GOLDER
MEMBER OF WSP

REPORT

Flood Risk Assessment and Inventory

Siksika Bow River Hazard Study

Submitted to:

Alberta Environment and Parks
11th Floor, Oxbridge Place
9820 - 106th Street NW
Edmonton, Alberta T5K 2J6

Submitted by:

Golder Associates Ltd.
3300, 237 – 4th Avenue SW, Calgary, Alberta, Canada T2P 4K3

+1 403 299 5600

1783054_6000_RevA

June 2022

Distribution List

1 Digital Copy - Alberta Environment and Parks

1 Digital Copy - Golder Associates Ltd.

Executive Summary

Alberta Environment and Parks (AEP) commissioned Golder Associates Ltd. (Golder) in August 2017 to conduct the Siksika Bow River Hazard Study. The primary purpose of the study is to assess and identify river and flood hazards along the Bow River reach from the Highwood River confluence to a location approximately 2 km downstream of Bow City.

The study is conducted under the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, Siksika Nation, Municipal District of Foothills No. 31, the Counties of Newell, Rocky View, Vulcan and Wheatland, and the public.

The Siksika Bow River Hazard Study includes multiple components and deliverables. This report documents the methodology and results of the flood risk assessment and inventory component. The assessment involved comparison of the flood extents created as part of the open water flood inundation and design flood hazard mapping components of the study, with the collected and interpreted spatial data that contains an inventory of land parcels, buildings, major transportation infrastructure, and population. Flood risk statistics were calculated to quantify flood vulnerabilities for each of the 13 open water flood events and the design flood scenario. The statistics pertain to the number of affected parcels, buildings, and population, as well as the length of affected road and infrastructure, including bridges and culverts.

The main results of the flood risk assessment for the open water floods in the study area are summarized below:

- The number of land parcels, buildings and population, as well as the length of roads affected increase steadily from the 2-year flood to the 1,000-year flood.
- There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties, including an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City, that would be increasingly affected by larger flood events.
- One water treatment facility is affected by direct flood inundation starting at the 350-year flood and is surrounded by direct inundation at the 35-year flood. No other critical, non-residential buildings (i.e., government buildings, hospitals, or schools) would be affected by any of the flood events.
- The length of roads affected by direct flood inundation increases steadily from the 2-year flood to the 1,000-year flood. There are several locations where roads cross the Bow River, and these roads are all increasingly affected by larger flood events. Some of the major roads that would be affected by floods in the study area include the following:
  - Highway 547 northeast of the Bow River crossing (Arrowwood Bridge) at return periods of 20 years and higher.
  - Highway 24 south of the Bow River crossing at return periods of 100 years and higher.
  - Highway 842 north and south of the Bow River crossing (Cluny Bridge) at return periods of 100 years and higher.
  - Highway 539 at the Bow River crossing at return periods of 200 years and higher (flooding of the bridge deck).

The main results of the flood risk assessment for the design flood in the study area are summarized below:

- There are 56 residential buildings and 10 non-residential buildings located in the floodway.
- There are 58 residential and one (1) non-residential buildings located in the flood fringe.
- No buildings are located in the high hazard flood fringe.
- There is a total population of 89 located in the floodway areas, and a total population of 105 located in the flood fringe areas.
- One water treatment facility is located in the floodway. No other critical, non-residential buildings (i.e., government buildings, hospitals, or schools) would be affected by the design flood.
- Some of the major roads that would be affected are Highway 24 south of the Bow River crossing, Highway 547 north of the Bow River crossing (Arrowwood Bridge), and Highway 842 south of the Bow River crossing (Cluny Bridge),

Acknowledgements

This component of the Siksika Bow River Hazard Study was led by Mr. Sean Kurash. Overall project management was provided by Dr. Hua Zhang with direction by Dr. Dejiang Long. The flood risk assessment and inventory were prepared by Mr. Sean Kurash and Mr. Peter Thiede.

The authors express their special thanks to Mr. Kurt Morrison, project manager for Alberta Environment and Parks, who provided overall study management, background data, and technical guidance.

Table of Contents

1.0 INTRODUCTION 1

1.1 Study Objectives 1

1.2 Study Area and Reaches 1

2.0 AVAILABLE SPATIAL DATA 3

2.1 Cadastral Data 3

2.2 Roads and Railroads 3

2.3 Buildings 3

2.4 Census Data 3

3.0 INTERPRETED SPATIAL DATA 4

3.1 Interpretation Method 4

3.2 Aerial Imagery Interpretation 4

3.3 Cadastral Data 4

3.4 Census Data 4

4.0 FLOOD RISK ASSESSMENT AND INVENTORY 5

4.1 Approach 5

4.2 Method 5

4.3 Open Water Flood Inundation Scenarios 6

4.3.1 General 6

4.3.2 Land Parcels 6

4.3.3 Residential Buildings 8

4.3.4 Non-Residential Buildings 9

4.3.5 Major Transportation Infrastructure 10

4.3.5.1 Roads 10

4.3.5.2 Bridges/Culverts 13

4.3.5.3 Railroads 15

4.3.6 Population 15

4.4 Design Flood Hazard Scenario 16

4.4.1 General 16
4.4.2 Land Parcels 16
4.4.3 Residential Buildings 17
4.4.4 Non-Residential Buildings 17
4.4.5 Major Transportation Infrastructure 17
4.4.5.1 Roads 17
4.4.5.2 Bridges/Culverts 18
4.4.5.3 Railroads 18
4.4.6 Population 18
5.0 CONCLUSIONS 19
THIRD PARTY DISCLAIMER 21
REFERENCES 21

TABLES

Table 1: Affected Land Parcels – Open Water Flood Inundation Scenarios 7
Table 2: Affected Residential Buildings – Open Water Flood Inundation Scenarios 8
Table 3: Affected Non-Residential Buildings – Open Water Flood Inundation Scenarios 10
Table 4: Lengths of Affected Roads – Open Water Flood Inundation Scenarios 11
Table 5: Bridge Clearances – Open Water Flood Inundation Scenarios 14
Table 6: Affected Population – Open Water Flood Inundation Scenarios 15
Table 7: Affected Land Parcels – Design Flood Hazard Scenario 17
Table 8: Affected Residential Buildings – Design Flood Hazard Scenario 17
Table 9: Affected Non-Residential Buildings – Design Flood Hazard Scenario 17
Table 10: Lengths of Affected Roads – Design Flood Hazard Scenario 18
Table 11: Bridge Clearances – Design Flood Hazard Scenario 18
Table 12: Affected Population – Design Flood Hazard Scenario 18

