	167.4
Powers Creek Tributary 3-2	0.0%	0	790.6
Powers Creek Tributary 3-2-1	0.0%	0	378.7
Powers Creek Tributary 3-3	12.0%	0.72	2733.2
Powers Creek Tributary 4	36.3%	2.18	1419.3
Powers Creek Tributary 5	14.7%	0.88	2397.1
Powers Creek Tributary 6	61.2%	3.67	1572.2
Powers Creek Tributary 6-1	52.8%	3.17	97.5
Glen Rosa Creek 1	28.2%	1.69	224.0
McKellar Road Creek 1	100.0%	6	37.1

Powers Creek Summary and Recommendations

Powers Creek is in relatively good condition, receiving a stream grade of 88%, and was not identified as being a priority stream for restoration and enhancement efforts. That being said, Powers Creek represents the most valuable stream from a fisheries stand point and maintenance of riparian buffers and incorporation of best management practices into new development and maintenance is paramount. Conservation of the habitat value of Powers Creek will be important when considering storm management practices in proximity to this watercourse.

Management concerns noted during the 2001 and 2003 field surveys and further supported by data review are as follows:

- The Highway 97 culvert is perched and poses a barrier to fish passage. Water samples obtained by Larratt Aquatic Consulting in the vicinity of this culvert outlet and associated storm outfalls were also found to be of concern for water quality in regards to chloride (H. Larratt, personal communications).
- Sediment deposition has occurred in association with active landslides in the upper watershed, livestock access, and downstream of the confluence with tributary streams. Encouragement of best management practices such as livestock fencing and maintenance and enhancement of vegetated riparian buffers would be beneficial and perhaps can be addressed on a property by property basis through tools such as the Sensitive Aquatic Development Permit process.
- Powers Creek tributaries have been heavily impacted, with issues identified including channelization, removal of riparian vegetation, increased runoff from impervious surfaces, introduction of exotic species (koi fish in Tributary 3), possible contamination from septic systems (Tributary 3-2), livestock access, and residential encroachment. As stated above, best management practices for living near water and education and enforcement through the development permit process is recommended.
- There are potential enhancement opportunities of the alluvial fan area at the confluence of Powers Creek and Okanagan Lake.
- A potential area for attenuation improvement was identified along Powers Creek Tributary 3-3.
- Conservation of wetlands within the upper Glenrosa area is also critical, and detailed wetland mapping and defined riparian setbacks from wetlands would be beneficial.

MCDOUGALL CREEK DRAINAGE

The McDougall Creek Drainage was surveyed between 2001 and 2003 and included approximately 9.4 km between the upper municipal boundary and the confluence of McDougall Creek and Okanagan Lake. In addition to the approximately 8.7 km main stem of McDougall Creek, watercourses surveyed included McDougall Creek 1, McDougall Creek 1-1 and McDougall Creek 1-2.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

McDougall Creek has been modified to some extent over approximately 32% of the surveyed stream length (Table 12.20 Values shown are based on SHIM field inventory and analysis of 8.7 linear km of McDougall Creek and tributaries within the District of West Kelowna). At the time of survey, it was noted that the channel has been modified extensively in the lower reaches to provide flood protection for adjacent residential and agricultural land uses. It was also noted that surface flows are intermittent in the lower stream reaches, as base flows fluctuate. Approximately 68% of the surveyed stream length exhibited a natural primary character, with the majority of natural segments occurring upstream of the McDougall Creek and Highway 97 crossing.

Segments 2, 5, 6, 15 and 17 have been channelized, while the stream has been ditched throughout Segment 4. Segments 3, 11, 14, and 19 have been modified to some extent over approximately 1.2 km (14%) of the surveyed stream length.

Table 12.20 – McDougall Creek Summary of Primary Stream Character

Segments	Primary Character	Length (m)	Percentage of stream length
2, 5, 6, 15, 17	Channelized	1280.8	14.7%
3, 11, 14, 19	Modified	1237.4	14.2%
1, 7, 8, 9, 10, 12, 13, 16, 18, 20, 21, 22, 23, 24	Natural	5966.6	68.4%
4	Ditch	235.11	3%

Tributaries to McDougall Creek within the District of West Kelowna had a total surveyed length of approximately 0.68 km. Of that total length, 50% was channelized, 43.5% remained in relatively natural condition and 6.5% was modified.

Culverts along McDougall Creek and its tributaries occurred over approximately 145 m, or 1.5%, of the SHIM stream length. Culverts varied in length from 3.5 to 75 m, and eight (8) of the 11 culverts documented were recorded as privately owned, rather than belonging to the municipality. It was also noted that five of the privately owned culverts were collapsed, and largely plugged with fines; these occurred along McDougall Creek Tributary 1.



Photo 12.11: Taken in 2010 along the lower reaches of McDougall creek upstream of Okanagan Lake looking at rock armouring along the left and right



Photo 12.12: Looking towards a culvert crossing occurring along McDougall Creek, as well as deposition of concrete debris.

Stream Channel and Hydraulic Character

McDougall Creek exhibits a primarily riffle/pool morphology for approximately 63% of the SHIM stream length. Approximately 36% of the 8.7 km surveyed exhibited cascade/pool characteristics, while the remaining Segment 1 was categorized as a run, accounting for 0.4% of the SHIM length. The hydraulic character details for the ~8.7 km of McDougall Creek surveyed are summarized in Table 12.21 (.Values shown are based on SHIM field inventory and analysis of 8.7 linear km of McDougall Creek and tributaries within the District of West Kelowna.) Tributaries to McDougall Creek were described as being 100% riffle morphology.

The average channel gradient throughout the surveyed portion of McDougall Creek was around 3%, with a minimum grade of 1 % and a maximum gradient of 6 % in the upper reaches. The mean bank full width for McDougall Creek was approximately 6 m, with the minimum recorded bank full width of 4 m and maximum of 15 m. The average channel gradient for McDougall Creek tributaries was 6.5%, with a minimum recorded gradient of 2% and a maximum of 10%. The mean bank full width of the tributary watercourses was 0.6 m, with a minimum of 0.3 m wide and a maximum of 0.9 m.

Table 12.21 – McDougall creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
1	Run	37.9	0.4%
2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	Riffle/Pool	5518.1	63.3%
15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Cascade/Pool	3163.9	36.3%

Instream Habitat Cover/Complexity

Approximately 48% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.22 Values shown are based on SHIM field inventory and analysis of 8.7 linear km of McDougall Creek and tributaries within the District of West Kelowna). Only one segment was estimated to have a total percentage of the wetted area occupied by cover of less than 10%, accounting for only 0.4% of the surveyed stream length. Approximately 12% of the stream length had estimated total cover between 11 and 20%, with cover type relatively evenly distributed between boulder, large woody

debris and overstream vegetation. Seven segments of stream, accounting for 25% of the SHIM length, had estimated total cover between 21 to 40%. The predominant cover type was overstream vegetation, although there were components of each of the seven identified habitat cover types. Nearly 3 km of SHIM stream length had an estimated 41-50% cover. There were six segments with an estimated 51-75% total cover, with instream vegetation being the dominant cover type. Only 649 m of McDougall Creek, located in Segment 21, was estimated to have total cover exceeding 75%.

Large woody debris, overstream vegetation and small woody debris were the only cover types noted to occur along tributaries to McDougall Creek. Approximately 43% of the SHIM stream length was estimated to have a total percentage of the wetted area occupied by cover of less than 10%, with a further 43.5% estimated to have total instream cover exceeding 75%. There was 6.5% of the stream length with instream cover between 11 to 20% and another 7%, or 48.3 m of SHIM length, estimated to have total instream habitat cover between 21 to 40%.

Table 12.22 – McDougall Creek Summary and Distribution of Instream/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
1	<10%	37.9	0.4%	0%	0%	100%	0%	0%	0%	0%
2, 11, 15, 19	11-20%	1057.7	12.1%	25%	13%	5%	20%	30%	0%	8%
3, 8, 14, 17, 18, 20, 22	21-40%	2187.5	25.1%	13%	9%	6%	17%	29%	15%	14%
9, 10, 12, 13, 16	41-50%	2959.0	33.9%	5%	18%	0%	25%	18%	2%	32%
4, 5, 6, 7, 23, 24	51-75%	1828.8	21.0%	4%	4%	62%	11%	8%	2%	8%
21	>75%	649.1	7.4%	30%	30%	0%	40%	20%	10%	0%

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications to the stream channel and riparian area were documented over 963 m, or approximately 10% of the surveyed length of McDougall Creek and its tributaries. Modifications had a cumulative linear measurement of over 426 m along the left bank, 522 m along the right bank, and 15 m instream (Table 12.23 Values shown are based on SHIM field inventory and analysis of 8.7 linear km of McDougall Creek and tributaries within the District of West Kelowna.). It should be noted that there were some modification points which did not have a recorded length within the database; this included one (1) bridge, one (1) dam, three (3) detention ponds, one (1) livestock crossing, one (1) retaining wall spanning both banks, one (1) garbage/pollution point, and six (6) pump stations. Additionally, modifications such as fencing and water withdrawals are not effectively quantified by stream length. There were two (2) fence crossings documented, 13 water withdrawals, and one (1) point classified as other which was identified as water being pumped from McDougall Creek into a pond.

Water removal is apparent throughout McDougall Creek, often with inadequate screening on intakes for fish protection. Modifications such as channelization, bank armouring and riparian vegetation removal is also extensive in lower stream reaches. Active mining was observed adjacent to the main stem of the creek, with an inadequate riparian buffer. A collapsed wooden bridge located approximately 1.3 km upstream of the Highway 97 crossing was noted to be contributing a significant amount of sediment to McDougall Creek at the time of the field survey. The above modifications contribute to reduced fish habitat value and potential water quality and quantity issues within the McDougall Creek drainage.



Photo 12.13: looking upstream along a residential section of McDougall Creek where modifications such as vegetation removal, retaining wall construction and encroachment within the riparian management area has occurred.

Table 12.23 – McDougall Creek Modifications Summary

Type	Left Bank			Right			Instream		
	Length (m)	% of total length of modifications	% of SHIM stream length	Length (m)	% of total length of modifications	% of SHIM stream length	Length (m)	% of total length of modifications	% of SHIM stream length
Bridge	148.0	15.4%	1.6%	148.0	15.4%	1.6%	0.0	0.0	0.0%
Dam	0.0	0.0%	0.0%	0.0	0.0%	0.0%	unknown	0.0	0.0%
Fences	0.0	0.0%	0.0%	0.0	0.0%	0.0%	0.0	0.0%	0.0%
Detention Pond	0.0	0.0%	0.0%	0.0	0.0%	0.0%	unknown	0.0	0.0%
Garbage/Pollution	0.0	0.0%	0.0%	0.0	0.0%	0.0%	3.0	0.3%	0.03%
Livestock Crossing	0.0	0.0%	0.0%	0.0	0.0%	0.0%	12.0	1.3%	0.13%
Retaining Wall/Bank Stabilization	238.0	24.7%	2.5%	374.0	38.8%	4%	0.0	0.0%	0.0%
Riprap	40.0	4.2%	0.4%	0.0	0.0%	0.0%	0.0	0.0%	0.0%
Other	0	0.0%	0.0%	0.0	0.0%	0.0%	unknown		
Pump Station	3 along left bank			2 along right bank			1 instream		
Water Withdrawal	6 along left bank			2 along right bank			5 instream		
	426.0			522.0			15.0		



Photo 12.14: This photo was taken during the 2001 field survey and was identified as a major contributor of sediment to McDougall Creek. It occurs within Segment 18.

Discharges/Waterbodies

A total of eight (8) discharges were documented along McDougall Creek during the field inventory. Of these, storm drains were most prevalent and a total of seven (7) were identified, with a minimum diameter of 0.2 m and a maximum of 0.7 m. The only other discharge documented was an overflow from a water storage facility which had a diameter of 0.09 m. It is not known whether or not any of the discharges were flowing during the field inventory.

A total of two (2) waterbody features were recorded along McDougall Creek, including one natural spring with a width of 0.7 m, and one tributary along the right bank.

Bank Stability and Erosion

Stream bank erosion was documented on nearly 4% of both the right and left banks of McDougall Creek and its tributaries (Table 12.24 Values shown are based on SHIM field inventory (2001) and analysis of 9.4 linear km of creek within the District of West Kelowna.). While erosion was identified within natural segments of McDougall Creek, anthropogenic influences and encroachment into the riparian area contributed to bank erosion throughout the watercourse. Trampling by livestock and subsequent widening of the stream channel and erosion were identified as a management issue of concern. Additionally, a sand berm that has been constructed to protect agricultural lands adjacent Hitchner Road was found to be introducing fines which are accumulating in the stream channel downstream.

The average height of erosion recorded for both banks was 1.5 m. The average area of exposure was around 21 m^2 for both banks. The recorded maximum exposure for a single continuous incident was 100 m^2, stretching for about 40m along both banks of Segment 6.

During data analysis, it was found that there were four (4) erosion points with missing length and or height data, two (2) of which were livestock access points affecting both banks, one (1) sloughing along the left bank, and one (1) point of erosion along the right bank due to streamside grazing.

Table 12.24 – Summary of Bank Erosion Recorded Along McDougall Creek and Tributaries

Left Bank						Right Bank				
Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length		Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length
316.00	1.45	411.50	20.58	3.36%		334.00	1.52	544.00	21.76	3.55%



Photo 12.15: Looking towards erosion occurring along the left bank of McDougall Creek.

Fish Habitat

McDougall Creek retains its natural character over approximately 68% of the SHIM stream length, and suitable spawning, rearing and foraging habitat is present to some degree throughout the watercourse. Rainbow trout occur throughout the system and were observed during the SHIM field survey. Kokanee have also been observed to spawn within the lower reaches of McDougall Creek. Since the original SHIM survey, some fish habitat enhancement work has occurred along the lower reaches of McDougall Creek.



Photo 12.16: Taken in 2010 looking upstream in Segment 2 of McDougall Creek where habitat enhancement work has occurred including planting of native vegetation and placement of instream rock weirs.

Obstructions / Barriers

In contrast to more intensively modified streams in West Kelowna, obstructions to fish passage were not prevalent within McDougall Creek. Potential obstructions documented during the field survey included:

- 1 m high beaver dam approximately 1.5 km upstream from the confluence of Okanagan Lake and McDougall Creek
- 1.2 m high log jam approximately 2.8 km upstream
- 1.5 m high constructed dam/detention pond 6.7 km upstream
- 1.2 m high log jam 6.9 km upstream

Stream Impact Summary

The sum of weighted SHIM scores equaled 3.15 (out of 6), with McDougall Creek receiving a stream grade of 52.5%. Figure 3 depicts the distribution of stream segments relative to their individual SHIM impact scores. Four segments, accounting for 11% of the stream length, received a score of 0, indicating that impacts were high along both banks. There were three (3) segments receiving an impact score of 1, exhibiting moderate impacts along one bank and high on the other, accounting for 12% of the stream length. An additional 11% of the stream length over four (4) segments received a score of 2, indicating that both banks exhibited moderate impacts or one bank was low and one high. Two (2) segments received a score of 3 (1 bank nil, 1 bank high, or 1 bank low and 1 bank moderate) and accounted for 8% of the stream length. Six stream segments, totaling 2.9 km, had relatively low impacts receiving a score of 4 for having both banks low, or 1 bank nil and 1 bank moderate. A total of 2.1 km had levels of impact considered to be nil on one bank and low on the other, while there were no segments given a 6, which would indicate nil impacts on both banks.

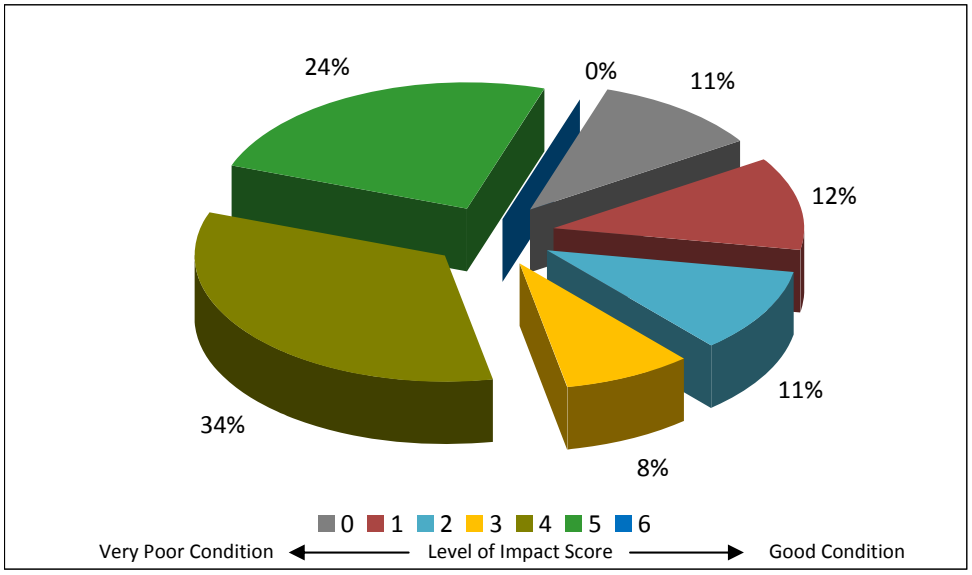


Figure 12.3. McDougall Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~8.7 linear km of McDougall Creek within the District of West Kelowna.

Table 12.25 outlines stream grades and scores for tributary streams within the McDougall Creek drainage.

Table 12.25 – Stream Impact Summary for Tributaries Within the McDougall Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
McDougall Creek	52.5%	3.15	8719.9
McDougall Creek 1	25.8%	1.55	480.4
McDougall Creek 1-1	49.5%	2.97	109.8
McDougall Creek 1-2	83.3%	5	93.4

McDougall Creek Summary and Recommendations

Increased development pressure along McDougall Creek has the potential to result in increased surface runoff from impervious surfaces and subsequent severe downcutting

and habitat degradation, such as that which is occurring along lower reaches of Smith Creek. This increase in development pressure, along with the fisheries habitat value of McDougall Creek makes it a priority stream for conservation, as well as habitat restoration and enhancement. Establishment of riparian setbacks with native riparian vegetation that provide an adequate buffer form development, as well as storm treatment prior to discharge is recommended.

Management concerns noted during the 2001 and 2003 field surveys and further supported by recent data review are as follows:

- Anthropogenic modifications occur throughout the system including bank armouring, removal of riparian vegetation, channelization, livestock access, and active mining adjacent the stream with inadequate buffers. As stated above, best management practices for living near water and education and enforcement through the development permit process is recommended.

- Sediment deposition was noted along McDougall Creek associated with sand berms along Hitchner Road, a collapsed bridge upstream of Shannon Lake Road (2001), and overall bank erosion.

- Several water withdrawals were also documented along the surveyed stream length, often with inadequate screening to prevent harm to aquatic life.

- Riparian and instream habitat enhancement downstream of Boucherie Road is recommended, including bank stabilization where sand berms along Hitchner Road have resulted in sedimentation of substrates. With low gradients, there may also be potential for incorporation of rock weirs and spawning gravels intended to provide spawning habitat for rainbow trout and kokanee along the lower reaches of McDougall Creek. This area could be a focal point for fisheries enhancement work, but its success will depend on incorporation of best management practices for stormwater management and maintenance of riparian corridors upstream.

- During the 2010 field review, water was observed to be pooling along both sides of Boucherie Road, although the connection to McDougall Ck was not located.



Photo 12.17: Water was noted to be pooling along both sides of Boucherie Rd. during the field review.

FAULKNER/KEEFE CREEK DRAINAGE

The SHIM field survey of Keefe Creek (Watershed Code 310-813300) was completed in 2001, and included approximately 1.7 km of stream length. This spring-fed drainage occurs primarily through Tsinstikeptum IR 10, and provides stable base flows and fish habitat for salmonids throughout its length.

Faulkner Creek (Watershed Code 310-813300-57900) is a tributary to Keefe Creek, which has been heavily impacted by damming of the Rose Valley Reservoir and residential development. Downstream of the dam, flows are intermittent and this watercourse has experienced a loss in surface water connection and base flows to downstream reaches. Throughout the year, flows experienced are primarily the result of surface runoff from impermeable surfaces. The 2001 SHIM field survey was completed on approximately 5.3 km from the Rose Valley Reservoir downstream to the confluence with Keefe Creek.

In addition to inventory of Keefe and Faulkner Creeks, several smaller watercourses within the Keefe/Faulkner Drainage were surveyed in 2003 by RDCO. These include Faulkner Creek Diversion, Faulkner Creek Tributary 1, Faulkner Creek Tributary 2, Faulkner Creek Tributary 3, Faulkner Creek Tributary 4, Lakeview Creek 1, Gully 1, Unnamed Creek 2, West Creek 1, West Creek 2, West Creek 3 and West Creek Tributary 1.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

At the time of the field survey, Keefe Creek was characterized as being primarily natural for approximately 94% of the SHIM length. The remaining 6% was cuvlerted. While much of the stream is considered natural, impacts that are present, such as sediment deposition, negatively affect the life history of resident fish species.

As discussed above, Faulkner Creek has been heavily impacted by anthropogenic activities, and 85% of the SHIM length has been modified to some degree (Table 12.26 Values shown are based on SHIM field inventory and analysis of 5.3 linear km of Faulkner Creek within the District of West Kelowna.). Channelization occurs over 30% of the 5.3 km stream length, while 1% is culverted, and a further 31% is ditched. General modifications occur over 23% of the stream length, while only 790 m of Faulkner Creek was classified as natural.

Watercourses within the Faulkner/Keefe Creek drainage occurred over approximately 5485 m. Approximately 1.3 km, or 24% of the surveyed length was channelized, 6% was culverted, 23% of stream length was ditched, and a further 8% was modified to some extent. Approximately 38% of the 5.5 km of stream length was considered to be natural.

Table 12.26 – Faulkner Creek Summary of Primary Stream Character

Segments	Primary Character	Length (m)	Percentage of stream length
11, 14, 15	Channelized	1575.5	29.8%
1	Culvert	55.8	1.1%
4, 5, 12	Modified	1213.8	23.0%
2, 6, 7, 8, 13	Natural	790.4	15.0%
3, 9, 10	Ditch	1650.79	31%

Culverts occurred over approximately 1157 m, or around 11%, of the SHIM stream length within the Faulkner/Keefe Creek Drainage at the time of the field survey. Culverts varied in length from 4.8 m to 237 m, with the latter being the Faulkner Creek diversion.

Stream Channel and Hydraulic Character

Faulkner Creek was described as dry over 17% of the 5.3 km stream length (Table 12.27 Values shown are based on SHIM field inventory and analysis of 5.3 linear km of Faulkner Creek within the District of West Kelowna.). A total of 959 m, or 18%, displayed a riffle morphology. Segments 11, 13 and 14, encompassing 23% of the stream length, were classified as standing water, while 4% of Faulkner Creek was described as wetland. There was no hydraulic data recorded for over 2 km of stream.

The average channel gradient throughout Faulkner Creek was around 1%, with a minimum gradient of 0% and maximum of 5%, recorded in Segment 9. Bank full width averaged 2.7 m.

Table 12.27 – Faulkner Creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
10	Dry	875.6	17%
2, 3, 6, 9	Riffle	959.2	18%
11, 13, 14	Standing Water	1228.8	23%
4, 5	Wetland	215.7	4%
1, 7, 8, 12, 15	No Hydraulic Data	2007.0	38%

Table 12.28 (values shown are based on SHIM field inventory and analysis of 1.7 linear km of Keefe Creek within the District of West Kelowna. provides hydraulic information for Keefe Creek, which was primarily riffle/pool, at 88% of the 1.7 km surveyed stream length. The average stream gradient along Keefe Creek was 1.3%, with 2% being the maximum and 0% the minimum. Bank full width averaged 4.6 m, while the maximum width was 15 m in Segment 4.

Table 12.28 – Keefe creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
1, 3	Riffle/Pool	1521.2	88%
4	Run	93.4	5%
2	No hydraulic info	109.6	6%

Smaller watercourses within the Faulkner/Keefe Creek drainage exhibited wetland characteristics over 6% of the ~5.5 km stream length and standing water occurred over 2%. A riffle morphology was recorded over 22% of the stream length, while riffle/pool characteristics occurred over 11% of the stream length. Cascade hydraulic character accounted for 14% and cascade/pool was representative of as much as 17% of the SHIM length. There was no hydraulic information provided for 28% of the stream length, which included drainages such as Gully 1 and the Faulkner Creek Diversion.

Instream Habitat Cover/Complexity

Approximately 13% of the SHIM stream length of Faulkner Creek was noted to provide structural instream cover for fish habitat (Table 12.29 Values shown are based on SHIM field inventory and analysis of 5.3 linear km of Faulkner Creek within the District of West Kelowna.). Eight (8) segments were estimated to have a total percentage of the wetted area occupied by cover of less than 10%, accounting for 72% of the surveyed stream length. Approximately 19% of the stream length had total cover estimated between 21 to 40%, with instream vegetation being the most prominent cover type. Segments 13 and 14 exhibited total instream cover between 51 to 75%, which accounted for only 9% of the stream length. The fact that Faulkner Creek is intermittent further undermines the value of habitat cover.

Table 12.29 – Faulkner Creek Summary and Distribution of Instream Cover/habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
1, 2, 3, 7, 8, 9, 10, 12	<10%	3805.7	72%	0%	0%	0%	0%	50%	50%	0%
	11-20%	0.0	0%							
4, 5, 6, 11	21-40%	1020.8	19%	0%	0%	57%	9%	24%	9%	0%
	41-50%	0.0	0%							
13, 14	51-75%	459.7	9%	8%	0%	0%	34%	34%	24%	0%
	>75%	0.0	0%							

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Keefe Creek alternatively was found to have 100% of the stream length exhibiting total instream cover over 75%. All four segments combined realized an estimated length of

total cover of 1.4 km. Undercut banks and deep pool habitat were the least represented habitat types, with large woody debris and overstream vegetation being the most prominent habitat type by stream length.

