Village of Linden

Infrastructure Master Plan

2021

CIMA+ file number : C04-00343
10 August 2021 – Review FINAL

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Infrastructure Master Plan

2021

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RM APEGA ID #: 164395
DATE: August 16 2021
PERMIT NUMBER: P8204
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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Table of involved resources

In addition to the signatories of this report, the following individuals have also been actively involved in the study and writing of the report as technical experts within the project team:

Name	Discipline
SFE Global	Hydrant Flow Tests
Thuro	CCTV Inspections

Review and submission register			
Review No.	Reviewed by	Date	Description of the change or submission
DRAFT	JP/SD/CS/JC	12/02/21	Draft report submission
DRAFT V2	JP/SD/JC/CS	30/03/21	Revised draft report submission
FINAL	JP/SD/JC/CS	09/07/21	Final report submission
FINAL V2	JP/SD/JC/CS	10/08/21	Minor revisions to final submission

Executive Summary

Introduction

The Village of Linden retained CIMA+ to prepare an Infrastructure Master Plan. This Infrastructure Master Plan will encompass a review of the existing conditions and constraints, as well as the future growth projections and required infrastructure for the proposed growth area. It will provide for broad scale planning and cost projections for the following components:

+ Water supply, storage, and distribution
+ Wastewater collection, transmission, and treatment
+ Stormwater management
+ Existing roads assessment

Growth and Population Projections

CIMA+ assessed the historical growth patterns of the Village and determined a population growth over a 20 year forecast. Linden also has a Municipal Development Plan (MDP), which outlines the growth areas, lands use types, and expected populations in each area.

Existing development areas were assessed, and growth areas were set out. These growth areas aligned with planned subdivided areas and areas in the MDP.

The MDP used a base population of 636 people, however since the development areas noted in the MDP have not been developed yet, the projected 2020 population of 882 was used for the base population.

Existing Area

+ Service population of 882 people in 2020 (Projected at 14 people per year from the 2016 census value of 828 people)
+ Service area of 62 ha

20 Year Forecast

+ 2.23% Annual population growth rate over 20 years
    - Linear growth rate of 14 people per year was used
+ Additional service population of 280 people
    - Residential growth area of 11 ha
+ Industrial growth area of 6.5 ha
+ Primary growth areas are the Northwest residential (R1) area, Northwest industrial area, and a portion of the Northeast Residential area
+ Total service population of 1164 people
+ Total service area of 79.5 ha

Full Buildout

- Additional service population of 1049 people above the 20 Year Forecast
  - Total Residential growth area of 80 ha
- Industrial growth area of 45 ha
- Total service population of 2211 people
- Total service area of 125 ha

Water System Assessment

An assessment of the existing water system and the future water system with the proposed growth area was performed by analysing historical water demands. Existing record drawings and County GIS data were used to develop GIS files representative of the infrastructure in the water system. A WaterCAD model was developed, using the analysed records and the GIS files, with scenarios for the existing system and the future water systems in order to assess the system's ability to meet design criteria. The model was used to determine deficiencies in the existing system and to develop servicing options and sizing requirements for the future systems.

Existing System (Figures W1 to W4)

Storage Reservoir

The reservoir has sufficient storage to accommodate the existing demands.

During a cleaning and investigation of the reservoir, cracking in the floor of the north cell was identified, both in 2015 and in 2018. A structural investigation of the cell should be performed to determine the source of cracking and its severity, as well as the cracking should be repaired.

Distribution System

Overall, the system performs well in the model. There is sufficient pressure throughout the system. Some of the lower areas experience higher than the recommended 80 psi, but they only marginally over the 80 psi limit and are not a concern.

One of the most notable deficiencies in the existing system is the low available fire flow on the north and west sides of the Village. This is due to two major factors. The first is that the north and west areas have minimal interconnection, resulting in large dead end areas. The other major contributor is small diameter pipes that are hydraulically restrictive.

There is currently an abandoned 200 mm pipe which used to supply raw water from a water well to the pump station. There is the potential to repurpose this line to connect with the treated water distribution system. Connecting this pipe at the pump station and near the south end of the Village to the existing piping would have an improvement to available fire flow and water quality. Testing would have to be performed to ensure the piping would be in adequate condition to be used for distribution piping.

There is some existing 100mm diameter and Asbestos Cement (AC) and Ductile Iron (DI) material pipe that should be replaced on an ongoing basis. 100 mm pipe is very hydraulically restrictive and limits available fire flows. The AC and DI pipe is aging, and should be proactively replaced. Locations are noted in the recommended projects.

It was indicated by operations that a previously unknown water line is supplying the retirement community northeast of Linden. This pipe should be located, identified, and put into the GIS for record.

Pumps and Pump Station

The fire flow tests performed revealed that the pumps are not operating as expected. They do not seem to be turning on or off at the correct pressure, and the fire pump did not turn on at all, despite the pressure dropping below the set point in the tests. *(2021 operational update – fire pump was turning on when recirculation line was opened. Unclear why the pump was not operating during fire flow tests, additional investigation is needed.)*

The 20 hp pump (Pump 1) was also behaving erratically, as noted by operations. It would aggressively turn on and off during certain flow conditions. This may be tied to the other operational concerns. An investigation into the pumps and control system will need to be performed. *(2021 operational update – run time on pump 1 was set to 5 minutes minimum, largely eliminating the on/off issues)*

The piping for the air relief valves at Pump 1 and Pump 2 is made of plastic pipe. With the erratic operation, the air relief valves were activating with a lot of force. To help mitigate potential damage, operations put a ratchet strap around the piping. This piping should be replaced with steel piping.

There is a redundant generator and transfer switch inside of the pump station, as a new generator has been constructed. The redundant equipment should be decommissioned and removed. *(2021 update – generator has been removed, and gas line disconnected. Transfer switch is still in place, it was recommended that the Village hire an electrician to look into removing it.)*

Fire Hydrants

During the hydrant flow tests, it was noted by the contractor that some of the hydrants were very difficult to operate, with one (on 1st St NW) being apparently seized. An investigation and repair program should be put in place to ensure proper hydrant operation.

It was found that there were some locations with hydrant spacing greater than the spacing recommended under the Fire Underwriters Survey. Several new hydrants have been recommended to close those gaps.

Recommended Projects

The following are the recommended upgrades to resolve the noted deficiencies:

+ Investigation of the operational issues in the pump station pumps (Project EX W1)
+ Replacement of the ARV piping for Pump 1 and Pump 2, along with Pump 1 rebuild (Project EX W2)
+ Decommissioning of old generator and transfer switch (Project EX W3)
+ Structural investigation of north cell in reservoir, along with patching/repairs (Project EX W4)
+ Hydrant investigation and maintenance program (EX W 5)

+ Small diameter (100mm) Asbestos Cement pipes recommended to be upsized to 150mm pipes due to hydraulic constriction of small diameter pipes and pipes nearing end of service life on the following streets:

    - 2nd Ave NE (Project EX W6)
    - 1st Ave S (Project EX W7)
    - 1st Ave N (Project EX W8)
- Program to install new hydrants where there are gaps in the hydrant spacing (Project EX W9)

20 Year Forecast Water System (Figures W5 to W6)

The water system requires minimal upgrades in order to support the 20 year growth horizon.

The storage reservoir has sufficient available capacity, and the pump station has sufficient pumping capacity for both fire flow and Peak Hour Demand levels of service.

The only projects that are required to support the additional growth are new waterlines connecting the north spurs of 1st ST NW, 5th St NW, and 6th St NW to remove the dead ends of the system, and an extension of the Central Ave waterline to the east end of the Village.

- 5th St NW and 6th St NW Cross Connection (Project W1)
- 1st St and 5th St NW Cross Connection (Project W2) – Due to the coulee, installation would likely have to be through horizontal directional drill (HDD)
- Central Ave Water Line Extension (Project W3)

Any additional water network installations would be the responsibility of the developers.

Full Buildout Water System (Figures W7 to W8)

The full buildout water system would require significant upgrades to the treated water supply, storage reservoir and the pump station in order to support the full buildout demands.

- The treated water supply would require an upgrade of approximately 7 L/s from the current maximum set point to support the Max Day Demand
- The storage reservoir would require approximately 900 m^3 of additional capacity to support the future demands
- The pump station would require replacing the 3 hp pump with a pump capable of approximately 41 L/s @ 40 m of head

Any additional water network installations would be the responsibility of the developers.

Summary of Water Projects

The following is a summary of the water projects, and costs, for the existing and future systems.

Number	Project Name	Project Cost
Existing Water System		
EX W1	Pump Station Operational Issues Investigation	$15,000.00
EX W2	Pump 1 ARV Piping Replacement and Rebuild	$25,000.00
EX W3	Old Generator Decommissioning	$30,000.00
EX W4	Reservoir North Cell Structural Investigation and Repairs	$40,000.00
EX W5	Hydrant Investigation and Maintenance/Repair Program	$50,000 - $150,000
EX W6	Small Diameter AC Pipe Replacement (2nd Ave N)	$135,000.00
EX W7	Small Diameter, AC and DI Pipe Replacement (1st Ave S)	$105,000.00
EX W8	Small Diameter, AC and DI Pipe Replacement (1st Ave N)	$255,000.00
EX W9	New Hydrants Program	$70,000.00
Future Water System		
W1	5th St NW and 6th St NW Cross Connect	$95,000.00
W2	1st St NW and 5th St NW Cross Connect	$435,000.00
W3	Central Ave Water Line Extension	$650,000

Wastewater System Assessment

An assessment of the existing wastewater system and the future wastewater system was performed by analysing wastewater historical record information and utilizing historical water distribution records to determine wastewater flows. A review of record drawings, county provided GIS, and field survey to confirm pipe inverts, materials and diameters was used to create GIS files representative of the infrastructure. A CCTV investigation of the collection system was performed. A SewerGEMS model was developed using the analysed records and developed GIS files with scenarios for the existing system and future system in order to assess flow rates and pipe capacities. The model was used to determine deficiencies in the existing system and to develop servicing options and sizing requirements for the future system.

Existing Wastewater System (Figures S1 to S5)

Collection System

Overall, the collection system performs well at the projected Peak Wet Weather Flow. No pipes in the system are over capacity, and calculated hydraulic grade line is within the grade of the pipe.

A CCTV investigation of the majority of the pipes in the Village was performed. The major outlier that was not captured is the trunk line leading to the Lagoon. The CCTV contractor was not willing to drive down the access road in the winter conditions that were present, and as such did not complete that portion of the investigation. This portion of the trunk line should still be investigated if possible, as in consists of Vitrified Clay Tile (VCT) pipe, which at its age is prone to failure. The majority of defects identified during the investigation were VCT pipe.

2021 Update – The lagoon trunk line was investigated in May 2021, and the majority of it presented significant defects, with three runs requiring immediate attention. In all cases, CIPP lining was identified as the preferred solution.

Nearly all of the severe defects identified can be addressed through a Cured in Place (CIPP) pipe lining program. This is a trenchless remediation solution that is much less disruptive and cost effective that excavation. Pipes identified as Severe condition were all candidates for CIPP lining, and are addressed as projects in the existing system. One pipe section, in front of 203 Linview Dr, was identified as repair requiring excavation due to a defective service connection. This appears to be a connection made after the installation of the sewer pipe, and appears to be the service for a new house. If this is the case, the cost for repair could potentially be the responsibility of the builder.

Three sections of pipe were identified as needing replacement through excavation, but on the condition of further development upstream. These were identified as projects in the 20 Year Forecast.

Lagoon

The existing lagoon has more than sufficient capacity for the demands of the existing system. The lagoon itself has not been discharged in more than three years, as the effluent has been pumped out of the lagoon for resource exploration projects on contract with the Village.

The lagoon does not have recent record of having a sludge investigation and cleaning. It is recommended that a sludge survey be performed of, at minimum, the two anaerobic cells in order to determine its current condition and sludge levels. If sludge levels are found to be high, then a dredging or cleaning program will need to be undertaken in order to keep the lagoon in peak operational condition. *(2021 Update – survey and cleaning of two of the anaerobic cells has been budgeted for next year. The Village has received several quotes for the work.)*

Recommended Projects

The following are the recommended upgrades to resolve the noted deficiencies:

- Lagoon sludge survey (Project EX S1)
- Lagoon sludge cleaning (Project EX S2)
- CIPP Lining Program
  - Trunk Line – Immediate Action (Project EX S8)
  - Trunk Line – Near Future Action (Project EX S9)
  - 1st St NE (Project EX S3)
  - 1st St NW (Project EX S4)
  - 1st St SE (Project EX S5)
  - 1a St NW (Project EX S6)
  - Trunk Line – Future Action (Project EX S10)
- Repair defective service 203 Linview Dr (Project EX S7)

20 Year Forecast Wastewater System (Figures S6 to S10)

The wastewater system requires minor upgrades to support the 20 year forecast.

The lagoon has sufficient capacity for the projected wastewater demands, however at the end of the 20 year forecast there is almost no available capacity remaining.

The major deficiency is the trunk main to the lagoon. Under the 20 year demands, the peak flows through the trunk main are greater than 100% of the pipe's capacity. This results in moderate surcharge events above the crown of the pipe, but below the ground level. At the worst location, there is approximately two metres of available freeboard, or distance from the top of surcharge to the ground level. This is generally higher than acceptable for most municipalities, however the trunk main is not connected to any services, and is significantly lower in elevation that the surround network, resulting in minimal risk of property damage in a surcharge event.

The recommended course of action is to upgrade the trunk main to a 300 mm diameter pipe prior to the end of the 20 year forecast. The trigger for this would be a measured peak flow of approximately 30 L/s in the trunk main. If a CCTV investigation shows the pipe has no limitations to capacity, and no significant repairs are required, then the Village can see if moderate surcharge events are within their risk tolerance and avoid upgrading the trunk main. Due to the lack of flow information entering or existing the lagoon, it would be beneficial to install an inline flow monitor upstream of the lagoon. This would aid in future assessments, and determine both pipe and lagoon capacity availability for future development.

In addition, the CCTV investigation revealed three sections of pipe that have capacity heavily restricted due to significant sags and ovaling. These should be replaced prior to upstream development. They are located on 6th St NW, 5th St NW, and 1st St NW, all of which have projected development upstream in the 20 year forecast.

The following projects are recommended to support the 20 year forecast.

- Trunk main flow monitor installation (Project S1)
- Trunk main upgrade to 300 mm diameter pipe, after peak flow of 30 L/s (Project S2)
- 1st St NW pipe replacement (Project S3)
- 5th St NW pipe replacement (Project S4)
- 6th St Pipe replacement (Project S5)
- Central Ave Sanitary Line Extension (Project S6)

Full Buildout Wastewater System (Figures S6 to S10)

The full buildout wastewater system would require significant upgrades to the lagoon system in order to support the projected wastewater flows. The upgrades to the trunk main recommended in the 20 year forecast would be adequate to support the peak flows. If the upgrades did not occur, they would have to be a priority project prior to any further development past the 20 year forecast.

The lagoon system would require the following expansions to support the full buildout wastewater flows. These volumes are likely not achievable with the current land area around the lagoon. A new lagoon site and lift station, or a mechanical wastewater treatment plant, would likely be required.

- Two new anaerobic cells with a capacity of 850 m^3 each
- Additional capacity of 20,000 m^3 in the facultative cell

- Additional capacity of 100,000 m^3 in the storage cell

Summary of Wastewater Projects

Number	Project Name	Project Cost
Existing Wastewater System		
EX S1	Lagoon Sludge Survey	$22,000.00
EX S2	Lagoon Sludge Cleaning	$40,000 - $100,000
EX S3	CIPP Lining Program: 1st St NE	$55,000.00
EX S4	CIPP Lining Program: 1st St NW	$75,000.00
EX S5	CIPP Lining Program: 1st St SE	$115,000.00
EX S6	CIPP Lining Program: 1a St NW	$85,000.00
EX S7	Repair Defective Service 203 Linview Dr	$30,000.00
EX S8	Trunk Line – Immediate Action	$95,000.00
EX S9	Trunk Line – Near Future Action	$156,000.00
EX S10	Trunk Line – Future Action	$30,000.00
Future Wastewater System		
S1	Trunk Main Flow Monitor	$20,000.00
S2	Trunk Main Upgrade	$890,000.00
S3	1st St NW Pipe Replacement	$140,000.00
S4	5th St NW Pipe Replacement	$145,000.00
S5	6th St NW Pipe Replacement	$270,000.00
S6	Central Ave Sanitary Line Extension	$470,000.00

Stormwater System Assessment

The stormwater system was analyzed through computer modelling to understand the performance of the current drainage system in Linden. The drainage network in Linden employs overland drainage infrastructure (i.e. ditches, culverts, and swales) and minor storm system infrastructure (i.e. catch basins, manholes, and underground storm sewers). The drainage network was analyzed for single event storm events (1:2-year, 1:5-year, and 1:100-year) and a continuous simulation including impacts of the runoff coming form upstream lands flowing through the Village.