FIGURES

Figure 1: Study Area (Provided by AEP) 2
Figure 2: Affected Land Parcels for Open Water Flood Inundation Scenarios 7
Figure 3: Affected Buildings - Open Water Flood Inundation Scenarios 9
Figure 4:Lengths of Affected Roads – Open Water Flood Inundation Scenarios 11
Figure 5: Affected Population – Open Water Flood Inundation Scenarios 16

1.0 INTRODUCTION

1.1 Study Objectives

Alberta Environment and Parks (AEP) commissioned Golder Associates Ltd. (Golder) in August 2017 to conduct the Siksika Bow River Hazard Study (the study). The primary purpose of the study is to assess and identify river and flood hazards along the Bow River reach from the Highwood River confluence to a location approximately 2 km downstream of Bow City. The study is conducted under the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, Siksika Nation, Municipal District of Foothills No. 31, the Counties of Newell, Rocky View, Vulcan and Wheatland, and the public.

The study includes multiple components and deliverables. This report documents the methodology and results of the flood risk assessment and inventory component. The assessment compares the flood extents, which were created as part of the open water flood inundation and design flood hazard mapping components of the study, with the collected and interpreted spatial data that inventory land parcels, buildings, major transportation infrastructure, and population. Flood risk statistics were calculated to quantify flood vulnerabilities for each of the 13 open water flood events and the design flood scenario. The statistics pertain to the number of affected parcels, buildings, and population, as well as the length of affected road and infrastructure, including bridges and culverts.

1.2 Study Area and Reaches

The study reach is along the 221 km Bow River reach. The study area includes the Siksika Nation, the Municipal District of Foothills No. 31, and the Counties of Newell, Rocky View, Vulcan and Wheatland (see Figure 1).

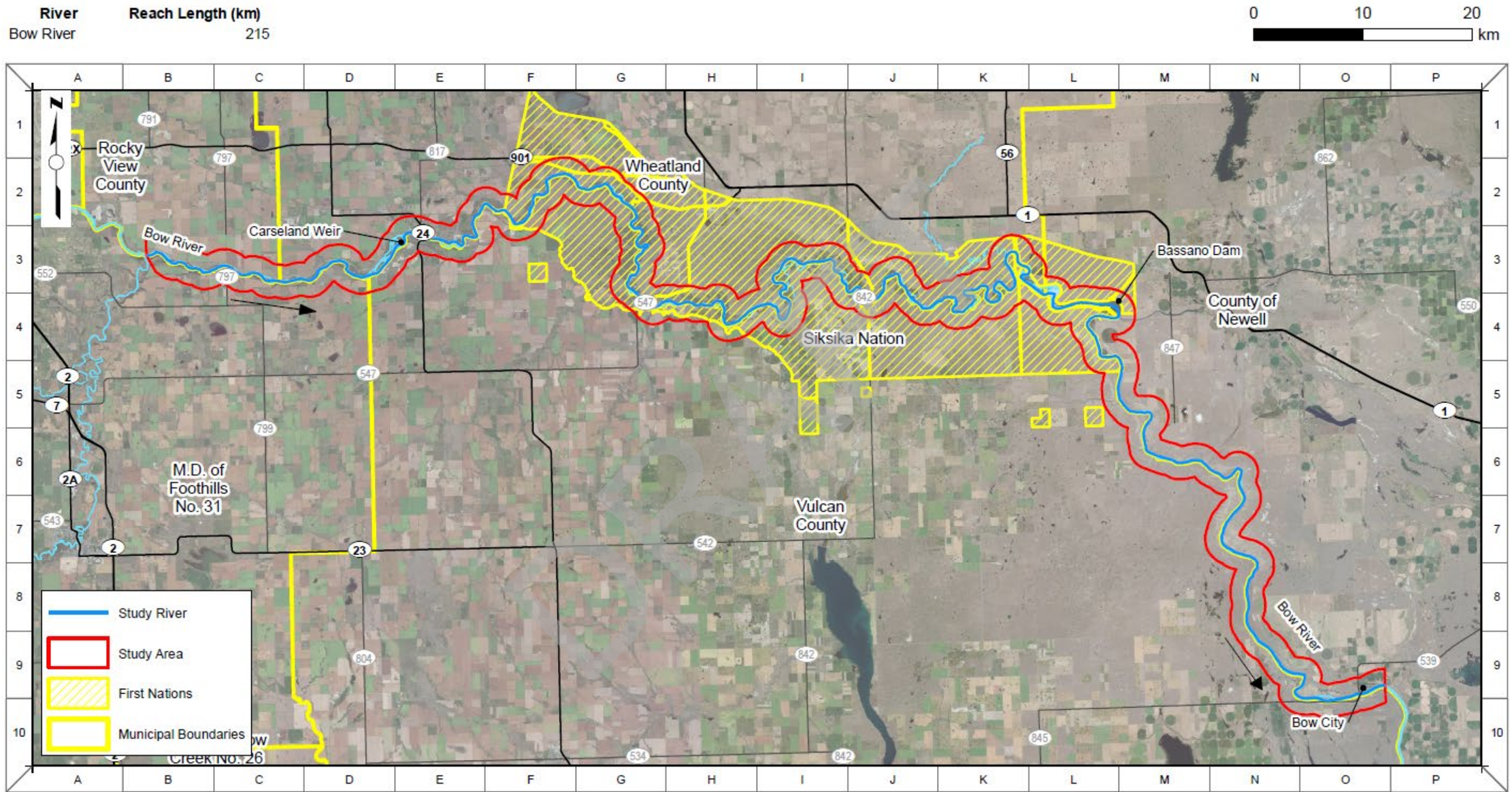

Figure 1: Study Area (Provided by AEP)

2.0 AVAILABLE SPATIAL DATA

2.1 Cadastral Data

Cadastral data (i.e., boundaries of registered land parcels) was provided to Golder by AEP in November 2017.