Watercourses within the Faulkner/Keefe Creek drainage had estimated total cover of less than 10% for over 38% of the 5.5 km stream length. Approximately 13% of the stream length had estimated cover between 11 and 20%, and 18% of stream length was estimated to have total cover between 21 and 40%. Around 890 m of stream length had cover estimated to be between 51 and 75% of the total wetted area. Only 15% of the stream length was estimated to have cover exceeding 75%.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications along the Faulkner/Keefe Creek drainage were noted to include one narrow wooden bridge crossing, four (4) catch basins, one (1) dam associated with the Rose Valley Reservoir, one (1) detention pond, 1 fence crossing, two (2) metal flumes, three (3) pipe crossings (including sewer crossings), and seven (7) water withdrawals. Garbage dumping was also noted to occur throughout Segments 3 and 4 of West Creek.

Additional modifications not picked up as a data point included riparian vegetation removal along Keefe Creek downstream of Horizon Drive, which had occurred around the time of the 2001 survey.

Discharges/Waterbodies

A total of 24 discharges were documented along the Faulkner/Keefe Creek Drainage during the SHIM field inventory (Table 12.30 Values shown are based on SHIM field inventory (2001-2003) and analysis of 12.5 linear km of stream length within the District of West Kelowna.). A total of 13 storm drains were recorded, with an average diameter of 0.6 m and a maximum observed discharge pipe diameter of 4 m. There were five (5) tile drains, one of which had an odour of septic during the field inventory. One separate point was recorded as septic effluent due to a strong odour coming from the discharge. There were also five (5) discharges recorded as other, with four (4) of those having unknown origin and function, and one which was used for irrigation purposes.

Table 12.30 Summary of Discharges identified within the Faulkner/Keefe Creek Drainage

Type	Count	Mean Diameter (m)	Min Diameter (m)	Max diameter (m)	Number flowing during survey
Storm Drain	13	0.60	0.2	4	0
Tile Drain	5	0.10	0.1	0.1	0
Septic Effluent	1	0.50	0.5	0.5	0
Other (irrigation pipe/unknown origin)	5	0.18	0.10	0.5	0
Total	24				0

A total of 19 waterbody features were recorded along the Faulkner/Keefe Creek drainage, many of which occurred in the West Creek area. There were 14 natural springs recorded during the stream survey, as well as five (5) tributary streams. Faulkner Creek Tributary 3-1 was noted to be a major contributor of sediment movement.

Bank Stability and Erosion

Stream bank erosion was documented along approximately 3% on both the right and left banks within the Faulkner/Keefe Creek drainage (Table 12.31 Values shown are based on SHIM field inventory (2001-2003) and analysis of 12.5 linear km of stream length within the District of West Kelowna.). Of the 16 erosion points recorded within the drainage, 88% had severity greater than $10m^2$. Erosion points were documented exclusively along Keefe Creek and West Creek 1. Down cutting was consistently noted throughout Keefe Creek and West Creek 1, with resulting sedimentation downstream. A heavy accumulation of sediment was noted within Keefe Creek. Surface runoff from Highway 97 was noted to be a key factor in causing slumping and bank erosion into the creek.

Table 12.31 Summary of Bank Erosion Recorded Along the Faulkner/Keefe Creek Drainage

Left Bank						Right Bank				
Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length		Length (m)	Average Height (m)	Area (m^2)	Average Area of Exposure (m^2)	Percent of SHIM stream length
326	2.2	491.5	37.8	2.6%		416	2.2	561.5	40.1	3.3%

Fish Habitat

Fish habitat was most abundant in Keefe Creek due to the natural character of the majority of its stream length. However, spawning habitat is limited due to a low percentage of gravel substrates throughout the stream. Gravels were only documented in substrate data in Segment 1 and only at 10% in comparison to 85% fines and 5% boulder. Segments 3 and 4 of Keefe Creek were noted to have exclusively fine substrates.

Fish access to Faulkner Creek from Keefe Creek is limited due to the lack of base flows in Faulkner Creek, with the exception of spring freshet when any fish that happened to enter the channel would become stranded, resulting in mortality.

Obstructions / Barriers

There were seven (7) obstruction features recorded within the Faulkner/Keefe Creek drainage. Of those, six (6) were noted to be confirmed barriers to fish passage. These included three (3) dams, one of course being Rose Valley Dam, which had a recorded height of 40 m. Table 12.32 outlines obstructions and approximate location along the watercourse. Values shown are based on SHIM field inventory (2001-2003) and analysis of 12.5 linear km of stream length within the District of West Kelowna.

Table 12.32 – Faulkner/Keefe Creek Drainage Summary Potential Obstructions/Barriers to Upstream Fish Migration

Approximate Distance from Okanagan Lake (km)	Stream Name	Type of Obstruction	Barrier
2.3	Faulkner Creek	Dam	Yes
2.4	Faulkner Creek	Falls	Yes
2.7	Keefe Creek	Cascade	Potential
2.9	Faulkner Creek	Dam	Yes
6.5	Faulkner Creek	Dam	Yes
N/A	Faulkner Creek Diversion	Falls	Yes
N/A	Faulkner Creek Tributary 3	Falls	Yes

Stream Impact Summary

The sum of weighted SHIM scores for Faulkner Creek equaled 1.65 (out of 6), receiving a stream grade of 27.5%. Figure 4 depicts the distribution of stream segments relative to their individual SHIM impact scores. Five (5) segments, accounting for 14% of the

stream length, received a score of 0, indicating that impacts were high along both banks. One (1) segment received an impact score of 1, exhibiting moderate impacts along one bank and high on the other, accounting for 9% of the stream length. There were eight (8) segments receiving a stream score of 2, indicating that both banks exhibited moderate impacts or one bank was low and one high, for 76% of the stream length. One (1) segment received a score of 3 (1 bank nil, 1 bank high, or 1 bank low and 1 bank moderate) and accounted for 1% of the stream length. Six stream segments totaling 2.9 km, had relatively low impacts receiving a score of 4 for having both banks low, or 1 bank nil and 1 bank moderate. A total of 2.1 km had levels of impact considered to be nil on one bank and low on the other, while there were no segments given a 6, which would indicate nil impacts on both banks.

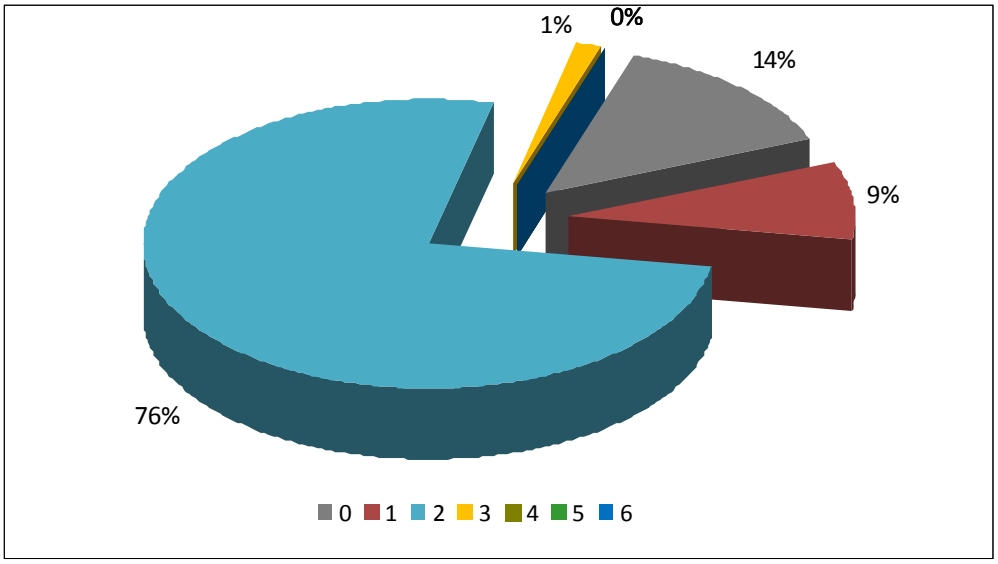


Figure 12.4. Faulkner Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~5.3 linear km of Faulkner Creek within the District of West Kelowna.

The sum of weighted SHIM scores for Keefe Creek equaled 3.23 (out of 6), receiving a stream grade of 53.8%. Figure 5 depicts the distribution of stream segments relative to their individual SHIM impact scores. Only one (1) segment, accounting for 6% of the stream length, received a score of 0, indicating that impacts were high along both banks; this segment occurred within a culvert. Two (2) segments received a score of 3 (1 bank nil, 1 bank high, or 1 bank low and 1 bank moderate), equating to 52% of the surveyed stream length. One (1) segment, accounting for 42% of the 1.7 km stream length received a score of 4 for having both banks low or 1 bank nil and 1 bank moderate.

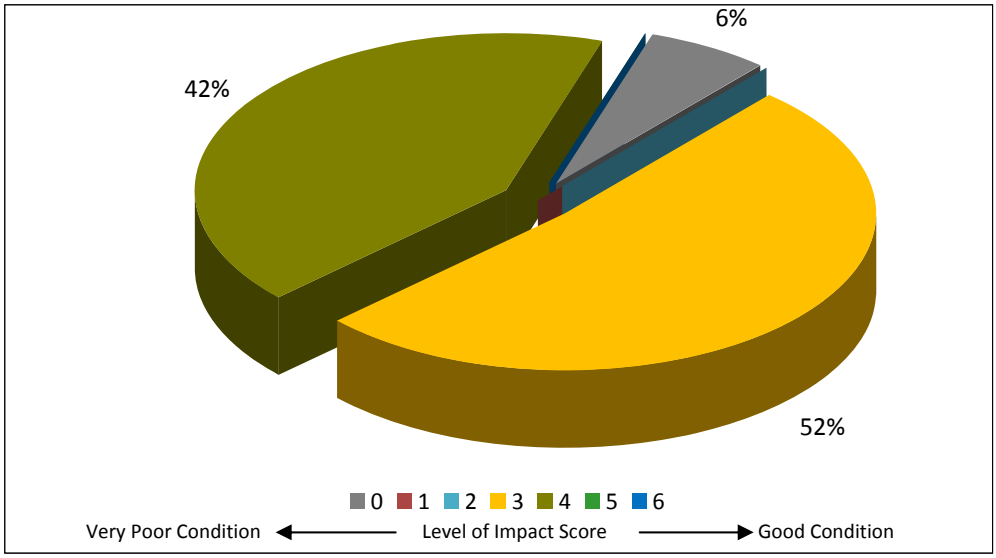


Figure 12.5. Keefe Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~1.7 linear km of Keefe Creek within the District of West Kelowna.

Table 12.33 outlines stream grades and scores for all surveyed watercourses within the Faulkner/Keefe Creek drainage.

Table 12.33 – Stream Impact Summary for Tributaries within the Faulkner/Keefe Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Faulkner Creek	27.5%	1.65	5.3
Keefe Creek	53.8%	3.23	1.7
Faulkner Creek Diversion	0.0%	0	299.3
Faulkner Creek Tributary 1	66.7%	4	258.3
Faulkner Creek Tributary 2	33.3%	2	562.1
Faulkner Creek Tributary 3	57.8%	3.47	1219.2
Faulkner Creek Tributary 4	33.3%	2	166.5
Faulkner Creek Gully 1	66.7%	4	430.1
Lakeview Creek 1	16.7%	1	323.5
Unnamed Creek 2	5.0%	0.3	564.4
West Creek 1	43.3%	2.6	1223.7
West Creek 2	37.2%	2.23	251.7
West Creek 3	0.0%	0	37.3
West Creek Tributary 1	0.0%	0	149.3

Faulkner/Keefe Creeks Summary and Recommendations

Faulkner Creek

- Sediment source for downstream reaches of Keefe Creek
- Lack of base flows prohibit fish access and overall fisheries values
- Flows result primarily from impermeable surface runoff
- Constructed wetlands require maintenance.

Keefe Ck

- Runoff from Highway 97 has resulted in bank erosion and sloughing of material into creek
- Sediment accumulation throughout channel
- Gravel substrates for spawning lacking
- Channel downcutting throughout
- Riparian vegetation removal downstream of Lower Horizon Drive crossing
- With increased development pressure, there is potential for loss of riparian communities between Westside Road and Okanagan Lake.
- Adequate pre-treatment and attenuation of storm water will be important considerations as this drainage becomes more developed.

BOWEN CREEK DRAINAGE

The SHIM field survey of Bowen Creek (Watershed Code 310-788300) and its associated watercourses within the Bowen Creek drainage was completed between 2001 and 2003. The Bowen Creek drainage totaled approximately 3.9 km. This spring fed system, with the exception of vegetated riparian gullies and wetland areas, has been altered by human development. Much of the stream is used for storm water runoff from impervious surfaces and agricultural areas.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

The primary character of Bowen Creek was described as modified over approximately 37% of the nearly 1 km stream length (Table 12.34 Values shown are based on SHIM field inventory and analysis of 0.9 linear km of Bowen Creek within the District of West Kelowna.). The remaining 63% was characterized as natural.

Table 12.34 – Bowen Creek Summary of Primary Stream Character

Segments	Primary Character	Length (m)	Percentage of stream length
3, 4, 5, 6	Modified	349.0	37.3%
1, 2, 7, 8	Natural	587.0	62.7%

Within the approximately 3.1 km of stream length within the Bowen Creek drainage, modifications occurred over 82%. A total of 1.8 km, or 59%, has been ditched, 13% culverted, 5% channelized and 5% modified to some extent. There was 18% of the drainage described as natural.

Culverts occurred over approximately 827 m, or 21%, of the SHIM stream length of watercourses surveyed within the Bowen Creek drainage. Culverts varied in length from 5 to 330 m, found in Bowen Creek 2 Segment 3.

Stream Channel and Hydraulic Character

Bowen Creek primarily exhibits a riffle morphology for approximately 87% of the SHIM stream length (Table 12.35 Values shown are based on SHIM field inventory and analysis of 0.9 linear km of Bowen Creek within the District of West Kelowna.). The remaining 13% was described as riffle/pool during the field survey. The average channel gradient throughout Bowen Creek was 9%. The stream gradients averaged for each of the 8 segments varied from 4 to 12%. The mean bank full width was 4.6 m, with a minimum of 2.5 m and maximum of 9 m.

Table 12.35 – Bowen Creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
1, 2, 3, 4, 5, 7, 8	Riffle	815.8	87%
6	Riffle/Pool	120.0	13%

Hydraulic character within watercourses of the Bowen Creek drainage was predominantly a run morphology, accounting for 63% of the 3.1 km stream length. Approximately 17% of the watercourses exhibited riffle morphology, while 11% were classified as riffle/pool. Nearly 1% was described as a cascade/pool, while 4% was classified as wetland, and 4% classified as standing water.

Instream Habitat Cover/Complexity

Approximately 45% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.36 Values shown are based on SHIM field inventory and analysis of 0.9 linear km of Bowen Creek within the District of West Kelowna.). There was 17% of the Bowen Creek stream length estimated to have a total percentage of the wetted area occupied by cover of less than 10%, comprised exclusively of instream vegetation. Segment 3 had estimated total cover between 21 to 40%, accounting for 13% of the stream length. Segments 1 and 2 cover 34% of the stream length and had estimated total cover between 41-50%. There was 36% of the stream length with estimated total cover between 51 to 75%, comprised of instream and overstream vegetation.

Table 12.36 – Bowen Creek Summary and Distribution of Instream Cover/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
6, 4	<10%	159.2	17%	0%	0%	100%	0%	0%	0%	0%
	11-20%									
3	21-40%	122.0	13%	0%	0%	0%	0%	100%	0%	0%
1, 2	41-50%	315.6	34%	0%	0%	25%	8%	53%	15%	0%
5, 7, 8	51-75%	339.1	36%	0%	0%	50%	0%	50%	0%	0%
	>75%									

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Tributaries within the Bowen Creek drainage experienced higher levels of instream cover, with 20% of the 3.1 km of stream length having greater than 75% total cover. That being said, 27% had an estimate of total cover less than 10%. Approximately 1.5 km, or 49%, of stream length had an estimated total cover between 21 to 40%. The remaining 5% had total cover between 51 to 75% coverage.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Only one modification point was recorded during the SHIM field survey, limited to a wooden pedestrian bridge approximately 4.4 m long.

Discharges/Waterbodies

A total of 19 discharges were documented along the Bowen Creek drainage during the field inventory (Table 12.37 Values shown are based on SHIM field inventory (2001-2003)and analysis of 4 linear km of Bowen Creek and tributaries within the District of West Kelowna.). A total of 6 storm drains were recorded, with an average diameter of 0.15 m and a maximum observed discharge pipe diameter of 0.3 m. There were two (2)

tile drains noted, and 11 discharges categorized as other, the majority of which were of an unknown origin.

Table 12.37 – Summary of Discharges Identified on Bowen Creek and Tributaries

Type	Count	Mean Diameter (m)	Min Diameter (m)	Max diameter (m)	Number flowing during survey
Storm Drain	6	0.15	0.1	0.3	0
Other	11	0.13	0.1	0.32	2
Tile Drain	2	0.1	0.10	0.1	0
Total	19				2

A total of 15 waterbody features were recorded within the Bowen Creek drainage. Of the 15 waterbodies recorded, 14 were natural springs and one (1) was a tributary.

Bank Stability and Erosion

Bank erosion was not a significant issue along streams within the Bowen Creek drainage. Only 30 m of eroding bank were documented along the right bank, and 25 m along the left bank. The 25 m of erosion occurred on both banks and was a result of channel down cutting.

Fish Habitat

While the Bowen Creek drainage is connected via surface water to Okanagan Lake, its value as fish habitat is largely limited to provision of allocthonous nutrients. Field notes from the SHIM field survey indicated that Bowen Creek is not accessible to fish due to impacts adjacent to Okanagan Lake. Fish presence or absence was not confirmed and was not within the scope of this project.

Obstructions / Barriers

A summary of potential obstructions or barriers to upstream fish migration within the Bowen Creek drainage is summarized in Table 12.38. An obstruction to fish passage occurs just over 100 m from the confluence of Okanagan Lake and Bowen Creek due to an improperly installed culvert perched 3 m above the channel. Values shown are based on SHIM field inventory and analysis of 0.9 linear km of Bowen Creek within the District of West Kelowna.

Table 12.38 – Bowen Creek Drainage Summary of Potential Obstructions/Barriers to Upstream Fish Migration

Approximate Distance from Okanagan Lake (km)	Stream Name	Type of Obstruction	Barrier
0.105	Bowen Creek	Falls	Yes
0.115	Bowen Creek 2	Lack of defined channel	Yes
0.413	Bowen Creek	Falls	Unknown
0.548	Bowen Creek	Cascade	Yes

Stream Impact Summary

The sum of weighted SHIM scores equaled 3.1 (out of 6), with Bowen Creek receiving a stream grade of nearly 52% (Table 12.39). Three (3) segments, or 26% of the stream length, received a score of 2, indicating that both banks exhibited moderate impacts or one bank was low and one high. Two (2) segments received a score of 3 (1 bank nil, 1 bank high, or 1 bank low and 1 bank moderate) and accounted for 38% of the stream length. Three (3) segments covering 36% of the stream length received a score of 4 for having both banks low, or 1 bank nil and 1 bank moderate.

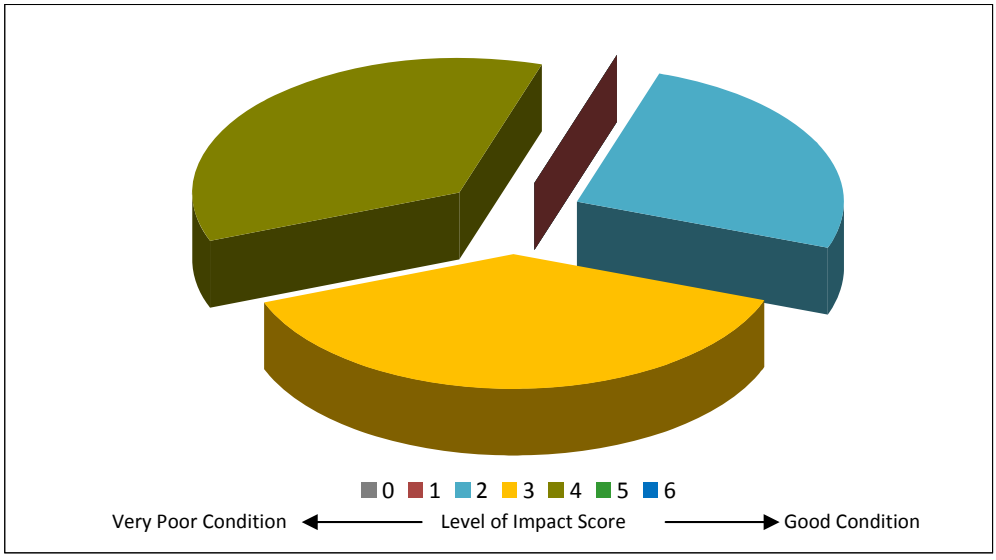


Figure 12.6. Bowen Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~0.9 linear km of Bowen Creek within the District of West Kelowna.

Table 12.39 outlines stream grades and scores for all surveyed watercourses within the Bowen Creek drainage.

Table 12.39 – Stream Impact Summary for Tributaries Within the Bowen Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Bowen Creek	51.7%	3.1	935.9
Bowen Creek 2	0.7%	0.04	2137.4
Bowen Creek 3	25.3%	1.52	383.4
Bowen Creek 5	69.8%	4.19	305.3
Bowen Creek Tributary 1	16.7%	1	107.2
Bowen Creek Tributary 2	16.7%	1	69.3
Unnamed Creek	100.0%	6	244.3

Bowen Creek Summary and Recommendations

Primary management issues include anthropogenic impacts throughout 100% of the spring fed stream, with its primary function as ditched/culverted storm drain runoff.

- Establish riparian area where ditched through agricultural areas, providing some buffer to pesticides and fertilizers used in agricultural practices.

- Allow cattails to become established to provide increased filtration. It is recognized that removal of cattails from roadside ditches is common maintenance practice due to accumulation of biomass and potential impairment of drainage function. However, staging clearing such that patches of vegetation are left to function essentially as check dams to promote filtration and infiltration may be beneficial to both water quality and habitat. Clearing of cattails should be timed to avoid disturbance or harm to nesting bird species, such as red-winged blackbirds. Clearing should generally not occur between April 1 and July 30.

LAW CREEK DRAINAGE

The SHIM field survey of Law Creek (Watershed Code: 310-742200-03600) and tributaries within the Law Creek drainage was completed between 2002 and 2003. The surveyed length of streams within the Law Creek drainage total approximately 16.7 km, including 7.9 km of Law Creek.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

Law Creek has been modified to some degree over approximately 1.4 km (17%) of the surveyed stream length, with approximately 6.5 km (82%) remaining natural (Table 12.40 Values shown are based on SHIM field inventory and analysis of 7.9 linear km of Law Creek within the District of West Kelowna.). Of the 1.4 km, about 105 m were characterized as being channelized, occurring in Segment 12, 175 m were culverted through Segment 2 and Segment 13 was ditched. Segments 16, 17, 18, 19, and 21 were described as modified.

Table 12.40 – Law Creek Summary O Primary Stream Character

Segments	*Primary Character*	*Length (m)*	*Percentage of stream length*
12	*Channelized*	*105.0*	*1.3%*
2	*Culvert*	*175.2*	*2.2%*
16, 17, 18, 19, 21	*Modified*	*601.5*	*7.6%*
1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 20, 20.1, 22, 23, 24, 25	*Natural*	*6511.9*	*82.4%*
13	*Ditch*	*508.7*	*6.4%*

Within the approximately 8.8 km of tributary stream length within the Law Creek drainage, modifications occurred over approximately 38%. Nearly 738 m, or 8%, has been ditched, 1% channelized, and 28% modified to some extent. Over 5.4 km or 62% of the drainage was described as natural during the SHIM field survey.

Culverts occurred over approximately 403 m, or 2.4%, of the 16.9 km of SHIM stream length of watercourses surveyed within the Law Creek drainage. Culverts varied in length from 2 to 180 m; the 180 m culvert is within Segment 2 of Law Creek.

Stream Channel and Hydraulic Character

The hydraulic character of Law Creek varied considerably, from 2% of the stream length considered to be wetland, to 27% of the SHIM stream length exhibiting a steeper gradient and cascade/pool morphology. Hydraulic character throughout the 25 segments is summarized in Table 12.41. The average channel gradient throughout the surveyed portion of Law Creek was around 4%. The stream gradients averaged for each of the 25 segments varied from 0.5 to 12%. The average bank full width of Law Creek was 2.8 m, with a minimum recorded bank full width of 0.7 m and a maximum of 12.2 m. Values shown are based on SHIM field inventory and analysis of 7.9 linear km of Law Creek within the District of West Kelowna.

Table 12.41 - Law Creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
16, 17, 18, 19, 21, 22, 23, 25	Run	1557.0	20%
2, 20	Riffle	478.0	6%
5, 7, 9, 11	Riffle/Pool	1534.2	19%
1, 3, 4, 8	Cascade/Pool	2109.7	27%
10, 12, 13, 20.1, 24	Slough	1952.7	25%
15	Standing	123.8	2%
6	Wetland	146.9	2%

The hydraulic character of Law Creek tributaries was variable as well. Over 2.3 km (27%) of stream length was described as having a run morphology, while 21% was described as wetland, 19% riffle, 16% cascade pool, 3% slough, 2% riffle/pool, 2% standing water, 1% cascade and 1% other. There was a further 8% of the 8.8 km stream length that had no hydraulic description associated with the SHIM data.

Instream Habitat Cover/Complexity

Approximately 61% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.42 Values shown are based on SHIM field inventory and analysis of 7.9 linear km of Law Creek within the District of West Kelowna.). There was 10% of the Law Creek stream length estimated to have a total percentage of the wetted area occupied by cover of less than 10%. Segment 13 had estimated total cover between 11 to 20%, accounting for 6% of the stream length. Segment 20.1, accounting for just

1% of the stream length, was described as having instream cover between 21 to 40%, with exclusively overstream vegetation. Segment 1 had estimated total cover between 41-50% and equated to 4% of the SHIM stream length. There was 44% of the stream length with estimated total cover between 51 to 75%, while over 2.7 km, or 36%, of the SHIM stream length had estimated total cover between 80 to 100%.