A review of intensity-frequency-duration (IDF) data from nearby Drumheller was used to create the synthetic storm events in the storm models. Additionally, record data from Kneehills Creek gauging station was analyzed to determine unit area release rates (UARR) to help guide stormwater management in future developments.

The hydrologic and hydraulic modelling identified a few areas within Linden where surcharging occurs during minor storm events (1:2-year and 1:5-year), including:

- Intersection of 1st St NW and 2nd Ave NE
- Intersection of 6th St NW and Central Ave
- 6th St NW where the ditch systems drainage enters the storm sewer
- 1st St NW where the catch basin picks up flow from the field

- Cul-de-sac at Center St
- Cul-de-sac at Linview Rd

The surcharging at these locations also causes surface ponding. Ponding is limited in the 1:2-year storm event to the intersections 1st St NW / 2nd Ave NE and 6th St NW /Central Ave with limited volumes (0 to 20 m³). During the 1:5-year storm event, surface ponding occurred at all locations noted above and range in surcharging volumes from 15 to 125 m³.

During the simulation for a major storm events (1:100-year), flows travel along the major system towards the natural outlet, the coulee and eventually Kneehills Creek. The Village generally employs curb and gutter; however, a designated overland escape route throughout parts of the Village could not be identified. This is most noticeable at the cul-de-sacs, where there is no overland flow escape above the catch basins, rather flow would escape through an undefined path across private property before reaching the coulee. Other areas where overland flow escapes to the coulee at the end of curb and gutter systems have been noted to experience erosion and require remediation work. Additionally, there is a low point in the lane behind 1st St SE / Centre St S south of Central Ave that would collect runoff during a large event.

In addition to the model results, the Village staff have noted a few locations within the community where drainage issues have been witnessed in the past.

- 5th Street townhouses
- Courtney Way
- Lane behind 3 Ave NW & field catch basin near 417 1st St NW
- Poor Major Drainage system on 6th St NW
- Poor Outlet NW of Central Ave W and 1 St NW intersection
- Poor Drainage from trailer park off of 1 St SE
- Ice concerns at concrete swale locations (Linview Road & north end of 1 St NW)

CCTV capture of the sewer systems in Linden identified two locations with blockages in the network. The CCTV of the storm sewer on 1st Ave N found a second pipe intercepting the storm sewer and noted a concrete blockage along the 1st St NE storm sewer immediately south of Central Ave. The concrete blockage was later identified by Linden Operations as an abandoned pipe, with a new line running parallel to the east of it.

Future development will have an impact on runoff within the Village. Based on the comparative basin UARR analysis, the recommended release rate for future development is recommended to be 1.40 L/s/ha. Future development may need to address upstream inflows and ensure a diversion strategy to safely bypass the future developments. The future developments are recommended to employ:

- Dual Drainage System (Minor/Major system where the minor system represents basic level of service for more frequent event, typically up to 1:5-year events, and major system for more severe events up to 1:100-year that are in excess of what the minor system can handle)
- Storm Pond
- LID Practices

A brief climate change analysis was completed to predict how the drainage network may perform in future years. The results of the climate change analysis suggest that there will be an increase in the amount of runoff and exacerbated inundation concerns.

Based on the comments from the Village, the hydrologic and hydraulic models, CCTV capture, and site visits, the following stormwater projects are identified.

Project	Project Name	Project Cost
EX SW1	Upgrade Storm Along Central Ave	$ 225,000.00
EX SW2	Upgrade Storm Along 1st Ave N	$ 150,000.00
EX SW3	Overland Diversion Around 5th St NW Townhouses	$ 65,000.00
EX SW4	Regrading and Berm Around Field Catch Basin (417 1st St NW)	$ 85,000.00
EX SW5	Ditch and Inlet Upgrade at Trailer Park	$ 65,000.00
EX SW6	Coulee Dam Inspection	$ 50,000.00
EX SW7	2nd Ave N Overland Escape Erosion Protection	$ 50,000.00

The identified development areas in Linden are limited in size. Based on the development areas and possible upgrades to the existing community, the following future stormwater projects have been identified.

Project	Project Name	Project Cost
FT SW1	6th St NW and Central Ave Sewer Upgrade	$ 350,000.00
FT SW2	Diversion Swale Around Picci Court and Culvert Underneath Roadway	$ 130,000.00
Additional Project	Storm Sewer Upgrade Across 1st St NW at 5th Ave	TBD

Existing Roads System Assessment

The existing roads in Linden were assessed through a review of photos taken along all roadways. They were rated in terms of asphalt condition, age, and structural integrity.

The majority of the roads are experiencing a moderate to high level of deterioration, however this is largely through age of the asphalt, hardening and raveling were the most prevalent deficiencies. There was some presence of structural failure, in which case a replacement to the road base may need to be considered. All severely deteriorated roads are recommended for mill and overlay remediation.

In total, there were six road sections that were classified as severely deteriorated with projects recommended.

+ Centre St N from Central Ave E to 1 Ave N (Project R1)
+ Centre St S from Central Ave W to 1 Ave S (Project R2)
+ Central Ave E from Centre St N to 1 St NE (Project R3)
+ Central Ave W from 1 St NW to Centre St N (Project R4)
+ 1 Ave S from Centre St S to 1 St SE (Project R5)
+ 4 Ave SE (branch out) from 1 St SE to Road End (Private Road)

Number	Project Name	Project Cost
Severely Deteriorated Roads		
R1	Centre St N from Central Ave E to 1 Ave	$145,000.00
R2	Centre St S from Central Ave W to 1 Ave S	$240,000.00
R3	Central Ave E from Centre St N to 1 St NE	$280,000.00
R4	Central Ave W from 1 St NW to Centre St N	$520,000.00
R5	1 Ave S from Centre St S to 1 St SE	$150,000.00
R6	Central Ave from 1st St SE to RR254	$960,000.00

Project Optimization

In order to best present the recommended upgrades to the Village, and optimize capital costs, the deep utility projects and roads projects have been reviewed to create unified projects where possible. Ideally this occurs where recommended roads projects and deep utility projects overlap.

Unified Project 1 – Central Ave (1st Street NW to Centre St N)

Unified Project 1 combines Project R4 and Project SW1. This captures what is likely to be one of the next roads project to be scheduled, and integrates a necessary storm upgrade project.

Number	Project Name	Project Cost
Individual Project Cost		
EX SW1	Upgrade Storm Along Central Ave	$225,000.00
R4	Central Ave W from 1 St NW to Centre St N	$520,000.00
Unified Project Cost		
UP1	Central Ave (1st St to Centre St)	$660,000.00

Unified Project 2 – 1st Ave S (Centre St S to 1st St SE)

Unified Project 2 combines Project R5 and Project EX W8. This captures a road rehabilitation project, and integrates a water upgrade project.

Number	Project Name	Project Cost
Individual Project Cost		
EX W8	Small Diameter, AC and DI Pipe Replacement (1st Ave S)	$105,000.00
R5	1 Ave S from Centre St S to 1 St SE	$150,000.00
Unified Project Cost		
UP2	1st Ave S (Centre St S to 1st St SE)	$200,000.00

Unified Project 3 – Central Ave (1st St NE to RR 254)

Unified Project 3 combines Projects R7 and Project W3 and Project S6. This captures a road rehabilitation project, and integrates water and wastewater extension projects which allow for future development. This project may need to be broken into three phases.

Number	Project Name	Project Cost
Individual Project Cost		
W3	New Water line along Central Ave	$650,000.00
S6	New Sanitary Line along Central Ave	$470,000.00
R7	Central Ave from 1 St NE to RR 254	$960,000.00
Unified Project Cost		
UP3	Central Ave from 1 St NE to RR 254	$1,450,000.00

Figure P1 - Projects Overlay

Scale 1:3000

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Roads Ratings

- Gravel
- Fair
- Good
- Poor to Fair
- Very Poor to Poor

Underground Projects

- Water Projects
- Sanitary Projects
- Stormwater Projects

Figure P2- Projects Overlay

Scale 1:3000

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Roads Ratings		Underground Projects
Gravel	Poor to Fair	Water Projects
Fair	Very Poor to Poor	Sanitary Projects
Good		Stormwater Projects

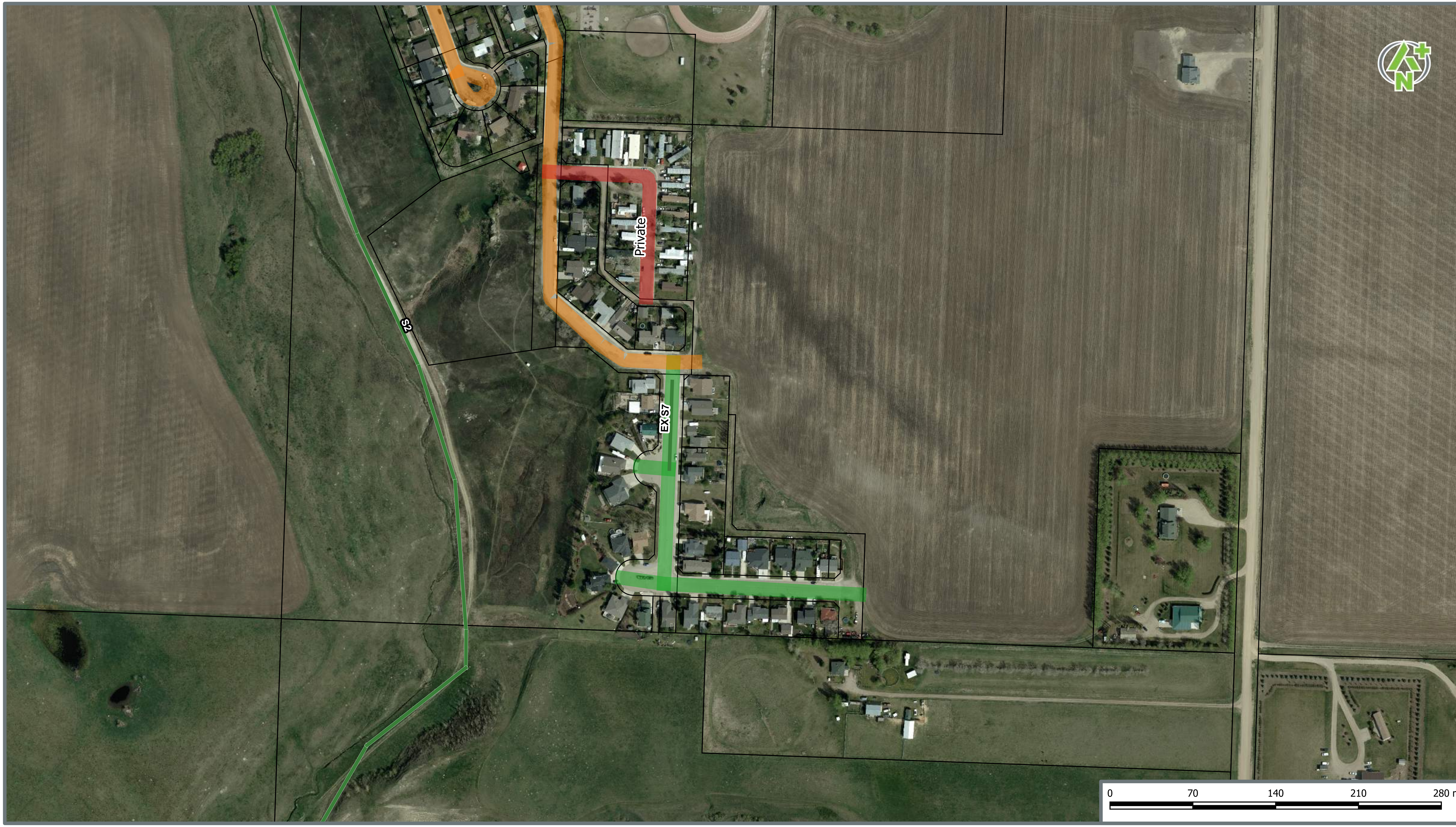
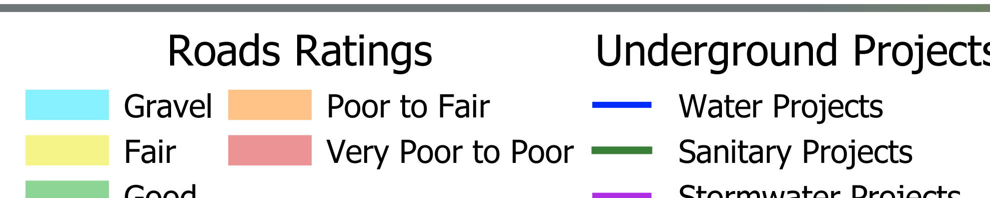


Figure P3- Projects Overlay

Scale 1:3000



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1. Introduction

1.1 Authorization and Terms of Reference

The Village of Linden retained CIMA+ to prepare an Infrastructure Master Plan. The purpose of the report is to investigate the condition of existing water, wastewater, stormwater, and roads infrastructure, identify deficiencies, and propose solutions. CIMA+ will investigate the future growth of the Village, and identify future growth projections so that the appropriate servicing solutions can be determined. This will result in a list of proposed projects identified in a Capital Plan that encompass the following:

+ Potable water storage, distribution, and consumption
+ Wastewater collection, transmission, and treatment
+ Stormwater management
+ Roads infrastructure assessment

1.2 Objectives

The stated objectives of the Infrastructure Master Plan are as follows:

+ To conduct a detailed onsite assessment of the existing water and sanitary systems' capacities. This will be done using real and historical data collected from the Village of Linden's facilities and networks.
+ To identify system deficiencies, provide recommendations for system maintenance and improvements.
+ To develop a servicing strategy for future growth and development on a 20 year timeline
+ To develop a list of capital projects that are of the greatest benefit to the community. The list will include a high–level estimated cost and an approximate timeline for implementation over the planning period.

2. Growth Areas and Population Horizons

2.1 Introduction

This section describes the assumptions and philosophies used in this report. The assumptions are related to:

+ Rates of population growth
+ Growth areas
+ Development horizons

2.2 Population and Population Projections

Historical census records for the Village of Linden were reviewed in order to determine the yearly population growth rate. Census data from Statistics Canada, dating back to 1986 is summarized in Table 2-1. Analysis of this data indicates an overall annual growth rate of 2.23%, or approximately 14 people per year.

Table 2-1 Historical Census Data

Year	Population
1986	417
1991	461
1996	565
2001	636
2006	660
2011	725
2016	828

Statistical analysis indicates that a linear growth trend (growth by a fixed number of people a year) is a better fit for the historical population growth that exponential growth (growth by a percentage of the population each year). Figure 2-1 shows the results of the statistical analysis. An R^2 value closer to 1 means a better fit.

The population used for this report will be from the projected growth from the 2016 census, which is a population of 884 people.

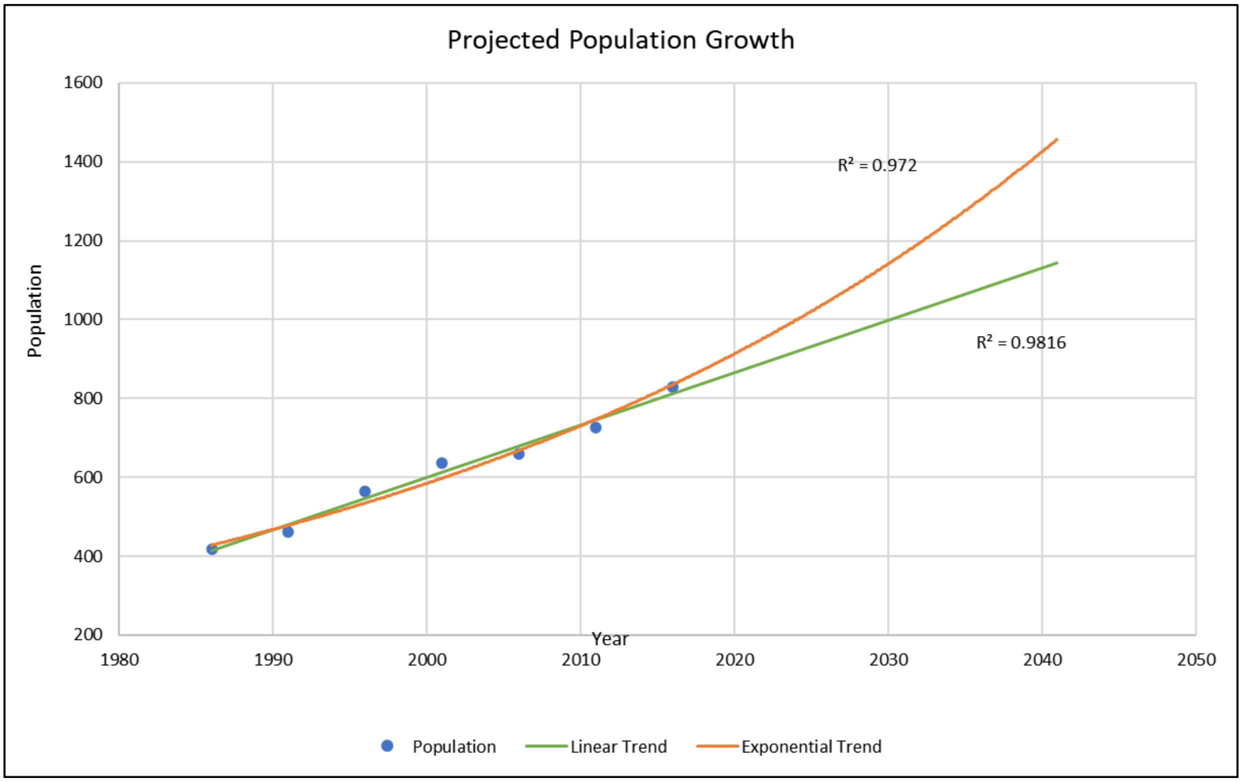

Figure 2-1 Statistical Analysis of Population Growth

For the purpose of this study, a 20 year forecast will be used for population projection and planning, along with a high level look of the full buildout of the Municipal Development plan development areas.