2.2 Roads and Railroads

Road and railroad data for the study area was obtained from AltaLIS (the distributor of provincial spatial data) in July 2018. There are no railroads in the study area. Within the Siksika Nation reserve, roads were updated in 2022 based on the data information provided by Siksika Nation.

2.3 Buildings

One water treatment facility is within the study area. No other major infrastructure features such as hospitals or schools are located within the study area. Within the Siksika Nation reserve, buildings were updated in 2022 based on the data information provided by Siksika Nation.

2.4 Census Data

Population statistics were obtained from the Statistics Canada 2016 census dissemination blocks (Statistics Canada 2017). The census tallies the number of people whose usual place of residence is in the area. Dissemination blocks are the smallest geographic area for which population counts are disseminated in Canada.

3.0 INTERPRETED SPATIAL DATA

3.1 Interpretation Method

Additional data for roads and other infrastructure was created by interpreting aerial imagery as required.

Cadastral data was converted from polygons to points (centroids) and census data was assigned to building points to allow for more efficient tallying of affected features.

The interpretation method is further described in the following sections.

3.2 Aerial Imagery Interpretation

Aerial imagery for the study area was collected for AEP by OGL Engineering on July 15, 2018 and provided to Golder. The imagery has a 0.30 m Ground Sampling Distance (GSD) resolution and was provided as 4-band orthophotos.

The imagery was used to derive building points (locations of residential and non-residential buildings) within the study area. It was also used to check and update roads throughout the study area.

Based on the 2018 imagery, it was determined that no residential buildings remain in the Hidden Valley Resort. Previously, one of the largest clusters of residential buildings in the study area was located in this area. Therefore, the flood control structure for the Hidden Valley Resort is no longer considered to be active. In addition, there are no other flood control structures along the 221 km long Bow River study reach.

Within the Siksika Reserve, building data provided by Siksika Nation was used.

3.3 Cadastral Data

The polygon datasets representing the land parcels were converted to points (centroid) for further analysis.

3.4 Census Data

To more accurately estimate the population affected by each flood event, the population count for each dissemination block was evenly distributed between all residential buildings that fall into the block. Where multifamily buildings existed, it was assumed that their average number of residents would be ten times that of the single family homes within the block. Spot checks showed reasonable estimates of residents per building.

Distributing the population numbers to the residential buildings ensures that residents are only counted as affected when their building falls within the inundation extent.

4.0 FLOOD RISK ASSESSMENT AND INVENTORY

4.1 Approach

After the spatial data was compiled, features affected by floods were identified by overlaying flood polygon datasets with the parcel, building, or infrastructure datasets. Features falling within a flood extent were flagged as being affected or potentially affected by the flood event.

Flood statistics were then generated by tallying all affected features for the following categories:

- land parcels;
- residential buildings;
- non-residential buildings;
- major transportation infrastructure; and
- population (based on residential buildings).

The following sections provide further information on the analysis methodology and results of the assessment.

4.2 Method

Using the inventory datasets developed and described in Sections 2.0 and 3.0, flood statistics were generated for various flood events and flood scenarios considered in this study.

The method to generate these flood statistics consisted of the following four steps:

- Flood polygons for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year flood events and the design flood scenario were generated as part of open water flood inundation and flood hazard mapping work undertaken for this study (Golder 2019 and 2022).
- For each flood event and scenario, the flood polygons were compared to the inventory dataset in GIS. Land parcels, buildings, and infrastructure were classified as being “affected” if they were located within a mapped flood extent (centroid for parcels). Road lengths affected by flooding were also calculated.
- The population affected in each flood scenario was calculated by tallying the number of residents assigned to each affected residential building (see Section 3.4).
- The flood statistics for each category were summarized in a series of Microsoft Excel tables.

Flood statistics were calculated separately for three areas of flooding based on flood inundation mapping (Golder 2019) and two areas of flooding based on design flood hazard mapping (Golder 2022), as summarized below:

- Direct flood inundation areas: These are areas expected to be inundated for various flood events and have a direct overland connection to the main river channels.
- Flood control structure failure inundation areas: These are areas that would be flooded if the flood control structure protecting the areas would fail.

- Floodway areas: The floodway is the portion of design flood hazard area where flows are generally deepest, fastest, and most destructive during a design flood event. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area.
- Flood Fringe areas: The flood fringe is the portion of the design flood hazard area outside the floodway. The flood fringe is divided into three zones:
  - Flood Fringe: Inundated areas outside of the floodway that are shallower and flow velocities are slower.
  - High Hazard Flood Fringe: Areas of deeper or faster-moving water outside of the floodway.
  - Protected Flood Fringe: Low lying areas behind dedicated flood control structures that are at risk of flooding if the structures would fail.

4.3 Open Water Flood Inundation Scenarios

4.3.1 General

Flood inundation extents were delineated for thirteen (13) open water flood events (Golder 2019). Flood statistics for direct inundation areas were calculated for each flood event, and the results are presented in the following sections.

4.3.2 Land Parcels

A summary of affected land parcels is presented in Table 1, including the total number, as well as a breakdown of parcels affected by direct inundation. Figure 2 shows affected parcels per flood event.

Table 1: Affected Land Parcels – Open Water Flood Inundation Scenarios

Flood Event	Direct Inundation
2-Year	29
5-Year	61
10-Year	80
20-Year	106
35-Year	123
50-Year	133
75-Year	145
100-Year	156
200-Year	181
350-Year	197
500-Year	210
750-Year	219
1,000-Year	231