Table 12.42 – Law Creek Summary and Distribution of Instream Cover/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
2, 15, 16, 17, 18, 19	<10%	810.0	10%	0%	0%	0%	0%	0%	0%	0%
13	11-20%	508.7	6%	0%	50%	50%	0%	0%	0%	0%
20.1	21-40%	62.3	1%	0%	0%	0%	0%	100%	0%	0%
1	41-50%	287.8	4%	0%	0%	0%	20%	50%	30%	0%
4, 5, 11, 21, 22, 23 , 24, 25	51-75%	3513.0	44%	6%	5%	0%	22%	38%	23%	7%
3, 6, 7, 8, 9, 10, 12, 20	>75%	2720.4	34%	6%	7%	9%	23%	36%	17%	2%

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Tributaries within the Law Creek drainage had an estimated 21% of the 8.8 km stream length with estimated total wetted cover less than 10%. Only 1% of the tributary stream length exhibited cover between 11 to 20%, while 17%, or 1.5 km exhibited cover between 21 to 40%. Approximately 10% of the stream length was described as having instream cover between 41 to 50%. Over 2.1 km of stream exhibited cover between 51 to 75% and a further 26% of SHIM stream length had instream cover estimated at 80%.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications to the stream channel had a cumulative linear measurement of approximately 82 m along the left bank, 57 m along the (2002-2003) right bank, and 116 m instream (Table 12.43 Values shown are based on SHIM field inventory and analysis of 16.7 linear km of Law Creek and its tributaries within the District of West Kelowna.). It should be noted that there were some modification points which did not have a recorded length within the database; this included two (2) road crossings, where one was described as a skid trail through the stream channel and in one instance the stream channel had been filled in with no culvert. Additionally, modifications such as water withdrawals, fencing and pipe crossings are not effectively quantified by stream length. There were six (6) documented water withdrawals along Law Creek and its tributaries.

Table 12.43 – Modifications Summary

	Left Bank			Right			Instream		
Type	**Length (m)**	**% of total modifications**	**% of SHIM stream length**	**Length (m)**	**% of total modifications**	**% of SHIM stream length**	**Length (m)**	**% of total modifications**	**% of SHIM stream length**
Bridge	22.7	8.9%	0.1%	22.7	8.9%	0.1%	6.9	2.7%	0.0%
Catch basin	0.0	0.0%	0.0%	0.0	0.0%	0.0%	6.0	2.4%	0.0%
Other	25.0	9.8%	0.1%	0.0	0.0%	0.0%	0.0	0.0%	0.0%
Detention Pond	0.0	0.0%	0.0%	0.0	0.0%	0.0%	12.0	4.7%	0.1%
Retaining Wall/Bank Stabilization	34.0	13.3%	0.2%	34.0	13.3%	0.2%	0.0	0.0%	0.0%
Road	0.0	0.0%	0.0%	0.0	0.0%	0.0%	91.4	35.9%	0.5%
Water Withdrawal	1 left bank						5 instream		
	81.70			56.7			116.3		

Discharges/Waterbodies

Only two (2) discharge locations were identified along the approximately 16.7 km of stream length associated with law Creek and its tributaries. One discharge point was identified due to a runoff ditch from a cut block upslope, while the second discharge point was associated with road runoff where no water bars were present.

A total of 17 waterbody features were recorded along Law Creek and its tributaries within the study boundary. Of the 17 waterbodies recorded, 7 were tributaries to law Creek, 9 were identified as natural springs and one wetland feature occurred where

extensive ponding was documented. Water temperatures were taken for recorded features, and ranged from 7.0°C to 13°C.

Bank Stability and Erosion

Stream bank erosion was documented along approximately 82 m of stream length, and only three (3) erosion points were recorded. The most significant erosion point was a landslide along Segment 3 of Law Creek which was 42 m in length along the left bank with an estimated surface area of 2542 m^2.

Fish Habitat

Law Creek and its tributaries were nearly all identified as being ephemeral streams; therefore, fisheries value is limited. Fish presence or absence was not confirmed and was not within the scope of this project. Law Creek is tributary to Trepanier Creek, which is known to provide habitat to fish species including burbot, kokanee, prickly sculpin, rainbow trout and sucker species (www.fishwizard.com).

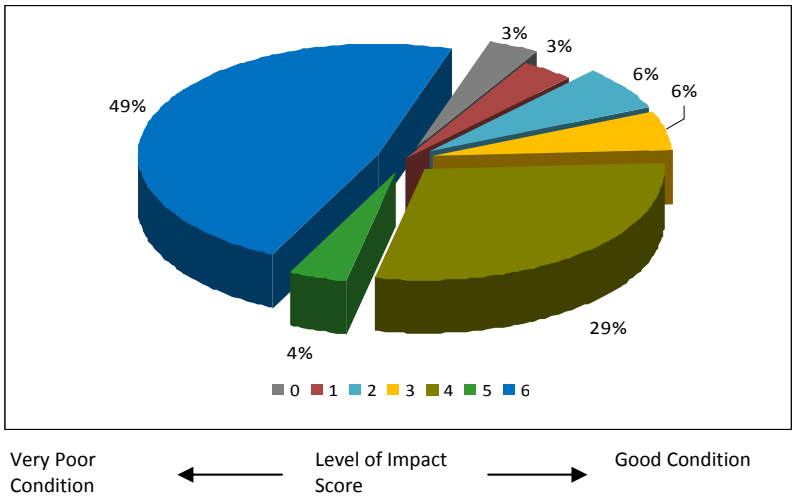
Obstructions / Barriers

Obstructions recorded along Law Creek include three sets of bedrock falls. A 2.3 m high falls was documented approximately 2.5 km upstream of the confluence of Trepanier Creek and Law Creek. A 12 m high falls was noted approximately 3.6 m upstream of the creek's confluence and an additional 2 m high falls was noted within 75 m.

Stream Impact Summary

The sum of weighted SHIM scores for Law Creek equaled 4.57 (out of 6), resulting in a stream grade of approximately 34% (Figure 12.7). A total of 11 segments received a score of 6, indicating that impacts were nil along both banks over 48% of the stream length.

Figure 12.7. Law Creek summary of Level of Impact.



Values shown above are based on SHIM field inventory and analysis of ~7.9 linear km of Law Creek within the District of West Kelowna.

Table 12.44 outlines stream grades and scores for all surveyed watercourses within the Law Creek drainage.

Table 12.44 – Stream Impact Summary for Tributaries within the Law Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Law Creek	76.2%	4.57	7902.3
Law Creek Tributary 1	100.0%	6	1605.6
Law Creek Tributary 1-1	100.0%	6	81.2
Law Creek Tributary 2	92.5%	5.55	2355.9
Law Creek Tributary 2-2	82.0%	4.92	328.4
Law Creek Tributary 2-2-1	83.3%	5	504.1
Law Creek Tributary 2-2-1-1	16.7%	1	179.3
Law Creek Tributary 3	37.7%	2.26	923.4
Law Creek Tributary 4	57.5%	3.45	956.4
Law Creek Tributary 5	80.2%	4.81	707.5
Law Creek Tributary 6	74.8%	4.49	1154.7

Law Creek Summary and Recommendations

Law Creek and its tributaries are primarily ephemeral drainages, exhibiting natural and well-established riparian areas. This watercourse has not been identified as a priority for channel or riparian restoration.

DROUGHT CREEK DRAINAGE

The SHIM field survey of Drought Creek (Watershed Code: 310-751500) and tributaries within the Drought Creek drainage was completed in 2003. The surveyed length of streams within the Drought Creek drainage total approximately 5.7 km, including 3.1 km of Drought Creek. While not tributary to Drought Creek, Hardy Slough, Seclusion Creeks 1, 2 and 3 and Seclusion Unnamed Creek were grouped in the Drought Creek Drainage for the purposes of this assessment.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

Drought Creek has been modified to some extent over approximately 1.2 km, or 40% of the surveyed stream length, while a further 1.9 km or 60% was documented as remaining natural. Segments 3, 5, 8 and 9 were classified as having a modified primary stream character in 2003, while Segments 1, 2, 4, 6, 7 and 10 were natural.

The primary character of Hardy Slough was recorded as ditch over 100% of the 874 m of stream length.

Over approximately 86%, or 669 m, of stream length surveyed along Seclusion Creeks was considered to be natural. Approximately 5%, or 37 m, occurred within a culvert, while a further 72 m, or 9%, of stream length was regarded as being primarily modified.

Culverts occurred over approximately 68 m, all of which were recorded within the Seclusion Bay area. Culverts varied in length from 6 to 37 m; the 37 m culvert was documented within Seclusion Unnamed Creek 1.

Stream Channel and Hydraulic Character

The hydraulic character of Drought Creek was characterized as riffle/pool over 1.4 km, or 46% of the approximately 3.1 km SHIM stream length. A further 34% was considered to be cascade/pool, while 3% had a hydraulic character of cascade and 6% was classified as wetland. A further 360 m, or 12% of the SHIM stream length, did not have an allocated hydraulic character due to a poorly defined channel which has grown over with the ephemeral nature of the watercourse. Hydraulic character throughout the 10 segments is summarized in Table 12.45. Values shown are based on SHIM field inventory and analysis of 3.1 linear km of Drought Creek within the District of West Kelowna.

Table 12.45 – Drought Creek Summary of Hydraulic Character

Segments	Hydraulic Character	Length (m)	Percentage of stream length
10	Wetland	175.1	6%
5, 7	Riffle/Pool	1438.5	46%
8	Cascade	95.7	3%
1, 2, 3, 4, 6	Cascade/Pool	1063.9	34%
10	No Hydraulic Data	360.4	11%

The average channel gradient throughout the surveyed portion of Drought Creek was around 15%. The stream gradients averaged for each of the 10 segments varied from 2 to

42%. The average bank full width of Drought Creek was 0.6 m, with a minimum recorded bank full width of 0.4 m and a maximum of 1.1 m.

The hydraulic character observed for Hardy Slough included approximately 386 m of run or 44% of the 0.87 km surveyed stream length, 24% of the stream length was described as slough, and a further 32% was classified as wetland. The average stream gradient observed throughout Hardy Slough was 1.3%, with the maximum gradient recorded as 2% and the minimum gradient 0%. Average bank full width documented for Hardy Slough was 3.1 m.

Streams within the Seclusion Creek area were primarily characterized as having a cascade hydraulic character, occurring over 69% of the surveyed stream length. Approximately 146 m, or 19% of stream length was classified as a riffle, while 95 m of stream length (exclusive to Seclusion Creek 3) had no hydraulic classification recorded. Watercourses within the Seclusion Creek area had a maximum gradient of 45% and a minimum gradient of 4%. The average stream gradient was 30%. Mean bank full width of Seclusion Creek watercourses was 1.2 m.

Instream Habitat Cover/Complexity

Approximately 19% of the SHIM stream length was noted to provide structural instream cover for fish habitat (Table 12.46 Values shown are based on SHIM field inventory and analysis of 3.1 linear km of Drought Creek within the District of West Kelowna.). There was approximately 51% of the Drought Creek stream length that did not have any type of instream cover present. Segment 5, accounting for 27% of the stream length, was estimated to have a total percentage of the wetted area occupied by cover between 11 and 20%. Segment 6, accounting for 16% of the stream length, was described as having instream cover between 41 to 50%. Only 7 %, or 215 m of the SHIM stream length exhibited total instream cover greater than 75%. Overstream vegetation was observed to be the predominant cover type.

Table 12.46 - Drought Creek Summary and Distribution of Instream Cover/Habitat Complexity

Segment Number	% Total Cover	Combined Segment Length (m)	Percentage of SHIM Stream Length	Percentage of Total cover by Cover Type [a]						
				B	DP	IV	LWD	OV	SWD	UC
3, 4, 7, 8, 9, 10	<10%	1589.9	50.7%	0%	0%	0%	0%	0%	0%	0%
5	11-20%	832.8	26.6%	0%	0%	0%	20%	60%	20%	0%
n/a	21-40%	0.0	0.0%	0%	0%	0%	0%	0%	0%	0%
6	41-50%	496.2	15.8%	0%	0%	0%	30%	50%	20%	0%
n/a	51-75%	0.0	0.0%	0%	0%	0%	0%	0%	0%	0%
1, 2	>75%	214.6	6.8%	0%	0%	0%	10%	70%	20%	0%

a. Cover codes: B=boulder; DP=deep pool; IV=instream vegetation; LWD=large woody debris; OV=overstream vegetation; SWD=small woody debris; UC=undercut bank

Hardy Slough exhibited total instream cover of 10% over approximately 32% of the total SHIM stream length of 874 m. Segment 2 exhibited total cover of 60% over 44% of the SHIM stream length, with overstream vegetation being the dominant cover type. Segment 1 exhibited total cover of 80% over 24% of the Hardy Slough stream length, with cover consisting exclusively of instream vegetation.

Tributaries within the Seclusion Bay area had an estimated 46% of the 0.8 km stream length with estimated total wetted cover of 0%. Only 10% of the tributary stream length exhibited cover between 51 to 75%, while 45%, or 0.35 km of the total stream length exhibited cover over 75%. Overstream vegetation was the only instrema habitat type documented during the SHIM survey.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

No modification points were recorded along watercourses within the Drought Creek drainage during the 2003 SHIM field survey.

Discharges/Waterbodies

A discharge includes any substance that enters a watercourse via an artificial structure (i.e., pipe), whether it is a contribution of clean cold water from a spring, or pollution from a sewage outlet or storm drain.

Only one discharge was recorded during the SHIM field survey of the Drought Creek drainage. A 0.10 m pvc tile drain was documented along the left bank along Segment X of Seclusion Creek X. The origin of the discharge was unknown and it was flowing at the time of the survey.

A total of 11 waterbody features were recorded within the Drought Creek drainage, including 1 tributary and 10 natural springs.

Bank Stability and Erosion

No incidents of stream bank erosion were documented during the 2003 SHIM survey of Drought Creek, Hardy Slough, or Seclusion Creeks 1, 2, 3, or Seclusion Unnamed Creek.

Fish Habitat

Fish presence or absence was not confirmed and was not within the scope of this project.

Obstructions / Barriers

There were no potential or confirmed obstructions to fish passage documented during the 2003 SHIM survey.

Stream Impact Summary

The sum of weighted SHIM scores equaled 4.3 (out of 6), with Drought Creek receiving a stream grade of approximately 72% (Figure 12.8). A total of 5 segments received a score of 6, indicating that impacts were nil along both banks over 40% of the stream length. There were no stream segments receiving a score of zero, which would indicate high impacts along both banks and only 4% of the stream length received an impact score of 1, meaning that impacts were considered to be high along one bank and moderate along the other.

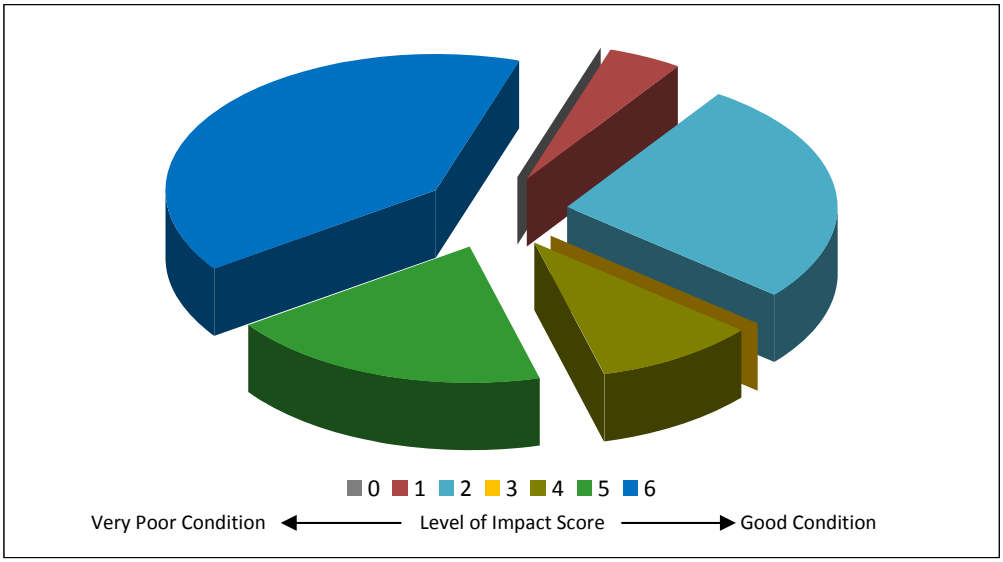


Figure 12.8. Drought Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~3.1 linear km of Drought Creek within the District of West Kelowna.

Table 12.47 outlines stream grades and scores for all surveyed watercourses within the Drought Creek drainage.

Table 12.47 – Stream Impact Summary for tributaries within the Drought Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Drought Creek	72%	4.3	3133.5
Hardy Slough	13%	0.8	874.1
Seclusion Creek 1	9%	0.5	136.1
Seclusion Creek 2	73%	4.4	301.1
Seclusion Creek 3	100%	6.0	94.7
Seclusion Unnamed Creek	100%	6.0	245.7

Drought Creek Summary and Recommendations

This watercourse has not been identified as a priority for channel or riparian restoration.

CASA LOMA SPRING DRAINAGE

The SHIM field survey of the Casa Loma Spring drainage area was completed in 2003. The Casa Loma Spring area consists largely of small, interconnected spring-fed channels, with the total stream length of approximately 705 m. Watercourses inventoried include Casa Loma Spring 1, Casa Loma Spring 2, Casa Loma Spring 3 and Casa Loma Spring 4. While components of this moisture receiving area retain mature, native riparian vegetation, there are several reaches which have been disturbed and consist of exposed soils and invasive plant species.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

The four identified springs were modified to some extent over approximately 436 m, with 38% of the springs retaining a natural primary character. Of the modified stream segments, approximately 29% of the SHIM stream length was ditched, 24% flowed through culverts, and 9% was classified as modified.

In addition to the 168 m of culverted stream length occurring within Casa Loma Spring 4, one 6 m long, 0.10 m diameter culvert was noted to occur between Segments 1 and 2 in Casa Loma Spring 4.

Stream Channel and Hydraulic Character

The hydraulic character of the Casa Loma Springs drainage was largely described as a riffle, with approximately 61% of the 705 m stream length exhibiting riffle characteristics. The remainder of the stream length was described as other, with 60% of this stream length running through corrugated plastic pipe rather than a natural drainage pattern.

The average stream gradient within the Casa Loma Springs area was 9.4%, with a minimum gradient of 0% and maximum recorded gradient of 18%. The average bank full width of the watercourses within this area was 2.3 m.

Instream Habitat Cover/Complexity

Total and relative instream cover is a field estimate of the type and amount of in-channel cover available to fish. Total cover represents the total percentage of the wetted area of

respective segments occupied by cover. The relative abundance (%) of cover types (e.g., deep pool, large woody debris, etc.) is an estimate of the distribution (of respective cover types) within the total cover estimate for the segment.

Approximately 12% of the 705 m SHIM stream length was estimated to have a total percentage of the wetted area occupied by less than 10% cover. Instream cover recorded along Casa Loma Springs included instream vegetation, large woody debris, overstream vegetation and small woody debris. Approximately 32% of the SHIM stream length had estimated total cover between 21 and 40%. A total of 305 m, or 56%, was estimated to have instream cover between 51 and 75%, with overstream vegetation being the dominant cover type.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Recorded modification features were limited within the Casa Loma area to a wooden boardwalk which was recorded at 22 m in length and 1.2 m wide.



Photo: Photo taken of wooden boardwalk during 2003 SHIM survey.

Discharges/Waterbodies

No discharges to Casa Loma Springs were recorded during the 2003 SHIM field survey. However, a total of nine (9) natural springs were documented to occur, with seepage areas noted along the slope toe and many small springs flowing along the hillside.



Photo: Photo taken during 2003 SHIM survey of one of the many seepage areas occurring within the Casa Loma Springs drainage.

Bank Stability and Erosion

Two areas of bank erosion were noted during the 2003 SHIM field survey. Both were identified as sloughing banks with a severity in excess of 10 m^2. The total length of erosion was 24 m, or 3.4% of the SHIM stream length. Exposed soils and disturbance have led to establishment of invasive plant species.



Photo: Sloughing bank noted during the 2003 SHIM field survey of the Casa Loma area.

Fish Habitat

Fish habitat value associated with the Casa Loma spring area is limited to provision of allochthonous nutrients downstream to Okanagan Lake.

Obstructions / Barriers

No obstructions or barriers were identified within the Casa Loma Area; however, the braided nature of the springs, prohibit fish passage.

Stream Impact Summary

Table 12.48 outlines stream grades and scores for all surveyed watercourses within the Casa Loma Springs drainage.

Table 12.48 – Stream Impact Summary for Tributaries within the Casa Loma Springs Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Casa Loma Spring 1	36.8%	2.2	181.2
Casa Loma Spring 2	67%	4.0	33.9
Casa Loma Spring 3	17%	1.0	205.0
Casa Loma Spring 4	29%	1.7	284.5

Casa Loma Springs Summary and Recommendations

The Casa Loma Springs area has been identified by Larratt Aquatic Consulting as being one of the areas of greatest concern in terms of water quality due to nutrients and bacteria. As such, this area is one of the priority sites for enhancement, which should include creation of natural wetlands which can aid in biofiltration and increased attenuation. Invasive plant species have become established throughout Casa Loma Spring area wherever soils have been disturbed, and enhancement efforts should focus on removal of invasive plant species and enhancement with native riparian vegetation.

LULUWAP CREEK DRAINAGE

The SHIM field survey of Luluwap Creek was completed in 2002 and occurred over approximately 329 m of stream length between Okanagan Lake and the District of West Kelowna boundary. For the purposes of this discussion, the Luluwap Creek drainage also encompasses Kitson Spring, an ephemeral watersource which was documented as being approximately 15.4 m in length and picked up during 2003 field surveys.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

While Luluwap Creek flows through a residential area, its primary stream character was natural over 100% of the surveyed length. Kitson Spring was also classified as being 100% natural. No culverts were recorded along the surveyed stream length.



Photo: Representative photo of Luluwap Creek taken during the 2002 SHIM field survey.



Photo: Representative photo of Kitson Spring taken during the 2003 SHIM field survey.

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Stream Channel and Hydraulic Character

The hydraulic character of Luluwap Creek was described as cascade over 100% of the SHIM stream length. The average channel gradient of Luluwap Creek was 19%, while the average bank full width was 2.2 m.

Kitson Spring exhibited run hydraulic characteristics with a gradient of 8% and bank full width of 0.7 m.

Instream Habitat Cover/Complexity

Luluwap Creek had an estimated total instream cover of 90% over its stream length. While types of instream cover included boulder, deep pool, large woody debris, small woody debris and overstream vegetation, the dominant cover type was overstream vegetation. Kitson Spring was estimated to have total instream cover of 50%, consisting primarily of overstream vegetation, but also including components of large woody debris and small woody debris.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications along Luluwap Creek documented during the 2002 SHIM survey included removal of riparian vegetation along the right bank, which had occurred recently at the time of the survey. Along Kitson Spring, modifications documented in 2003 included two points of water withdrawal, one with an electric pump and one with pipes and barrels for collecting water.

Discharges/Waterbodies

There were no recorded discharges along Luluwap Creek or Kitson Spring during the 2002 and 2003 field surveys. One natural spring was documented along Luluwap Creek, while Kitson Spring was also picked up as a waterbody feature during the survey.

Bank Stability and Erosion

No points of bank instability or erosion were documented along Luluwap Creek or Kitson Spring during the SHIM field inventory.

Fish Habitat

While sampling for fish presence or absence was not within the scope of the assessment, the lower reaches of Luluwap Creek would provide default fish habitat given the surface water connection to Okanagan Lake.

Obstructions / Barriers

No barriers or obstructions were documented within the Luluwap Creek drainage during the SHIM field surveys.

Stream Impact Summary

Table 12.49 outlines stream grades and scores for all surveyed watercourses within the Casa Loma Springs drainage.

Table 12.49 – Stream Impact Summary for Watercourses within the Luluwap Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Luluwap Creek	67%	4.0	328.7
Kitson Spring	67%	4.0	15.4

Luluwap Creek Summary and Recommendations

Some modifications to stream bank as it flows through residential properties, although largely natural at time of survey (2002). While increased anthropogenic impacts could occur if best management practices for living near water are not adhered to, this system is not a priority for enhancement.

DAVIDSON CREEK DRAINAGE

The SHIM field survey of Davidson Creek (Watershed Code: 310-772800-31800) and tributaries within the Davidson Creek drainage was completed between 2001 and 2002. The Davidson Creek drainage has experienced anthropogenic impacts associated with water diversion practices and urban development. The surveyed length of streams within the Davidson Creek drainage total approximately 5.2 km, including 2.5 km of Davidson Creek. Tributaries surveyed include Davidson Creek 1, Davidson Creek Tributary 1, Davidson Creek 1 Tributary 1, Davidson Creek 1 Tributary 1-1, Davidson Creek 2, Davidson Creek Overflow, Davidson Creek Tributary 2 and Davidson Creek Tributary 2-1.

Components of stream segment attributes are discussed and watercourse and habitat features are analyzed and summarized in the following paragraphs.

Stream Primary Character

Only 14% of the surveyed stream length of Davidson Creek remains in a natural state, occurring in Segments 1, 3 and 5. A further 8%, or 204 m, of stream length was characterized as modified. The remainder of the 2.5 km, accounting for 78% of the stream length was culverted.

Approximately 2.7 km of tributaries within the Davidson Creek drainage were surveyed, with over 77% of the stream length characterized as being natural. There was 12% of the stream length which had been ditched, nearly 2% had been confined to a culvert, and a further 9% was modified to some degree. Tributary streams are ephemeral, with lower reaches showing little evidence of flow during the field survey. However, upper reaches of tributary streams flow intermittently, primarily during the spring.

Of the 5.2 km of stream length surveyed within the Davidson Creek drainage, 41% of the stream occurs within culverts. In addition to the 1.9 km of Davidson Creek which has been culverted, there were 12 other culverted sections of stream documented, accounting for approximately 2.1 km of stream length.



Photo: Looking upstream towards 1.9 km culverted segment of Davidson Creek.