The 20 year population is 1164 people, or approximately 280 additional people. The full buildout of the Municipal Development Plan is approximately 2211 people.

2.3 Growth Areas

Linden has significant opportunity for future growth due to available area, with the Municipal Development Plan (MDP) establishing four potential areas where that growth can occur. In the MDP, the development areas are broken into four quadrants, Northwest, Northeast, Southwest, and Southeast. The Northeast and Southeast quadrants are primarily residential, and the Northwest and Southwest have a mix of commercial, industrial, and residential.

Table 2-2 shows a summary of the growth areas and their estimated populations and land use areas at full buildout of the MDP.

Table 2-2 Growth Areas

Quadrant	Residential Population	Residential Area (ha)	Commercial / Industrial Area (ha)	Total Area (ha)
Northwest	220	10	10	20
Northeast	828	45	7	52
Southwest	22	7	20	27
Southeast	313	18	8	26
Total	**1383**	**80**	**45**	**125**

For the purpose of this report, and the 20 year planning forecast, the residential development will be focused on the Northwest and Northeast quadrant. These areas already either had some subdividing occur, or have subdividing laid out in the MDP. The residential growth areas will contain the entirety of the residential portion of the Northwest quadrant, and the subdivided portion of the Northeast quadrant.

The estimated 280 additional population over the 20 year forecast is equivalent to approximately 11.5 ha of residential development. It is further assumed that a proportional 6 ha of commercial or industrial development will also occur in the 20 year timeline. For modelling purposes, this development focus will be in the Northwest quadrant.

General pipe alignments used are along the high level road alignments shown in the MDP.

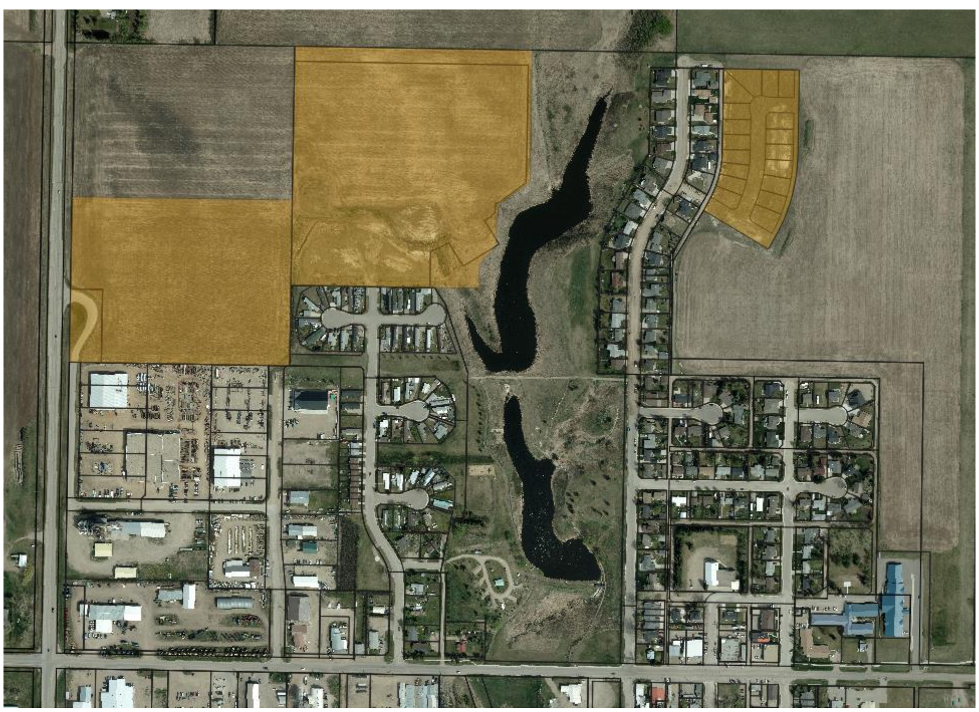

Figure 2-2 20 Year Development Area

3. Water Infrastructure

3.1 Existing Water System

The Village of Linden is part of the Aqua 7 Regional Water Commission. Raw water is treated offsite and delivered to Linden through the regional transmission line. Raw water and water treatment capacities will not be assessed in this report, as the regional system encompasses other municipalities that are not in the scope of this report.

3.1.1 System Characterization

3.1.1.1 Water Supply and Treatment

The water supply in Linden is provided by the Aqua 7 Regional Water Commission (formerly Kneehill Regional Water Services Commission). Raw water is pulled from the Red Deer River, treated in Kirkpatrick, and delivered to the Linden reservoir through a regional transmission line.

The treated water supply was designed to deliver a maximum of 14 L/s to the reservoir, or approximately 1210 m^3/day.

Currently the maximum flow rate is set at 6 L/s (518 m^3/day), as per information provided by the Aqua 7 Regional Water commission.

3.1.1.2 Storage

The Linden treated water reservoir is a concrete reservoir with three cells. The original two cells, one storage cell and one small cell for the pump inlets, were constructed in approximately 1981. An additional cell was constructed sometime after 2004.

The current operating level of the reservoir is 3.5 m, as per information provided by the Aqua 7 Regional Water Commission. The low level alarm is set at 2.0 m.

Table 3-1 shows the volume of each of the storage cells.

Table 3-1 Treated Water Storage Reservoir Volumes

Cell	Volume(m^3)
North (Cell 1)	817.9
South (Cell 2)	993.7
East (Cell 3)	107.5
Total	**1919.1**

3.1.1.3 Distribution

Pumps

Treated water is distributed from the Linden reservoir by one submersible pump and two three vertical turbine pumps, along with one engine driven vertical turbine fire pump. Table 3-2 contains a summary of the installed pumps, along with their operating points.

Table 3-2 Distribution Pumps

Pump Name	Pump Details	Duty Point
Pump 1 (Peerless 8 MA)	20 HP, 10 Stage Vertical Turbine	25.4 L/s @ 45.7 m
Pump 2 (Crane 34027)	3 HP, 7 Stage Vertical Turbine	4 L/s @ 36.3 m
Pump 3 (Berkeley S2AL)	7.5 HP, 3 Stage Submersible	15.5 L/s @ 50.6 m
Fire Pump (Crane 4700)	Engine Drive, 6 Stage	60.6 L/s @ 99.4m

Pump 3 and the fire pump have both recently been rebuilt, Pump 3 in 2015 and the Fire Pump in 2018.

According to the HMI in the pump station, the pumps have the following set points:

Table 3-3 Pump Operating Points

Pump Name	Pump Start (psi)	Pump Stop (psi)
Pump 1	50	56
Pump 2	55	58
Pump 3	58	72
Fire Pump	45	55

Network

The existing water pipes in Linden are majority PVC pipes, with some original Asbestos Cement pipes and Ductile Iron pipe remaining. There are a large number of 100 mm and 150 mm diameter pipes on the west side of town. This pipe size is generally considered too small for modern fire flow requirements.

The following tables show the breakdown of pipe sizes and materials.

Table 3-4 Water Distribution Network Pipe Sizes

Pipe Size (mm)	Pipe Length (m)	Percentage of Total
25	658	7%
50	493	5%
100	1177	12%
150	4813	49%
200	2469	25%
250	120	1%
Total	**9729**	

Table 3-5 Water Distribution Network Pipe Materials

Material	Pipe Length (m)	Percentage of Total
AC	822	8%
PVC	8311	85%
Ductile Iron	101	1%
HDP	290	3%
Abandoned	101	1%
Copper	104	1%
Total	**9729**	

3.1.2 Model Development

A hydraulic model of the Linden water system was developed to assess the level of service that the system is capable of. The model was developed using Bentley WaterCAD, with the schematic linework, pipe sizes, and material provided by the Village in the form of record drawings, which were then georeferenced into GIS shapefiles, and GIS files.

Elevation data was attained in the form of high-resolution LiDAR, which was used to assign elevations to nodes in the hydraulic model.

Water demands were assigned to Linden for the ADD, MDD, and PHD scenarios calculated in 3.1.4 and distributed evenly across the system.

3.1.2.1 Model Calibration

Five fire flow tests with multiple remote pressure sensors on residual hydrants were performed by SFE Global in order to calibrate the model and validate its output. The residual pressure at each hydrant was monitored prior to flowing the hydrant, during the hydrant flow, and after the hydrant flow. Two system residual hydrants were also monitored for the duration of the tests. Pressure at the pump station was monitored through a pressure monitor at a nearby hydrant, which was one of the system residuals. The other system residual was on Central Ave east of 5^{th} Street NW.

Calibration of the model proved to be particularly difficult. During the fire flow tests, the various pumps were operating sporadically, and were not turning on or off at predictable set points. Due to this, and there being no available information for which pumps were operating at what time, calibration was done by estimating which pumps were operating which would best match the observed pressures and flows. This will be discussed further in 3.1.5.3

In addition to the pump issues, there were several areas that appeared to have a different pipe size or material than the latest GIS information indicated, which didn't agree with earlier record drawings. Some of these were in key areas that, when the latest GIS information was implemented in the model, had significant impacts to the results which were not feasible when compared against the field observations. These areas will be discussed further in 3.1.5.3

Typically, a successful calibration has the calculated pressures fall within 5%-10% of the observed pressures. In the calibration process, all observed values were less than 10% variance from the calculated values, which indicates an accurately calibrated model.

Table 3-6 Calibration Results

Test	Residual Hydrant			System Residual 1			System Residual 2		
	Observed (psi)	Calculated (psi)	Variance	Observed (psi)	Calculated (psi)	Variance	Observed (psi)	Calculated (psi)	Variance
1	28.25	26.90	-5.0%	31.10	31.50	1.3%	36.60	39.85	8.2%
2	37.00	35.40	-4.5%	36.50	36.50	0.0%	42.20	42.70	1.2%
3	40.30	40.75	1.1%	51.80	51.80	0.0%	68.70	64.00	-7.3%
4	37.60	39.60	5.1%	39.30	39.30	0.0%	57.50	54.80	-4.9%
5	31.80	32.02	0.7%	47.40	47.30	-0.2%	65.90	64.50	-2.2%

3.1.3 Level of Service Criteria

The intention of the master plan is to maintain the level of service for the existing and future systems. The level of service criteria has been set in accordance with Alberta Environment's Standards and Guideline. The level of service is shown in the following table.

Table 3-7 Distribution System Pressure Requirements

Parameter	Design Criteria
Minimum Pressure in Distribution System	350 kPa (50 psi)
Minimum Pressure in Distribution System During Fire Flow	150 kPa (22 psi)
Maximum Pressure in Distribution System	550 kPa (80 psi)
Maximum Allowable Velocity in Distribution System	3.0 m/s

3.1.3.1 Pumping Requirements

Alberta Environment and Parks (AEP) requires that a water distribution pumping system should be able to provide the greater of PHD or MDD + Fire Flow.

AEP also requires that the water distribution system facility be designed to deliver maximum design flow with the largest pump out of service.

3.1.3.2 Treated Water Storage Requirements

AEP guidelines recommend the storage requirements where the supply of treated water is only capable of satisfying the maximum daily design flow.

For a storage facility to meet these recommendations it must be sufficiently sized to store the sum of the following:

+ Fire storage (As per fire flow requirements)
+ Equalization storage (25% MDD)
+ Contingency storage (15% ADD)

In addition to the regular storage requirements, it would also be prudent to set aside some storage volume as emergency storage, in the event that the water supply is cut off upstream due to some unforeseen event or emergency. As the water supply is not in the control of the Village, extra precautions should be taken.

An additional storage of two days at average day demand (2xADD) should be allowed for to accommodate any potential disruptions to the potable water supply.

3.1.3.3 Fire Flow Requirements

The Fire Underwriters Survey (FUS) gives recommendations for fire flow requirements and should be used when fire flows are not directly indicated by municipality design standards and guidelines. Based on this document, a summary of required fire flows is provided below:

Table 3-8 Recommended Fire Flow

Exposure Distance	Suggested Required Fire Flow	Required Duration of Fire Flows (hours)
3m to 10m	4000 L/min	1.50
10m to 30m	3000 L/min	1.25
Over 30m	2000 L/min	1.00

The average household exposure distance (separation between dwelling units) is in the 3 m to 10 m range. As such, the recommended available fire flow for Linden should be at least 4000 L/min, or 66.7 L/s. For the purpose of this study, a 70 L/s available fire flow requirement will be used.

The FUS also recommends the length of time that a water system should be able to support the recommended fire flow, known as fire storage. Fire storage varies based on the fire flow requirements. In the FUS, a flow rate of 4000 L/min has a required duration of 1.5 hours. 70 L/s for 1.5 hours results in a fire storage requirement of 378 m^3.

Typically, municipalities have varying levels of required available fire flow dependant on land use, with the highest being Industrial, Commercial, and Institutional (ICI) land uses. The larger municipalities in Alberta typically require 200 L/s – 300 L/s available fire flow. This would be an unrealistic target for the Village, given its current infrastructure isn't sized to support these levels. As such, it may be beneficial for the Village to require new developments of ICI land uses to include some level of on site fire protection, especially with the drive in the MDP to focus on Industrial and Commercial development.

3.1.4 Water Demand Analysis

Average water consumption is represented by Average Day Demand (ADD) and represents the average flow that is distributed into the water system. This can be shown as instantaneous flow (L/s), or as a per capita consumption, which is the average amount of water a person uses in a day regardless of season. This is a combined water demand, which takes into account all commercial and industrial water usage. The ADD is determined from historical flow records and is then used to project future demands on the system related to growth. When designing and managing a water system it is also important to know the Maximum Daily Demand (MDD) and Peak Hourly Demand (PHD) which are typically directly proportional to the ADD.

The monthly totals, including maximum day and average day for each month, were retrieved from the yearly report records, and used to determine the water demands and peaking factors.

3.1.4.1 Existing Water Demands

The following are the previous seven years of recorded water distribution volumes, with max day and average day noted, as provided by Linden Operations staff. The water is metered before it enters the treated water reservoir. Due to this, daily readings may not line up with actual daily usage, as the fill cycles can be somewhat erratic. The regional water commission may divert the water supply to other communities based on demand, such as fire flows. Since the water supply may fill the reservoir at different rates than usage, daily readings will not be reliable to determine maximum day demand.

Table 3-9 Yearly Water Supply Volumes

Year	Max Day (m^3)	Average Day (m^3)	Total (m^3)
2012	1,079	197	72,217
2013	1,037	205	74,944
2014	1,036	231	84,206
2015	1,231	224	81,930
2016	964	204	74,588
2017	1,007	223	81,536
2018	945	245	89,547
2019	396	228	83,076
Average	**962**	**220**	**80,256**

Due to the steadily increasing population of Linden, only the average of the previous three years will be used to determine the water demands

Table 3-10 Three Year Average Water Demands

Year	Population	Average Day (m^3)	Average Day (L/s)	Per Capita (L/c/d)
2017	842	223	2.6	265
2018	856	245	2.8	287
2019	870	228	2.6	262
Average	**856**	**232**	**2.7**	**271**

For the purpose of this report, a per capita water use rate of 270 L/c/d will be used.

3.1.4.2 Peaking Factors

The relationship between the ADD, MDD and PHD are typically directly proportional through factors usually between 1.5 and 6 (i.e. typically MDD is approximately 2xADD and PHD is approximately 4xADD).

Due to the uncertainty of daily water volumes from the water meter being upstream of the reservoir, on the supply side, daily readings are not reliable in determining the MDD of the system. For the purpose of this study, a peaking factor of **2x** will be used for the MDD.

In addition, there is no flow meter downstream of the reservoir, which means that no peak hour demand values can be calculated. As such, a typical peaking factor of **4x** will be used for the PHD.