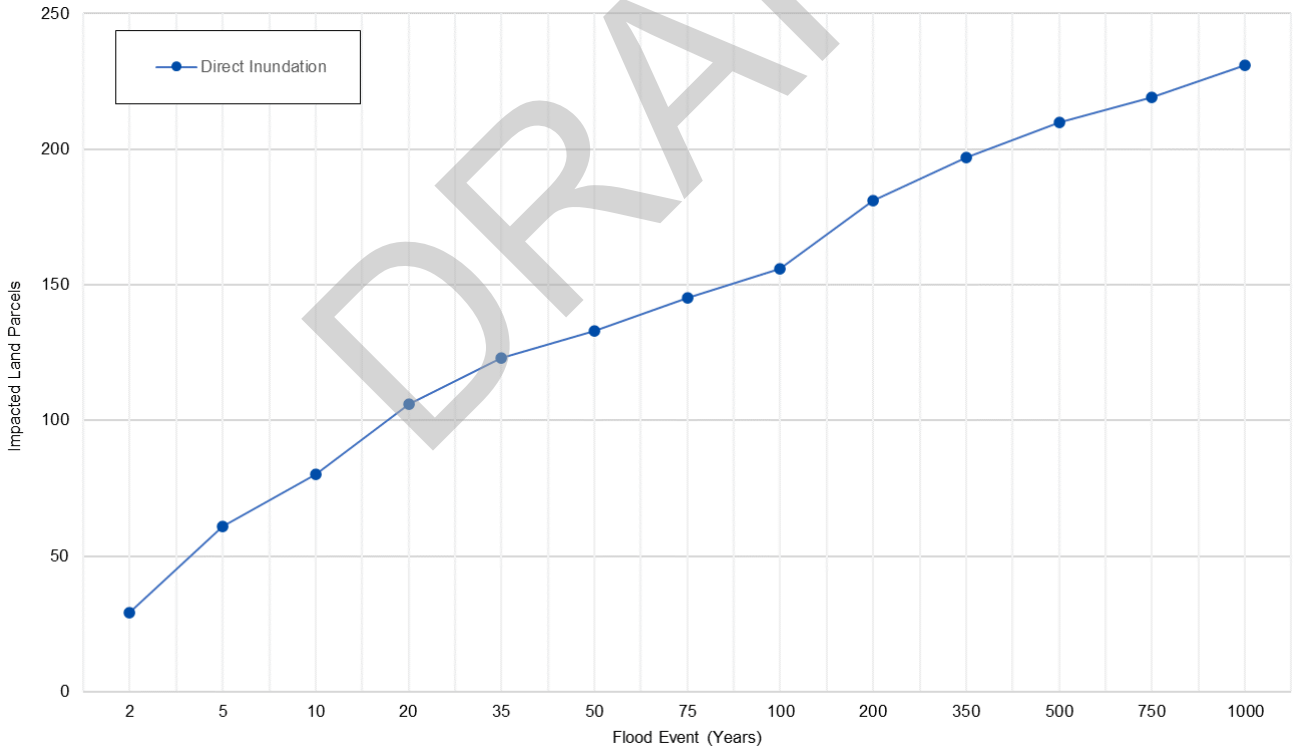

Figure 2: Affected Land Parcels for Open Water Flood Inundation Scenarios

The number of parcels affected by direct flood inundation increases steadily from the 5-year flood to the 1,000-year flood.

There are no urban areas located within the study area. However, there are several clusters of smaller parcels, including an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City, that would be increasingly affected by larger flood events. There are also large, rural parcels located along the Bow River throughout the study area.

For the 100-year flood, 156 land parcels would be directly inundated. In comparison, 231 land parcels would be directly inundated for the 1,000-year flood.

4.3.3 Residential Buildings

A summary of affected residential buildings is presented in Table 2, including the total number, as well as a breakdown of residential buildings affected by direct inundation. Figure 3 shows affected buildings per flood event, including residential buildings.

The number of residential buildings affected by direct flood inundation increases steadily from the 5-year flood to the 1,000-year flood.

There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties that would be increasingly affected by larger flood events. These include an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City.

For the 100-year flood event, 111 residential buildings would be directly inundated. In comparison, 176 residential buildings would be directly inundated by the 1,000-year flood event.

Table 2: Affected Residential Buildings – Open Water Flood Inundation Scenarios

Flood Event	2-Year	5-Year	10-Year	20-Year	35-Year	50-Year	75-Year	100-Year	200-Year	350-Year	500-Year	750-Year	1,000-Year
Total	**0**	**1**	**9**	**18**	**35**	**59**	**92**	**111**	**139**	**156**	**167**	**172**	**176**
Single Family	0	1	9	18	35	59	92	111	139	156	167	172	176
Multifamily	0	0	0	0	0	0	0	0	0	0	0	0	0
Retirement Home	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Inundation	**0**	**1**	**9**	**18**	**35**	**59**	**92**	**111**	**139**	**156**	**167**	**172**	**176**
Single Family	0	1	9	18	35	59	92	111	139	156	167	172	176
Multifamily	0	0	0	0	0	0	0	0	0	0	0	0	0
Retirement Home	0	0	0	0	0	0	0	0	0	0	0	0	0