Stream Channel and Hydraulic Character

The hydraulic character of Davidson Creek was described as 12% riffle/pool, 5% run and the remaining 83% had no recorded hydraulic character. This is primarily a result of the culverted stream segments. Watercourses within the Davidson Creek drainage exhibited various hydraulic characteristics. Approximately 52%, or 1.4 km, of the stream length was described as a cascade, while 11% exhibited run morphology, 3% riffle and 2% riffle/pool. A further 31% did not have hydraulic character information, again likely due to the stream being confined within culverts.

Davidson Creek has an average stream gradient of 2%, ranging from 0 to 4%. The average bank full width of Davidson Creek was 3.1 m, with a maximum recorded bank full width of 12 m. Davidson Creek Tributaries had steeper gradients, with an average of 19% and a maximum of 45%. The average bank full width was 0.8 m.

Instream Habitat Cover/Complexity

Approximately 83% of the SHIM stream length of Davidson Creek was described as having 0% structural instream cover for fish habitat. Segment 2 had estimated total cover in the form of instream vegetation of 20%, accounting for 8% of the SHIM stream length. Approximately 4% of the stream length was estimated to have total cover of 40%, consisting of instream vegetation, large woody debris, and overstream vegetation. Only Segment 3 exhibited cover between 51 to 75%, accounting for 5% of the total stream length and consisting exclusively of instream vegetation.

Davidson Creek tributaries were documented to have approximately 27% of the 2.7 km of stream length with 0% instream cover. Approximately 24% of the stream length had estimated cover of 20%, consisting of overstream vegetation, small woody debris, and undercut banks. Over 1 km of stream length had estimated total instream cover between 21 and 40%, accounting for 37% of the tributary stream length. Instream vegetation and overstream vegetation were the dominant cover types noted. The only tributary reaches with cover exceeding 51% occurred in Davidson Creek 2, where cover was estimated at 60%, accounting for 11% of the total tributary stream length.

Watercourse and Habitat Features

The following section summarizes feature data collected and nested within the line segments. All features are measured and recorded individually and provide a more robust and quantitative measure of watercourse impairment and habitat quality.

Modifications

Modifications within the Davidson Creek drainage consisted of three water withdrawals associated with irrigation ditches and one well. A water outlet was documented along the right bank described as discharge from McDougall Creek. A detention pond and concrete barrier was documented which diverted water to a pump station. A second old pump station was noted to occur along the surveyed stream length of Davidson Creek. The only bridge documented was a golf cart bridge approximately 5 m long by 2.5 m wide.

Discharges/Waterbodies

Discharges to Davidson Creek documented during the SHIM field survey included four PVC storm drains, three of which were located in the same location. Diameters of discharges ranged from 0.1 to 0.2 m.

Bank Stability and Erosion

Erosion due to a lack of riparian vegetation was documented along Davidson Creek and its tributaries totaling 15 m along both the right and left banks. Down-cutting was noted to be occurring throughout the entire segment, resulting in exposure of clay banks. Erosion within the Shannon Lake Golf Course is largely attributed to lack of riparian vegetation.

Obstructions / Barriers

Obstructions with the potential to prevent the normal passage of fish during all or part of the year were documented along Davidson Creek. A concrete dam with a height of 1 m occurs approximately 212 m upstream from the SHIM starting point, located in Shannon Lake Golf Course. A 1.2 m high perched culvert was documented between Segments 3 and 4, which was also noted as a potential obstruction to fish passage.



Photo: Looking upstream towards the concrete dam occurring within Shannon Lake Golf Course that poses a potential obstruction.

Stream Impact

The sum of weighted SHIM scores equaled 0.5 (out of 6), with Davidson Creek receiving a stream grade of approximately 8.2% (Figure 12.9). Over 78% of the stream length received a score of 0, indicating high impacts along both banks.

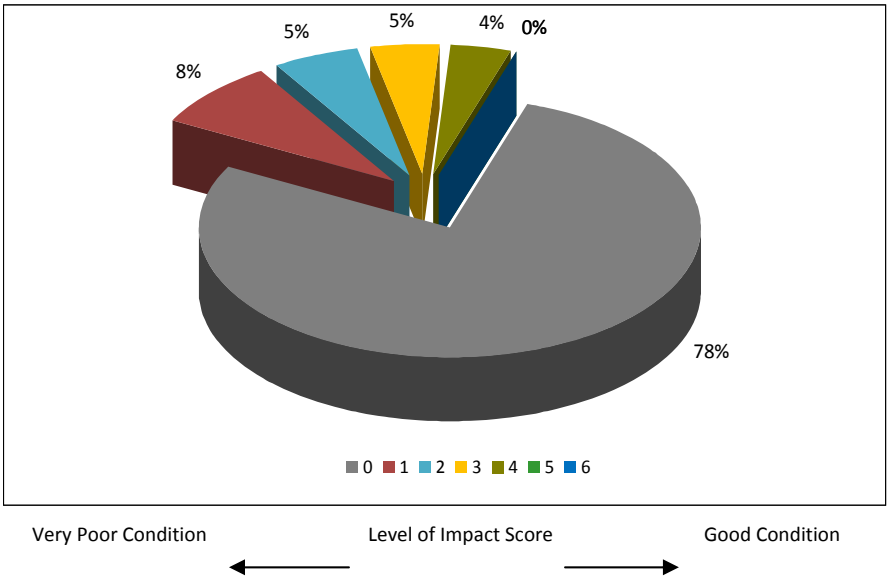


Figure 12.9. Davidson Creek summary of Level of Impact. Values shown above are based on SHIM field inventory and analysis of ~2.5 linear km of Davidson Creek within the District of West Kelowna.

Table 12.50 outlines stream grades and scores for all surveyed watercourses within the Davidson Creek drainage.

Table 12.50 – Stream Impact Summary for Tributaries within the Davidson Creek Drainage

Stream	Stream Grade (%)	Weighted Score (0-6)	Stream Length (m)
Davidson Creek	8.2%	0.5	2489.0
Davidson Creek 1	100.0%	6	111.8
Davidson Creek 1 Tributary 1	100.0%	6	917.8
Davidson Creek 2	79.5%	4.77	308.0
Davidson Creek Overflow	27.0%	1.62	100.7
Davidson Creek Tributary 1	16.7%	1	82.5
Davidson Creek Tributary 2	44.0%	2.64	481.2
Davidson Creek Tributary 2-1	100.0%	6	604.0

Davidson Creek Summary and Recommendations

- Primary channel impacts include culverts and water diversion with urban development.

- Erosion occurs throughout Shannon Lake Golf course due to a lack of riparian vegetation.
- The stream has been culverted extensively upstream of Shannon Lake Road.
- Establishment of a riparian buffer within Shannon Lake golf course.

12.4. WATERCOURSE EVALUATION SUMMARY

The following section is a stream condition and habitat rating summary for all streams surveyed during the DWK SHIM project initiative and updated DWK Storm Water Management Plan. Data was originally collected between 2001 and 2003 by RDCO and subsequently summarized by Ecoscape in this inventory catalogue. Ecoscape revisited many of the watercourses based on local knowledge of watercourse changes and development activity that has occurred since the original survey was completed. While areas throughout the DWK were revisited during this project, data collected is not sufficient to provide an inclusive update of SHIM data. The DWK has undergone substantial development since the original SHIM survey and it is recommended that detailed SHIM of each watercourse be repeated. This will allow an additional snapshot in time which can reflect the current state of watercourses within DWK leading into the next decade. A more robust quantitative comparison between survey years can then be completed and will allow for evaluation of where improvements or further impairments have occurred.

Table 12.51 provides an overview of primary streams surveyed, which is discussed at greater depth below. Prioritization for restoration and enhancement efforts as well as conservation, are based on the existing habitat condition and habitat potential. Habitat ratings were assigned primarily on aquatic habitat values. However, while some watercourses may receive a relatively low habitat rating, their intrinsic value should not be overlooked. Many of these ephemeral riparian gullies support or have the potential to support high biodiversity values in an urban and sub-urban context. Recognizing this, efforts should continue to protect and restore associated riparian, transitional, and wetland sites along these watercourses regardless of aquatic habitat values.

Watercourses such as Smith Creek have fisheries value, but have been severely impacted and are in need of rehabilitation and improvements in storm water management practices. Streams such as McDougall Creek and Keefe Creek are fisheries streams, which have been impacted to a lesser degree, but are under ongoing development pressure and must be prioritized for implementation of conservation efforts and enforcement of Best Management Practices both for development and stormwater management. As these larger watercourses traverse across both District of West Kelowna and Westbank First Nation land, it is paramount that future land-use and drainage planning involve collaboration between governing bodies.

Table 12.51 – Stream/Watercourse Impact Habitat Condition/Potential Summary

Stream	Impact/Condition Score (%)	Habitat Value/Potential Score	Rank (Condition (%)/Habitat Score)
Davidson Creek	0.082	0.25	0.33
Smith Creek	0.338	0.70	0.48
McDougall Creek	0.525	0.80	0.66
Keefe Creek	0.538	0.60	0.90
Powers Creek	0.880	0.90	0.98
Drought Creek	0.720	0.50	1.44
Law Creek	0.762	0.50	1.52
Luluwap Creek	0.667	0.40	1.67
Bowen Creek	0.517	0.30	1.72
Faulkner Creek	0.275	0.15	1.83
Casa Loma Spring	0.368	0.20	1.84

Highlighted watercourses are those with moderate to very high habitat potential which are currently highly impaired by Urban Stream Syndrome.

Very High Habitat Rating (0.76-1.0) was assigned to streams where high-value spawning or rearing habitats were recorded or have the potential to occur with appropriate restoration (eg. Locations with abundance of suitably sized gravel, deep pools, undercut banks, stable large woody debris and well-vegetated, natural riparian area).

High Habitat Rating (0.51-0.75) was assigned to watercourses with suitable spawning habitat and a moderate rearing potential for fish species present. These systems may also have higher gradients (limiting the availability of higher quality spawning and production capacity) in conjunction with smaller catchment areas.

Moderate Habitat Rating (0.26-0.50) was assigned to watercourses without suitable spawning habitat and having low rearing potential (eg. Locations with highly modified banks, lacking in fish habitat features). A moderate habitat rating may have been assigned to watercourses which remain in a relatively natural state with limited anthropogenic impacts, although fisheries value may be limited due to ephemeral drainage.

Low Habitat Rating (0-0.25) was assigned to ephemeral, intermittent and discontinuous watercourses/drainages. A low rating may also be assigned to streams that have been intensively modified.

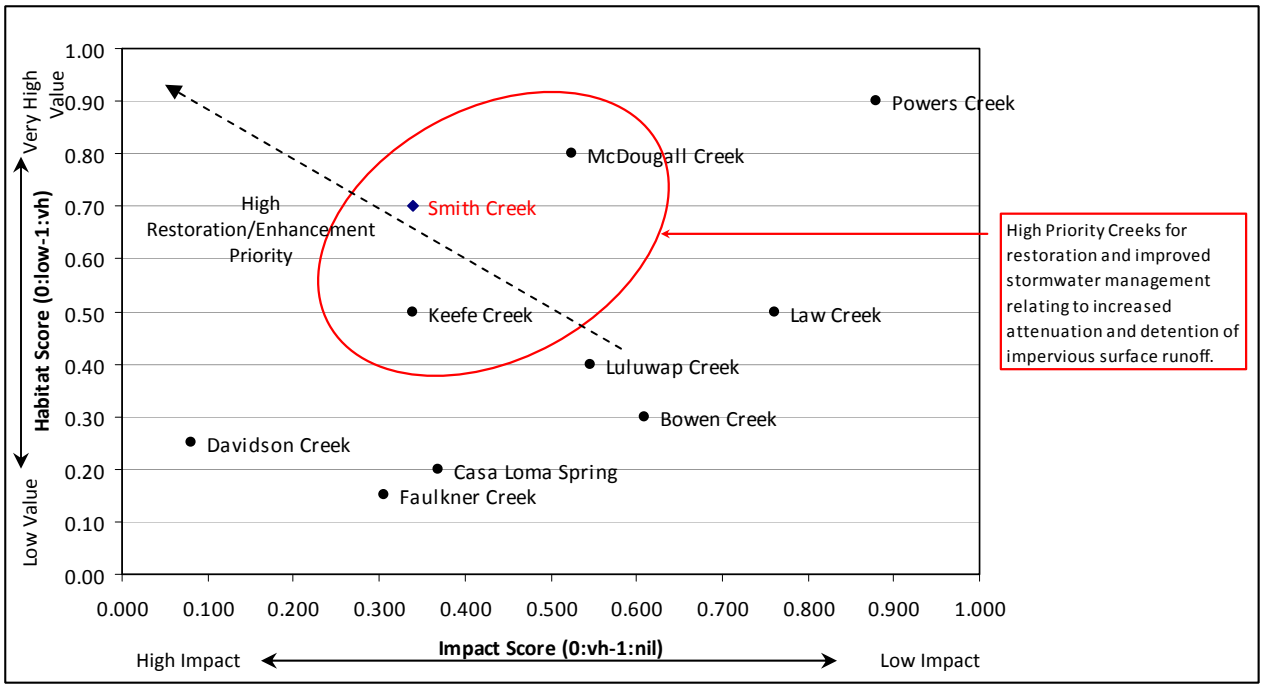


Figure 12.10. Stream impact scores against aquatic habitat ratings/potential for the primary watercourses occurring in the District of West Kelowna.

In addition to Smith, McDougall and Keefe Creeks, watercourses identified as priorities for restoration and enhancement include the Casa Loma Spring and Bowen Creek drainages. Both of these systems, along with Smith Creek at Okanagan Lake, were identified by Larratt Aquatic Consulting as areas of greatest concern for water quality associated with nutrients and bacteria (H. Larratt, personal communications).

Powers Creek was identified as having the highest habitat score accompanied by the most favourable impact score. That being said, it is critical to preserve and restore wetlands in the upper Glenrosa area and maintain and enhance existing riparian habitat along Powers Creek and its tributaries to reduce and control sediment and deleterious inputs to Powers Creek.

Restoration and Enhancement Opportunities

Restoration and enhancement opportunities along priority watercourses within the District of West Kelowna should focus on the following objectives, which will realize benefits to stormwater management, fisheries and wildlife habitat, water quality, air quality and community aesthetics:

- Increased biofiltration via creation and integration of wetlands, vegetated swales, maintenance and enhancement of well-vegetated riparian buffers along streams and wetlands, and incorporation of green infrastructure into new development and community planning such as rain gardens (vegetated depressions within the cityscape for retention and treatment of runoff), rain barrels/cisterns, green roofs (vegetated) and green streets (swales or rain gardens where storm water is directed to vegetation) [3].

- Infiltration and filtration of storm runoff prior to discharge to local streams, rather than the current influx of high volumes of surface runoff associated with increased impervious surfaces and direct discharge.

- Reduced stormwater runoff and peak flows.

- Increased groundwater recharge

One of the primary issues identified is the increasing impervious surfaces and associated runoff which directly contributes pollutants and increased water volumes to local watercourses. This is most evident in Smith Creek, where severe down-cutting of the stream banks has occurred, resulting in erosion, increased sedimentation and impairment of fish habitat and water quality. As Smith Creek flows along Gellatly Road, erosion has increased in severity in the past year, resulting in sedimentation, loss of riparian habitat and potential instability of Gellatly Road. Smith Creek is currently highly impaired and does not appear to have the capacity to handle the influx of stormwater. The ongoing degradation of this watercourse is having severe impacts on both the habitat and water quality along the stream corridor and within Gellatly Bay of Okanagan Lake. In addition to impaired aquatic ecosystem function along the Smith Creek corridor and within Gellatly Bay, persistent poor water quality within this drainage is resulting in negative aesthetic impacts and health concerns relating to pathogens.

Smith Creek downstream of Highway 97 should be reviewed as a priority site for restoration and enhancement. Previous works within the municipal park should be renovated from recent high flow deterioration and expanded upon, including wetland creation, potential channel reconstruction where severe down-cutting has occurred and riparian restoration. Mitigating the existing barrier to fish passage within 155 m upstream from the confluence of Okanagan Lake should also be a goal which would allow greater access to spawning kokanee. Habitat restoration at the confluence of Smith Creek and Gellatly Bay should also be considered, although upstream water quality

[3] Environmental Protection Agency. 2010. Green Infrastructure in Arid and Semi-Arid Climates. Available online: www.epa/gov/ow/eparecovery. Pp 9.

issues should first be addressed for instream habitat enhancement to be of value. Nevertheless wetland and additional biofiltration at the confluence of Smith Creek with Okanagan Lake may afford some water quality benefits before the creek discharges into the lake.



Photo: Taken in 2010 of Smith Creek as it flows along Gellatly Road upstream of Okanagan Lake. Note that channel down-cutting exceed 1 m in places; attributed to increased flows over large impervious areas.

McDougall Creek has the potential for salmonid spawning enhancement in its lower reaches downstream of Old Boucherie Road. The stream is channelized along Hitchner Road and sand berms and lack of riparian vegetation are contributing to erosion and sedimentation. While the creek is confined by agriculture and Hitchner Road, stream banks should be re-vegetated and native vegetation planted to provide a riparian buffer and bank stability. A series of rock weirs and deposition of clean spawning gravels could be installed to provide opportunities for kokanee and rainbow trout. Additionally, stormwater retention and treatment, maintenance and creation of vegetated riparian buffers and minimizing anthropogenic impacts adjacent the stream should be a priority along McDougall Creek and throughout the watershed.

The Casa Loma Spring drainage area is a prime candidate for wetland creation and riparian enhancement which would help to address water quality and habitat issues. Removal of invasive plant species from disturbed areas within the Casa Loma drainage should also be incorporated into enhancement initiatives. Creation of a natural wetland or series of wetlands within this area will provide wildlife habitat value and has aesthetic benefits to the community.

The Bowen Creek drainage includes several segments of stream which have been ditched along roadsides or through agricultural areas. It is recognized that removal of cattails from roadside ditches is common maintenance practice due to accumulation of biomass and potential impairment of drainage function. However, staging clearing such that patches of vegetation are left to function essentially as check dams to promote filtration and infiltration may be beneficial to both water quality and habitat. Clearing of cattails should be timed to avoid disturbance or harm to nesting bird species, such as red-winged blackbirds. Clearing should generally not occur between April 1 and July 30. Where Bowen Creek flows through residential or agricultural areas, native vegetation should be planted and maintained to create a riparian buffer.

12.5 CLOSURE

This report has summarized detailed field inventory data collected during SHIM surveys conducted in 2001, 2002 and 2003 within the District of West Kelowna. The collection and management of data conformed to the SHIM methodology, which is a standard for fish and aquatic habitat mapping in urban and rural watersheds in British Columbia.

The 2009/2010 inventory included updating areas with known stream changes, and identification of priority areas for restoration and enhancement initiatives. This project has resulted in a baseline catalogue of watercourse and habitat features occurring within respective watercourses, which has numerous applications and can be used by the community, stewardship groups, individuals, and the District, as well as senior regulatory agencies. In maintaining the integrity of this SHIM database, periodic field inspections should be carried out to update watercourse and habitat feature mapping.

The inventory that has been summarized within this report was commissioned by and prepared for the District of West Kelowna. The collection, processing, and management of data have conformed to SHIM standards. No other warranty is made, either expressed or implied.

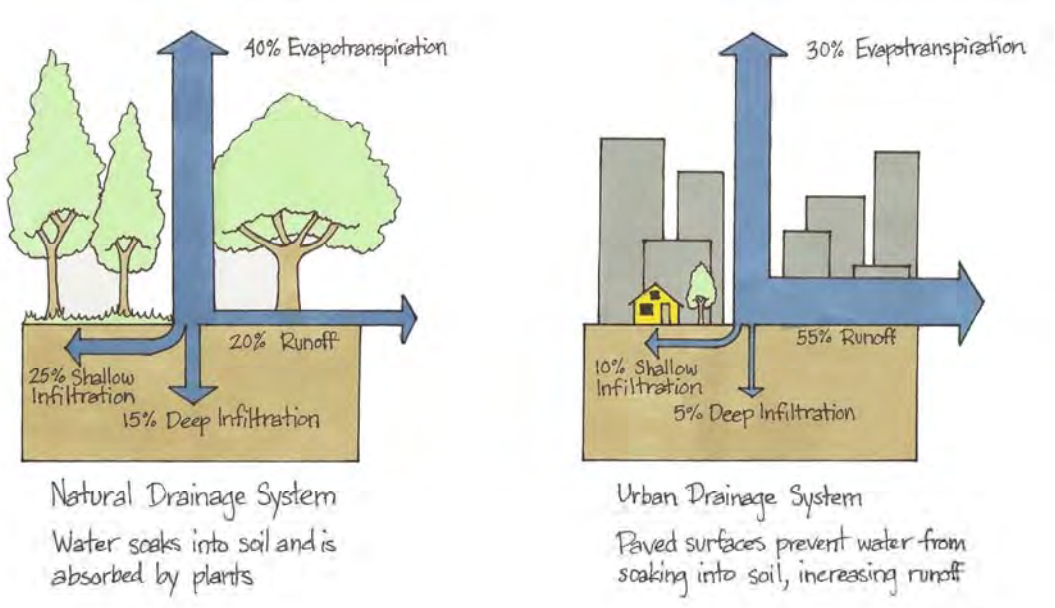
SECTION 13
WATER QUALITY

13.1 INTRODUCTION

Like many urban areas, stormwater in the Okanagan region routinely carries large loads of hydrocarbons, chemicals released from the paving materials, road salt, pathogens, detergents and landscaping chemicals including fertilizer and pesticides. It may also carry other contaminants when people illegally dispose of materials down storm drains. Resolving water quality issues is complicated by runoff volumes. Both the total runoff volume and the peak storm flow increase with urban roads and roofs (Figure 13.1).

Very little rain water is retained on urban properties in District of West Kelowna. In a modest 1cm rainfall, a single home roof will generate 2600 litres of stormwater and a city block 150 m long by 10 m wide will produce 15,000 litres. As this study shows, Okanagan stormwater quality is impacted by roadway run-off, agricultural drainage and animal feces. Even after DWK stormwater mixes with creek flows, contaminant concentrations are high enough to impact stream life and ultimately impact Okanagan Lake.

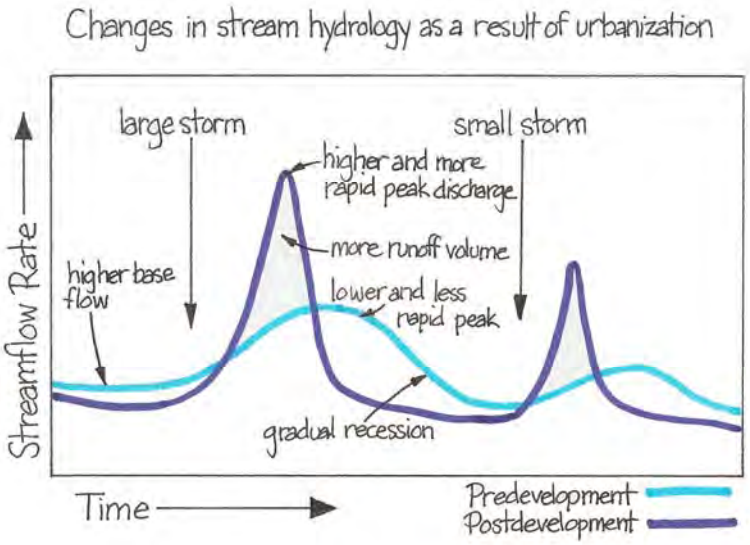
Figure 13.1: Stormwater Distribution in Natural and Urbanized Drainage Systems



Urban impervious surfaces (driveways, walkways, roofs) skew the drainage system from the natural 40% infiltration / 20% runoff to the urban 15% infiltration / 55% runoff, with expensive consequences in stormwater management (Figure 13.1).

The increased volume of stormwater also hits water courses in shorter, larger peaks from urban areas (Figure 13.2).

Figure 13.2: Urban Stream Hydrology; Powers Creek Inflow Plume





Stormwater treatment is complicated by the several orders of magnitude changes in flow and water quality within hours of a storm. Currently there is no water chemistry treatment of stormwater in the Okanagan beyond the naturally occurring filtration performed by riparian areas and ground infiltration, and a few stormwater detention wetland ponds. Even the existing filtering capacity of riparian areas is often damaged by urban stormwater. The recently deployed stormwater contact units are basically gravel and oil traps and are not designed to improve overall water chemistry or provide disinfection.

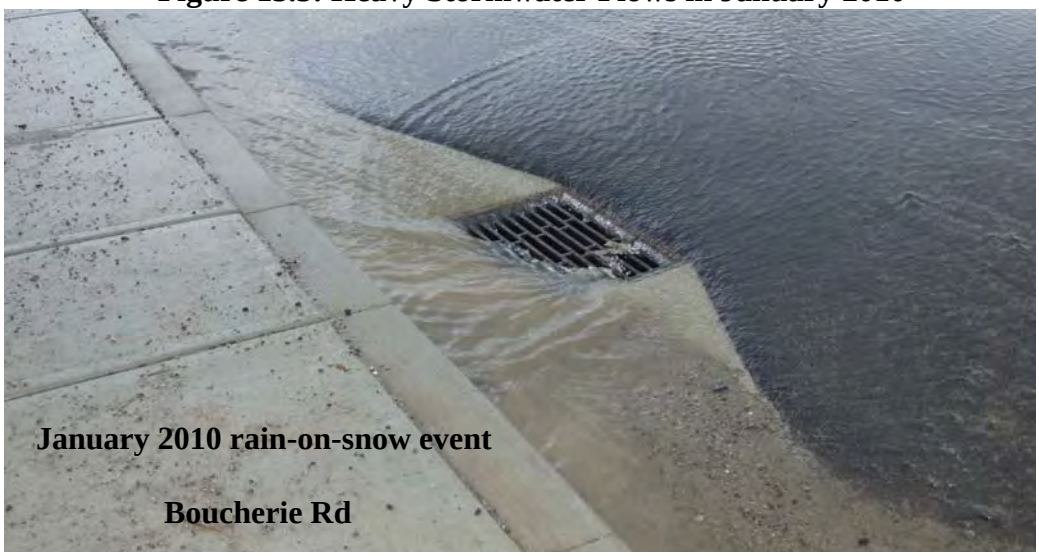
Most streams convey stormwater after they pass through an urban area in the Central Okanagan. Stormwater-laden creek flows enter Okanagan Lake and form plumes (Figure 13.2). A surface flow of buoyant debris is often visible following a storm but the travel path of the plumes is more complicated. If the particulate load is heavy during the initial flush of rain washing materials off the streets into the stormwater, then the inflow can form a density plume that travels along the lake bottom like a dirty cloud. During the summer, the stormwater plume should be trapped by the thermocline and remain in the surface water. It will often travel parallel to the shore dropping large particulates quickly while finer particulates and bacteria will travel further. During the non-stratified winter period, stormwater can form a deep pool in front of the outfall or creek and travel as a packet of water, diluting as it moves with water currents.