3.1.4.3 Water Demands Summary

The demands and factors developed in this section were used to determine the current level of service and what, if any, deficiencies are present in the system. The following table is a summary of those demands.

Table 3-11 Existing Water Demands Summary

Water Demands	Per Capita Demand (L/c/day)	Water Demand (L/s)	Water Demand (m^3/day)
Average Day Demand (ADD)	270	2.8	239
Maximum Day Demand (2xADD)	540	5.5	477
Peak Hourly Demand (4xADD)	1080	11.1	955
Total Annual Demand (m^3)	**87,118**		

3.1.5 Existing System Evaluation

3.1.5.1 Treated Water Supply

The current setpoint from the Aqua 7 Regional Water Commission is 6 L/s. This an adequate level of supply for the existing system, as it is greater than the current MDD of 5.5 L/s.

As shown in Table 3-12, Linden is utilizing approximately 90% of its available supply at the current setpoint established by the regional water commission.

Table 3-12 Available Water Supply

Current Max Day Demand (L/s)	Available Supply (Current Set Point) (L/s)	Remaining Capacity (L/s)	Remaining Capacity (%)
5.5	6	**0.5**	**8%**

3.1.5.2 Fire Hydrants

Fire Hydrants – Condition

During the fire flow tests, it was noted by the sub contractor that several of the residual hydrants were very difficult to open, and one of the hydrants appeared to be seized. Of the 10 hydrants operated in the fire flow tests, approximately 4 had operational issues. Extrapolating that out to the 30 hydrants in the Village, an estimated 12 hydrants will need maintenance or repair.

It is recommended that a hydrant investigation and repair program is put in place to ensure all hydrants in the Village are in good operation. The Village has begun this program in 2021.

Fire Hydrants – Coverage

In the FUS, hydrant coverage is recommended to be no more than 180m between hydrants in residential areas, with one hydrant being within 90m of the front of any buildings. Industrial, commercial, or institutional areas are recommended to have a coverage of 90m between hydrants. For the purpose of this study, 180m hydrant spacing will be used to assess all land uses.

There are several locations that have gaps in the hydrant coverage. These would be low priority to install, but should be considered. The locations are:

- 1st Ave NW, west of 6th St NW
- The north end of 6th St NW,
- 1st Ave N near 1a St NW
- 1st St SE near Linview Dr.

Hydrant Coverage and proposed hydrants can be found in Figure W2 (Appendix A – Water Figures)

Level of Service – Fire Flow

Figure W3 (Appendix A – Water Figures) shows the hydraulic model results for the MDD+Fire Flow scenario for the existing system. The water model was used to calculate the available fire flow at each node while maintaining at least 150 kPa (22 psi) residual at any point in the distribution system.

The central areas with high network connectivity have an available fire flow over the required level of service of 70 L/s. The extremities of the system, particularly west of 5th St NW, north of 2nd Ave, and south of Centre St S do not meet the level of service. This is largely due to the hydraulic restrictions of the small 100mm and 150mm diameter pipes, and the lack of connectivity of the system. There are many spurs without much looping, which decreases the available flow that can reach any particular point in the system.

The biggest concern would be the industrial land uses on the west end of town, as these are typically higher risk land uses that many municipalities designate higher fire flow requirements. This would also likely be the most difficult area to increase available fire flow t. This is due to it being at the far end of the town with, with a large amount of infrastructure that would need to be upgraded to achieve higher available fire flow targets. When planning for future development, there should be specific focus on increasing available fire flow to that area, especially with the potential for further industrial development occurring. This would include looping 5th St NW and 6th St NW together, along with installing larger diameter pipes, and any other efforts made to increase available fire flow to the northern portions.

The northern portions of the Village will also be difficult and costly to improve available fire flow to in the short term, as it would likely require upsizing existing infrastructure, and increasing interconnectivity between the west and east sides of the Village. Specifically, 1st St NW and 5th St NW should be looped together, and the existing water line on 1st St NW should be upgraded to a 200 mm or 250 mm PVC pipe. In addition to that, the water line on 2nd Ave NE is noted as being a 150mm PVC line in more recent documentation, however as discussed in 3.1.5.3 it is likely that it is the original 100mm AC pipe in place. If this is verified in the field, this pipe should be replaced with a 200mm PVC pipe.

3.1.5.3 Distribution System

Level of Service

Figure W4 (Appendix A – Water Figures) shows the hydraulic model results for the Peak Hour Demand scenario for the existing system. Pressure nodes that do not meet the minimum pressure requirement of 350 kPa (50 psi) or maximum of 550 kPa (80 psi) set out in the Design Criteria are shown in red for low pressure, and orange for high pressure.

The hydraulic results indicate that there are no pressure deficient areas throughout the Village, and there is only a small section at the south end of the Village that is slightly above the recommended 80 psi. These areas are not of any concern.

Pump House

Overall, the pump station is in good physical condition, with a recently replaced roof. There is some equipment that has been made redundant, such as the old generator and transfer switch. The old generator, which is only large enough to power the 3 hp pump, is still connected to the gas line and appears to still be connected to the motor starters as well.

The generator and relevant electrical equipment should be decommissioned from the pump station.

Pumps

During the hydrant flow tests, it was discovered that the pumps were not operating as expected. Each pump has a pressure set point for turning on and off, and during the calibration process it became apparent that the pumps were not being appropriately triggered at the set points. For reference, the following table shows the pressure set points of each pump.

Table 3-13 Pump Pressure Set Points

Pump Name	Pump Start (psi)	Pump Stop (psi)
Pump 1	50	56
Pump 2	55	58
Pump 3	58	72
Fire Pump	45	55

The following table shows the measured pressures for each hydrant flow test, the pumps assumed to be on to reach those pressure with the measured flows, and the calculated pressure for the three distribution pumps all on. It should be noted that the distribution pressure is measured after the pressured stabilized, the lowest measured pressure would have been significantly lower.

Table 3-14 Hydrant Flow Test - Pumps on and Pressure

Flow Test	Distribution Pressure (psi)	Assumed Pumps On	Calculated Pressure – All Distribution Pumps On (psi)
1	31.1	P2, P3	47.9
2	36.5	P2, P3	52.4
3	51.8	P1, P3	55.5
4	39.3	P2, P3	54.5
5	47.4	P1, P3	51.3

As this shows, each flow test except for Test 3 sustained pressures below the start points of all the distribution pumps (and that would have dropped below the start point for all pumps when the flow started) and with all distribution pumps on, the resultant pressure would still be below their relative stop points.

The most concerning of these is the emergency fire pump. It is set to turn on at 45 psi, however there were three flow tests where the pressure stabilized below 40 psi and the fire pump never turned on. This was confirmed by operations staff, as an alarm would have been sent out of the fire pump had started.

Village operations staff indicated that during high demands, the 20 hp pump has a concerning operation cycle in which it repeatedly starts up and stops, which aggressively triggers the air relief valves. This could possibly cause damaging water hammer effects. Operations staff currently have an automobile strap securing the air relief valve piping to help prevent damage. Schedule 40 PVC pipe is currently being used for the air relief valves, which may not be adequate for the pressures and forces it may encounter. The plastic piping should be replaced with steel. A rebuild of the pump should also be considered.

Chamco has been out to investigate and modify the pump set points to avoid the Pump 1 operational issues, however, there appears to be a larger issue at hand with various pumps not operating at their designated setpoints. The cause of why the pumps aren't operating at their correct set points needs to be investigated. One possibility is the pressure sensor is not operating correctly, or that there are issues with it communicating with the HMI, or between the HMI and starters.

Distribution Lines

The Village water distribution system is composed largely of PVC, with some remaining Asbestos Cement (AC) and Ductile Iron (DI) pipes. Any remaining AC or DI pipes should be slowly phased out and replaced as budget allows, particularly if it lines up with roads improvement projects. Alongside this, small diameter pipe, such as 100mm pipe or smaller, should be phased out as it is hydraulically restrictive. New construction is typically a minimum of 200 mm pipe unless in a cul-de-sac.

There were several locations of note that had possible discrepancies in pipe size and material where record drawings did not line up with the most recent GIS information.

The first was located at 2nd Ave NE. The GIS record indicate that it is a 150 mm PVC pipe and previous records show it as a 100mm AC pipe. When performing calibration of the water model through hydrant flow tests, the calculated results could not feasibly line up with the observed results with the GIS pipes in place. The calculated results lined up with observed results very well when the original 100mm AC pipe was in place at that location. As such, this leads to the theory that the GIS record is incorrect at that location.

Another location is along 1st Street NW. The record information indicates this is a 150mm DI pipe, however the GIS information shows it as a 100mm PVC pipe. If a utility upgrade had occurred, it would not be replaced with a smaller pipe. In addition, the model calibration process indicated that a 100mm pipe could not be in place to achieve the observed results. As such, it is assumed that a 150mm DI pipe is in place for the whole length of 1st St NW. These assumptions should be confirmed in the field prior to commencement of any projects concerning these areas.

It was also noted by operations that a pipe servicing the retirement community north of Linden was recently discovered, fed off of the municipal system. This was not documented in the record information or the GIS.

3.1.5.4 Treated Water Storage

Storage Analysis

The existing system must have enough storage available to satisfy the storage requirements set out in the design guidelines. The greatest portion of the storage is fire storage. As such, the existing system needs to be able to supply the required fire flow for the period of time indicated by the FUS. For Linden, this is 70 L/s for 1.5 hours, or a total of 378 m^3.

An additional storage of two days at average day demand (2xADD) should be allowed for to accommodate any potential disruptions to the potable water supply. The existing ADD is 239 m^3/day, for a total of 478 m^3 of additional storage that should be set aside.

Even at the limited capacity resulting from the lower operational level in the reservoir, the Linden reservoir has sufficient storage capacity to meet the existing system needs. The results are shown in Table 3-15.

Table 3-15 Existing System Storage Analysis

15% ADD (m^3)	25% MDD (m^3)	Fire Storage (m^3)	2xADD Emergency Storage (m^3)	Total Recommended (m^3)	Total Available (m^3)	Spare Capacity (m^3)
36	119	378	477	1011	1919	**908**

Reservoir Condition

The original south cell and pump chamber of the existing treated water reservoir is approximately 40 years old, and the north cell is approximately 15 years old.

The reservoir was last cleaned and inspected on the interior in 2018, and previously in 2015. That inspection noted that the walls and roof of all cells appeared to be in good condition. Minor cracking on the floor of the north cell was noted, between several areas that had been patched already. The actuator rod for the equalization valve between the pump chamber and the south cell was broken off. This valve and rod were replaced in 2019.

The cracking is currently a minor concern, but should be monitored, and possibly repaired if there are funds available. A structural investigation of the north cell should be considered to determine if cracking is superficial or if there are structural issues.

3.1.6 Existing Water System Projects

3.1.6.1 EX W1 – Pump Station Operational Issues Investigation

Project Description

Investigate the operational issues that are causing the distribution pumps and emergency fire pump to not operate at their pressure set points.

Project Rationale

Performing hydrant flow tests for model calibration led to the discovery that the pumps are not operating as expected, with the distribution pumps and fire pump not turning on in a predictable manner at their pressure set points. The fire pump, in particular, never turned on despite three of the five flow tests all stabilising well below the pressure set point for the fire pump.

Investigation of the pump station to discover the source of the operational issues should be performed to ensure adequate distribution and fire flows in the system.

Project Details

+ Investigate operational issues with pumps

Project Trigger

+ None, project should be completed in the near future

Project Cost

Engineering	$	10,000.00
Contingency	$	5,000.00
Total	**$**	**15,000.00**

3.1.6.2 EX W2 – Pump 1 ARV Piping Replacement and Rebuild

Project Description

Replace the plastic piping at Pump 1 and Pump 2 air release valves (ARV) with steel piping and perform a rebuild on the Pump 1. Replacement of the ARV may also need to be considered.

Project Rationale

Operations staff noted that under certain high flow scenarios, Pump 1 rapidly and aggressively starts and stops, which causes blow offs through the ARV. Pump 1 and Pump 2 ARVs are connected by plastic piping and is currently being provided additional support through at automotive strap. The plastic piping should be replaced with steel due to the forces involved.

In addition, Pump 1 should be sent away for a rebuild. The pump has not been rebuilt as per Chamco's records and has been in place for more than 20 years. This combined with the potentially damaging start and stop cycles indicate that the pump is likely due for maintenance.

The noted operational issues will hopefully be determined through Project EX W1.

Project Details

+ Replace plastic piping with steel
+ Rebuild Pump 1
+ Potentially replace the ARV

Project Trigger

+ None, project should be completed in a short timeframe

Project Cost

Engineering	$	5,000.00
Implementation	$	15,000.00
Contingency	$	5,000.00
Total	**$**	**25,000.00**

3.1.6.3 EX W3 – Old Generator Decommissioning

Project Description

Decommission old generator, gas line, transfer switch and electrical connections in pump station.

Project Rationale

The original backup generator, sized to power just the one 3 hp pump, is still fully connected in the pump station, including gas line and electrical equipment. This equipment is outdated, and no longer sufficient to power the 7.5 hp duty pump. The 3 hp pump can not adequately supply the required flow or pressures to the Village on its own.

Project Details

+ Remove generator
+ Disconnect and decommission gas supply line
+ Remove old transfer switch and power lines connecting to motor starters

Project Trigger

+ None, project should be completed in a short timeframe

Project Cost

Engineering	$	7,000.00
Implementation	$	17,500.00
Contingency	$	5,500.00
Total	**$**	**30,000.00**

3.1.6.4 EX W4 – Reservoir North Cell Structural Investigation and Repairs

Project Description

Perform structural investigation to determine cause and severity of cracking in the north cell of the reservoir, as well as patch the existing cracking.

Project Rationale

Cracking on the floor of the north reservoir was observed in the 2015 and 2018 reservoir cleaning and inspection videos from Aquatech. The cracking appears to be new cracking that has spread from previous patches.

In order to avoid potential issues such as a leaking reservoir, or the worst case scenario of structural failure of the cell, a structural investigation should be performed. The cracking does not appear severe and can likely wait until the next reservoir cleaning and inspection. This would allow an opportunity to monitor the cracking and see if it is worsening.

Project Details

+ Perform structural investigation of north cell
+ Repair existing cracking

Project Trigger

+ During next reservoir cleaning and inspection

Project Cost

Engineering	$	7,000.00
Implementation	$	25,000.00
Contingency	$	8,000.00
Total	**$**	**40,000.00**

3.1.6.5 EX W5 – Hydrant Investigation and Maintenance/Repair Program

Project Description

Perform an investigation of all hydrants in the Village and develop a repair or replacement program.

Estimated costs will be a range, depending on if repair or replacement is required. Estimated cost for repairing a single hydrant is $5,000, which includes excavation, removal of hydrant barrel, repairs, and reinstallation. Estimated cost for replacing a single hydrant is $15,000.

Project Rationale

During the hydrant flow tests it was found that three hydrants were very difficult to operate, with one being apparently seized. A total of 12 hydrants were opened during the flow tests.

Extrapolating that out to the 30 hydrants in the Village, an estimated 10 hydrants may need maintenance or repair.

Project Details

+ Perform investigation on all 30 hydrants in the Village
+ Repair or replace deficient hydrants as needed

Project Trigger

+ None, project should be completed in a short timeframe

Project Cost

+ Estimated $50,000 to $150,000, depending on number of hydrants found to be deficient, and needing to be repaired or replaced

3.1.6.6 EX W6 – Small Diameter, AC and DI Pipe Replacement (2nd Ave NE)

Project Description

Replace the 100mm AC pipe along 2nd Ave NE, between 1st St NW and 1st St NE

Project Rationale

Older pipe made of AC or DI and small diameter pipes should be replaced as funds are available in order to improve system hydraulics and avoid future line breaks.

Evidence shows 2nd Ave NE was likely to have a 100 mm AC pipe as shown in older record drawings, as opposed to the 150 mm PVC pipe noted in the GIS. Field verification should be done prior to project initiation to confirm the pipe diameter.

Project Details

+ Verify in field through hydrovac pipe diameter and material
+ Remove and replace 200 m of 100 mm AC pipe with 200 mm PVC pipe

Project Trigger

+ Project should be completed as a part of an ongoing program in the next 10 years

Project Cost

Engineering	$	25,000.00
Implementation	$	165,000.00
Contingency	$	50,000.00
Total	**$**	**240,000.00**

3.1.6.7 EX W7 – Small Diameter, AC and DI Pipe Replacement (1st Ave S)

Project Description

Replace the 100mm DI pipe along 1st Ave S, between Centre St S and First St SE

Project Rationale

Older pipe made of AC or DI and small diameter pipes should be replaced as funds are available in order to improve system hydraulics and avoid future line breaks.