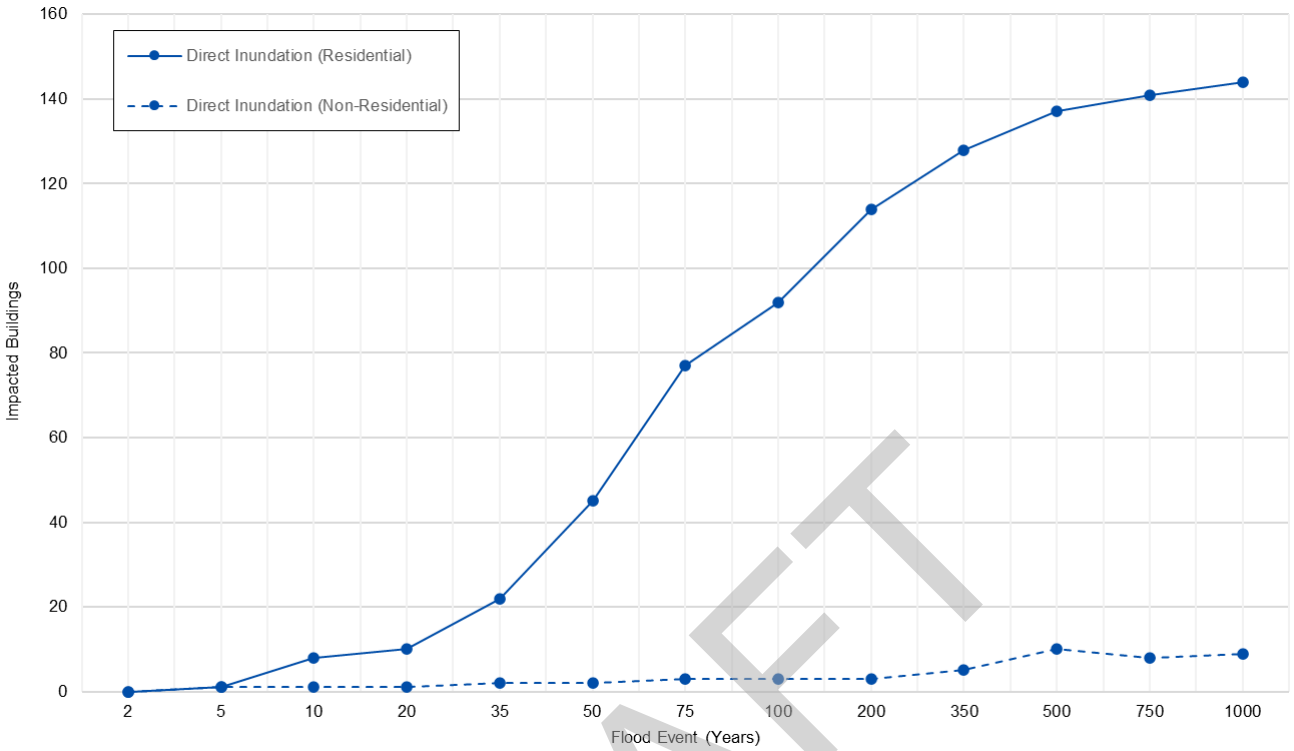

Figure 3: Affected Buildings - Open Water Flood Inundation Scenarios

4.3.4 Non-Residential Buildings

A summary of affected non-residential buildings is presented in Table 3, including the total number, as well as a breakdown of non-residential buildings affected by direct inundation. Figure 3 shows affected buildings per flood event, including non-residential buildings.

The number of non-residential buildings affected by direct flood inundation increases slowly from the 5-year flood to the 1,000-year flood.

There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties that would be increasingly affected by larger flood events. These include an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City.

For the 100-year flood event, 9 non-residential buildings would be directly inundated. No schools would be directly inundated or would be potentially inundated in the case of a flood control structure failure. In comparison, 17 non-residential buildings, would be directly inundated by the 1,000-year flood.

One water treatment facility is affected by direct flood inundation starting at the 350-year flood. This facility is located in the floodway and is surrounded by direct inundation at the 35-year flood. No other critical, non-residential buildings (i.e., government buildings, hospitals, or schools) would be affected by any of the flood events.

Table 3: Affected Non-Residential Buildings – Open Water Flood Inundation Scenarios

Flood Event	2-Year	5-Year	10-Year	20-Year	35-Year	50-Year	75-Year	100-Year	200-Year	350-Year	500-Year	750-Year	1,000-Year
Total	**0**	**2**	**2**	**4**	**6**	**7**	**9**	**9**	**10**	**13**	**14**	**16**	**17**
Commercial	0	0	0	1	2	2	3	3	4	4	4	5	5
Industrial	0	0	0	0	1	1	2	2	2	2	2	3	3
Government Building	0	0	0	0	0	0	0	0	0	0	0	0	0
Hospital	0	0	0	0	0	0	0	0	0	0	0	0	0
School	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Facility	0	0	0	0	0	0	0	0	0	1	1	1	1
Other Non-Residential	0	2	2	3	3	4	4	4	4	6	7	7	8
Direct Inundation	**0**	**2**	**2**	**4**	**6**	**7**	**9**	**9**	**10**	**13**	**14**	**16**	**17**
Commercial	0	0	0	1	2	2	3	3	4	4	4	5	5
Industrial	0	0	0	0	1	1	2	2	2	2	2	3	3
Government Building	0	0	0	0	0	0	0	0	0	0	0	0	0
Hospital	0	0	0	0	0	0	0	0	0	0	0	0	0
School	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Facility	0	0	0	0	0	0	0	0	0	1	1	1	1
Other Non-Residential	0	2	2	3	3	4	4	4	4	6	7	7	8

4.3.5 Major Transportation Infrastructure

4.3.5.1 Roads

A summary of affected roads is presented in Table 4, including the total length of affected roads, as well as a breakdown of roads affected by direct inundation. Figure 4 shows affected roads per flood event.

Table 4: Lengths of Affected Roads – Open Water Flood Inundation Scenarios

Flood Event	Affected Length (km)
	Direct Inundation
2-Year	2.0
5-Year	12.1
10-Year	24.3
20-Year	43.6
35-Year	62.8
50-Year	80.1
75-Year	97.3
100-Year	105.1
200-Year	122.2
350-Year	131.7
500-Year	137.6
750-Year	143.7
1,000-Year	147.5