These stormwater packets are the most immediate potential source of contaminants to domestic water intakes including WFN#9, Shanboolard and Sunnyside intakes. Both Smith Creek and Powers Creek discharge into Gellatly Bay – a key summer destination adjacent to these intakes - and both of these creeks are currently degraded by stormwater.

Excess nutrients carried in by stormwater stimulate algae in the vicinity of the stormwater outfall or creek. The increased growth can become attached periphyton slimes or planktonic algae blooms and include cyanobacteria, creating a localized risk. Nutrient enriched halos along Okanagan Lake were often encountered around stream mouths that convey stormwater in the Central Okanagan. These halos were marked by significantly increased algae growth with its characteristic odors.

A lake is always a reflection of its watershed. With increasing urbanization within the Central Okanagan, stormwater is now a key component of that reflection in Okanagan Lake.

Figure 13.3: Heavy Stormwater Flows in January 2010



Examples of turbid and clear stormwater during rain-on-snow event



13.2 STUDY DESIGN

Three parameters were selected to indicate the impact of stormwater quality on receiving drainages in District of West Kelowna (DWK) and ultimately on Okanagan Lake. Each one acts as an indicator for a class of contaminants:

Nitrate indicates the nutrient loading from lawns, gardens and agricultural areas.

Chloride is a persistent constituent of salt and indicates road salt and septic contributions.

E. coli are a group of bacteria that indicate fecal contamination from livestock, pet and avian feces near roads and from damaged septic fields.

There are literally hundreds of other parameters that could be studied in DWK stormwater. This trio of analyses was chosen because it identifies stormwater quality problem areas and is cost-effective. A stormwater monitoring program should be financially sustainable because long-term data for a limited parameter set provides a better indication of change than intermittent, detailed sampling. There are relatively inexpensive Hach-kit or field probes that could be purchased and used by DWK staff for nitrate, chloride and turbidity but bacterial parameters are best sent to an accredited lab.

13.3 SAMPLING

District of West Kelowna stormwater samples were collected from three seasonal / flow regimes:

November 26 2009: fall rain event - small storm during mild, dry weather

January 11 2010: rain-on-snow event - high flow rates and most samples were turbid

April 12 2010: no rain, during a light freshet – low flows and low turbidity

Sample sites were selected from major drainages and known problem areas in DWK. Additional sample sites were added in January based on the November results. The conditions in April were much drier than normal and several sites had no flow (11-2 Boucherie Rd at Tuscany Villa; 11-3 storm drain in Bowen Ck ravine). An additional sample was collected in April from the seepage along West Kelowna Estates, Parkinson Road.

One of the Bowen Creek sub-channels is ditched along Boucherie Road and travels through the Quail's Gate property before entering Green Bay via a broad, braided

channel. Because there is interest in using this water for irrigation, more detailed sampling was conducted at this location and is reported in section 13.5 of this report.

Figure 13.4 shows the sampling points used in this study. GPS of the sampling points is contained in Appendix 13.3.

13.4 WATER QUALITY SAMPLING RESULTS FOR INDICATOR PARAMETERS

Stormwater samples from the District of West Kelowna showed diverse water chemistry, depending on the human activities and natural flows in the area. Results for the selected stormwater chemistry parameters are presented in this section. The full data set for the three indicator parameters is graphed in Figure 13.5 (see also Appendix 13.1).

Figure 13.4 - Water Quality Sampling Point Locations

Project:	Sensitive Habitat Inventory and Mapping Update
Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	December, 2010

Meters 1,000 500 0 1,000 2,000

1:75,000

N W E S

SOURCE INFORMATION

Base Map:	82E
Orthophoto:	Province of British Columbia
Waterbody Information:	District of West Kelowna Streams
Location Information:	Field, GPS (Trimble GeoXT)
Feature Information:	Airphoto and Topographic Estimate Field Inventory (RDCO SHIM)
Date of Inventory:	2001-2003
Inventory Management:	Brent Magnan

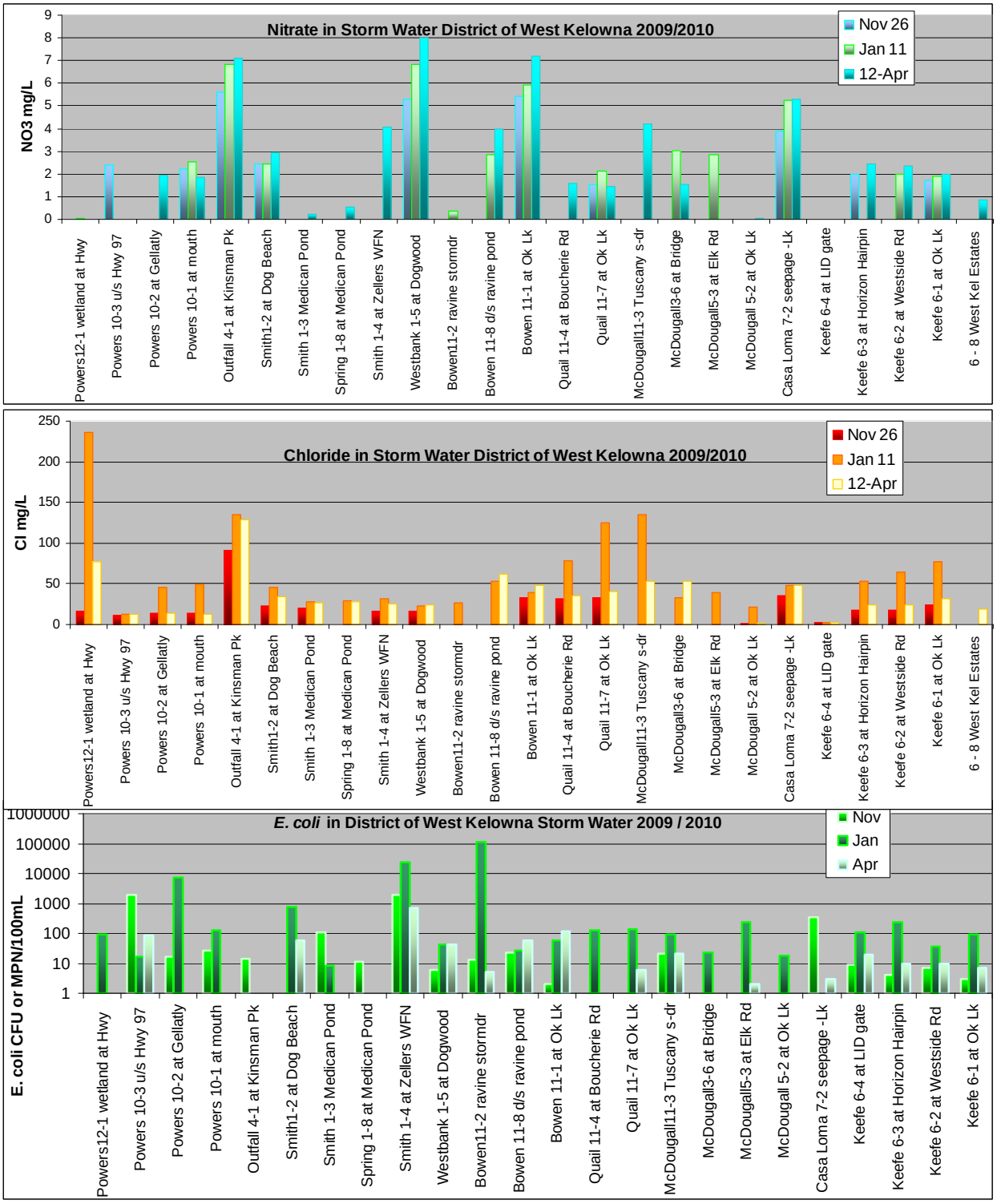
LEGEND

- Water Quality Sampling Locations (Summer, 2010)
- Stream
- District of West Kelowna Boundary
- Smith/Tomat Creek Drainage Index
- Davidson Creek Drainage Index
- Powers Creek Drainage Index
- McDougall Creek Drainage Index
- Luluwap Creek Drainage Index
- Law Creek Drainage Index
- Faulkner/Keefe Creek Drainage Index
- Drought Creek Drainage Index
- Casa Loma Spring Drainage Index
- Bowen Creek Drainage Index

ECOSCAPE Environmental Consultants Ltd.

DISTRICT OF WEST KELOWNA

Figure 13.5: Nitrate, Chloride and E. coli in DWK Stormwater



NOTE: Logarithmic scale for *E. coli*; Site numbers were derived from Basin numbers within the RDCO Westside Master Drainage Plan, 1999

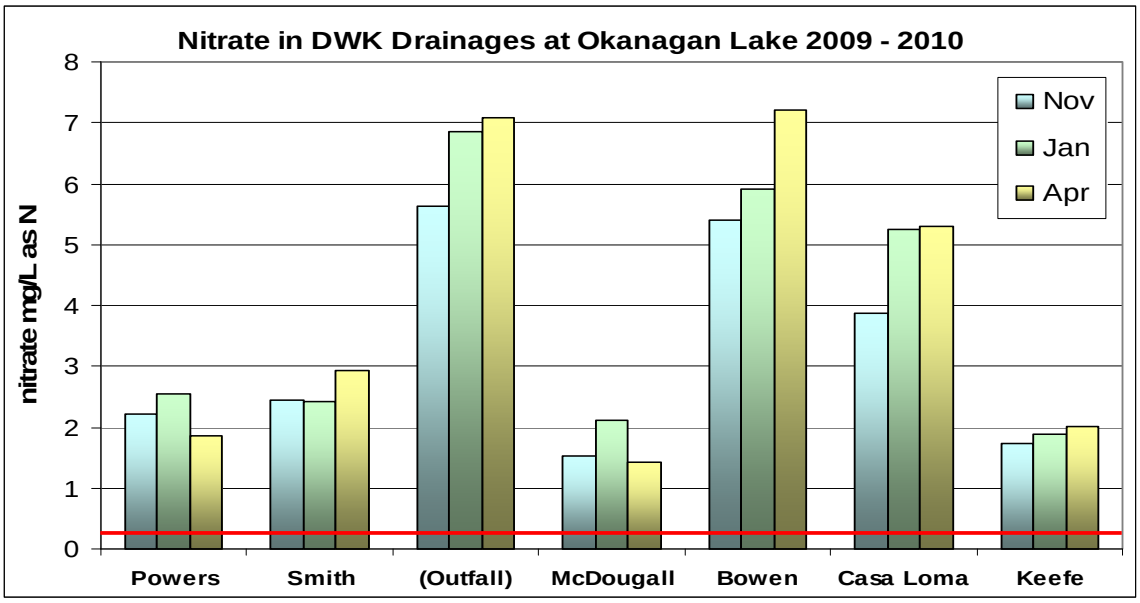
Nitrate

The major drainages in DWK showed escalating nitrate concentrations as the creeks received more and more stormwater before discharging to Okanagan Lake. Nitrates increased significantly as flows traveled through agricultural or residential areas. Many of the sites with high nitrate concentrations in the November sample set were also high in the January and April sets. While all of the sample sites showed nutrient enrichment from either agriculture or urban areas, a low-flow outfall, Bowen Creek and the Casa Loma springs/seepage had very high nitrate concentrations in all three sample sets (Figure 13.6). These drainages may be picking up nitrates from old septic fields or from orchards.

At the time of sampling, both McDougall and Keefe Creeks had riparian areas capable of removing nutrients and they had the lowest nutrient concentrations on all three sample dates (Figure 13.6, 13.7). Unfortunately, both were damaged after the sampling concluded. Several large areas of the McDougall riparian buffers have been stripped back to 15 m or less during 2010 to allow for subdivision development and an automotive repair centre within WFN jurisdiction. A boat storage facility within WFN jurisdiction punctured LID's main water line in summer 2010 and the flows were diverted to Keefe Creek where they caused extensive siltation. Both streams may now have reduced capacity to filter nitrates.

Figure 13.6: DWK Creek Discharges to Okanagan Lake with Stormwater Influence

Nitrate mg/L	Powers	Smith	(Outfall)	McDougall	Bowen	Casa Loma	Keefe
Nov	2.21	2.45	5.63	1.52	5.41	3.88	1.73
Jan	2.55	2.43	6.85	2.12	5.91	5.24	1.88
Apr	1.86	2.92	7.09	1.43	7.21	5.29	2.01



NOTE: Red line is Okanagan Lake average nitrate concentration

In all creek systems except Smith, the upland reaches had low nitrate concentrations (<0.01 – 0.05 mg/L as N) while the lower reaches showed nutrient enrichment as stormwater collected nutrients off lawns/gardens, agricultural areas and possibly septic fields (Figure 7). Smith Creek begins as a spring in the Ruffli Rd area - an area with low intensity animal husbandry, agriculture, a plant nursery and septic fields. Residents report that a pig farm was located in the area prior to subdivision and the smell of pig manure is unpleasant if they dig deeper than the fill layer in their yards. The resulting nitrate concentrations are extremely high, ranging from 5.2 to 8.0 mg/ nitrate as N. A

gravel extraction / silt–infill operation commenced operation in the draw on upper Ruffli Road after the sampling was completed. Blasting residual from this operation can further increase nitrogen concentrations.

At the interface with Okanagan Lake, creeks in DWK carrying stormwater ranged from 1.52 to 7.21 mg/L nitrate as N (Figure 13.5). This range is very high and contributes to a "halo" of enriched algae growth around the mouth of these creeks. This nutrient-rich halo was particularly evident on Smith Creek at the Dog Beach where the filamentous algae *(Spirogyra/Mougeotia)*) generated a pungent skunky odor during the spring and summer. A cyanobacteria bloom led by *Anabaena* (also *Aphanizomenon flos-aquae*, *Dichothrix, Scytomena*) was detected here in October, and November 2009 as part of this study (Appendix 13.4). Cyanobacteria blooms can produce toxins as they decay.

MoE data gives a range of total nitrogen of 0.13 – 0.35 mg/L as N for Okanagan Lake. Creeks within the DWK carried 4 – 21 times the upper range of nitrate expected in Okanagan Lake and are therefore a significant source of nutrient enrichment. The International Lake Environment Committee lists the risk of eutrophication on Okanagan Lake as "serious". Of the tons of nutrients entering Okanagan Lake every year, the majority will arrive via creeks and outfalls (MoE database).

Soluble nutrients are usually not effectively removed in stormwater ponds that rely on sedimentation only. Nutrient removal from stormwater can be accomplished in cattail wetlands designed for that purpose, but these systems require large tracts of low-slope land – definitely a premium commodity in West Kelowna.

Chloride

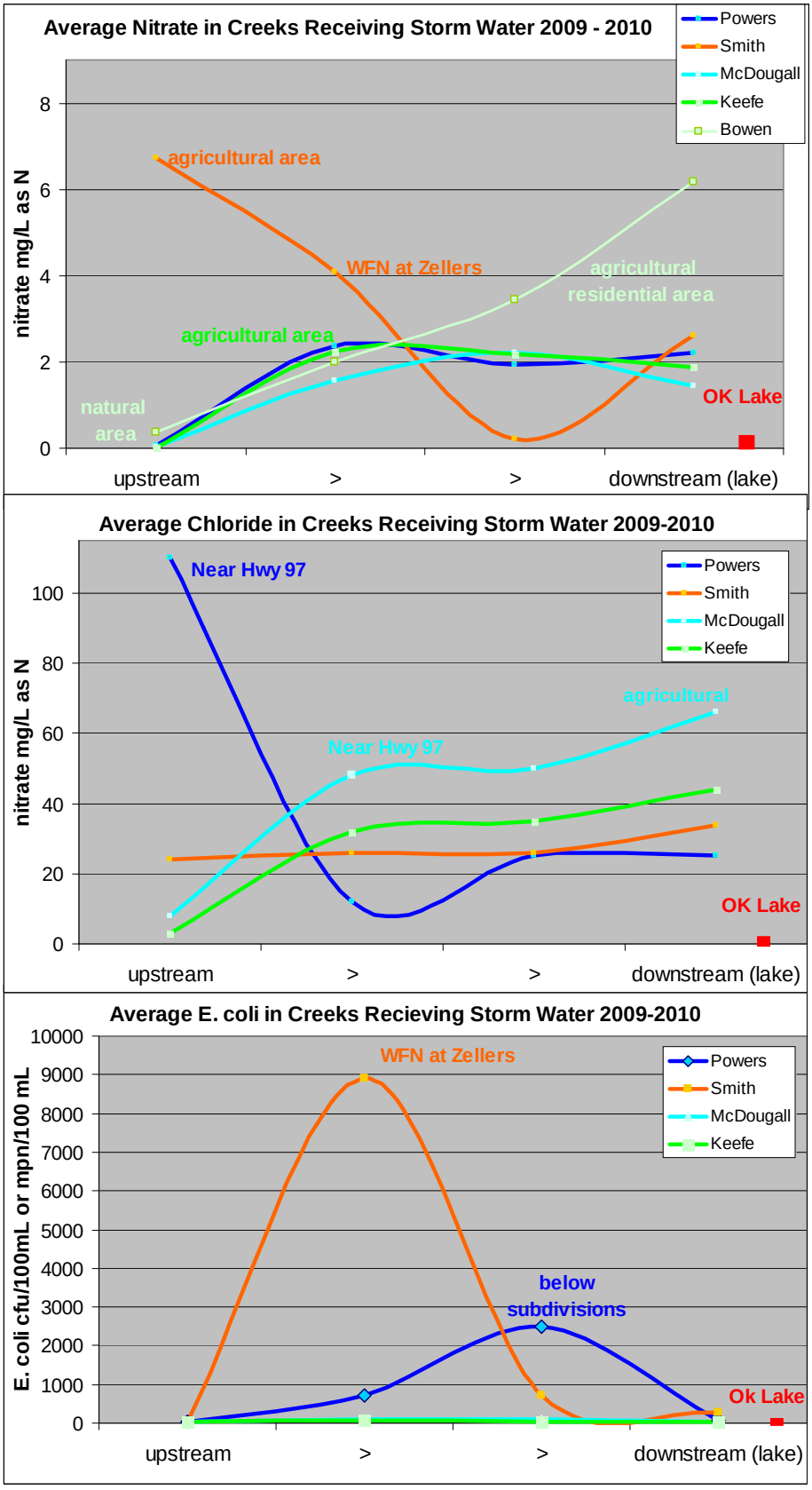
Chloride is an urban stormwater contaminant that is contributed primarily by winter road salting and sanding (Baker, 2007). Other sources of chloride include residential use of de-icers and fertilizers. In this study, chloride concentrations increased where run-off from Highway 97 entered a drainage system. Other roads in West Kelowna did not contribute the salinity that flows off the highway did. As expected, the winter samples showed higher chloride concentrations from road salt than fall or spring samples (Appendix 1). January samples with very high chloride concentrations include Hwy 97 drainage to Powers Creek at 236 mg/L Cl- and the storm drain on Boucherie Rd / Tuscany Villa at 135 mg/L Cl- .

Chloride is challenging to treat in stormwater. It is a conservative ion that seldom participates in chemical reactions compared to other ions, but it also is not as harmful to the environment for the same reason. In this study, chloride was used as a "marker" for

more harmful metal ions such as sodium and zinc. In most cases, metal concentrations correlated with chloride (Appendix 13.1 Figure 1).

Saline flows from Hwy 97 should not discharge directly into creeks with low winter flows wherever possible. While wetlands are better than most ecosystems at retaining metals, they can only perform limited removal when stormwater retention times are a matter of hours or less. Large wetland facilities would be ideal but impractical to intercept Hwy 97 flows in DWK. Sediment-bound metals can be removed in small stormwater ponds that have sufficient capacity to allow sand and silt to settle out. A pond's removal of salt and metals will be enhanced when a sedge component can be planted. Sedges have a high salt tolerance and withstand both flooding and drought.

Figure 13.7: Average Parameters in Creek Systems, District of West Kelowna



Bacteria

Escherichia coli are a species of bacterium normally present in intestinal tract of humans and other warm-blooded animals. While most *E. coli* strains are harmless, a few are pathogenic, but the presence of these bacteria indicates possible contamination with other pathogenic bacteria that are harder to test for. *E. coli* are often used to detect fecal contamination of water. DWK stormwater sites with high *E. coli* counts are identified below. They should be investigated and remediated to prevent the potential for illness.

E. coli counts were low (20 – 40 cfu/100 mL) for raw water in the upper reaches of every creek system of West Kelowna (Figure 13.5, 13.7). Once the drainage system received run-off from urban paved areas, *E. coli* counts climbed.

Urban stormwater routinely carries pet and bird feces and may include human *E. coli* if septic systems do not perform properly, such as may be the case in the Bowen Creek ravine immediately below Boucherie Rd. City of Kelowna conducted *E. coli* typing and found human *E. coli* in creeks after they received stormwater. The suspected source of the human *E. coli* was malfunctioning septic systems. They also documented an apparent drop in canine (dog) *E. coli* from 2006 to 2008 that may be the result of a campaign to get owners to pick up after their pets (Appendix 3). *E. coli* typing should be considered for the sites where *E. coli* were consistently high, including the Tomat Creek discharge to Smith Creek.

Bacterial numbers were very high at urbanized sites in the January samples despite low temperatures (Figure 13.7). By observation, fewer pet owners pick up dog feces in the winter. In contrast, bacterial numbers were generally moderate in April. Pet feces have been noted on streets throughout district, and especially at the Smith Ck dog beach in the winter months.

Bacteria counts were particularly high along ditched and urbanized Smith Creek. The agricultural area in the Westbank Creek tributary to Smith Creek contributed 6 to >1000 cfu/100 mL *E. coli.* Low intensity animal husbandry and old septic fields contribute to the *E. coli* loading. Ditches in the area that were constructed to help drain groundwater could be planted with riparian vegetation (willow sedge cattail) to increase their filtering capacity for nutrient removal. Further down Westbank Creek, riparian areas that should act as a filter have been cleared. These creek banks could be re-planted with the owner's cooperation.

One of the largest *E. coli* contributors detected in this sampling is the culverts discharging Tomat Creek flows from WFN developed lands behind Zellers. Bacterial numbers are consistently high, ranging from 700 to 24,000 *E coli cfu*/100 mL and even overgrown with *E. coli* - a result too high to count. The infill of the former Old

MacDonald's Farm site with its septic disposal field or septic fields in the upstream mobile home parks may be the cause. Again, *E. coli* typing would help pinpoint the source(s) of the bacteria loading to WFN/DWK stormwater.

13.5 WATER QUALITY RESULTS FOR BOWEN CREEK AT QUAIL'S GATE VINEYARD

A separate but related study was conducted on the stormwater and Bowen Creek flows ditched along Boucherie Road. The flows are picked up in a culvert under Boucherie Road and piped across Quail's Gate vineyard and discharged to a braided channel into Green Bay.

Quail's Gate stormwater samples were collected on three occasions:

January 15 2010: followed rain on snow event

February 11 2010: followed storm

April 12 2010: no rain during a light freshet

Samples were collected from the seepage before it passes under Boucherie Road, and from the braided channels as it flows to Okanagan Lake.

The results are presented in Table 13.1. The key differences between the ditched flows at Boucherie Road and the flows at Okanagan Lake after passing through the volunteer cattail stand include:

Decreased: nitrate (35%), total N (33%), total suspended solids and total iron

No significant change: alkalinity, chloride, pH

Increased: Water color (50%) *E. coli* counts and total phosphorus (65%)

Table 13.1:
Water Chemistry of Bowen Seepage/Stormwater Near Quail's Gate Winery

high result result of concern result of high concern	Quail's Seep 2009/10	11-4 Quail's Boucherie 15-Jan-10	11-7 Quail's at Ok Lk 15-Jan-10	11-4 Quail's Boucherie 11-Feb-10	11-7 Quail's at Ok LK 11-Feb-10	11-4 Quail' Boucherie 12-Apr-10	11-7 Quail's at Ok LK 12-Apr-10
Colour, True	Color Unit	8	14	7	16	<5	
Alkalinity, Total as CaCO3	mg/L	457	452	534	491	521	
Carbon, Total Organic	mg/L	8.1	8.8	17.4	13.1	13.6	
Chloride	mg/L	33.3	38.9	40.1	40.8	53.3	52.7
Nitrogen, Nitrate as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Nitrite as N	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen, Dissolved Kjeldahl,	mg/L	0.37	0.25	0.33	0.34	0.36	0.31
Nitrogen, Nitrate+Nitrite as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Total Dissolved	mg/L	3.38	3.1	4.91	3.64	4.58	1.87
Phosphorus, Total	mg/L	0.1	0.1	0.13	0.23	0.03	
Phosphorus, Dissolved	mg/L	0.07	0.09	0.05	0.04	0.02	
Solids, Total Suspended	mg/L	15	2	104	2	10	
pH	pH Units	8.28	8.27	8.28	8.26	8.39	
Iron	mg/L	0.4	<0.10	7.23	<0.10	1.23	
E. coli	CFU/100m	130	140	<1	7	<1	6
Conductivity (EC)	uS/cm					1220	
Hardness (as CaCO3)	mg/L					400	
Calcium	mg/L					71.4	
Iron	mg/L					1.23	
Magnesium	mg/L					53.8	

Bacterial de-nitrification would be the main process behind the nitrate reduction in the volunteer cattail stand, while settling/filtering of solids would be primarily responsible for the drop in suspended solids and iron. pH was buffered and stabilized to a relatively high range by the high alkalinity. Increased water color and total phosphorus would be caused by exposure to decayed material in the winter months. Decayed organic materials release nutrients and color to water, particularly under anaerobic soil conditions. Waterfowl use of the area would contribute to the increased *E. coli* concentrations.