Project Details

- Remove and replace 100 m of 100 mm DI pipe with 150 mm PVC pipe

Project Trigger

- Project should be completed as a part of an ongoing program in the next 10 years

Project Cost

Engineering	$	15,000.00
Implementation	$	75,000.00
Contingency	$	15,000.00
Total	**$**	**105,000.00**

3.1.6.8 EX W8 – Small Diameter, AC and DI Pipe Replacement (1st Ave N)

Project Description

Replace the 100mm DI pipe along 1st Ave N, between 1st St NW and 1st St NE

Project Rationale

Older pipe made of AC or DI and small diameter pipes should be replaced as funds are available in order to improve system hydraulics and avoid future line breaks.

In addition, 1st Ave N is the primary pipe feeding the West and North portions of the Village. As such, this pipe should be upsized to accommodate future development.

Project Details

+ Remove and replace 200 m of 150 mm AC pipe with 250 mm PVC pipe

Project Trigger

+ Project should be completed as a part of an ongoing program in the next 10 years
+ Project should be completed prior to further development in the Northeast development area

Project Cost

Engineering	$	25,000.00
Implementation	$	175,000.00
Contingency	$	55,000.00
Total	**$**	**255,000.00**

3.1.6.9 EX W9 – New Hydrants Program

Project Description

Program to add additional hydrants to the existing system in order to close the noted gaps in the hydrant coverage.

Project Rationale

The Fire Underwriters Survey recommends a minimum hydrant spacing to ensure adequate hydrant coverage for fire protection. There were several locations identified as having inadequate spacing, which should have additional hydrants installed at those locations as a part of an ongoing program in the Village

Project Details

+ New hydrant – 1st Ave W west of 6th St NW
+ New hydrant – 1st Ave N near 1a St NW
+ New hydrant - 1st St SE near Linview Dr

Project Trigger

+ Project should be completed as a part of an ongoing program in the next 10 years

Project Cost

Engineering	$	10,000.00
Implementation	$	45,000.00
Contingency	$	15,000.00
Total	**$**	**70,000.00**

3.2 Future Water System

3.2.1 Water Demands Analysis

As described in Section 2.3, the future water system will consist of additional growth areas in the Northeast development area for residential development, and the Northwest are for industrial development. This will include an additional 280 people for planning purposes, for a total population of 1164 people at a 20-year growth horizon.

The same per capita rate of 270 L/c/day will be used for water consumption.

For the future industrial, commercial, and institutional areas, a daily water usage rate of 8 m^3/ha/day will be used. In our experience, this has been found to be a reasonable water usage rate that had been determined by analysis of water usage of industrial areas in other municipalities.

The same peaking factors of 2.0 for Max Day Demand and 4.0 for Peak Hourly Demand will also be used.

Table 3-16 shows the future residential demands, and Table 3-17 shows the future industrial, commercial, and institutional demands.

Table 3-16 Future Residential Water Demands

Growth Horizon	Population	Per Capita (L/c/day)	Average Daily Demand (m^3)
Existing System	884	270	239
20 Years	1164	270	314
Full Buildout	2050	270	554

Table 3-17 Future Commercial, Industrial and Institutional Demands

Growth Horizon	Area (ha)	Water Usage Rate (m^3/ha/day)	Average Daily Demand (m^3)
Existing System	-	-	-
20 Years	6.5	8	52
Full Buildout	45	8	360

Table 3-18 shows the water demands for the 20-year forecast at ADD, MDD and PHD, along with the annual volume.

Table 3-18 20 Year Forecast Water Demands Summary

Water Demands	Daily Demand (m^3/day)	Water Demand (L/s)
Average Day Demand (ADD)	366	4.6
Maximum Day Demand (2xADD)	732	9.2
Peak Hourly Demand (4xADD)	1464	18.4
Total Annual Demand (m^3)	**133,590**	

Table 3-19 shows the water demands for the full buildout at ADD, MDD and PHD, along with the annual volume.

Table 3-19 Full Buildout Water Demands Summary

Water Demands	Daily Demand (m^3/day)	Water Demand (L/s)
Average Day Demand (ADD)	914	10.6
Maximum Day Demand (2xADD)	1827	21.1
Peak Hourly Demand (4xADD)	3654	42.3
Total Annual Demand (m^3)	**333,428**	

3.2.2 Model Development

A hydraulic model of the full buildout water system was developed in Bentley WaterCAD. Water lines were placed along the proposed road alignments in the MDP.

The water demands established for the growth areas were applied to the model, and the infrastructure was sized accordingly. Two future scenarios were prepared, one for the 20-year forecast, and one for the full buildout of the MDP.

Demands were assigned using the populations and areas described in Section 2.3, with 220 people assigned to the Northwest residential area, 60 people assigned to the Northeast residential area, and 6.5 ha of industrial assigned to the Northwest industrial area for the 20 year forecast.

3.2.3 Water Supply Analysis

As described in Section 3.1.5.1 Linden is currently consuming approximately 90% of their available water supply with the current set points from the Aqua 7 commission.

20 Year Forecast

At an MDD of 9.1 L/s, the 20-year water demand will be higher than the available supply at the current set points, but within the noted maximum of 14 L/s.

Table 3-20 summarizes the available supply versus the projected demand.

Table 3-20 Future Water Supply

Current Max Day Demand (L/s)	Available Supply - Current Set Point (L/s)	Available Supply - Maximum Set Point (L/s)	Remaining Capacity - Current Set Point (L/s)	Remaining Capacity - Maximum Set Point (L/s)
9.1	6.0	14.0	**-3.1**	**4.9**

No upgrades to the water supply are required to support the 20-year growth horizon. However, prior to further development, discussions should be held with the regional commission to increase the water supply set point.

Full Buildout

At an MDD of 21.1 L/s, the full buildout water demand will be higher than the available supply at the maximum set points. As such, the existing water supply is not sufficient to support the full buildout of the MDP.

Table 3-21 Full Buildout Water Supply Analysis

Current Max Day Demand (L/s)	Available Supply - Current Set Point (L/s)	Available Supply - Maximum Set Point (L/s)	Remaining Capacity - Current Set Point (L/s)	Remaining Capacity - Maximum Set Point (L/s)
21.1	6.0	14.0	**-15.1**	**-7.1**

Upgrades would likely be required to support the full buildout of the MDP, which should begin to be considered after the 20-year forecast.

3.2.4 Future Water Storage Analysis

The treated water reservoir should be of sufficient size to support the following requirements, as established in the design criteria in Section 3.1.3:

+ Fire storage (70 L/s for 1.5 hours)
+ Equalization storage (25% MDD)
+ Contingency storage (15% ADD)
+ Emergency Storage (2x ADD)

Using the existing level of service that Linden is providing, Linden should be able to supply 70 L/s fire flow for 1.5 hours. This translates into a fire storage of 378 m^3.

20-Year Forecast

The ADD for the 20 year forecast is 394 m^3/day. 2x ADD for the emergency storage equals 788 m^3.

Table 3-22 shows the total storage requirements for the 20-year forecast.

Table 3-22 20 Year Water Storage Analysis

Growth Horizon	15% ADD (m^3)	25% MDD (m^3)	Fire Storage (m^3)	2xADD Emergency Storage (m^3)	Total Recommended (m^3)	Total Available (m^3)	Remaining Capacity (m3)
20 Years	59	197	378	789	1,423	1,919	**496**

As the above table shows, the existing reservoir has more than sufficient capacity for the 20-year forecast.

Full Buildout

The ADD for the Full Buildout is 914 m^3/day. 2x ADD for the emergency storage equals 1,827 m^3/day.

Table 3-23 shows the total storage requirements for the full buildout scenario

Table 3-23 Full Buildout Water Storage Analysis

Scenario	15% ADD (m^3)	25% MDD (m^3)	Fire Storage (m^3)	2xADD Emergency Storage (m^3)	Total Recommended (m^3)	Total Available (m^3)	Remaining Capacity (m^3)
Full Buildout	137	457	378	1,827	2,799	1,919	**-880**

As the above table shows, the existing storage reservoir is not adequate to support the full buildout scenario given the proposed design criteria. This is largely due to the proposed 2xADD emergency storage, which is suggested as a way to mitigate risk in the event of a service disruption to the Village's water supply. This is not a requirement under the Alberta Environment Standards and Guidelines, which dictates the other portions of the reservoir design criteria.

Depending on the Villages acceptable risk tolerance, the emergency ADD storage could be reduced to one day, or eliminated entirely, which would result in the existing reservoir being adequate to service the full buildout demands. Ultimately the full buildout scenario is not in the scope of this report with regards to recommending upgrades or developing project timelines, but this matter should be taken into consideration when this level of development is in a closer timeframe.

3.2.5 Pump Station Analysis

AEP requires that the water distribution system facility be designed to deliver maximum design flow with the largest pump out of service. Level of service is then assessed for the MDD+FF and PHD scenarios.

The level of service was determined by modelling the distribution system with the 20 hp pump turned off, under the MDD+FF and PHD scenarios. Under the PHD scenario, the fire pump was also considered to be off.

20 Year Forecast

The pump station is adequate to deliver both the MDD+FF level of service and the PHD level of service under the 20-year forecast.

Full Buildout

The pump station is adequate to deliver the MDD+FF level of service under the 20-year forecast, however under the PHD scenario there are found to be pressure deficient areas. One of the pumps would likely need to be upgraded in order to achieve the level of service for minimum pressure.

In the model, a pump designed to provide 41 L/s @ 40 m of head was used to simulate the upgraded pump.

3.2.6 Water Distribution Mains

New water distribution lines were placed in such a way as to best service the new growth areas, which aligned with the proposed road alignments shown in the MDP. Upgrades recommended in the existing system were assumed to have been completed.

The proposed water distribution network and the results for the MDD+FF and PHD scenarios can be seen on figures W5 through W8 (Appendix A – Water Figures)

When all of the pipes in the proposed alignments are installed, along with the recommended upgrades to the existing system and under the 20-year forecast, the result is a water distribution system that meets all of the design criteria.

20 Year Forecast

Outside of the pipes required to service the development areas, two additional projects are recommended to ensure adequate service levels, especially with regards to fire flow.

+ A 200 mm pipe on the north end of town connecting 1st St W with 5th St west. This pipe is necessary to ensure network connectivity, and allows for adequate available fire flow in the northern portions.
+ A 200 mm pipe connecting 5th St W and 6th St W along 1st Ave NW This pipe is necessary to ensure network connectivity, and allows for adequate available fire flow in the western industrial portion.

Full Buildout

One project that will be required to service the northeast area is a water line down Central Ave, to Range Road 254. This should be planned to be completed in conjunction with Central Ave upgrades.

Outside of the pipes required to service the development area, one additional project should be undertaken to ensure network connectivity, and to not have a large area serviced off of a single feed

- A 200mm pipe connecting the Southwest residential area to the Southeast, through the coulee and connecting to Linview Dr

3.2.7 Future Water System Projects

The following recommended projects are to satisfy the 20-year forecast. Any recommended upgrades past this were outside the scope of this report and will not fall under this project list.

For this section, all recommended projects for the existing system were assumed to have been completed.

3.2.7.1 W1 – 5th St NW and 6th St NW Cross Connect

Project Description

Install a 200 mm pipe connecting 5th St NW and 6th St NW along the 3rd Ave NW alignment

Project Rationale

To improve system connectivity and achieve the required level of service for available fire flow, a 200 mm pipe should be installed to connect 5th St NW and 6th St NW along 3rd Ave NW.

This should be considered as part of the development requirements for the industrial portion of the Northwest quadrant.

Project Details

+ Install 120 m of 200 mm pipe

Project Trigger

+ Project should be completed in conjunction with development of the industrial portion of the Northwest quadrant

Project Cost

Engineering	$	15,000.00
Implementation	$	60,000.00
Contingency	$	20,000.00
Total	**$**	**95,000.00**

3.2.7.2 W2 – 1st St NW and 5th St NW Cross Connect

Project Description

Install a 200 mm pipe connecting the north ends of 1st St NW and 5th St NW

Project Rationale

To improve system connectivity and achieve the required level of service for available fire flow, a 200 mm pipe should be installed to connect the north ends of 1st St NW and 5th St NW. Due to the coulee, installation would likely have to be through horizontal directional drill (HDD).

This should be considered as part of the development requirements for the residential portion of the Northwest quadrant, as that infrastructure still needs to be installed to make this cross connection.

Project Details

+ Install 380 m of 200 mm pipe through HDD

Project Trigger

+ Project should be completed in conjunction with development of the residential portion of the Northwest quadrant

Project Cost

Engineering	$	45,000.00
Implementation	$	300,000.00
Contingency	$	90,000.00
Total	**$**	**435,000.00**

3.2.7.3 W3 – Central Ave Water Line Extension

Project Description

Install a 200 mm pipe along Central Ave from the pump station to Range Road 254

Project Rationale

In order to service the northeast area, and allow for potential future connections outside of Linden, a new water line should be installed along Central Ave to the Village limits

Project Details

+ Install 540 m of 200 mm pipe

Project Trigger

+ Project should be completed in conjunction with development of the residential portion of the Northwest quadrant

Project Cost

Engineering	$	70,000.00
Implementation	$	450,000.00
Contingency	$	135,000.00
Total	**$**	**655,000.00**

4. Sanitary Infrastructure

4.1 Existing Wastewater System

The Village of Linden sanitary assets are owned and operated by the Village. The system consists of a gravity collection system and a lagoon treatment system.

4.1.1 System Characterization

4.1.1.1 Pipe Diameters and Materials

The gravity sewer pipes in Linden range between 100mm and 250mm in diameter. The pipe materials are a mix of Vitrified Clay Tile (VCT) and Polyvinyl Chloride (PVC). The majority of the pipes are VCT. It is unknown how old the majority of the VCT pipes are. Table 4-1 shows the proportions of the pipe sizes and Table 4-2 shows the materials.

Table 4-1 Gravity Collection System Pipe Sizes

Pipe Size (mm)	Pipe Length (m)	Percentage of Total
100	24	0%
150	76	1%
200	7903	93%
250	524	6%
Total	**8527**	

Table 4-2 Gravity Collection System Materials

Material	Pipe Length (m)	Percentage of Total
Clay	5448	64%
PVC	3079	36%
Total	**8527**	

4.1.1.2 Wastewater Treatment

The wastewater treatment consists of a lagoon system south of Linden. (Figure S2, Appendix B – Wastewater Figures). A gravity system conveys effluent to the lagoon. The lagoon consists of two anaerobic cells, two facultative cells, and one storage cells.

The storage cell is designed to be discharged yearly, with the effluent draining into Kneehill Creek. However, since 2017 the effluent has been pumped out by third parties for other uses. As such, the lagoon has not been discharged since prior to 2017.

Table 4-3 summarizes the volumes of each lagoon cell:

Table 4-3 Lagoon Cell Volumes

<table>
<tr><th>Cell Type</th><th>Quantity</th><th>Required Retention Time</th><th>Depth (m)</th><th>Total Volume (m^3)</th><th>Serviceable ADWF (L/s)</th></tr>
<tr><td>Anaerobic</td><td>2</td><td>2 Days</td><td>3</td><td>1,524</td><td>4.4</td></tr>
<tr><td>Facultative Pond 1</td><td>1</td><td rowspan="2">60 Days</td><td rowspan="2">1.5</td><td>12,500</td><td rowspan="2">5.3</td></tr>
<tr><td>Facultative Pond 2</td><td>1</td><td>14,800</td></tr>
<tr><td>Storage Pond</td><td>1</td><td>1 Year</td><td>3</td><td>184,250</td><td>5.8</td></tr>
</table>

4.1.1.3 Design Criteria

The design criteria used to review the performance of the sanitary sewer system were:

+ A gravity sewer's hydraulic capacity must be greater than the peak expected flow
+ Minimum flow velocity must be greater than 0.6 m/s
+ Maximum flow velocity must be less than 3.0 m/s
+ A lagoon's wastewater retention capacity must exceed the average wastewater flow generated.

The capacity of a gravity sewer is evaluated based on the peak expected flow and the flow capacity of the pipe which is calculated using pipe slope and diameter at 80% flow depth. Pipe capacity must be greater than the expected peak flow or surcharging of the collection system can occur. This value is represented as a percentage which is calculated by dividing the peak flow by the pipe's flow capacity. A percentage less than 100% means that peak flow is less than the capacity of the pipe.

The collection system will also be assessed against the minimum slope requirements set out in the Alberta Environment Standards and Guidelines, as shown in Table 4-4.

Table 4-4 Minimum Pipe Slopes

Pipe Diameter (mm)	Minimum Slope (%)
150	0.80
200	0.40
250	0.28
300	0.22
375	0.15

4.1.1.4 Model Development

A hydraulic model of the Linden wastewater system was developed to assess the level of service the system is capable of. The schematic linework, pipe sizes and material were established by record drawings of the utilities and GIS. Invert information was retained from record drawings and GIS information, and missing information was surveyed in the field. This information was used to update the GIS shapefiles for the gravity pipes and manholes.

The shapefiles were imported into Bentley SewerGEMS, a hydraulic modeling software. This modelling software calculates pipe slopes and flow rates based on pipe data and calculated sewer flow generation.