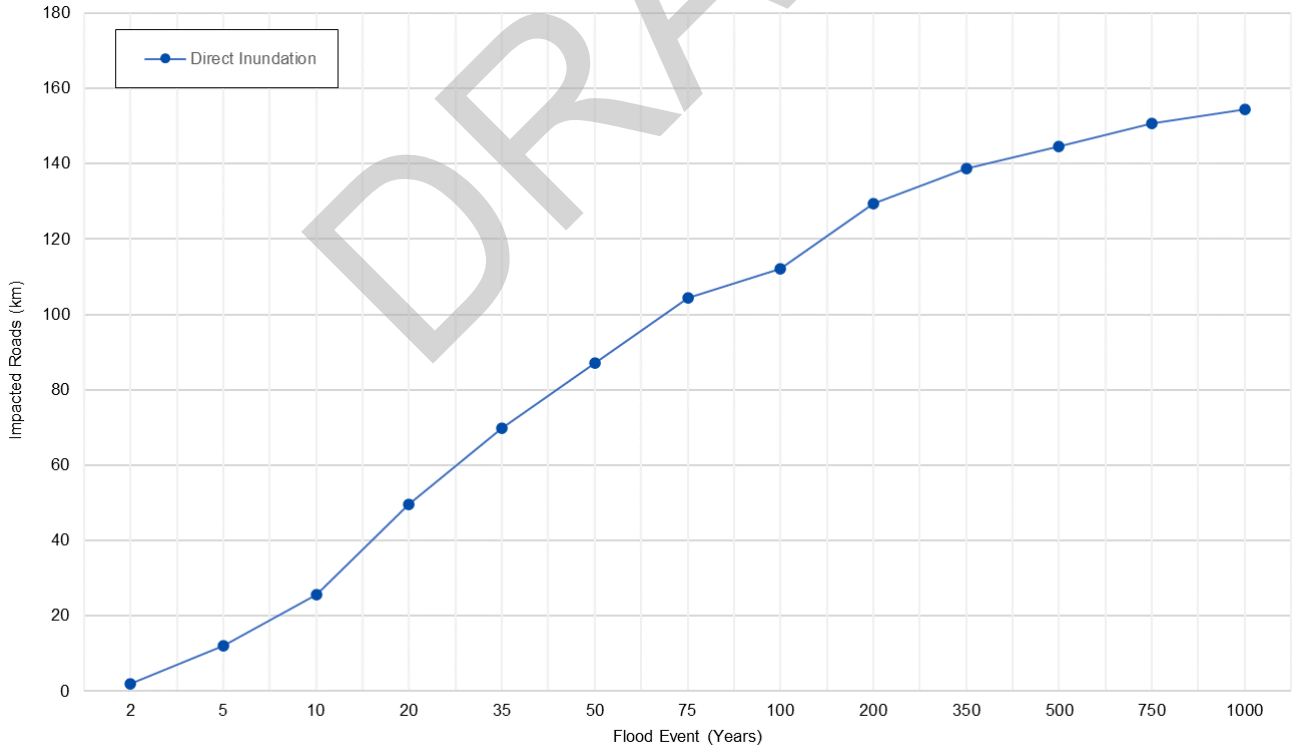

Figure 4:Lengths of Affected Roads – Open Water Flood Inundation Scenarios

The length of roads affected by direct flood inundation increases steadily from the 2-year flood to the 1,000-year flood.

There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties, including an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City. Rural and access roads in these areas would be increasingly affected by large flood events. There are also several locations where roads cross the Bow River, including Highway 24 southeast of Carseland, Highway 547 (Arrowwood Bridge), Highway 842 (Cluny Bridge), Crowfoot Ferry and Highway 539 at Bow City. These roads would also be increasingly affected by large flood events.

The following roads within the study area would be affected by direct inundation:

- Unnamed road located in 32-021-23 W4M and 29-021-23 W4M by floods with return periods of 5 years and higher.
- Unnamed road located in 09-021-23 W4M, connecting Highway 547 and Range Road 233 by floods with return periods of 5 years and higher.
- Unnamed road located in 24-021-20 W4M at the Crowfoot Ferry by floods with return periods of 5 years and higher.
- Unnamed road located in 20-021-21 W4M and 21-021-21 W4M by floods with return periods of 10 years and higher.
- Township Road 215A between Highway 24 and Range Road 253 by floods with return periods of 20 years and higher.
- Highway 547 northeast of the Bow River crossing (Arrowwood Bridge) by floods with return periods of 20 years and higher.
- Unnamed road located in 15-021-21 W4M by floods with return periods of 20 years and higher.
- Unnamed road located in 14-021-21 W4M by floods with return periods of 20 years and higher.
- Range Road 252A by floods with return periods of 35 years and higher.
- Unnamed local road located in 08-022-23 W4M by floods with return periods of 5 years and higher.
- Unnamed road located in 04-022-23 W4M and 34-021-23 W4M, connecting Highway 901 and Highway 547 by floods with return periods of 35 years and higher.
- Unnamed road located in 19-021-21 W4M and 17-021-21 W4M by floods with return periods of 35 years and higher.
- Unnamed road located in 09-021-20 W4M by floods with return periods of 50 years and higher.
- Unnamed road located in 30-021-21 W4M and 24-021-22 W4M by floods with return periods of 75 years and higher.
- Township Road 172A west of the intersection with Highway 539 by floods with return periods of 75 years and higher.

- Highway 24 south of the Bow River crossing by floods with return periods of 100 years and higher.
- Highway 842 north and south of the Bow River crossing (Cluny Bridge) by floods with return periods of 100 years and higher.
- Township Road 215A west of Highway 24 by floods with return periods of 200 years and higher.
- Unnamed road located in 23-021-20 W4M by floods with return periods of 200 years and higher.
- Highway 539 at the Bow River crossing by floods with return periods of 200 years and higher (flooding of the bridge deck).
- Unnamed road west of the Bassano Dam by floods with return periods of 350 years and higher.

At the 100-year flood, about 112 km of roads would be directly inundated. In comparison, 154 km of roads would be directly inundated for the 1,000-year flood.

4.3.5.2 Bridges/Culverts

There are no culvert crossings in the study area. A summary of bridge clearances during floods is presented in Table 5.

Table 5: Bridge Clearances – Open Water Flood Inundation Scenarios

River	Name	Minimum Low Chord/ Road Surface Elevation (m)	2-Year		5-Year		10-Year		20-Year		35-Year		50-Year		75-Year		100-Year		200-Year		350-Year		500-Year		750-Year		1,000-Year	
			Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)	Water Level (m)	Clearance (m)
Bow River	Highway 24 Bridge	909.7	903.9	5.8	904.6	5.1	905.1	4.6	905.7	4.0	906.1	3.5	906.5	3.2	906.8	2.9	907.1	2.6	907.8	1.9	908.3	1.3	908.7	1.0	909.1	0.6	909.4	0.3
Bow River	Highway 547 (Arrowwood) Bridge	854.7	851.4	3.2	852.3	2.4	852.9	1.7	853.6	1.1	854.1	0.5	854.4	0.3	854.8	-0.1	855.0	-0.4	855.7	-1.1	856.2	-1.6	856.6	-1.9	857.0	-2.3	857.3	-2.6
Bow River	Highway 842 (Cluny) Bridge	818.3	813.6	4.7	814.5	3.7	815.3	3.0	816.0	2.3	816.5	1.8	816.9	1.4	817.4	0.9	817.7	0.6	818.6	-0.3	819.5	-1.2	820.1	-1.8	820.7	-2.4	821.4	-3.2
Bow River	Highway 539 Bridge	747.5	742.4	5.1	743.3	4.2	743.9	3.6	744.7	2.9	745.3	2.2	745.7	1.8	746.2	1.3	746.6	0.9	747.5	0.0	748.4	-0.8	748.9	-1.4	749.6	-2.1	750.1	-2.6

Note: The clearances are the elevation differences between bridge low chord elevations and simulated water levels. A negative value indicates the water depth above the low chord for a bridge.