In terms of chemistry that could affect this water's use as irrigation water, the Bowen Ck seepage/stormwater is very alkaline, hard and has high conductivity. The resulting pH ranged from 8.26 to 8.39. Iron concentrations were also high, probably with most of it occurring in particulate forms. The total suspend solids load can also be very high (15 – 104 mg/L). The turbid initial flushing during the first few hours of a storm would probably need to bypass any irrigation system and could be addressed by a lake-side constructed wetland. Nitrogen and phosphorus concentrations were very high. While the nutrients conveyed by these flows would be beneficial to agriculture as "fertigation", the alkalinity may be unsuitable for irrigating grapes long-term. There may be a benefit to mixing the relatively soft, low iron Lakeview Irrigation District water with the stormwater prior to irrigation.

Some or all of the Bowen/stormwater flow could be treated below the Quail's vineyard in a constructed wetland using a multi-stage design (Figure 13.13). It should have a settling basin prior to subsurface flow-through cells designed for macrophyte harvesting to allow permanent nutrient and metal removal.

Areas above the high water mark could be planted in sections with the locally rare Giant wild rye *Leymus condensatus* in drier areas and shrub willow *Salix spp*. in wetter areas to provide the main plant structure. These plants uptake nutrients and metals directly and their root zones also host bacteria that perform biofiltration for nutrients and metals. Since this wetland would provide habitat opportunities, monitoring of metal/toxin concentrations would be recommended. A functional wetland would take about three years to mature but would improve the water quality reporting to Green Bay.

The first phase of this design would involve conveying Bowen water further down Boucherie Road and delivering it to a 200 m long serpentine channel planted with local cattail, bulrush, shrub willow and red osier dogwood. This phase can be monitored for the sedimentation rates and stormwater volumes that a future multi-stage wetland system would have to manage.

Stormwater samples with high turbidity allow bacteria to attach onto particulate surfaces, potentially accelerating bacterial removal from storm flows in a wetland. Turbidity will also reduce bacterial counts reported from the lab because bacterial samples are filtered before processing. This underestimate of bacteria should be taken into account during wetland design.

13.6 WATER QUALITY RESULTS - FULL METALS SCAN

Due to cost, a full metals scan was completed on the first set of DWK stormwater samples only. The total metals results were graphed to locate high groundwater contributions in Appendix 13.1, Figure 1. They indicate that Outfall 4-1, Medican Pond, Bowen Creek at Okanagan Lake and upper Westbank Creek all receive significant groundwater inflow.

Although creeks receiving stormwater would never be considered for drinking water, comparing the metals scan to the Canadian Drinking Water Guidelines provides the suitability of that water for uses involving animal or human contact and irrigation. Total metals concentrations that exceeded the CDWG at one or more DWK site includealuminum, iron, manganese, selenium, sodium, and uranium.

Aluminum and zinc increase when water is exposed to those metals such as during passage through galvanized culvert. The sites that exceeded the CDWG for aluminum and had elevated zinc concentrations were the Power's Creek volunteer wetland that receives highway run-off and the Casa Loma seepage. No problems are anticipated from these metals.

The iron and manganese guidelines are based primarily on aesthetic concerns as opposed to toxicity concerns. Both metals behave similarly and are released from substrates under anaerobic conditions. Anaerobic conditions occur in permanently saturated soils. The sites with high iron and manganese include: Power's Creek volunteer wetland, outfall 4-1 Smith Creek at Medican Pond, Smith Creek at the Dog Beach and McDougall Creek at Elk Rd. No problems are anticipated from these metals.

Selenium is a concern for drinking water and is a common contaminant of granular fertilizer. It was high in the outfall 4-1 and the Casa Loma seepage. The later site is a greater concern because the flows are far larger than the outfall. Similarly, sodium also exceeded the CDWG for sodium in the low-flow outfall. Smith Creek below Hwy 97 also had elevated sodium concentrations. Excessive exposure to these metals can cause health concerns.

Uranium is locally abundant in the Okanagan, particularly in gravelly deposits in former lake sediments. As such, it can increase in groundwater. Sites where total uranium exceeded CDWG include the outfall 4-1, Smith Creek at Medican Pond, Bowen Creek at Okanagan Lake and the Casa Loma seepage – all sites where groundwater inflows are expected. These sites would not be suitable as drinking water (Appendix 1).

When the stormwater total metals data is considered as a whole, sites where remediation is indicated include: the low volume outfall 4-1, lower Smith Creek, lower Bowen Creek and the Casa Loma seepage.

This stormwater total metals dataset can be mined for other concerns in the future.

13.7 STORMWATER QUALITY ENHANCEMENT OPPORTUNITIES

Stormwater ponds and stormwater retention/detention facilities will always be a necessary part of a stormwater management program, however they accumulate pollutants and are expensive to install and maintain. DWK should consider a multiple-barrier approach aimed at reducing urban stormwater pollution by encouraging source reduction in addition to stormwater facilities.

Stormwater Source Reduction - Divert /Utilize Rainwater

Reducing the volume of stormwater at its source would reduce the overall cost of stormwater treatment for District of West Kelowna.

Reducing the amount of stormwater can be achieved by retaining rainwater on properties whenever subsurface drainage is appropriate. Instead of an expensive liability, rainwater remains a valuable commodity when it is used as irrigation water and is not discharged to the stormwater system. Expensive techniques involve storing rainwater in cisterns or in underground reservoirs and pumping it for irrigation. Simpler techniques for rain harvesting and rain gardens are presented in Figures 13.8 and 13.9.

Figure 13.8 contrasts a suburban landscape that is poorly designed and does not retain stormwater falling on the impervious surfaces (driveway, walkway, roof) with a landscape that does. The rainwater–retaining landscape is not only more attractive, it will cost less to irrigate. It features:

Gutter-fed rain barrel directed to garden(s)

Lowered rain gardens in swales that are capable of absorbing adjacent runoff

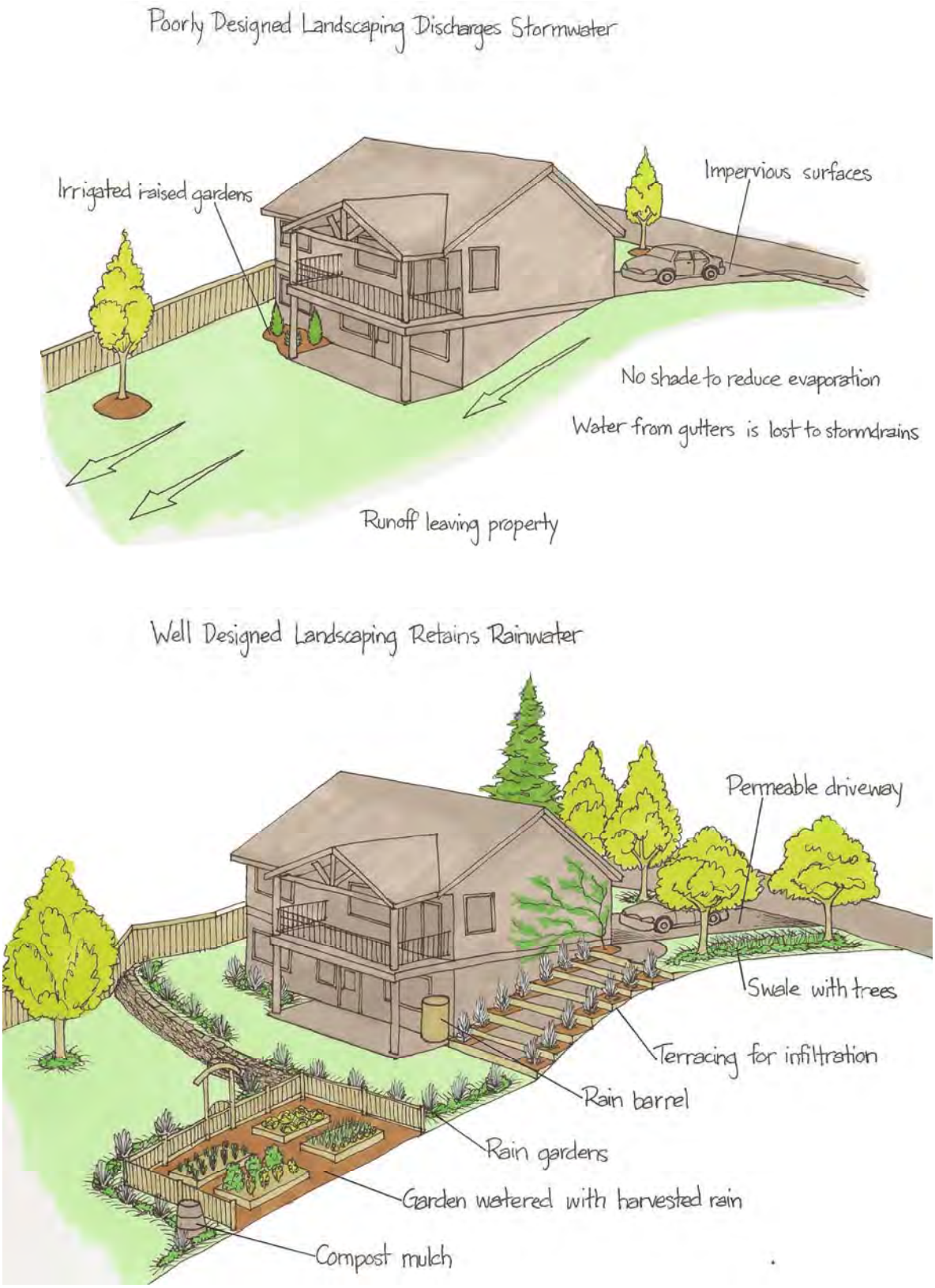
Terracing to encourage infiltration to ground

Permeable driveway (gravel crush or crushed limestone)

Large soak-away zones or rain garden swales can be developed on DWK public property. These rain garden swales temporarily store rain water where it re-charges the root zone, and gradually releases surplus water to ground where impurities can be filtered out (Figure 13.9) that temporarily store the rainwater, gradually releasing it to ground. Drainage pipe connected to storm sewers would still be necessary to safely convey excess stormwater during large rainfall events.

Stormwater use or treatment that involves infiltration to groundwater should not be sited in areas with high water tables or where there are shallow soils over bedrock. Where infiltration is contemplated for a large development, a groundwater hydrologist should be consulted. Managing stormwater for onsite erosion and sediment control on large developments would also greatly reduce sediment inputs to stormwater ponds.

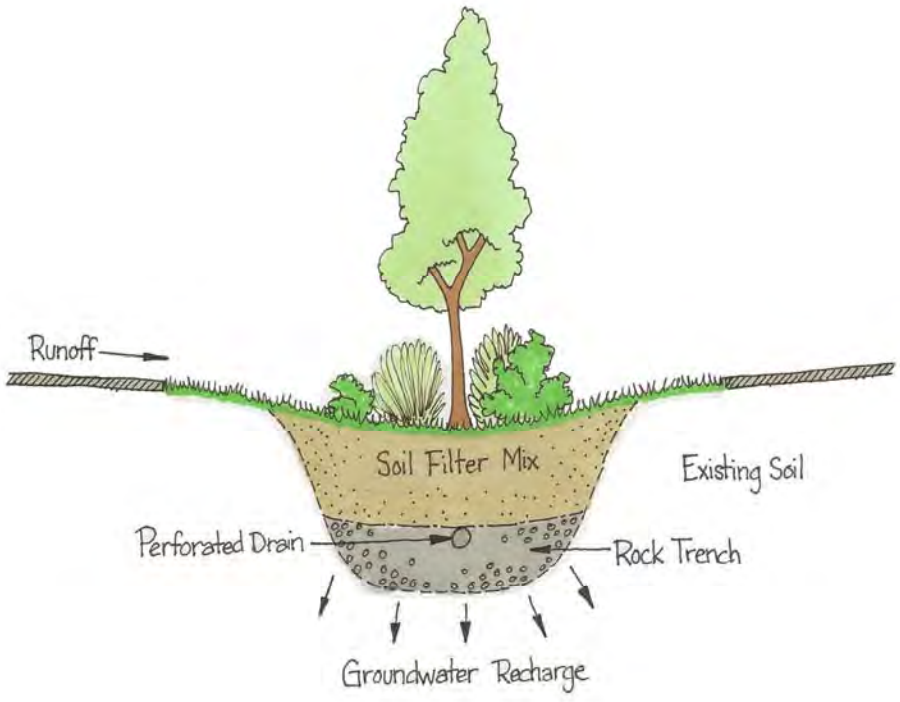
Figure 13.8: Techniques for Retaining Rainwater on Residential Properties



Commercial and residential developments can be retro-fitted with the raingarden/swale concept and they can minimize impervious walk-ways (Figure 13.9). New development properties could incorporate underground detention reservoirs or soak-away infiltration galleries to reduce peak stormwater discharges. At sites where it is hydrologically appropriate, these methods recharge the groundwater and maintain normal velocities in creeks, thus avoiding undercutting creek banks and undermining roadways.

There are several products available for pervious side walks that incorporate recycled tire chips. Alternately, crushed limestone can be laid and will form into a pervious solid surface within a year (G. O'Roarke, pers. comm.).

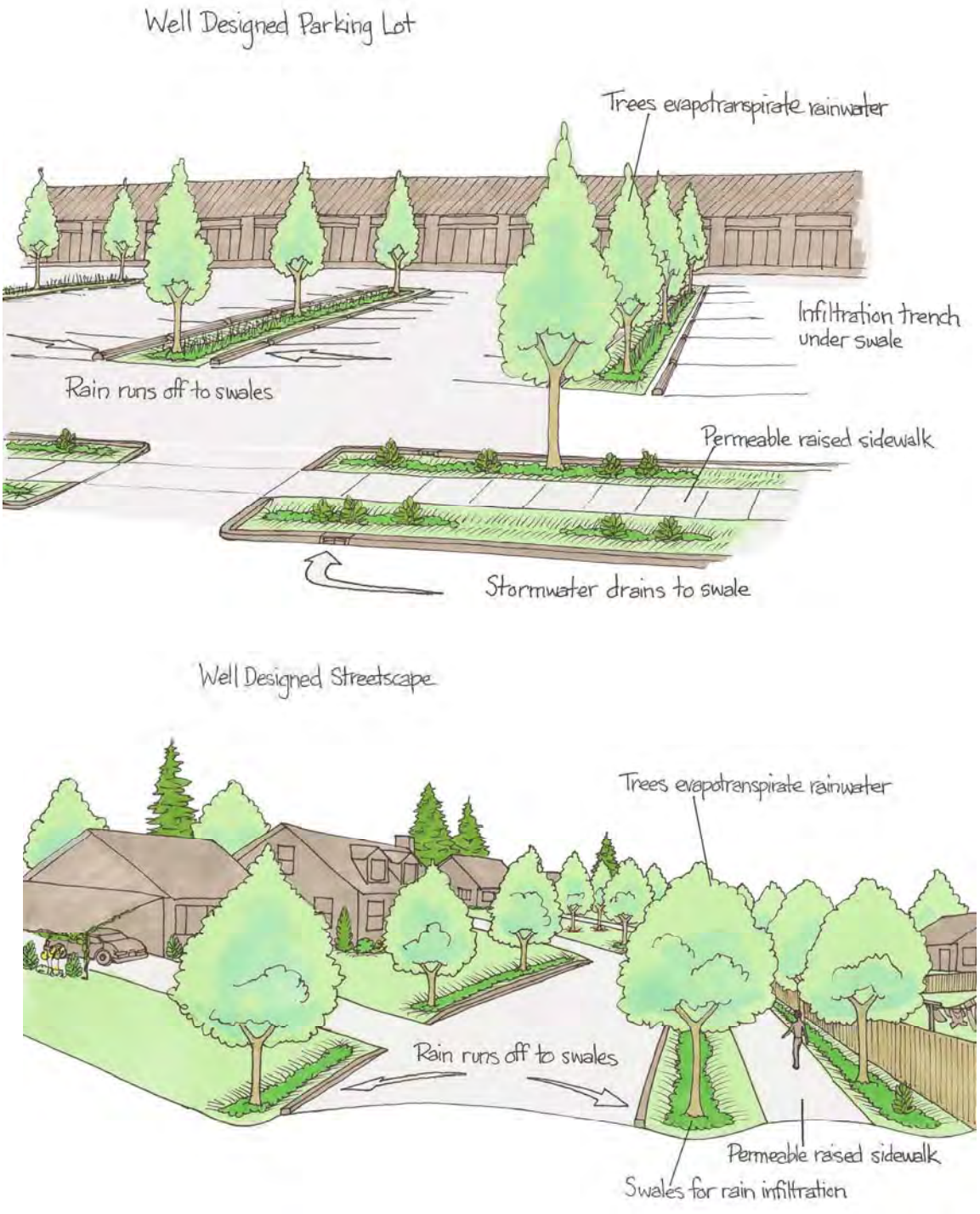
Figure 13.9: Cross Section of a Rain Garden Swale



The City of Toronto Urban Forestry Services is currently engaged in a project to double the tree canopy in Toronto for a variety of benefits including reducing stormwater peaks. The value of trees for this purpose should be recognized in DWK.

Figure 13.10:

Well-Designed Parking Lot and Streetscape for Rainwater Retention



Treatment in Stormwater Ponds and Constructed Wetlands

When suitable land is available, constructed wetlands are a cost-effective means improving stormwater quality (Weiss et al, 2007). Constructed wetlands consist of interacting plants and animals that remove contaminants from the water column by mechanical filtration and biochemical conversion. These processes are summarized in Table 13.2.

Table 13.2: Contaminant Removal Mechanisms in a Constructed Wetland

Parameter	Removal mechanism in a constructed wetland
Suspended solids	Sedimentation, filtration
Biol. O2 Demand	Microbial degradation (aerobic, anaerobic) accumulation of organic material
Nitrogen	Bacterial de-nitrification; plant uptake; ammonia volatilization
Phosphorus	Soil adsorption/precipitation with Al, Fe, Ca, clay minerals; plant uptake
Pathogens	Sedimentation, UV deactivation, zooplankton predation; excretion of antibiotics from macrophyte roots
Trace metals	Adsorption/complexation with organic matter, plant uptake, microbial transformations

After Brix, 1993.

A major component of the wetland environment is microbial activity, which is limited by substrate surface area, nutrients and water temperature. The microbial contribution to wetland efficacy can be improved by increasing a wetland's substrate surface area and increasing water circulation rates through that substrate (Stewart at al., 2008). Even though constructed wetlands perform less effectively in cold weather, they can be designed to remain operational through the winter months. The effects of constructed wetlands on wildlife need to be monitored and ecotoxicological risks controlled (Crow et al., 2007).

One of the biggest constraints on the application wetlands and stormwater ponds in DWK is the shortage of low-slope land near water courses. Although they are not as good as large multi-stage wetlands, small stormwater ponds and wetlands can be effective if they are carefully designed. Table 13.3 summarizes a number of emerging styles of constructed wetlands/storm ponds in order of complexity.

Table 13.3: Types of Constructed Wetland/Pond Systems for Stormwater Treatment

Type	Main use	Main constraint	Lifespan
Dry detention	Used on high sediment stormwater settled sediment can be readily cleaned out	Provides the least water quality treatment of all pond systems	>20 yrs
Infiltration trenches	Used on the perimeter of parking lots or road to direct water to trees/shrub roots	Limited capacity high maintenance costs	N/A
Simple 2 stage surface flow	Highway run-off with brief detention and little treatment	Storm inflow volumes short-circuit especially when pond freezes	>5 yrs
Multi-stage sub-surface flow	Water travels slowly through root zones of marsh/ pond/ meadow for polishing stormwater and infiltrating	Low peak capacity; may accumulate toxicity –become unsuitable as habitat	>10 yrs
Harvested Wetlands	Reeds/sedge/cattail/or duckweed is grown then harvested for salt removal	More labor-intensive management	>10 yrs
Bio-island	Uses floating bio-island to maximize natural microbial water tmt for metal, nutrient, organic contaminant removal	Bio-island matrix is proprietary and expensive	>5 years
Biofilter	Mimic water treatment in natural wetland using planted filter strips	Can take years to establish	>10 yrs
Filter	Incorporates granular filtering media for debris and contaminant removal	Need constant maintenance	> 2 yrs
Alum-based	Used for highly contaminated stormwater	Creates sludge, sludge disposal issues	N/A
Massive >5 ha	Polishing stormwater to strict standards by incorporating many features of the ponds shown above	Large land acquisition	>10 yrs
Retention underground	Hold stormwater underground in pipe gallery then infiltrate it to ground for nutrient, metal, bacterial removal	Infiltrated volume cannot exceed groundwater capacity, can introduce contaminants	N/A
Detention underground	Temporary u/g storage then gradual release to wetland (beneath parking lots) to reduce peak loading rates to wetlands	Require pre-screening and maintenance of storage vessel	N/A

(Berezowski, 1995; Crow et al., 2007; Pries 2010; Reddy and Smith, 1989; Stewart et al., 2008; Zwick, 2010)

Stormwater Treatment in Small Constructed Ponds and Wetlands

The easiest stormwater treatment ponds to install in District of West Kelowna are the small surface flow ponds that perform primarily as settling and detention basins (Figure 13.11, 13.12) Stormwater sampling conducted in this study indicates that constructed ponds or wetlands large enough for suspended sediment to settle (sand / silt) also achieve a significant reduction in *E. coli* bacteria loads. The pond retained at the Lakewind (Medican) property is an excellent example of a functional pond that lowers bacteria counts despite resident waterfowl. It receives a mixture of stormwater and a diverted spring (Figure 13.11).

The appropriate sizing of a stormwater facility to achieve contaminant removal can be calculated from Table 13.4. The fall velocity of sand is rapid at >100 m/day, while fine clay is slow at 1 m/day and for free-floating bacteria, the fall velocity is negligible at 0.00354 m/day (Hayco, 2009; USGS 2007). The settling of individual bacteria would take months; but only a day or less after bacteria clumps with other materials (larger sediment particles, organics). Table 13.4 presents fall velocities in still water at 10-20^{o}C.

Table 13.4: Size and Fall Velocity Estimates for Stormwater Particulates

Material	Size	Fall velocity
Inorganic		
Sand	>63 – 100 microns	> 100 m/day
Silt	4 – 63 microns	21 m/day
Clay	0.1 – 4 microns	1 m/day
Marl	<1.5 microns	0.6 m/day
Biological		
Organic clumps	> 100 microns	>100 m/day
Large algae and diatoms	22 – 70 microns	< 50 m/day
Small algae	6 – 14 microns	<1 m/day
Lg filament cyanobacteria	5 x 200 microns	0.1 m/day
Sm filament cyanobacteria	1 x 100 microns	>0.007 m/day
Giardia / crypto cysts	4 – 8 microns	0.02 - 0.1 m/day
Bacteria – *E. coli*	0.7 – 10 microns	>0.0035 m/day

(Dia and Boll, 2006; USGS 2007; Hayco, 2009; Larratt 2010)

Very fine particles cannot be settled out in a simple pond but can be removed by filtering the water through a band of wetland vegetation.

Figure 13.11: Constructed and Enhanced Stormwater Ponds in DWK



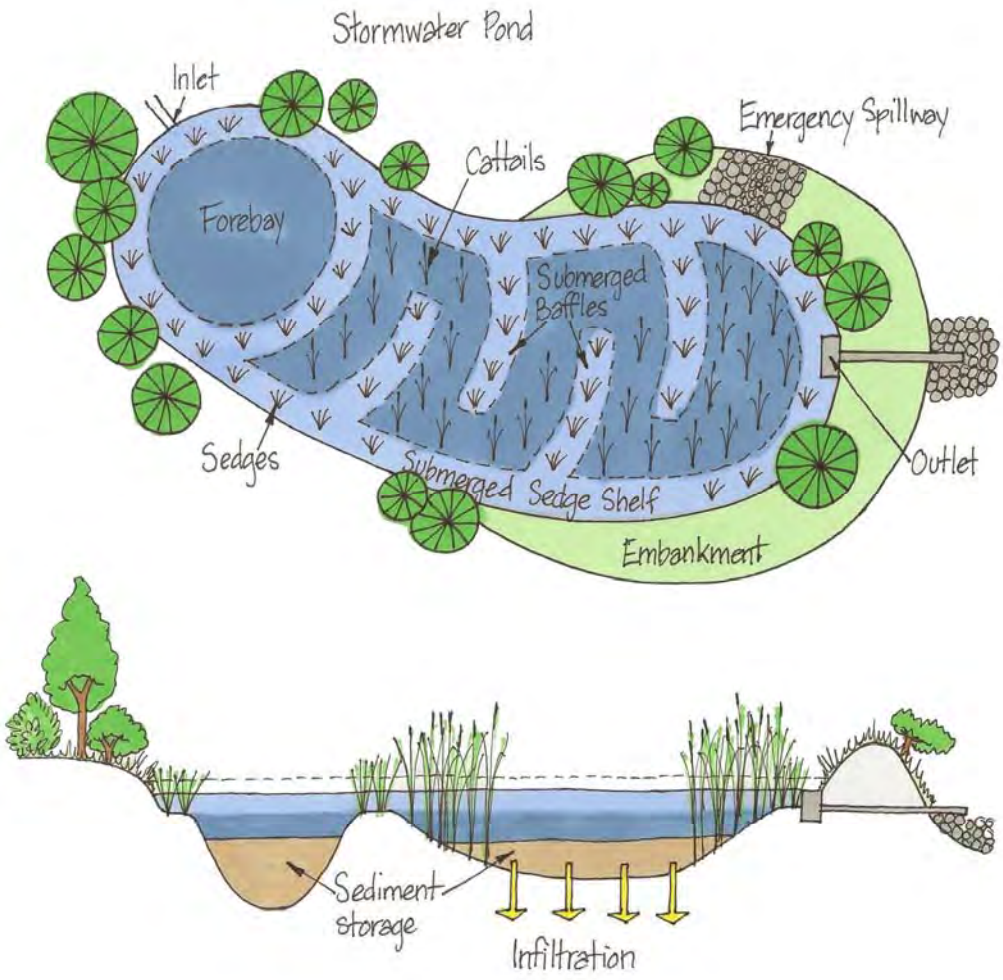
Stormwater ponds adjacent to Smith Creek, above Hwy 97



Preserved and enhanced ponds on Smith Creek, below Hwy 97

Figure 13.12 gives a generic design of a surface flow stormwater pond/wetland. It features a forebay for grit accumulation, submerged baffles to prevent short-circuiting in lower flows but allows storm peaks to travel quickly, and sedge/cattail plantings to further improve water quality. Unless the pond is lined to prevent it, water will infiltrate to ground.