The model calculates pipe capacity for gravity pipes using the Manning equation. A Manning's roughness coefficient of 0.013 was used for those calculations.

4.1.2 Wastewater Demands Analysis

4.1.2.1 Existing Population

As described in Section 2.2 the projected population for Linden in 2020 is 884 people.

4.1.2.2 Flow Generation

Typically, wastewater flow generation is calculated either through annual lagoon discharge volumes, or lift station pumping volumes. As Linden has no lift station, and has not discharged the lagoon for more than three yeas, an alternative method had to be used. Effluent has been pumped out of the lagoon for the last several years by a third party, however it has been an inconsistent amount and would not be a good indication of yearly wastewater generation.

A common assumption for wastewater generation rates is 80%-90% of water usage. However, due to the age of the system, which can contribute to higher groundwater infiltration rates, a more conservative assumption of 100% of water usage will be used to determine the wastewater flow rates. As such, a per capita rate of 270 L/c/day will be used to calculate wastewater flow generation.

Table 4-5 Average Dry Weather Flow

Wastewater Demand	Population	Per Capita Demand (L/c/day)	Average Dry Weather Flow (L/s)	Average Dry Weather Flow (m^3/day)	Annual Volume (m^3)
Average Dry Weather Flow	884	270	2.8	239	87,118

As the above table shows, the Average Dry Weather Flow (ADWF) of Linden is 2.8 L/s, or 239 m^3/day.

4.1.2.3 Peaking Factor

Peak Dry Weather Flow (PDWF) is calculated using Harmon's Peaking Factor. This is an international standard that AEP includes in their Guidelines. The calculation is based on the contributing populations.

Harmon's Equation: $PF = 1 + 14/(4+P^{1/2})$ where P is the contributing population in thousands and PF has a minimum value of 2.5 and a maximum of 4.0.

Peak Dry Weather Flow (PDWF) is determined by applying the peaking factor to the ADWF. Table 4-6 summarizes the peaking factor and PDWF for Linden.

Table 4-6 Sanitary Peaking Factors

Location	Population	ADWF (L/s)	PF	PDWF (L/s)
Existing System	884	2.8	3.83	10.7

The calculated PDWF for Linden is 10.7 L/s.

4.1.2.4 Inflow and Infiltration

Inflow and Infiltration (I&I) is assumed to be 0.28 L/s/ha throughout Linden. The I&I allowances are attributed to the gross development area of the collection area. The I&I assumption of 0.28 L/s/ha is based on recommendations from AEP's Standards and Guidelines for estimating and designing for Inflow and Infiltration. I&I typically accounts for inflow through manholes, or infiltration into pipes and manholes. AEP also recommends a flow of 0.4 L/s be added for each manhole at a sag or low point in a road. For the purposes of this study we have used the 0.28 L/s/ha exclusively.

After the I&I has been calculated, it can be added to the PDWF to establish the Peak Wet Weather Flow (PWWF) which is the peak flow anticipated in the collection system and is the value used to establish pipe and pumping capacity.

Linden was determined to have a collection area of 62 ha. The I&I boundaries used to determine the collection are shown in Figure 4-1.

Table 4-7 Peak Wet Weather Flow

Location	Area (ha)	PDWF (L/s)	I&I (L/s)	PWWF (L/s)
Existing System	62	10.7	17.4	28.1

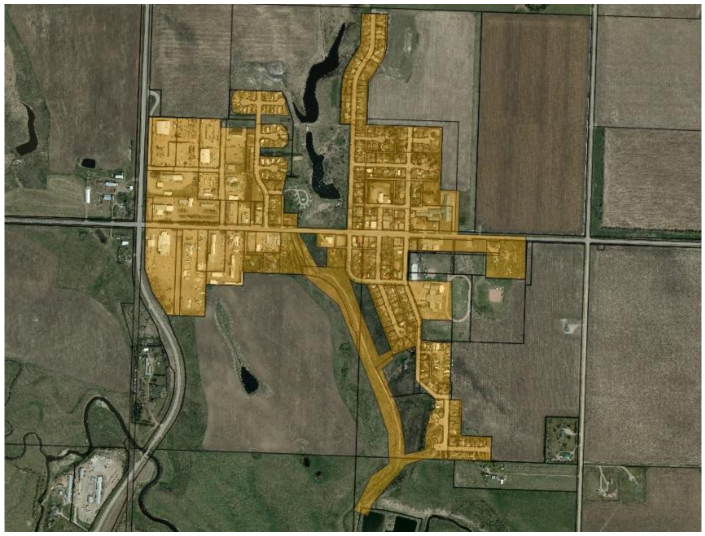

Figure 4-1 Infiltration Boundaries

As Table 4-7 shows, the Peak Wet Weather Flow in Linden has been calculated to be 28.1 L/s.

4.1.3 Existing System Evaluation

4.1.3.1 Collection System Analysis

Hydraulics

The gravity collection system of Linden was modeled using the Peak Wet Weather Flow scenario. The pipes were evaluated on their hydraulic capacity, hydraulic grade line relative to top of pipe, and pipe velocity. The results are shown in Figure S4 and Figure S5 (Appendix B - Wastewater Figures).

Only two sections of pipe were above the design capacity of the pipe, with hydraulic grade lines (HGL) above the top of the pipe. These were the sections south of S MH 37, after the last residential tie in before the lagoon. These are of no immediate concern, as the HGL is not very high above the pipe, the pipes are quite deep, and there are no services ties into the pipes. Any potential for surcharge would be short lived and have minimal impact to the system upstream.

Approximately two thirds of the pipes in Linden are below the stipulated minimum velocity of 0.6 m/s. It is understood that an annual flushing program is in place, this program should continue to ensure operational efficacy of the collection system.

Pipe Slopes

The collection system was also assessed against the Alberta Environment Standards and Guidelines for minimum pipe slopes. Table 4-8 summarizes the pipes that are below the minimum slope. Figure S3 (Appendix B – Wastewater Figures) shows an overview of the pipe slopes.

Table 4-8 Pipes Below Minimum Slope

Start MH	Stop MH	Diameter	Length	Slope (%)	Minimum Slope (%)
S MH 20	S MH 16	200	100.1	0.23	0.4
S MH 24	S MH 22	200	63.7	0.22	0.4
S MH 43	S MH 42	200	120.7	0.26	0.4
S MH 47	S MH 48	200	41.1	0.33	0.4
S MH 59	S MH 60	200	60.5	0.27	0.4
S MH 73	S MH 72	150	52.6	0.67	0.8
S MH 82	S MH 83	200	31.1	0.29	0.4
S MH 85	S MH 84	200	31.5	0.00	0.4

All of the pipe runs on the table should be included in the annual maintenance and flushing program, due to their low slopes.

Pipe Condition – CCTV Investigation

A CCTV investigation of the majority of the pipes in the Village was performed in November and December of 2020. The videos and reports were then reviewed by CIMA+, and pipes were given a condition rating. Due to concerns with the access road by the subcontractor, along with debris in some of the first segments obstructing the cameras path, the trunk main south of Central Ave leading to the lagoon was not surveyed. If possible, this area should still be inspected during the Spring or Summer of 2021, as the lines consist of VCT (Vitrified Clay Tile pipe), which has the highest potential of having potentially severe deficiencies.

The remaining portion of the CCTV Inspections along the Lagoon Trunk Line was performed in May 2021. The results of the investigation are included in Appendix J. Any projects that arose from this have been included in this report and in the Capital Plan. Significant defects were found in the trunk line, which will necessitate immediate action.

The condition rating indicates the general type of repair that is required, and whether it is an immediate concern or should be resolved in the future. It also indicates areas that will need increased maintenance or operational concerns, and others that should be monitored for worsening condition.

The major repair types are Cured in Place Pipe (CIPP) lining, which is a trenchless repair solution that can structurally reinforce significantly damaged pipes, and excavation. Pipes that are damaged beyond the point of being able to be lined will need to be removed and replaced to repair the deficiency.

CIPP lining can significantly increase the lifespan of pipes, while improving flow capabilities by reducing friction losses. This solution is viable for most defects, outside of significant structural failure such as collapsed pipes. It can also significantly reduce groundwater infiltration, which can have an impact on the available capacity of the lagoon

Table 4-9 shows the condition rating metric.

Table 4-9 CCTV Condition Rating Metric

Condition Rating	Condition Type	Recommendation
0	Adequate	No Action Required
1	Maintain	Requires Maintenance
2	Minor	Minor Issues (Sags, Ovals)
3	Moderate	Moderate Issues (Sags, Ovals)
4	Moderate with Lining	Moderate Lining Repairs - Near Future Action
5	Severe with Lining	Severe Lining Repairs - Immediate Action
6	Moderate with Excavation	Moderate (requires Replacement) - Near Future Action
7	Severe with Excavation	Severe (Requires Replacement) - Immediate Action

A summary of the severe condition pipes are provided below. The full CCTV assessment and contractor reports can be found in Appendix F. These deficient areas consist entirely of CIPP lining repairs. No areas were found to be deficient to the point of requiring excavation to service the existing system. Visual results of the CCTV program are summarized in Figure S13 (Appendix B – Wastewater Figures)

There were several areas that will require replacement prior to future development, due to sags limiting potential future capacity. These will be addressed in the Future System section.

Table 4-10 CCTV Severe Results – Full Pipe Lining

Start MH	End MH	Length	Comment	Recommendation	Rating
MH 28	MH 29	69	Broken Section / Fractures, roots	CIPP lining of full pipe	5
MH 49	MH 48	110	Multiple Breaks/Fractures	CIPP lining of full pipe	5
MH 48	MH 50	98	Multiple Breaks/Fractures	CIPP lining of full pipe	5
MH 57	MH 58	96	Large joint offsets, Multiple Breaks & Fractures	CIPP lining of full pipe (high priority)	5
MH 97	MH 65	119	Fracture/Defective Joints	CIPP lining of full pipe	5
MH 77	MH 81	77	Roots/Cracks/Fractures/Broken Joint	CIPP lining of full pipe due to broken pipes, roots intrusion, cracking, and joint offsets	5
MH 87	MH 86	38	Broken Pipe	CIPP liner for clay tile portions of pipe (may be more cost effective to line entire pipe)	5
MH 80	MH 80A	129	Roots, Fracture, cracking, broken sections	CIPP lining of entire pipe	5
MH 80	MH 33	88	Multiple Breaks	CIPP lining of entire pipe (high priority)	5
MH 62B	MH 31	78	Multiple Breaks / Roots	CIPP lining of entire pipe	5

Table 4-11 CCTV Results - Pipe Excavation

Video #	Start MH	End MH	Length	Comment	Recommendation	Rating
108	MH 87	MH 88	80	Defective Service Connection/Offset Joint	CIPP spot repair at offset joint 68m from MH 87. Repair defective service at 20.5m from MH 87 (Should hold builder accountable, is likely service for 203 Linview Dr and was installed after Sewer line was built)	4/6

Table 4-11 shows the one location that requires excavation to repair that won't be driven by development pressure. There is a defective service from what appears to be 203 Linview Dr, which appears to have been built after the sewer line was installed. This defective service should be the responsibility of the builder to repair.

Table 4-12 CCTV Severe Results - Spot Repairs

Start MH	End MH	Length	Comment	Recommendation	Rating
MH 44	MH 45	84	Broken Section / Sags	CIPP Liner / spot repair at 10m from MH 44. Regular flushing due to multiple sags	5
MH 45	MH 46	67	Broken Pipe	CIPP Liner / spot repair at 13m from MH 46. Regular flushing due to multiple sags	5
MH 45	MH 46	14	Broken Pipe	CIPP Liner / spot repair at 13m from MH 46. Regular flushing due to multiple sags	5
MH 55	MH 53	95	Broken Section / Fractures after material change, infiltration runner	CIPP lining of clay tile portion of pipe (15m from MH 53)	5
MH 53	MH 57	53	Offset Joint / Fracture, minor root infiltration	CIPP spot repair at joint offsets / material changes (2m and 12m from MH 53), or replace section of pipe (medium priority)	5
MH 74A	MH 74	67	Broken Pipe/Roots/Offset Joint	Clean out roots. Consider lining pipe due to significant root intrusion and cracking. At minimum CIPP spot repair broken pipe at MH 74	5
MH 83	MH 84	82	Broken pipe at MH 84	CIPP spot repair of broken pipe at MH 84. Consider CIPP lining of full pipe due to root intrusion (very low priority)	5
MH 86	MH 85	95	Severe Break - Unable to pass	CIPP liner spot repair at broken section at minimum. Consider lining entire pipe to prevent future breakage	5

4.1.3.2 Lagoon Analysis

Lagoon Capacity

As per AEP standards, wastewater lagoons of the type used in Linden should have 0, 2 or 4 anaerobic cells which have a 2-day retention time per cell, depending on the original Daily Design Flow of the lagoon. The lagoon has two anaerobic cells, which indicates that the original daily design flow was between 250 m^3/day and 500 m^3/day, however these regulations may have been different when the lagoon was originally designed. The lagoon should also have 1 facultative (aerobic) cell with a 60-day retention time, and 1 storage cell with a 12-month retention time. In the case of the Linden lagoon, there are two facultative cells due to an upgrade that was performed to the lagoon system, however they are cross connected and function as a single cell.

The requirements for anaerobic cells in lagoons can be found in Table 4-13. The retention time should be based on the average daily flow, which according to Section 4.1.2, is 239 m^3/day.

Table 4-13 Lagoon Cell Requirements

Average Daily Design Flow (m^3)	Number of Anaerobic Cells	Requirement for Facultative Cells	Requirement for 12-month Storage Cells
Less than 250	0	Yes	Yes
250 to 500	2	Yes	Yes
Greater than 500	4	Yes	Yes

As the above table shows, anaerobic cells are not strictly required for the current average day demand, however they are present, which provides an additional level of treatment.

Table 4-14 Existing Lagoon Capacity

	2 Day Anaerobic Cells – Each	60 Day Facultative Cells	12 Month Storage Cells (Both Cells)
Actual Capacity (m^3)	715	27,300	184,250
Required Capacity (m^3)	478	13,184	80,205
Days of Retention	3.0	124	838
Additional Capacity (m^3)	**237.6**	**14,116**	**104,045**
Additional Capacity (L/s)	**1.4**	**2.7**	**3.3**

Table 4-14 shows the performance of the lagoon cells with respect to the Alberta Environment requirements for retention times. The 2-day anaerobic cells, the 60 day facultative cells and the 12 month storage cell all have a moderate excess in capacity. Overall, the anaerobic cells are the bottleneck, but are more than sufficient to accommodate existing demands. The village is currently using approximately 2/3 of the available lagoon capacity.

No upgrades are needed for the existing lagoon system.

Lagoon Condition

To the best of our knowledge, the lagoon system has not had a sludge survey or cleaning in the recent past. It is recommended that, at a minimum, the two anaerobic cells be surveyed for sludge depth, and potentially be cleaned or dredged if the results of the survey indicate it is necessary. A sludge survey of the facultative and storage cells would also be beneficial, but at this time with the current demands and the size of the cells, is likely not a necessity.

In addition, an inline flow meter installed upstream of the lagoon would provide valuable data for determining the future performance of the lagoon, and verifying capacity for further development.

4.1.4 Existing Wastewater System Projects

4.1.4.1 EX S1 – Lagoon Sludge Survey

Project Description

Perform sludge survey on anaerobic cells of the lagoon

Project Rationale

In order to ensure the continued effective operation of the lagoon, the anaerobic cells should be surveyed for sludge depth to determine if they will need to be cleaned or dredged out in the near future.