4.3.5.3 Railroads

No railroads are located within the study area.

4.3.6 Population

Each residential building in the study area (including single family, multifamily, and retirement homes) was assigned a number of residents based on the population count of the census block they are located in (see Section 2.2). The population affected by a flood event was estimated based on a tally of the residents of all affected residential buildings.

A summary of affected population is presented in Table 6, including the total numbers, as well as a breakdown of population affected by direct inundation. Figure 5 shows affected population per flood event.

Table 6: Affected Population – Open Water Flood Inundation Scenarios

Flood Event	Direct Inundation
2-Year	0
5-Year	1
10-Year	17
20-Year	36
35-Year	63
50-Year	100
75-Year	150
100-Year	188
200-Year	246
350-Year	289
500-Year	309
750-Year	325
1,000-Year	344

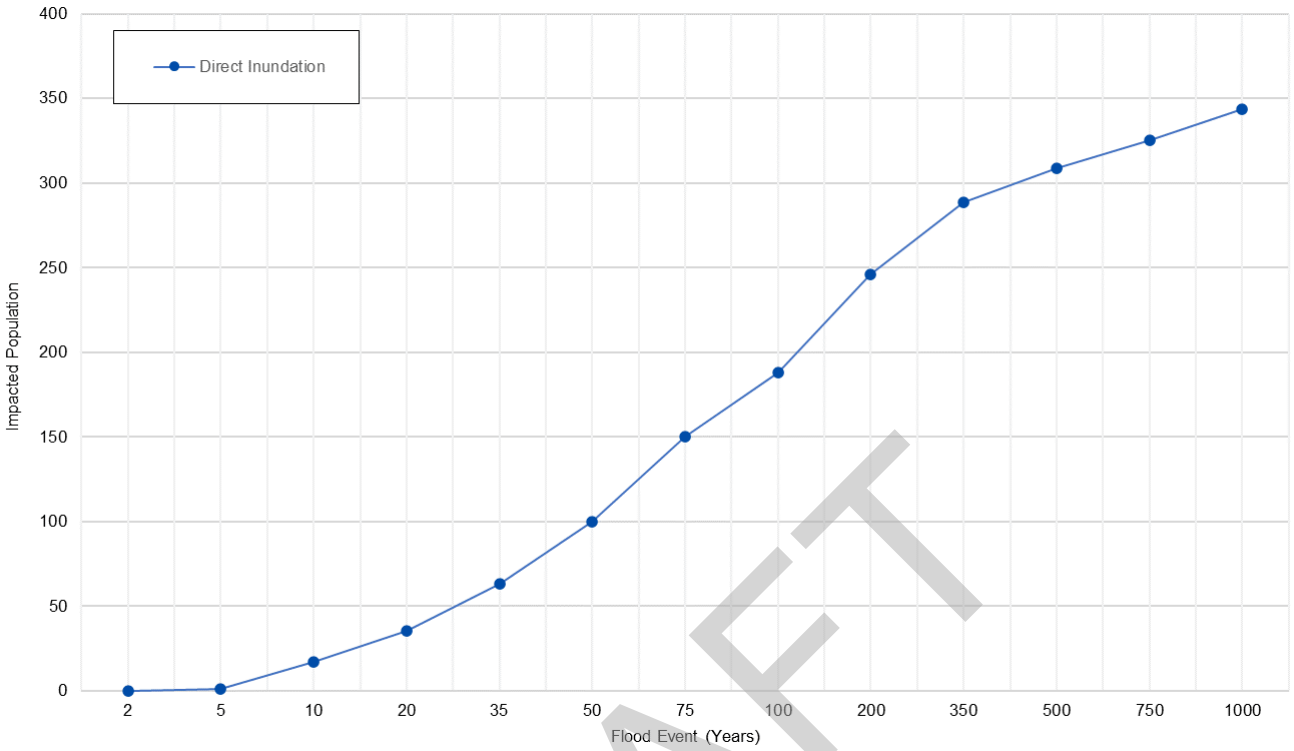

Figure 5: Affected Population – Open Water Flood Inundation Scenarios

The population affected by direct flood inundation increases steadily from the 5-year flood to the 1,000-year flood.

There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties that would be increasingly affected by larger flood events. These include an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City.

For the 100-year flood event, a population of 188 would be affected by direction inundation. In comparison, a population of 344 would be affected by direct flood inundation for the 1,000-year flood event.

4.4 Design Flood Hazard Scenario

4.4.1 General

Flood statistics were generated for the design flood event using the flood hazard maps prepared as part of this study (Golder 2022), and the results are presented in the following sections.

There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties as well as river crossings (bridges and one ferry) that would be affected by the design flood event.

4.4.2 Land Parcels

A summary of affected land parcels is presented in Table 7, including the total number, as well as a breakdown of parcels located in the floodway and flood fringe.

Table 7: Affected Land Parcels – Design Flood Hazard Scenario

Flood Event	Floodway	High Hazard Flood Fringe	Flood Fringe	Total
Design Flood	132	1	25	158

For the design flood, there are 132 land parcels located in the floodway, one (1) in the high hazard flood fringe and 25 in the flood fringe.

4.4.3 Residential Buildings

A summary of affected residential buildings is presented in Table 8, including the total number, as well as a breakdown of residential buildings located in the floodway and flood fringe.

Table 8: Affected Residential Buildings – Design Flood Hazard Scenario

Residential Category	Floodway	High Hazard Flood Fringe	Flood Fringe
Multifamily	0	0	0
Single Family	56	0	58
Retirement Home	0	0	0
Total	**56**	**0**	**58**

For the design flood, there are 55 residential buildings located in the floodway, and 62 located in the flood fringe. There are no residential buildings located in the high hazard flood fringe.

4.4.4 Non-Residential Buildings

A summary of affected non-residential buildings is presented in Table 9, including the total number, as well as a breakdown of non-residential buildings located in the floodway and flood fringe.