Figure 13.12: Generic Design of Surface Flow Stormwater Ponds/Wetlands



The embankment around the perimeter of the pond could be planted with riparian vegetation. The submerged shelf could be planted with sedge, while rush and cattail will thrive in the deeper water. All of these riparian plants will host bacteria along their roots that sequester metals. Periodic dredging of accumulated sediment would be required.

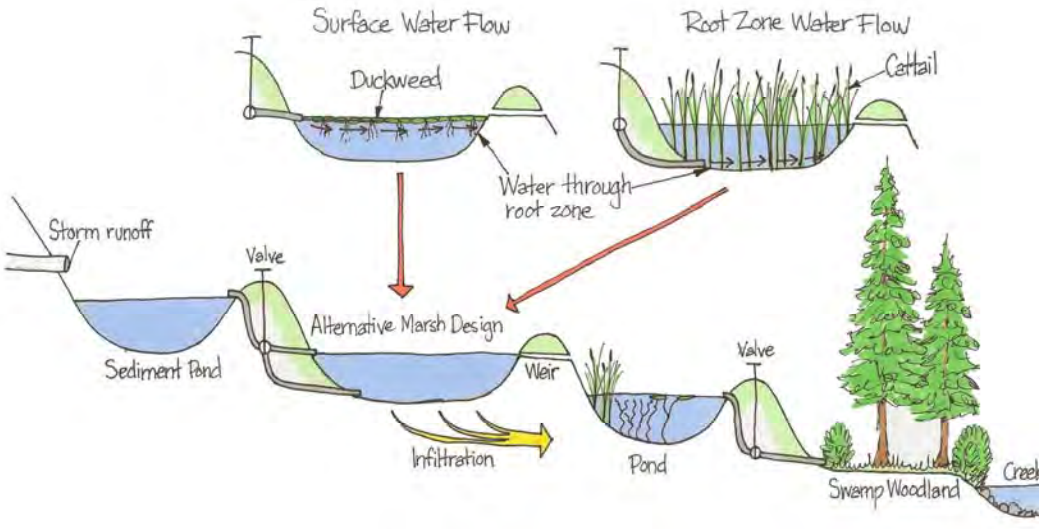
Harvesting the emergent vegetation can further improve nutrient and salt/metal removal from a stormwater system. Many researchers report limited value of wetlands for salt removal, however research involving selected harvesting of halophytic macrophytes (duckweed, cattail, sedge) has been effective for long-term salt removal (Hegedus et al., 2010). More metal including sodium is also taken up into the woody tissue of willows (Reddy and Smith, 1987). Small stormwater ponds could be developed below Highway 97 to intercept saline runoff and below the existing Medican pond to intercept storm flows.

Stormwater Treatment in Multi-stage Wetlands

Multi-stage wetlands are large and there are only a few locations in District of West Kelowna where they would be feasible. Like simple flow-through wetlands, multi-stage wetlands encourage initial sediment deposition but they also provide biological nutrient and bacteria removal. Pathogenic bacteria can be consumed in these wetlands by zooplankton and deactivated by sunlight or by aging (Wetzel, 2007).

Where metals and nutrients are excessive, wetland segments can be designed for harvesting using suitable plants (duckweed *Lemna minor;* cattail *Typha latifolia*; sedge *Carex spp*.; spikerush *Eleocharis spp*.; bulrush *Scirpus spp*.). Lower cells can pass water through the root zones of shrub willows for further polishing. These plants provide uptake and host microbes that remove nutrients and metals from stormwater. Since constructed wetlands that treat stormwater provide habitat opportunities, monitoring metal/toxin concentrations would be recommended.

Figure 13.13: Generic Design of Multi-stage Wetland for Stormwater Treatment



After Berezowski, 1996.

A good example of a multi-stage wetland is the wetland system on lower Keefe Creek (Figure 13.14). To be functional, multi-stage wetlands must be much larger than stormwater ponds. The Quail's Gate site would be an excellent choice for a constructed multi-stage wetland. There may be a second opportunity for a multi-stage wetland adjacent to the Medican pond, below Hwy 97 on WFN land. There is an existing depression on the property and management of WFN parking lot flows will be important to Smith Creek.

Figure 13.14: Enhanced Wetland on Lower Keefe Creek



Wetland on Lower Keefe Creek

Preserve and Restore Riparian Areas

Preserve wetlands and riparian areas

Existing wetlands should be conserved at all costs – purchasing land for a constructed wetland to treat stormwater can be prohibitively expensive or hydraulically impossible. Similarly, all riparian areas should be conserved to meet or exceed all legislation and bylaws.

Restore riparian areas

Riparian areas in the DWK can be restored by planting native trees/shrubs as nursery stock or as live stakes. Willow, cottonwood, red osier dogwood are all suitable as stakes. Willow poplar and cottonwood can be obtained as nursery stock. In several cases, the

creek banks will have to be stabilized with rip-rap and/or live logs and re-sloped before planting can proceed. Restoration of damaged riparian areas with native shrubs along Smith Creek is a top priority, and then damaged stretches of McDougal, Keefe and Powers Creeks need to be addressed.

Direct communication with residents on water courses

Numerous examples of riparian damage by adjacent land-owners was noted during the sampling for this project. Riparian damage is documented in the SHIM section 5.3 of this report. In one extreme case, a resident near Bowen Creek built a shed on a bridge over the creek. Residents should be informed of the value of retaining riparian vegetation and encouraged to restrict fertilizer use and storage of hazardous chemicals near the watercourses of DWK.

13.8 SUMMARY

Key Findings for Stormwater Quality

In all creek systems except Smith, the upland reaches had low nitrate concentrations (<0.01 – 0.05 mg/L as N) and the lower reaches showed nutrient enrichment as stormwater collected nutrients off lawns/gardens, agricultural areas and possibly septic fields.

At the interface with Okanagan Lake, creeks in DWK carrying stormwater ranged from 1.52 to 7.21 mg/L nitrate as N while the range of total nitrogen is 0.13 – 0.35 mg/L as N for Okanagan Lake. The stormwater nitrate loading causes a "halo" of enriched algae growth around the mouth of these creeks.

In this study, chloride concentrations increased where run-off from Highway 97 entered a drainage system. Other roads in West Kelowna did not contribute the salinity that flows off the highway did. Most metal concentrations correlated with chloride in the DWK stormwater quality sampling.

E. coli counts were low (20 – 40 cfu/100 mL) for raw water in the upper reaches of every creek system of West Kelowna. Once the drainage system received run-off from urban paved areas, *E. coli* counts climbed. Bacteria counts were particularly high along ditched and urbanized Smith Creek and Tomat Creek.

Stormwater sampling in this study indicate that constructed ponds or wetlands large enough for suspended sediment to settle (sand / silt) also achieve a significant reduction in *E. coli* bacteria loads. The appropriate sizing of a stormwater facility to achieve contaminant settling can be calculated from Table 13.4.

The depth in Okanagan Lake that stormwater / creek plumes travel in will be deeper in the fall/winter than in the summer. Stormwater plumes are the most immediate potential source of contaminants to shallow domestic water intakes in West Kelowna including WFN#9, Shanboolard and Sunnyside intakes.

DWK should consider a multiple-barrier approach aimed at reducing urban stormwater pollution by encouraging source reduction in addition to stormwater ponds, wetlands and detention storage. The ultimate recipient of stormwater from DWK and WFN lands is Okanagan Lake. Both Smith Creek and Powers Creek discharge into Gellatly Bay – a key summer destination and both creeks are currently degraded by stormwater.

Recommendations for Stormwater Quality Improvement

General

- Conserve all existing wetlands within DWK jurisdiction
- Conserve existing intact riparian areas on all creeks with DWK
- Conduct an *E. coli* ribo-typing experiment and include sample sites that showed consistently high bacterial counts in this study (e.g. Powers, Smith drainages); then target a reduction in the bacterial sources identified.
- Encourage reduction of stormwater volumes through a publicity blitz on rain gardens, and reducing impermeable surfaces in hydraulically suitable areas
- Incorporate swales into subdivision and parking lot design
- Consider detention reservoirs beneath large parking lots to reduce peak storm flows
- Residents with creeks adjacent to their properties should be informed of the value of retaining riparian vegetation and encouraged to restrict fertilizer use and storage of hazardous chemicals near creeks in DWK
- Encourage dog-owners to pick after their pets during the winter months, particularly at the DWK Gellatly dog beach

Specific

- Engage WFN in discussion of construction of an off-channel multi-stage wetland beside the Medican pond to treat Hwy 97, parking lot and Smith Creek storm flows (on WFN lands)

- Small sedge stormwater ponds could be developed below Highway 97 to intercept saline runoff before it reaches creeks

- Small stormwater pond(s) could be developed immediately below the existing Medican pond to intercept Smith Creek storm flows.

- Re-plant damaged riparian areas with native shrubs along Smith Creek as a top priority, and then damaged stretches of McDougall, Keefe and Powers Creeks as indicated in the SHIM work

- Design and develop a multi-stage wetland below Quail's Gate Winery to intercept and treat turbid stormwater based on samples collected in this study and additional water quality samples to be taken during a summer season

- Develop a multi-stage wetland below Quail's Gate Winery to intercept and treat turbid stormwater. As a first phase, convey the Bowen drainage to a 200 m serpentine ditch planted with riparian species.

- Identify sources of nutrients in Casa Loma seepage and consider a small nutrient removal wetland (harvested) below the foot bridge in Kalamoir Park

- Identify cause/source of extremely high nutrient/ metal seepage discharging to Okanagan Lake immediately north of Kinsman Park (outfall 4-1 WFN land)

- Establish Gellatly Bay as a priority water quality area and commence remediation of creeks receiving stormwater that report to Gellatly Bay

Appendix 13.1: Stormwater Water Quality Data DWK 2009-2010

Table 1: DWK Stormwater Quality Results 2009 - 2010

high result result of concern result of high concern	rain event	Nitrate as N mg/L 0.01	Sodium mg/L 0.1	Chloride mg/L 0.1	E. coli CFU/100m 1
Powers12-1 wetland at Hwy	26-Nov-09		12.8	16.9	E.coli OG
Powers 10-3 u/s Hwy 97	26-Nov-09	2.4	8.89	11.1	17
Powers 10-2 at Gellatly	26-Nov-09		13.7	14.5	26
Powers 10-1 at mouth	26-Nov-09	2.21	12.8	14.3	14
Outfall 4-1 at Kinsman Pk	26-Nov-09	5.63	203	90.7	<1
Smith1-2 at Dog Beach	26-Nov-09	2.45	46.8	22.9	110
Smith 1-3 Medican Pond	26-Nov-09		136	20.2	11
Smith 1-4 at Zellers WFN	26-Nov-09		17	16.6	E. coli OG
Westbank 1-5 at Dogwood	26-Nov-09	5.31	13.4	16.6	6
McDougall3-6 at Bridge	26-Nov-09		8.39	1.19	13
McDougall5-3 at Elk Rd	26-Nov-09		40.9	31.4	23
McDougall 5-2 at Ok Lk	26-Nov-09	1.52	45.9	32.6	21
Bowen 11-1 at Ok Lk	26-Nov-09	5.41	83.4	33.3	350
Keefe 6-4 at LID gate	26-Nov-09	<0.01	11.5	2.16	2
Keefe 6-3 at Horizon Hairpin	26-Nov-09		35	17.5	9
Keefe 6-2 at Westside Rd	26-Nov-09	2.01	35.4	18.2	4
Keefe 6-1 at Ok Lk	26-Nov-09	1.73	37.3	23.6	7
Casa Loma 7-2 seepage -Lk	26-Nov-09	3.88	98.5	35.1	3

OG = overgrown

high result result of concern result of high concern	rain on snow	Nitrate as N mg/L 0.01	Chloride mg/L 0.1	E. coli CFU/100m 1	E. coli MPN/100m 3
Powers12-1 wetland at Hwy	11-Jan-10	0.06	236		91
Powers 10-3 u/s Hwy 97	11-Jan-10		13.1	17	
Powers 10-2 at Gellatly	11-Jan-10		46		7500
Powers 10-1 at mouth	11-Jan-10	2.55	48.9	130	
Outfall 4-1 at Kinsman Pk	11-Jan-10	6.85	135	<1	
Smith1-2 at Dog Beach	11-Jan-10	2.43	46		750
Smith 1-3 Medican Pond	11-Jan-10		28.2	8	
Spring 1-8 at Medican Pond	11-Jan-10		28.8	<1	
Smith 1-4 at Zellers WFN	11-Jan-10		31		24000
Westbank 1-5 at Dogwood	11-Jan-10	6.84	22.2	41	
Bowen11-2 ravine stormdr	11-Jan-10	0.37	26.9		110000
Bowen 11-8 d/s ravine pond	11-Jan-10	2.87	53.1	26	
Bowen 11-1 at Ok Lk	11-Jan-10	5.91	39.5	58	
Bowen 11-3 Tuscany st-dr	11-Jan-10		135		91
Quail 11-4 at Boucherie Rd	11-Jan-10	3.02	33.3	130	
Quail 11-7 at Ok Lk	11-Jan-10	2.85	38.9	140	
McDougall3-6 at Bridge	11-Jan-10		21.7	22	
McDougall5-3 at Elk Rd	11-Jan-10		78.3		230
McDougall 5-2 at Ok Lk	11-Jan-10	2.12	125	18	
Casa Loma 7-2 seepage -Lk	11-Jan-10	5.24	48.3	<1	
Keefe 6-4 at LID gate	11-Jan-10	0.02	2.59	110	
Keefe 6-3 at Horizon Hairpin	11-Jan-10		53.6		230
Keefe 6-2 at Westside Rd	11-Jan-10	1.98	63.9		36
Keefe 6-1 at Ok Lk	11-Jan-10	1.88	76.5	92	

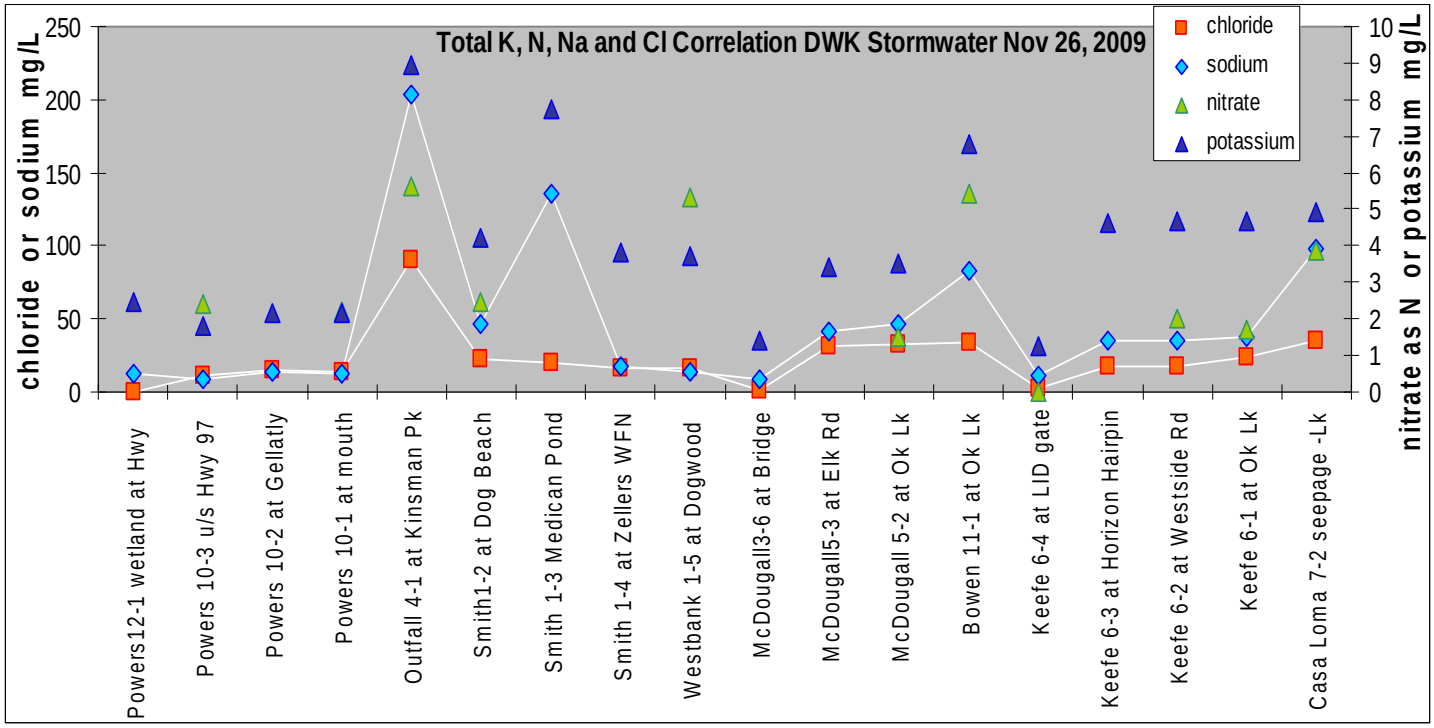
high result result of concern result of high concern	sm freshet	Nitrate as N mg/L 0.01	Chloride mg/L 0.1	E. coli CFU/100m 1	E. coli MPN/100m 3
Powers12-1 wetland at Hwy	12-Apr-10	<0.01	77	<1	
Powers 10-3 u/s Hwy 97	12-Apr-10	2.31	13.1	87	
Powers 10-2 at Gellatly	12-Apr-10	1.93	13.3	1	
Powers 10-1 at mouth	12-Apr-10	1.86	13	1	
Outfall 4-1 at Kinsman Pk	12-Apr-10	7.09	129	<1	
Smith1-2 at Dog Beach	12-Apr-10	2.92	33.6	58	
Smith 1-3 Medican Pond	12-Apr-10	0.21	26.4	1	
Spring 1-8 at Medican Pond	12-Apr-10	0.53	28	<1	
Smith 1-4 at Zellers WFN	12-Apr-10	4.09	25.8	700	
Westbank 1-5 at Dogwood	12-Apr-10	8.02	23.8	44	
Bowen 11-8 d/s ravine pond	12-Apr-10	3.98	62.4	5	
Bowen 11-1 at Ok Lk	12-Apr-10	7.21	47.4	120	
Quail 11-4 at Boucherie Rd	12-Apr-10	4.22	53.3	<1	
Quail 11-7 at Ok Lk	12-Apr-10	1.56	52.7	6	
McDougall3-6 at Bridge	12-Apr-10	0.04	1.37	60	
McDougall5-3 at Elk Rd	12-Apr-10	1.58	34.9	21	
McDougall 5-2 at Ok Lk	12-Apr-10	1.43	41	2	
Casa Loma 7-2 seepage -Lk	12-Apr-10	5.27	47.8	3	
Keefe 6-4 at LID gate	12-Apr-10	<0.01	3.06	20	
Keefe 6-3 at Horizon Hairpin	12-Apr-10	2.44	23.6	10	
Keefe 6-2 at Westside Rd	12-Apr-10	2.36	24	10	
Keefe 6-1 at Ok Lk	12-Apr-10	2.01	31.1	7	
6 - 8 West Kel Estates	12-Apr-10	0.87	18.5	1	

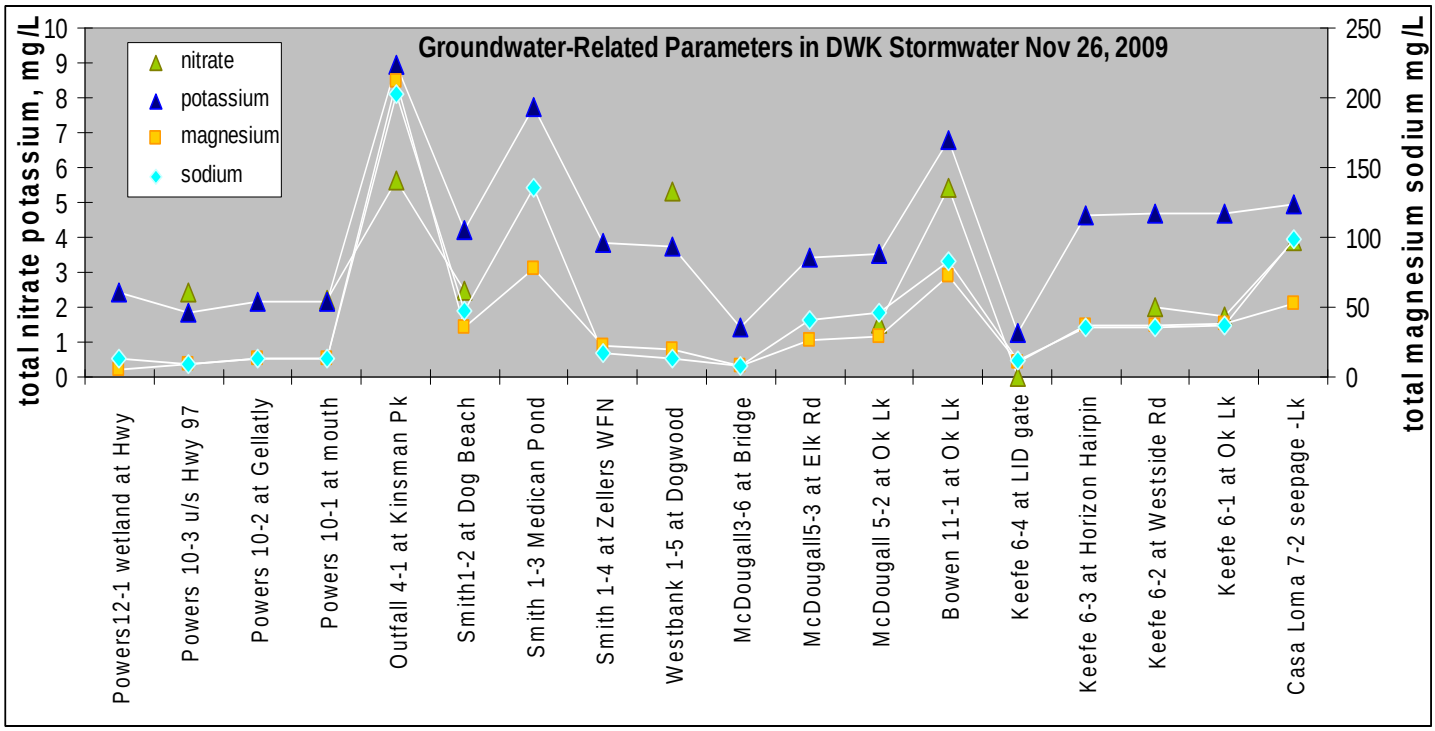
Appendix 13.1 Table 2

Table 2: Water Chemistry of Seepage/Stormwater Near Quail's Gate Winery

high result result of concern result of high concern	Quail's Seep 2009/10	11-4 Quail's Boucherie 15-Jan-10	11-7 Quail's at Ok Lk 15-Jan-10	11-4 Quail's Boucherie 11-Feb-10	11-7 Quail's at Ok LK 11-Feb-10	11-4 Quail' Boucherie 12-Apr-10	11-7 Quail's at Ok LK 12-Apr-10
Colour, True	Color Unit	8	14	7	16	<5	
Alkalinity, Total as CaCO3	mg/L	457	452	534	491	521	
Carbon, Total Organic	mg/L	8.1	8.8	17.4	13.1	13.6	
Chloride	mg/L	33.3	38.9	40.1	40.8	53.3	52.7
Nitrogen, Nitrate as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Nitrite as N	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen, Dissolved Kjeldahl,	mg/L	0.37	0.25	0.33	0.34	0.36	0.31
Nitrogen, Nitrate+Nitrite as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Total Dissolved	mg/L	3.38	3.1	4.91	3.64	4.58	1.87
Phosphorus, Total	mg/L	0.1	0.1	0.13	0.23	0.03	
Phosphorus, Dissolved	mg/L	0.07	0.09	0.05	0.04	0.02	
Solids, Total Suspended	mg/L	15	2	104	2	10	
pH	pH Units	8.28	8.27	8.28	8.26	8.39	
Iron	mg/L	0.4	<0.10	7.23	<0.10	1.23	
E. coli	CFU/100m	130	140	<1	7	<1	6
Conductivity (EC)	uS/cm					1220	
Hardness (as CaCO3)	mg/L					400	
Calcium	mg/L					71.4	
Iron	mg/L					1.23	
Magnesium	mg/L					53.8	

Appendix 13.1
Figure 1: Metals in District of West Kelowna Stormwater 2009 - 2010