Project Details

+ Sludge survey of the anaerobic cells of the lagoon

Project Trigger

+ None, project should be completed in the near future

Project Cost

Engineering	$	2,000.00
Implementation	$	15,000.00
Contingency	$	5,000.00
Total	**$**	**22,000.00**

4.1.4.2 EX S2 – Lagoon Sludge Cleaning

Project Description

Remove sludge from anaerobic cells if sludge survey indicates this to be required

Project Rationale

To ensure the continued effective operation of the lagoon, the anaerobic cells may require sludge to be dredged from them, depending on the results of the sludge survey

Project Details

+ Sludge cleaning from anaerobic cells – amount to be determined by sludge survey

Project Trigger

+ Project should be completed in timeline indicated by sludge survey

Project Cost

Estimated Project Cost: $40,000 - $100,000

4.1.4.3 EX S3 – CIPP Lining Program: 1st St NE

Project Description

CIPP lining program along 1st St NE, between 3rd Ave NE and 1st Ave NE

Project Rationale

CCTV inspection identified severely deteriorated areas in pipes along 1st St NE, with areas with multiple breaks and fractures and broken pipes

Project Details

- Full CIPP lining from S MH 57 to S MH 58 (100m)
- Spot repairs between S MH 55 and S MH 53 (15m)
- Spot repairs between S MH 53 and S MH 57 (10 m)

Project Trigger

- None, project should be completed in the near future

Project Cost

Engineering	$	10,000.00
Implementation	$	35,000.00
Contingency	$	10,000.00
Total	**$**	**55,000.00**

4.1.4.4 EX S4 – CIPP Lining Program: 1st St NW

Project Description

CIPP lining program along 1st St NW, on sections between 5th Ave N and 2nd Ave NE

Project Rationale

CCTV inspection identified severely deteriorated areas in pipes along 1st St NW, with areas with multiple breaks and fractures and broken pipes

Project Details

+ Full CIPP lining from S MH 48 to S MH 50 (100 m)
+ Full CIPP lining from S MH 49 to S MH 48 (110 m)
+ Spot repairs between S MH 44 and S MH 45 (10 m)
+ Spot repairs between S MH 45 and S MH 46 (10 m)

Project Trigger

+ None, project should be completed in the near future

Project Cost

Engineering	$	10,000.00
Implementation	$	60,000.00
Contingency	$	15,000.00
Total	**$**	**75,000.00**

4.1.4.5 EX S5 – CIPP Lining Program: 1st St SE

Project Description

CIPP lining program along 1st St SE, between 1st Ave S and Linview Dr

Project Rationale

CCTV inspection identified severely deteriorated areas in pipes along 1st S, with areas with multiple breaks, fractures, and broken pipes

Project Details

+ Full CIPP lining from S MH 77 to S MH 81 (80 m)
+ Full CIPP lining from S MH 85 and S MH 86 (105 m)
+ Full CIPP lining from S MH 86 and S MH 87 (120 m)

Project Trigger

+ None, project should be completed in the near future

Project Cost

Engineering	$	15,000.00
Implementation	$	75,000.00
Contingency	$	25,000.00
Total	**$**	**115,000.00**

4.1.4.6 EX S6 – CIPP Lining Program: 1a St NW

Project Description

CIPP lining program along 1a St NW, from 1st Ave N to Central Ave W

Project Rationale

CCTV inspection identified severely deteriorated areas in pipes along 1a St NW, with areas with multiple breaks, fractures, and broken pipes

Project Details

- Full CIPP lining from S MH 79 to S MH 80 (145 m)
- Full CIPP lining from S MH 80 and S MH 33 (90 m)

Project Trigger

- None, project should be completed in the near future

Project Cost

Engineering	$	10,000.00
Implementation	$	60,000.00
Contingency	$	15,000.00
Total	**$**	**85,000.00**

4.1.4.7 EX S7 – Repair Defective Service 203 Linview Dr

Project Description

Repair the defective service at 203 Linview drive

Project Rationale

CCTV inspection identified a defective service at 203 Linview Dr. This appears to be from a new construction, installed after the sanitary line was in place. If this is the case, the builder should be held accountable for the costs of the repair.

Project Details

+ Repair service at 203 Linview Dr

Project Trigger

+ None, project should be completed in the near future

Project Cost

Engineering	$	2,500.00
Implementation	$	20,000.00
Contingency	$	7,500.00
Total	**$**	**30,000.00**

4.1.4.8 EX S8 – 2021 Lagoon Trunk Line CCTV - Immediate Action

Project Description

Full pipe CIPP lining of pipes identified as immediate action in the 2021 Lagoon CCTV investigation.

Project Rationale

CCTV inspection performed in 2021 of the lagoon trunk line identified three pipe sections requiring immediate action due to broken or collapsing pipes. Refer to Appendix J for CCTV review and location map.

Project Details

+ Full pipe CIPP lining between SMH 33A and SMH 33 (124 m)
+ Full pipe CIPP lining between SMH 31 and SMH 32A (86 m)
+ Full pipe CIPP lining between SMH 29 and SMH 30 (104 m)

Project Trigger

+ None, project should be completed as soon as possible

Project Cost

Implementation	$	79,000.00
Contingency	$	16,000.00
Total	**$**	**95,000.00**

4.1.4.9 EX S9 – 2021 Lagoon Trunk Line CCTV – Near Future Action

Project Description

Full pipe CIPP lining of pipes identified as near future action in the 2021 Lagoon CCTV investigation.

Project Rationale

CCTV inspection performed in 2021 of the lagoon trunk line identified five pipe sections requiring near future action due to significant defects. Refer to Appendix J for CCTV review and location map.

Project Details

+ Full pipe CIPP lining between SMH 32 and SMH 33A (125 m)
+ Full pipe CIPP lining between SMH 33 and SMH 34 (132 m)
+ Full pipe CIPP lining between SMH 37 and SMH 38 (107 m)
+ Full pipe CIPP lining between SMH 32 and SMH 32A (30 m)
+ Full pipe CIPP lining between SMH 34 and SMH 35 (125 m)

Project Trigger

+ None, project should be completed in the next 5 years

Project Cost

Implementation	$	130,000.00
Contingency	$	26,000.00
Total	**$**	**156,000.00**

4.1.4.10 EX S10 – 2021 Lagoon Trunk Line CCTV – Future Action

Project Description

Full pipe CIPP lining of pipes identified as future action in the 2021 Lagoon CCTV investigation.

Project Rationale

CCTV inspection performed in 2021 of the lagoon trunk line identified one pipe sections requiring near future action due to defects. Refer to Appendix J for CCTV review and location map.

Project Details

+ Full pipe CIPP lining between SMH 35 and SMH 36 (98 m)

Project Trigger

+ None, project should be completed in the next 5 to 10 years

Project Cost

Implementation	$	25,000.00
Contingency	$	5,000.00
Total	**$**	**30,000.00**

4.2 Future Wastewater System

4.2.1 Wastewater Demands Analysis

As described in Section 2.3, the future wastewater system will consist of additional growth areas in the Northeast development area for residential development, and the Northwest are for industrial development. This will include an additional 280 people for planning purposes, for a total population of 1164 people at a 20-year growth horizon.

The existing system assumed 100% of water demands for the wastewater in order to be conservative and accommodate for potential existing infiltration. New construction is much more watertight, and assuming 100% of water demands is likely a conservative assumption. As such, wastewater demands for new development will be assumed to be 80% of water demands, which is standard for high level planning.

+ A per capita rate of 220 L/c/day (80% of 270 L/c/day)
+ An industrial/institutional/commercial rate of 6.4 m^3/ha/day (80% of 8 m^3/ha/day)

4.2.1.1 Flow Generation

Residential Flows

Table 4-15 shows the calculated residential ADWF for the existing system, the 20 Year Forecast, and the Full Buildout.

Table 4-15 Future Residential Year ADWF

Growth Horizon	Population	ADWF (m^3)	ADWF (L/s)	Annual Volume (m^3)
Existing	884	239	2.8	87,118
20 Years	1164	300	3.5	109,602
Full Buildout	2050	495	5.7	180,748

Industrial, Commercial and Institutional Flows

Table 4-16 shows the calculated industrial, commercial, and institutional ADWF for the existing system, the 20 Year Forecast, and the Full Buildout.

Table 4-16 Future Industrial ADWF

Growth Horizon	Area	Water Usage Rate (m^3/ha/day)	ADWF (m^3)	ADWF (L/s)	Annual Volume (m^3)
Existing System	-	-	-	-	-
20 Years	6.5	6.4	41.6	0.5	15,184
Full Buildout	45	6.4	288	3.3	105,120

4.2.1.2 Peaking Factor

Residential Peak Dry Weather Flow (PDWF) is calculated using Harmon's Peaking Factor. This is an international standard that AEP includes in their Guidelines. The calculation is based on the contributing populations.

Harmon's Equation: PF = 1 + 14/(4+P1/2) where P is the contributing population in thousands and PF has a minimum value of 2.5 and a maximum of 4.

Industrial, commercial, and institutional peaking factors will be a flow based peaking factor established by AEP Standards and Guidelines. The peaking factor equation is $PF= 6.659(Q_{AVG})^{-0.168}$ where Q_{AVG} is the average flow rate in L/s, with a maximum PF of 5.

Peak Dry Weather Flow (PDWF) is determined by applying the peaking factor to the ADWF.

Residential Flows

Table 4-17 shows the calculated residential PDWF for the existing system, the 20 Year Forecast, and the Full Buildout

Table 4-17 Future Residential PDWF

Location	Population	ADWF (L/s)	PF	PDWF (L/s)
Existing System	884	2.8	3.8	10.7
20 Years	1164	3.5	3.8	13.1
Full Buildout	2050	5.7	3.6	20.5

Industrial, Commercial and Institutional Flows

Table 4-18 shows the calculated industrial, commercial, and institutional ADWF for the existing system, the 20 Year Forecast, and the Full Buildout.

Table 4-18 Future Industrial PDWF

Growth Horizon	ADWF (L/s)	PF	PDWF (L/s)
Existing System	-	-	-
20 Years	0.5	5.0	2.4
Full Buildout	3.3	5.0	16.7

4.2.1.3 Inflow and Infiltration

Inflow and Infiltration (I&I) is assumed to be 0.28 L/s/ha throughout Linden. The I&I allowances are attributed to the gross development area of the collection area. The I&I assumption of 0.28 L/s/ha is based on recommendations from AEP's Standards and Guidelines for estimating and designing for Inflow and Infiltration. I&I typically accounts for inflow through manholes, or infiltration into pipes and manholes. AEP also recommends a flow of 0.4 L/s be added for each manhole at a sag or low point in a road. For the purposes of this study we have used the 0.28 L/s/ha exclusively.

After the I&I has been calculated, it can be added to the PDWF to establish the Peak Wet Weather Flow (PWWF) which is the peak flow anticipated in the collection system and is the value used to establish pipe and pumping capacity. Residential and Industrial PDWFs were summed up for each growth horizon.

The new developable area for the 20-year forecast is 17.5 ha. The new developable area for the full buildout is 125 ha.

Table 4-19 Future PWWF

Growth Horizon	Area (ha)	PDWF (L/s)	I&I (L/s)	PWWF (L/s)
Existing System	62.0	10.7	17.4	28.1
20 Years	79.5	15.5	22.3	37.7
Full Buildout	187.0	37.2	46.8	83.9

4.2.2 Model Development

A hydraulic model of the full buildout wastewater system was developed in Bentley SewerGEMS. Wastewater lines were placed along proposed road alignments as shown in the MDP.

The wastewater demands established for the growth areas were applied to the model, and the infrastructure was sized accordingly. Two future scenarios were prepared, one for the 20-year forecast, and one for the full buildout of the MDP.

Demands were assigned using the populations and areas described in Section 2.3, with 220 people assigned to the Northwest residential area, 60 people assigned to the Northeast residential area, and 6.5 ha of industrial assigned to the Northwest industrial area for the 20 year forecast.

The wastewater demands described in Section 4.2.1 at PWWF were used to size the collection system. High density LiDAR imagery was used to develop ground elevations for the model area.

4.2.3 Future System Analysis

4.2.3.1 Collection System Analysis

The gravity collection system of Linden was modeled using the Peak Wet Weather Flow scenario under the 20-year forecast, and the Full Buildout. The pipes were evaluated on their hydraulic capacity, hydraulic grade line relative to top of pipe, and pipe velocity. The results are shown in Figure S6 through S12 (Appendix B - Wastewater Figures).

20 Year Forecast

During the peak wet weather flow event, the trunk main leading to the lagoon is at over 150% capacity in some locations. This results in surcharging through most of the trunk main. The risk to residences is quite low, due to the location of the trunk main in the coulee being significantly lower than residential developments, however the surcharging could pose risks of sewage flooding manholes in these low areas.

The model shows a remaining freeboard, or distance from top of surcharge to the surface, of approximately 2 meters at the worst location. This is lower than what is deemed acceptable in many municipalities.

This is further complicated due to the fact that this assumes the pipes are in perfect working order, with no obstructions or anything else that would limit flow through them. As the CCTV was not completed along the trunk main by the contractor, it cannot be verified that this assumption is correct. In addition, if the pipes were found to be extensively damaged, and required at minimum CIPP lining to rehabilitate them, this would further reduce the pipe capacity, further magnifying the issue.

Outright replacement of the trunk main would be very expensive, and difficult logistically, as all incoming wastewater would require bypass pumping during the length of the project. A trenchless solution such as pipe bursting may be more cost effective than open excavation.

One potential alternative would be to twin the line, installing a new wastewater line along the same alignment, then either connecting and sharing the flows with the existing line, or fully diverting flows to the twinned line and abandoning the existing line in place.

Prior to making a decision, the Village should ensure the remainder of the trunk main has a CCTV investigation. If the line is in particularly poor condition, with evidence of limited or obstructed flow, then an upgraded trunk line would be the best course of action. A 300 mm diameter pipe is recommended, in order to ensure the pipe can service up to the full buildout of the MDP.

In addition to the trunk main, the CCTV investigation identified three areas that have pipe segments that should be replaced prior to future upstream developments, due to sags creating flow restrictions. These are on 6th St NW, 5th St NW, and 1st St NW, all of which have development planned under the 20 year forecast. These replacements should take place as development pressure occurs.

Table 4-20 CCTV Results - Replacement Prior to Future Development

Video #	Start MH	End MH	Length	Comment	Recommendation	Rating
3	MH 4	MH 3	179	50% Sag	Monitor, flush regularly. Regrade end of pipe if sag worsens or prior to further development upstream	6
4	MH 4	MH 5	108	Multiple 50% Sags, evidence of surcharging	Monitor, flush regularly, replace prior to further development upstream due to sags impacting capacity	6
5	MH 5	MH 10	91	50% Sag, evidence of surcharging	Monitor, flush regularly, replace between 20m and 30m from MH 5 prior to further development upstream due to sags impacting capacity	6
25	MH 16A	MH 15	121	Multiple Sags	Monitor, flush regularly, replace prior to further development upstream due to sags impacting capacity	6
35	MH 46	MH47	111	30% - 50% Sag / Ovaling	Monitor, flush regularly, replace prior to further development upstream due to sags impacting capacity	6

Full Buildout

One project that will be required to service the northeast area is a sanitary line down Central Ave, to Range Road 254. This should be planned to be completed in conjunction with Central Ave upgrades.

During the peak wet weather flow event in the full buildout growth horizon, the flow through the trunk main leading to the lagoon is near 200% of the pipe's capacity. This leads to significant surcharging through the extent of the trunk line, with sewage flooding to surface in multiple locations.

The trunk main will require an upgrade to at least a 300 mm diameter pipe to satisfy the peak flows. If the trunk main is not upgraded prior to the end of the 20-year forecast, then the upgrades will need to be put into place prior to any further development.

Monitoring

To make informed decisions surrounding the trunk main and potential upgrades, an inline flow monitor could be installed. This would observe the peak flow events real time and give good data on them and the performance of the trunk main.

If a flow monitor is installed, peak flows of greater than 30 L/s should be considered to be nearing the capacity of the trunk main, at which point the discussed upgrades should be considered.

4.2.3.2 Lagoon Analysis

As discussed in 4.1.3.2, the Village is utilizing approximately 2/3 of its available lagoon capacity. The limiting factor of the lagoon is the anaerobic cells, which had 1.4 L/s of ADWF remaining capacity.

Each anaerobic cell must be capable of two days of retention of the ADWF.

20 Year Forecast

Table 4-21 20-Year Lagoon Analysis

	2 Day Anaerobic Cells - Each	60 Day Facultative Cell	12 Month Storage Cells (Both Cells)
Actual Capacity (m^3)	715	27,300	184,250
Required Capacity (m^3)	684	20,513	124,786
Days of Retention	2.1	80	539
Additional Capacity (m^3)	**31.2**	**6,787**	**59,464**
Additional Capacity (L/s)	**0.2**	**1.3**	**1.9**

As Table 4-21 shows, the existing lagoon is sufficient to accommodate the 20-year forecast. However, it is very near to reaching the capacity of the anaerobic cells.

It would be advantageous to monitor incoming flows and development proceeds in the Village to ensure the future flows are not outpacing the projected flows, which would result in the lagoon being over capacity.

Full Buildout

Table 4-22 Full Buildout Lagoon Analysis

	2 Day Anaerobic Cells - Each	60 Day Facultative Cell	12 Month Storage Cells (Both Cells)
Actual Capacity (m^3)	715	27,300	184,250
Required Capacity (m^3)	1,566	46,992	285,868
Days of Retention	0.9	35	235
Additional Capacity (m^3)	**-851.4**	**-19,692**	**-101,618**
Additional Capacity (L/s)	**-4.9**	**-3.8**	**-3.2**

As Table 4-22 shows, the existing lagoon is not sufficient to accommodate the Full Buildout of the MDP. Available capacity would run out shortly after the 20-year forecast.

Due to land constraints, expansions to the lagoon cells would likely not be feasible. Either a new lagoon, or a mechanical wastewater treatment plant, would have to be constructed to support that level of development.