Table 9: Affected Non-Residential Buildings – Design Flood Hazard Scenario

Non-Residential Category	Floodway	High Hazard Flood Fringe	Flood Fringe
Commercial	2	0	1
Industrial	2	0	0
Government Building	0	0	0
Hospital	0	0	0
School	0	0	0
Water Treatment Facility	1	0	0
Other Non-Residential	5	0	0
Total	**10**	**0**	**1**

For the design flood, there are 10 non-residential buildings located in the floodway, and one (1) located in the flood fringe. There are no non-residential buildings located in the high hazard flood fringe.

No schools would be affected by the design flood.

4.4.5 Major Transportation Infrastructure

4.4.5.1 Roads

A summary of affected roads is presented in Table 10, including the total length, as well as a breakdown of roads located in the floodway and flood fringe.

Table 10: Lengths of Affected Roads – Design Flood Hazard Scenario

Flood Event	Affected Road Length (km)			
	Floodway	High Hazard Flood Fringe	Flood Fringe	Total
Design Flood	72.9	2.2	32.4	107.4

Details on inundation of major roads within the study area during the design flood are provided below:

- Highway 24 south of the Bow River crossing, Highway 547 north of the Bow River crossing (Arrowwood Bridge) and Highway 842 south of the Bow River crossing (Cluny Bridge) are located in the flood fringe.
- Highway 547, directly north of the Bow River crossing is located in the floodway.

For the design flood, a total length of 72.9 km of roads are located in the floodway, 2.2 km in high hazard flood fringe and 32.4 km in the flood fringe.

4.4.5.2 Bridges/Culverts

There are no culvert crossings in the study area. A summary of bridge/culvert clearances for the design flood hazard scenario in Table 11.

Table 11: Bridge Clearances – Design Flood Hazard Scenario

River	Name	Minimum Low Chord / Road Surface Elevation (m)	Water Level (m)	Clearance[1] (m)
Bow River	Highway 24 Bridge	909.7	907.1	2.5
Bow River	Highway 547 (Arrowwood) Bridge	854.7	855.0	-0.3
Bow River	Highway 842 (Cluny) Bridge	818.3	817.7	0.6
Bow River	Highway 539 Bridge	747.5	746.6	0.9

Note 1: The clearances for the 100-year design flood event are the elevation differences between bridge low chord elevations and simulated water levels. A negative value indicates the water depth above the low chord for a bridge.

4.4.5.3 Railroads

No railroads are located within the study area.

4.4.6 Population

A summary of affected population is presented in Table 12, including the total number, as well as a breakdown of population located in areas falling into the floodway and flood fringe.

Table 12: Affected Population – Design Flood Hazard Scenario

Flood Event	Floodway	High Hazard Flood Fringe	Flood Fringe	Total
Design Flood	89	0	105	194

For the design flood, there is a population of 89 located in the floodway and 105 in the flood fringe. There is no population in the high hazard flood fringe.

5.0 CONCLUSIONS

The main results of the flood risk assessment for the open water floods in the study area are summarized below:

- The number of land parcels, buildings and population, as well as the length of roads affected increase steadily from the 2-year flood to the 1,000-year flood.
- There are no urban areas located within the study area. However, there are several clusters of residences and commercial properties, including an area around the Highway 24 bridge southeast of Carseland, several settlement areas on the Siksika Reserve and Bow City, that would be increasingly affected by larger flood events.
- One water treatment facility is affected by direct flood inundation starting at the 350-year flood and is surrounded by direct inundation at the 35-year flood. No other critical, non-residential buildings (i.e., government buildings, hospitals, or schools) would be affected by any of the flood events.
- The length of roads affected by direct flood inundation increases steadily from the 2-year flood to the 1,000-year flood. There are several locations where roads cross the Bow River, and these roads are all increasingly affected by larger flood events. Some of the major roads that would be affected by floods in the study area include the following:
  - Highway 547 northeast of the Bow River crossing (Arrowwood Bridge) by floods with return periods of 20 years and higher.
  - Highway 24 south of the Bow River crossing by floods with return periods of 100 years and higher.
  - Highway 842 north and south of the Bow River crossing (Cluny Bridge) by floods with return periods of 100 years and higher.
  - Highway 539 at the Bow River crossing by floods with return periods of 200 years and higher (flooding of the bridge deck).

The main results of the flood risk assessment for the design flood in the study area are summarized below:

- There are 56 residential buildings and 10 non-residential buildings located in the floodway.
- There are 58 residential and one (1) non-residential buildings located in the flood fringe.
- There is a total population of 89 located in the floodway areas, and a total population of 105 located in the flood fringe areas.
- There are no buildings of any kind or population located in the high hazard flood fringe.
- One water treatment facility is located in the floodway. No other critical, non-residential buildings (i.e., government buildings, hospitals, or schools) would be affected by the design flood.
- Some of the major roads that would be affected are Highway 24 south of the Bow River crossing, Highway 547 north of the Bow River crossing (Arrowwood Bridge), and Highway 842 south of the Bow River crossing (Cluny Bridge),

Signature Page

This report was prepared and reviewed by the undersigned:

Golder Associates Ltd.

Prepared by:

Sean Kurash, B.Sc.
GIS Specialist

Reviewed by:

Hua Zhang, Ph.D., P.Eng.
Associate, Senior Water Resource Engineer

SK/HZ/al/tt

https://golderassociates.sharepoint.com/sites/140764/project files/5 technical work/05_siksika bow/05_update reports/riskassessmentreport/final-flood-risk-assessment-inventory-report_siksika bow_rhs.docx

THIRD PARTY DISCLAIMER

This report has been prepared by Golder Associates Ltd. (Golder) for the benefit of the client to whom it is addressed. The information and data contained herein represent Golder's best professional judgment in light of the knowledge and information available to Golder at the time of preparation. Except as required by law, this report and the information and data contained herein area to be treated as confidential and may be used and relied upon only by the client, its officers and employees. Golder denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of Golder and the client.

REFERENCES

Golder Associates Ltd. 2019. *Siksika Bow River Hazard Study, Open Water Flood Inundation Mapping Report.* Prepared for Alberta Environment and Parks. July 2019.

Golder Associates Ltd. 2022. *Siksika Bow River Hazard Study, Design Flood Hazard Mapping Report.* Prepared for Alberta Environment and Parks. June 2022.

Statistics Canada. 2017. Data Products 2016 Census. Retrieved on 20 November 2017, from https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm.

GOLDER
MEMBER OF WSP

golder.com