NOTES: Groundwater appears to influence Outfall 4-1, Medican Pond (has spring inflow) and Bowen Ck at Okanagan Lake

high result
result of concern
result of high concern

Full Metals Scan from DWK SWMP Sampling, November 26, 2009

DWK SWMP Metals scan 2009			Powers12-1 v	Powers 10-3	Powers 10-2	Powers 10-1	Outfall 4-1 at	Smith1-2 at D	Smith 1-3 Me	Smith 1-4 at	Westbank 1-9	McDougall3-6	McDougall5-3	McDougall 5-	Bowen 11-1 a	Keefe 6-4 at	Keefe 6-3 at	Keefe 6-2 at	Keefe 6-1 at	Casa Loma 7-
			wetland Hwy	u/s Hwy	at Gellatly	at mouth	low volume	Dog Beach	Medican Pd	Zellers/Tom	Dogwood N	at bridge	Elk Rd	at Ok Lk	at Ok Lk	at LID gate	Horizon	Westside Rd	at OK Lk	seepage
Parameter	units	RDL	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09
Nitrate as N	mg/L	0.01		2.4		2.21	5.63	2.45			5.31			1.52	5.41	<0.01		2.01	1.73	3.88
Chloride	mg/L	0.1		11.1	14.5	14.3	90.7	22.9	20.2	16.6	16.6	1.19	31.4	32.6	33.3	2.16	17.5	18.2	23.6	35.1
Aluminum	mg/L	0.05	0.82	<0.050	<0.050	<0.050	<0.050	0.258	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.084	0.067	0.07	0.202
Antimony	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.0088	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium	mg/L	0.005	0.0387	0.0165	0.0202	0.0209	0.0282	0.0293	0.0346	0.0283	0.0206	<0.0050	0.0285	0.0293	0.0452	<0.0050	0.0414	0.0379	0.0428	0.011
Beryllium	mg/L	0.001	<0.0010	<0.0010	0.001	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0017	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010
Bismuth	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron	mg/L	0.02	0.039	0.032	0.033	0.027	0.049	0.048	0.056	0.049	0.045	<0.020	0.044	0.039	0.091	<0.020	0.038	0.038	0.034	0.052
Cadmium	mg/L	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	mg/L	1	28.1	37.5	47.2	44.7	490	96.5	124	78.9	96.8	36.3	88.3	94	92.3	46.2	152	146	139	92.8
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.0135	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0132	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	0.00054	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Copper	mg/L	0.001	0.005	<0.0010	0.0013	0.0012	0.0037	0.0025	0.0024	0.0012	<0.0010	<0.0010	0.0029	0.0021	0.0021	0.0014	0.0011	0.0019	0.0021	0.0027
Iron	mg/L	0.1	0.88	<0.10	<0.10	<0.10	0.59	0.36	0.18	<0.10	0.1	<0.10	0.94	<0.10	<0.10	<0.10	0.24	0.2	0.2	0.26
Lead	mg/L	0.001	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium	mg/L	0.001	0.0036	0.0039	0.0045	0.0053	0.0192	0.0142	0.0176	0.0109	0.0095	0.0041	0.0125	0.0129	0.0148	0.0085	0.0135	0.0135	0.016	0.0106
Magnesium	mg/L	0.1	5.01	9.4	13.7	13.1	212	35.5	77.1	22.5	19.8	7.95	26.6	28.9	72.7	10.8	36.7	37.4	37.7	53.1
Manganese	mg/L	0.002	0.316	<0.0020	0.0025	0.0027	0.0035	0.019	0.0892	0.0035	<0.0020	<0.0020	0.0091	<0.0020	0.0042	<0.0020	0.0136	0.006	0.0226	0.0052
Mercury	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Molybdenum	mg/L	0.001	0.0013	0.0019	0.0027	0.0025	0.0119	0.0069	0.0232	0.0055	0.0027	0.0021	0.0047	0.0034	0.0088	0.0027	0.0027	0.0027	0.0036	0.0095
Nickel	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	0.0075	0.0027	0.0024	<0.0020	<0.0020	<0.0020	0.0037	0.0032	0.0024	<0.0020	0.0031	0.003	0.0029	0.0022
Phosphorus	mg/L	0.2	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Potassium	mg/L	0.1	2.44	1.83	2.16	2.17	8.94	4.21	7.73	3.82	3.73	1.4	3.42	3.53	6.78	1.26	4.64	4.67	4.67	4.93
Selenium	mg/L	0.003	<0.0030	<0.0030	<0.0030	<0.0030	0.249	<0.0030	0.0047	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0161	<0.0030	0.0072	0.0063	0.0065	0.0357
Silicon	mg/L	2	7.6	5.7	6.7	6.4	11.5	13.3	11.2	10.7	11.9	10.4	11.8	11.4	10.5	14.1	10	9.9	10.4	8.8
Silver	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Sodium	mg/L	0.1	12.8	8.89	13.7	12.8	203	46.8	136	17	13.4	8.39	40.9	45.9	83.4	11.5	35	35.4	37.3	98.5
Strontium	mg/L	0.005	0.2	0.184	0.291	0.276	3.23	0.671	1.17	0.533	0.381	0.214	0.721	0.76	1.2	0.174	0.816	0.81	0.796	0.521
Tellurium	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Thallium	mg/L	0.0002	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thorium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Tin	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Uranium	mg/L	0.0002	0.00027	0.0029	0.00424	0.00403	0.0923	0.012	0.0305	0.0096	0.00847	0.0025	0.00874	0.00992	0.0312	0.00062	0.0178	0.0174	0.0181	0.057
Vanadium	mg/L	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc	mg/L	0.01	0.111	<0.010	<0.010	<0.010	<0.010	0.02	0.088	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.022
Zirconium	mg/L	0.001	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010

Appendix 13.2: *E. coli* Source Tracking in City of Kelowna Creeks Receiving Stormwater and at Beaches

City of Kelowna Creeks with Storm Water 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	13
Canine	6	25
Bovine		0
Horse		0
Song birds		0
Gulls	1	4
Duck	7	29
Canada Goose	1	4
Racoon		0
Deer	4	17
Unknown	2	8
SUM	24	100

City of Kelowna Creeks and Beaches 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	8	8
Canine	15	14
Bovine	1	1
Horse		0
Song birds	14	13
Gulls	18	17
Duck	20	19
Canada Goose	16	15
Racoon	4	4
Deer	5	5
Unknown	4	4
SUM	105	100

City of Kelowna Creeks with Storm Water 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	5
Canine	2	3
Bovine	6	9
Horse	2	3
Song birds	14	21
Gulls	5	8
Duck	7	11
Canada Goose	12	18
Racoon	1	1
Deer	6	9
Unknown	8	12
SUM	66	100

City of Kelowna Creeks and Beaches 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	10	5
Canine	13	6
Bovine	21	10
Horse	11	5
Song birds	44	21
Gulls	18	8
Duck	18	8
Canada Goose	26	12
Racoon	6	3
Deer	19	9
Unknown	28	13
SUM	214	100

- Courtesy of City of Kelowna
M. Toma

Appendix 13.3: GPS Locations of DWK Stormwater Sample Points

Site Names by Drainage System	GPS	GPS – co ordinates
Smith/Tomat Creek Drainage		
1-5 Westbank Ck at Dogwood N.	237	N49.838565° W119.635982°
1-4 Smith Ck at Zellers WFN	410	N49.834713° W119.622351°
1-8 Spring at Medican Pond	409	N49.830068° W119.618979°
1-3 Medican Pond	409	N49.830148° W119.619230°
1-2 Smith Ck at Dog Beach	408	N49.823280° W119.617564°
4-1 Outfall at Kinsman Beach	407	N49.824225° W119.613980°
Powers Creek Drainage		
12-1 wetland at Hwy 97	403	N49.823971° W119.647947°
10-3 Powers u/s of Hwy 97	404	N49.828749° W119.643672°
10-2 Powers at Gellatly	405	N49.814506° W119.631762°
10-1 Powers at Mouth	406	N49.816103° W119.622752°
McDougall Creek Drainage		
11-3 storm drain at Tuscany villa		N49.827686° W119.600166°
3-6 McDougal at bridge	412	N49.868268° W119.592032°
5-3 McDougall at Elk Rd WFN	413	N49.837790° W119.598839°
5-2 McDougall mouth at Ok Lk	414	N49.822366° W119.595506°
Faulkner/Keefe Creek Drainage		
6-4 Keefe at LID gate	416	N49.879823° W119.578921°
6-3 Keefe at Horizon hairpin	417	N49.876594° W119.548420°
6-2 Keefe at Westside Rd WFN	420	N49.884319° W119.542687°
6-1 Keefe at mouth Ok Lk WFN	419	N49.893703° W119.538085°
6-8 West Kel Estates seepage		N49.889910° W119.553948°
Casa Loma Spring Drainage		
7-2 Casa Loma seepage	418	N49.855249° W119.538730°
Bowen Creek Drainage		
11-2 ravine stormdrain		N49.847707° W119.557943°
11-8 Bowen d/s ravine pond		N 49.844824° W 119.558562°
11-1 Bowen at mouth Ok Lk	415	N49.840280° W119.557872°
11-4 Quail at Boucherie Rd	426	N49.841204° W119.572650°
11-7 Quail at Ok Lk (braided)	428	N49.837725° W119.570827°

Appendix 13.4:
Shoreline Plankton Tows from Gellatly Bay, Okanagan Lake
November 3, 2009

		Algae samples in abundance classe **Okanagan Lake Gellatly Bay**				
cell size		November 3 2009				
approx vol cubic		Shoreline tows through shallow water 2009				
microns		*Nov 3*	*Nov 5*	*Nov 5*	*Nov 5*	
Biovolume	**DIATOMS**	Rotary B	Rotary B	Ferry Dock	The Cove	
80	Acnanthes spp.	P	P	P	P	
	Asterionella formosa			P		
230	Aulacoseira italica		L			
	Cymbella spp		P		P	
	Fragilaria capucina		P		L	
120	Fragilaria crotonensis			C	L	
750	Gomphonema sp.	L	L			
500	Navicula spp.			L		
	Pinnularia gibba					
1500	Rapholodia gibba	L	P		L	
100	Synedra acus			C	L	
500	Tabellaria fenestrata					
	YELLOW-BROWN ALGAE					
	Botryococcus	D				
500	Cryptomonas ovata				P	
	DESMIDS					
	Cosmarium spp.					
	GREEN ALGAE					
Toxin 150	Closteriopsis longissima					
Possible	**BLUE-GREEN ALGAE**					
X	Anacytis cyanea			**L**		
X	Anabaena planktonica	C				
	Pseudanabaena				P	
X 2	Planktolyngbya limnetica	**L**	**C**	**C**	D	
	Limnothrix redekei					
X 10	Planktothrix agardhii	**D**	**L**	L	**L**	
X 5	Synechocystis sp.		M		L	
X 5	Synechococcus	L				
	DINOFLAGELLATES					
700	Peridinium sp. (large)					
	PROTOZOA					
3	micro-flagellates	L	L	M	M	
20	Large flagellates	L	L	M	M	
180	ciliates		L	L	L	
1	bacteria	**H**	**H**	**M**	L	
	detritus	**L**	**VH**	**C**	L	
5-100	silt	L	M	**L**	L	
	DENSITY	high	mod	mod	mod	
	Notes		debris!	copepods		
	P=Present L=Low M=Moderate =Common H=High D=Dominsant					

SECTION 14
CONCLUSIONS AND RECOMMENDATIONS

14.1 INTRODUCTION

This section presents a summary of the results and general recommendations arising from the field reviews, hydrologic and hydraulic analysis, as well as recommendations for District staff in moving forward with the improvement options identified within this report.

14.2 CONCLUSIONS

The drainage analysis was carried out on the existing drainage network and watercourses, within the District of West Kelowna, for the 1 in 5 year and the 1 in 100 year return frequencies. The drainage areas within the District of West Kelowna boundaries were delineated based on the existing topographic mapping and then modeled using the PCSWMM computer model to estimate the magnitude of runoff resulting from the 5 year and 100 year storm events. The upper watershed areas were modeled using a Regional Analysis technique to estimate the runoff rates on a unit area basis for varying recurrence intervals.

Based on the modeling results and field reviews, the majority of the West Kelowna drainage network has adequate capacity to convey the anticipated flow rates. Within each sub-basin area, the noted deficiencies or problem areas have been summarized by priority. The deficiencies that were expected to result in property damage or flooding were rated as High priority items. Table 14.1 presents a summary of the High priority projects.

The Medium priority projects were identified as those having a lower risk of flooding or property damage. These Medium priority projects are listed within Table 14.2.

Deficiencies or proposed improvement works having a Low priority include those with a low risk of flooding, may present only nuisance ponding problems or may include easement acquisitions within existing drainage routes. The Low priority items have been presented within Table 14.3.

Table 14.1
Summary of High Priority Projects

Basin	Project No.	Improvement Description	Estimated Cost
Glenrosa	3.2	Drainage Improvements – McAllister Road	$28,800
Glenrosa	3.3	Drainage Improvements – McMann Road	$28,800
Smith Creek	5.1	Creek Restoration – Smith Creek	$647,500
Smith Creek	5.6	Construct Detention Storage – Rubicon Road	$359,500
McDougall Creek	7.3	Drainage Improvements on Ponderosa Road	$275,000
McDougall Creek	7.4	Channel Improvements – Hitchner Road to Jenner Road	$46,500
Mt. Boucherie	8.4	Conveyance Improvements – Boucherie Road to Okanagan Lake	$738,000
Mt. Boucherie	8.12	Inspect/Clean Outfall Pipe – Green Bay Road	$21,600
Mt. Boucherie	8.13	Install Storm Overflow Pipe – Green Bay Road	$67,500
Keefe Creek	9.8	Channel Improvements/Drainage Easement – Spyglass Way to Westview Way	$23,250
Keefe Creek	9.9	Repair Detention Pond - Northeast of Westview Way	$21,550
Keefe Creek	9.12	Install Infiltration System - Stevens Road and Ross Road	$164,750
		Total	**$2,422,750**

Table 14.2
Summary of Medium Priority Projects

Basin	Project No.	Improvement Description	Estimated Cost
Glenrosa	3.1	Erosion Protection – Glenrosa Road from Gates Road to Ranch Road	$60,300
Glenrosa	3.5	Erosion Protection – Glenrosa Road from McIvor Road to Morningstar Road	$74,200
Glenrosa	3.7	Erosion Protection – Webber Road to Inverness Road	$31,500
Smith Creek	5.3	Stream Stabilization – Smith Creek	$668,250
McDougall Ck	7.1	Bank Stabilization – Shannon Lake Road to Pike Road	$258,000
McDougall Ck	7.2	Detention Storage and Erosion Protection – Darrock Park to East Boundary Road	$46,000
Mt. Boucherie	8.14	Relocate Catchbasin Leads – Green Bay Road	$17,000
Keefe Creek	9.1	Storm Infrastructure Inventory - Stevens Road Industrial Area	-
Keefe Creek	9.2	Channel Improvements/Drainage Easement – Rosewood Drive to Westside Road	$200,400
Keefe Creek	9.3	Erosion Protection/ Drainage Easement – Griffiths Place to McNaughton Road	$152,725
Keefe Creek	9.4	Erosion Protection – Bear Creek Rd from Vancouver Road to I.R. boundary	$113,150
Keefe Creek	9.5	Erosion Protection/ Drainage Easement – Parkinson Road to Bear Creek Road	$46,825
Keefe Creek	9.6	Drainage Improvements – Horizon Drive	$3,650
Keefe Creek	9.10	Creek Improvements – Keefe Creek between Horizon Dr and Spyglass Way	$259,000
Keefe Creek	9.11	Erosion Protection/ Drainage Easement – Horizon Drive to Spyglass Way	$46,925
Keefe Creek	9.13	Erosion Protection – Spyglass Way to Keefe Creek	$38,750
Keefe Creek	9.14	Erosion Protection - Horizon Drive west of I.R. boundary near Hwy 97	$13,000
Keefe Creek	9.15	Erosion Protection/ Drainage Easement – Horizon Drive to Covington Court	$32,300
Keefe Creek	9.16	Erosion Protection - Westlake Road southwest of Devon Court	$38,800
		Total	**$2,100,775**

Table 14.3
Summary of Low Priority Projects

Basin	Project No.	Improvement Description	Estimated Cost
Glenrosa	3.4	Drainage Easement – Webber Road to Powers Creek	-
Glenrosa	3.6	Drainage Easement – Webber Road to Inverness Road	-
Smith Creek	5.2	Obtain Drainage Easement – Doucette Drive to Elliot Road	-
Smith Creek	5.4	Obtain Drainage Easement – Bridlehill Road to Rubicon Road	-
Smith Creek	5.5	Storm Pipe Installation – Copper Ridge Drive to Wild Horse Drive	$46,600
Shannon Lake	6.1	Drainage Improvements – Shannon Hills Place to Walkway	$2,800
Shannon Lake	6.2	Obtain Drainage Easement – Shannon Lake Golf Course	-
Shannon Lake	6.3	Obtain Drainage Easement – Ridge Place to Shannon Lake	-
Mt. Boucherie	8.1	Obtain Drainage Easement – Braeburn Court to Mission Hill Road	-
Mt. Boucherie	8.2	Erosion Protection – Menu Road to Gregory Road	$55,075
Mt. Boucherie	8.3	Erosion Protection/ Drainage Easement – Gregory Road to Mission Hill Road	$113,150
Mt. Boucherie	8.5	Storm Sewer Upgrades – Sunnyview Road	$275,600
Mt. Boucherie	8.6	Obtain Drainage Easement – Stevenson Road to Douglas Road	-
Mt. Boucherie	8.7	Obtain Drainage Easement – Douglas Road to Odgen Road	-
Mt. Boucherie	8.8	Obtain Drainage Easement – Lakeview Cove Road to Ourtoland Road	-
Mt. Boucherie	8.9	Obtain Drainage Easement – Ogden Road to Westbrook Road	-
Mt. Boucherie	8.10	Obtain Drainage Easement – McCartney Road to Montigny Road	-
Mt. Boucherie	8.11	Obtain Drainage Easement – Bazett Road to Sunnyside Road	-

Basin	Project No.	Improvement Description	Estimated Cost
Keefe Creek	9.7	Obtain Drainage Easement – Bear Creek Road to Westside Road	-
Lakeview Hts.	10.1	Obtain Drainage Easement – Harmon Road to Boucherie Road	-
Lakeview Hts	10.2	Obtain Drainage Easement – Hayman Drive to Boucherie Road	-
Lakeview Hts	10.3	Obtain Drainage Easement – Bridgeview Road to Campbell Road	-
Lakeview Hts	10.4	Obtain Drainage Easement – Kelview Crescent to Campbell Road	-
Lakeview Hts	10.5	Obtain Drainage Easement – Thacker Drive to Campbell Road	-
Lakeview Hts	10.6	Obtain Drainage Easement – Lakeridge Road to Okanagan Lake	-
Lakeview Hts	10.7	Obtain Drainage Easement – Weatherhill Crescent to Okanagan Lake	-
Lakeview Hts	10.8	Obtain Drainage Easement – Graymar Road to Okanagan Lake	-
Lakeview Hts	10.9	Obtain Drainage Easement – King Road to Okanagan Lake	-
		Total	**$493,225**

Hydrogeological Review

A component of this assignment included a hydrogeological review to determine pre-development conditions, evaluate on a cursory level the suitability of specific development areas for stormwater disposal to ground and to identify areas which would be prone to impacts from up-slope disposal to ground.

One of the specific features of this study is the concept of a "limiting condition": that may restrict water from further migration downwards. The limiting condition may be influenced by the depth to groundwater, bedrock, glacial till or fine-grained soils such as silt or clay.

The suitability for infiltration of stormwater to ground was completed using spatial data storage and Multiple Criteria Analysis for three dominant factors influencing infiltration including ground slope, soil type and the depth to a limiting condition. The

categories of suitability of storm water to ground include *Not Suitable*; *Possibly Suitable* and *Well Suited*. The results of the hydrogeological review are presented within Section 11 of this report.

Applying the concept of limiting condition, the majority of the Study Area is not considered to be well suited for disposal of stormwater to ground. The areas where it is considered feasible are generally limited to glacio-fluvial and alluvial sediments associated with McDougall Creek and Powers Creek. Figure 11.4 presents the mapping results of the Multiple Criteria Analysis.

Watercourse Evaluation

A watercourse and wetland evaluation was carried out for the prominent drainage subbasins including Smith Creek, Powers Creek, McDougall Creek, Bowen Creek, Law Creek, Drought Creek, Luluwap Creek, Davidson Creek, and Casa Loma spring. The detailed results of the biophysical attributes and values of each drainage course are presented within Section 12 of this report. Habitat ratings and SHIM data have been presented within the enclosed report, and the accompanying maps are presented under a separately bound document, due to the volume of maps.

The watercourse evaluation data was originally collected between 2001 and 2003 by the RDCO, and then subsequently summarized within this report. Watercourses were re-visited based on local knowledge of known watercourse changes and development activity that has occurred since the original survey was completed.

Watercourses such as Smith Creek have fisheries value, but have been severely impacted and are in need of rehabilitation and improvements in stormwater management practices. Streams such as McDougall Creek and Keefe Creek are fisheries streams, which have been impacted to a lesser degree, but are under ongoing development pressure and must be prioritized for implementation and stormwater management. As these larger watercourses traverse both District of West Kelowna and Westbank First Nation land, it is paramount that future land-use and drainage planning involve collaboration between governing bodies.

Powers Creek was identified as having the highest habitat score, accompanied by the most favourable impact score

Water Quality Review

As a part of the Master Drainage Plan preparation, periodic water samples were obtained to review the runoff water quality in terms of chloride concentration,

presence of nitrates as well as *E. Coli*. Figure 13.5 presents a summary of the nitrate, chloride, and *E. Coli* sampling results.

Chloride is an urban stormwater contaminant that is generally associate with winter road salting and sanding. Within this study chloride concentrations were found to be elevated where runoff from Highway 97 enters a drainage system. Other roads within West Kelowna were not found to contribute the salinity that flows from Highway 97 did.

The major drainage basins within the District showed escalating nitrate concentrations as the creeks received more and more stormwater before discharging into Okanagan Lake. Nitrates increased significantly as flows traveled through agricultural or residential areas. The creeks within the District of West Kelowna carried in the order of 4 to 21 times the nitrate concentrations of Okanagan Lake.

E. Coli counts were found to be low for raw water in the upper reaches of every creek system of West Kelowna. The *E. Coli* bacteria counts were found to climb in the lower sections, once the drainage system received runoff from the urban areas. Bacteria counts were found to be exceptionally high in the highly urbanized and ditched system of Smith Creek. *E. Coli* typing should be considered for the sites where *E. Coli* were consistently high, particularly Smith Creek, to pinpoint the sources of bacteria loading.

14.3 RECOMMENDATIONS

Based on the enclosed analysis, field review and data collection tasks, the following recommendations are presented for District Staff.

PROGRAMMATIC RECOMMENDATIONS

- That the District engage a summer student position to research and assemble the historical subdivision and roadway plans that may be in the archives of the Ministry of Transportation and Infrastructure. There are a number of early subdivision files in which the design or as-built drawings were not available. This information, would be valuable in confirming the existing infrastructure and updating the District's asset management database.

- That the District implement a Roadside Ditch Inventory Program. During the field inspections, a number of roadside ditches appeared to have been filled in over the years, and in some cases culverts have been installed Much of the District's drainage network is dependent upon the roadside ditch network and

gradual infilling and modifications to these systems will result in alterations of the overland flow directions. To record the current condition, and help maintain the existing drainage patterns, documenting the existing conditions will strengthen the District's position in undertaking the desired reinstatement works in future years.

- The developed storm water model, as assembled with the PCSWMM computer model includes relevant data on the drainage infrastructure components, wherever this information was available. Data such as pipe size, lengths, materials and date of installation were entered into the model for future inclusion within the District's Asset Management programs. The District can import this data, directly from the model files, and adapt to the selected asset management software.

- That the District initiate a data collection program for the geotechnical boreholes and soils test holes within new development areas. This geotechnical data can be very useful in assembling and updating the initial work done in the hydrogeological review, as part of this assignment. In order to utilize the available information from the development proponents, and update the existing database, it may be necessary to obtain authorization from the development proponents during the subdivision application process. Thus requirement may become a part of the subdivision approvals process.

- That the District implement a Right-of-Way inventory program to research existing Right-of-Way documents, and carry out field inspections to confirm if the drainage easements are still functional as intended. Existing drainage courses, either overland or piped may become altered or built-upon by residents over time, and the ability for the District to access or maintain these facilities can become restricted. This information could be assembled within a GIS database format, for ease of reference and to record the current status, in the event that conditions change in the future. This inventory and mapping work can be combined with other utilities such as sewer and water easements to help ensure unencumbered access for the District.

- Although the District has a number of ongoing activities and infrastructure upgrade projects, in looking forward, it is recommended that the District consider establishing a Municipal Drainage Utility, similar to that of the Sanitary Sewer and Water utilities. The Drainage Utility would be funded through a dedicated tax and utility charge, that is dependent upon the land-use

criteria. As a self sufficient utility, it would be better able to plan for priority improvement and restoration projects, maintain a consistent level of service and establish longer term objectives.

- That the District continue, and if possible increase the frequency of culvert inspections and catchbasin cleaning. A number of culverts were noted as blocked, partially blocked or damaged, during the field inspections. These may reduce the hydraulic efficiency of the culverts and increase the potential for localized flooding. A number of catchbasins were observed to have significant sediment accumulation, and these should be cleaned regularly to ensure that the sediment capture and hydraulic capacity remain at the optimum levels.

- As an integral part of future roadway construction and transportation planning, it is recommended that Best Management Practices for roadway construction be included in the design of the DCC Roadway Program. Roadway construction, can significantly alter the pre-existing drainage patterns, and will also increase the amount of impervious surface within a watershed. Careful planning, design and commitment from the District to pursue low impact initiatives can help mitigate the effects on the downstream receiving waters.

RECOMMENDED IMPROVEMENT WORKS

Based the field reviews and enclosed analysis, additional recommendations include:

- Proceed with the recommended improvement projects identified as High priority projects as soon as funding is available. Coordinate project implementation with other utility or roadway improvement projects as the opportunities may arise.

- Improvement projects stipulated as Medium and Low priority projects should be completed once the High priority projects are completed. Similar to the above comment, the Medium and Low property projects should be coordinated with other utility or roadway improvement projects.

- Runoff flow rates presented within the enclosed report can be used as a guideline for sizing drainage infrastructure; however detailed design should be carried out to confirm grades and final conveyance capacities.

- Maintain predevelopment drainage patterns to ensure a continued and stable hydrological regime, without compromising or impacting the wetland communities from the potentially harmful effects of storm water runoff.

- Establish and preserve buffers around wetlands.

- Pursue opportunities to preserve, expand or create additional wetland areas;

- Continue with, and expand upon public education programs that reinforce the importance of pollution prevention and riparian habitat protection, particularly among landowners along the major creeks and tributaries within the District.