Incoming flow should be monitored as development proceeds in the Village, to get a better understanding of the flows, and to create a more detailed plan to accommodate growth past the 20-year forecast

4.2.4 Future Wastewater System Projects

4.2.4.1 S1 – Trunk Main Flow Monitor

Project Description

Install flow monitor upstream of lagoon

Project Rationale

Development projections over the next 20 years has the trunk main to the lagoon going over capacity during peak flows and has the lagoon very near to capacity. A flow monitor would help provide guidance for if increased flows from development align with projected flows, and whether upgrades to the lagoon or the trunk line would be required.

Project Details

+ Install flow monitor upstream of lagoon

Project Trigger

+ Project should be completed prior to significant development

Project Cost

Engineering	$	2,500.00
Implementation	$	15,000.00
Contingency	$	2,500.00
Total	**$**	**20,000.00**

4.2.4.2 S2 – Trunk Main Upgrade

Project Description

Upgrade trunk main to a 300 mm diameter pipe

Project Rationale

Development projections over the next 20 years has the trunk main to the lagoon going over capacity during peak flows, leading to moderate surcharge.

An upgraded pipe should be installed along the same alignment, with the flows entering the existing trunk main diverted to it and the existing line abandoned in place. Trenchless options such as pipe bursting should also be considered.

Upgrade is contingent on the Village's risk tolerance with surcharging pipe. If CCTV indicates that the pipe is severely damaged or otherwise flow is restricted, then the upgrade should be done.

Project Details

+ Replace 1000 m of trunk line with 300 mm pipe

Project Trigger

+ Project should be completed after 30 L/s peak flows are observed in the trunk main
+ Project should be accelerated if CCTV indicates heavily damaged pipes

Project Cost

Engineering	$	90,00.00
Implementation	$	600,000.00
Contingency	$	200,000.00
Total	**$**	**890,000.00**

4.2.4.3 S3 – 1st St NW Pipe Replacement

Project Description

Replace pipe between S MH 46 and S MH 47 on 1st St NW

Project Rationale

CCTV identified this pipe section as having significant sags and ovaling. While the current performance of this pipe appears to be adequate, it should be replaced and regraded prior to upstream development, as the sags and ovaling cause a restriction in the pipe's capacity.

Project Details

+ Replace 115 m of 200 mm PVC pipe

Project Trigger

+ Project should be completed prior to upstream development pressure

Project Cost

Engineering	$	15,00.00
Implementation	$	95,000.00
Contingency	$	30,000.00
Total	**$**	**140,000.00**

4.2.4.4 S4 – 5th St NW Pipe Replacement

Project Description

Replace pipe between S MH 16 A and S MH 15 on 5th St NW

Project Rationale

CCTV identified this pipe section as having significant sags. While the current performance of this pipe appears to be adequate, it should be replaced and regraded prior to upstream development, as the sags and cause a restriction in the pipe's capacity.

Project Details

+ Replace 125 m of 200 mm PVC pipe

Project Trigger

+ Project should be completed prior to upstream development pressure

Project Cost

Engineering	$	15,00.00
Implementation	$	100,000.00
Contingency	$	30,000.00
Total	**$**	**145,000.00**

4.2.4.5 S5 – 6th St NW Pipe Replacement

Project Description

Replace pipe between S MH 4 and S MH 10 on 6th St NW

Project Rationale

CCTV identified this pipe section as having significant sags and some evidence of surcharging. While the current performance of this pipe appears to be adequate, it should be replaced and regraded prior to upstream development, as the sags and cause a restriction in the pipe's capacity.

Project Details

- Replace 200 m of 200 mm PVC pipe
- Replace/regrade 10 m upstream of S MH 4

Project Trigger

- Project should be completed prior to upstream development pressure

Project Cost

Engineering	$	25,00.00
Implementation	$	170,000.00
Contingency	$	50,000.00
Total	**$**	**270,000.00**

4.2.4.6 S6 – Central Ave Sanitary Line Extension

Project Description

Install new sanitary line along Central ave from S MH 69A to RR 254

Project Rationale

An extension of the sanitary line along Central Ave is required to service future development in the Northeast portion of Linden.

Project Details

- Install 370 m of 200 mm PVC sanitary pipe
- Install 3 sanitary manholes

Project Trigger

- Project should be completed prior to upstream development pressure

Project Cost

Engineering	$50,000.00
Implementation	$320,000.00
Contingency	$100,000.00
Total	**$470,000.00**

5. Stormwater Management

5.1 Introduction

The stormwater analysis was undertaken to evaluate the effectiveness of the existing drainage patterns within the Village of Linden. Aside from the Village itself, upstream lands contribute runoff from the north, west, and east to the drainage infrastructure. A drainage area delineation was completed to determine the catchment boundaries and computer modelling was used to complete the hydrologic and hydraulic analyses.

There are no existing Watershed Management Plans, Master Drainage Plans (MDP) or Staged Master Drainage Plans (SMDP) for the Village of Linden. Although no technical surface water plans for Kneehill Creek have been prepared, there is an existing report that examines the impacts of runoff within the watershed.

- *Kneehill Subwatershed* (Red Deer River Watershed Alliance, 2009)

The stormwater analysis aims at evaluating pre-development and post-development conditions to predict and manage stormwater. This includes developing a target release rate, volume controls, and water quality enhancement. Evaluation of pre-development conditions will establish the controls for development and assist in identifying key storm servicing requirements for the drainage system and stormwater storage facilities.

5.1.1 Scope of Analysis

The objective of this analysis is to evaluate the existing drainage patterns within the Village of Linden (study area) and provide an outline for future stormwater infrastructure to control the post-development peak flows, increased runoff, and water quality. The analysis involves the overall surface water drainage in the study area to examine impacts to the existing stormwater systems and drainage patterns in Linden. The analysis also includes an examination of pre-development discharge in the drainage area to assist in providing guidance for the sizing of future stormwater management facilities (SWMF) to control the volume of stormwater, discharge release rates, and to improve the water quality being released to the environment.

No structural or geotechnical engineering considerations, assessment of subsurface drainage conditions, or drainage of individual development lots were undertaken. Estimation of soil characteristics were based on City of Calgary Guidelines; for subdivision design, a site specific geotechnical study would be required to obtain local values.

A preliminary analysis utilizing 2D hydraulic modelling was completed for the Village of Linden to identify areas of frequent ponding. The analysis was undertaken using existing data and reports completed by CIMA+ and others in the past. Survey data for the existing catch basins, manholes, outlets, sewer pipes, and culverts used in the 2D model of Linden was completed by CIMA+ earlier in 2020. LiDAR data used in the delineation of the watersheds and 2D modelling was based on a twenty five meter grid provincial data for the surrounding lands and two meter grid data within the Village's boundary.

Assessments undertaken in this analysis include:

Pre-development hydrologic and hydraulic analyses

- Identify existing drainage paths
- Identify existing drainage concerns
- Establish drainage boundaries based on topographical information, aerial imagery, and site visits
- Obtain information from Water Survey of Canada for stream gauges for comparative basin analysis
- Identify applicable intensity-frequency-duration (IDF) curves for use in Linden
- Complete single event hydrologic and hydraulic modelling based on IDF curves
- Complete a continuous simulation model of the study area to estimate conditions
- Complete a 2D hydraulic model for the Village of Linden to better understand localized flooding
- Identify any areas that require immediate upgrade for flood protection within Linden

Post-development and future hydrologic and hydraulic analysis

- Establish future release targets for developments
- Prepare a preliminary climate adaptation model to predict the function of the stormwater infrastructure in the future
- Estimate storage requirements for new developments based on existing land use map

5.1.2 Existing Reports

Drainage within the Village of Linden will need to adhere to provincial regulations, outlined in:

- *Stormwater Management Guidelines for the Province of Alberta* (AEP, 2011)

The drainage network will be examined and compared against current standards, including deficiencies and limitations in the storm system. However, much of the Village was constructed prior to the publishing of the current provincial standard document. Areas defined as deficient may behave satisfactorily and future system upgrades could bring the system up to the current standards. In areas with significant hurdles, the drainage network may not be able to reach current standards and would convey runoff in its existing form.

In addition to the provincial requirements, a memo prepared by LGN Consulting examined drainage issues on both the west and east side of Linden in 2012. A SWMHYMO model was completed using City of Calgary precipitation data and examined pipe capacities and storage requirements.

The *Kneehills Subwatershed* report noted that no site specific assessments had been completed along Kneehills Creek in Linden; however, an existing assessment within the watershed noted that riparian health is satisfactory. Although the site assessment noted an adequate health, the *Kneehills Subwatershed* report noted that as an overall assessment, the watershed is in a poor condition with a medium risk level for further deterioration. Specifically, concerns with land use practices have contributed to riparian and water quality deterioration, including increased nitrogen and phosphorus levels in Kneehills Creek, which periodically exceed Canadian Council of Ministers of the Environment water quality guidelines for the protection of aquatic life (CCME PAL).

5.1.3 Reported Drainage Concerns

CIMA+ met with Village representatives in the summer of 2020 to review current drainage concerns within the community. The drainage areas of concern that were discussed are listed below.

- 5th Street townhouses
- Courtney Way
- Lane behind 3 Ave NW & field catch basin near 417 1st St NW
- Poor Major Drainage system on 6th St NW
- Poor Outlet NW of Central Ave W and 1 St NW intersection
- Poor Drainage from trailer park off of 1 St SE
- Ice concerns at concrete swale locations (Linview Road & north end of 1 St NW)

In addition to the noted concerns from the Village, there also appears to be a low point in the lane behind 1st St SE / Centre St S / Central Ave based on the LiDAR data. This area may be prone to the accumulation and pooling of water before it can spill to the adjacent streets.

Some of these areas overlap with previous reports (LGN Consulting, 2012).

- Dry ponds east of 1st St NW
- Traplow storage along 6th St NW
- Traplow storage along 1st St NE
- Dry pond and new sewer system upstream of Picci Court
- Dry pond and storm sewer upstream of the Senior Lodge

None of the proposed dry ponds or storm sewers in the LGN Consulting memo (2012) appear to have been constructed. Additionally, there is no record to confirm if the traplow storage has been increased along 6th St NW or 1st St NE; however, the volumes reported to accommodate a major storm event are relatively high (greater than 400 m³ at each location) and these volumes are currently not available with the existing topography/grading.

Based on a review of historical images and record information, there has been some work completed in the Village for stormwater projects in the past two decades to alleviate previous drainage items. It appears some work has been completed to alleviate erosion concerns at the major spill location south of 412 1st St NW. There has been an expansion of the storm sewer system on 1st St SE towards the tennis courts. The 5th St NW storm sewer extension appears to have been constructed up to the intersection with 1st Ave NW and new curb and gutter has been installed to help guide the runoff to the new catch basins. New catch basins and curbs along Central Ave at the intersection with 6th St NW. A drainage swale north of 400 Picci Court was constructed in 2006 to address runoff from the development flowing north towards the agricultural lands.

Additionally, based on site review, lot drainage generally appears to be split (half to front of the lot and half to rear of the lot) through much of Linden. Due to this, drainage routing is reliant on the rear lanes to convey flow to the street.

5.1.4 Computer Model

To complete the hydrologic and hydraulic modelling outlined above, a computer modelling software is necessary. For this analysis, the PCSWMM Version 7.3.3095 Professional 2D with the EPA SWMM5 Version 5.1.015 engine was used to complete the single event and continuous simulations, as well as the integrated 2D hydraulic model for Linden.

5.2 Study Area

The study focuses on the Village of Linden, predominately the built regions, and includes the upstream lands that contribute overland runoff towards the Village. The study area was defined as the lands that contributing flow to one of the culverts or storm sewer outlets within the Village boundary. The study area is shown in Figure 5-1. The catchments within the study area are shown in Figure 5-4. Further details about the catchment delineation and total contributing area can be found in Section 5.2.4.

The catchments do not encompass all of the space within the Village's limits. Lands that are downstream of outlets or do not drain to a culvert or storm sewer were not examined in the PCSWMM modelling (e.g. lands draining directly to Kneehills Creek).

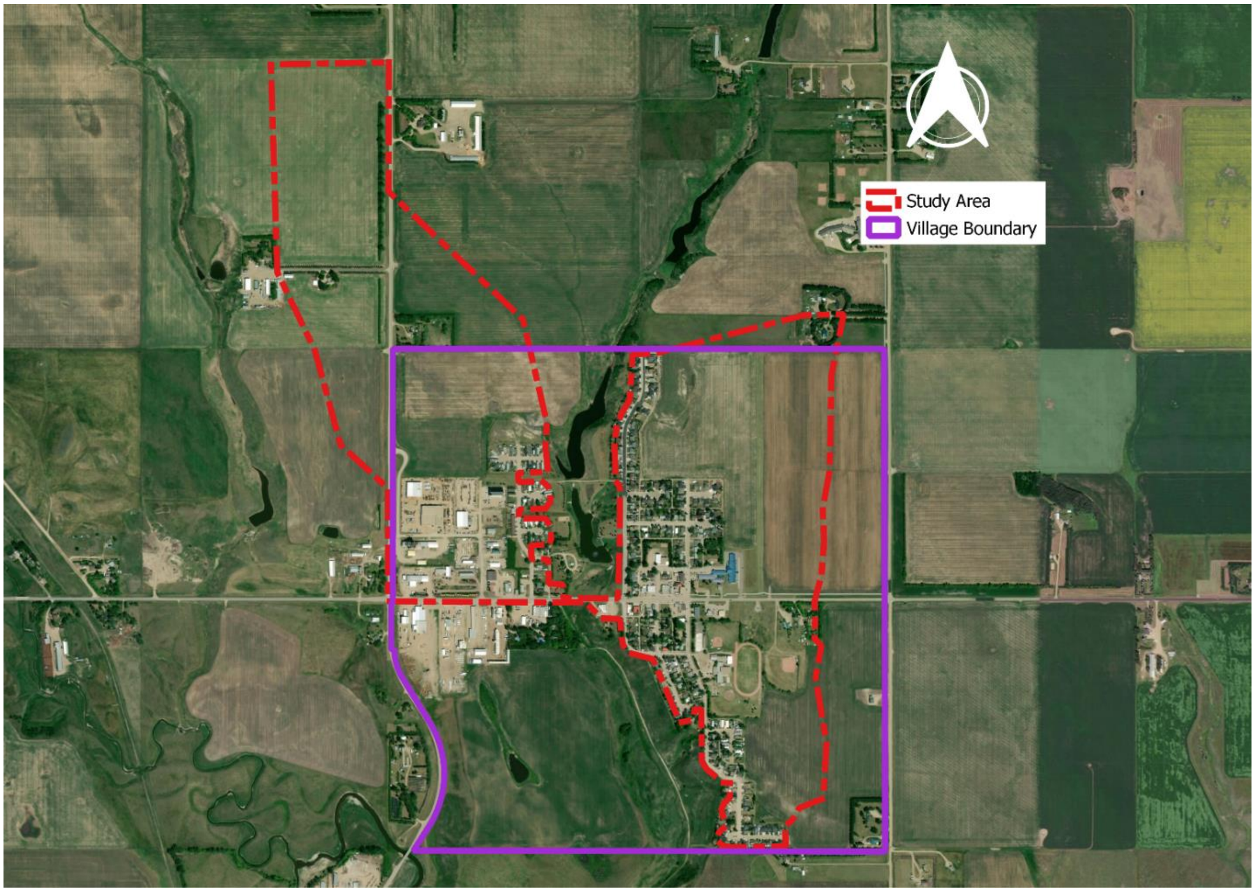

Figure 5-1: Study Area

5.2.1 Topography

Generally, the lands around Linden are relatively flat but closer to the coulee and Kneehills Creek, the land becomes quite steep. The Village limits encompass both the valley of Kneehills Creek and terraced lands above the ancient valley; however, almost all of the developed land in Linden are within the flatter lands along the terrace.

Generally, overland drainage patterns around Linden are from north to south towards Kneehills Creek. Flow enters Kneehills Creek through various tributaries and coulees, much like the one through the center of the Village. The lands upstream and surrounding Linden generally flow towards the central coulee that drains through the Village. Lands significantly upstream enter the Kneehills Creek tributary without flow through any developed lands within Linden; however, closer to the Village, lands to the west and east flow through the community towards the coulee. The general boundary for the overland break points is Highway 806 to the west of Linden and a natural high point to the east Linden between the community and Range Road 254. However, there is a culvert crossing Highway 806 south of the intersection with Service Road that contributes some drainage from lands west of Highway 806 to the Village.

To the west of the coulee, lands along the terrace have a general slope of approximately 1% (± 0.25%) from west to east (i.e. towards the coulee). To the east of the coulee, the lands along the terrace have a general slope of approximately 2.75% (± 0.25%) from east to west (i.e. towards the coulee). Along the escarpment, the slopes become relatively steep, approximately 10% (± 5%) throughout the Village. There is one section of relatively steep development and this is along 1st St SE between the trailer park and Linview Road, where the slope of the road is approximately 8%. The topographic information for Linden is shown in Figure 5-2.

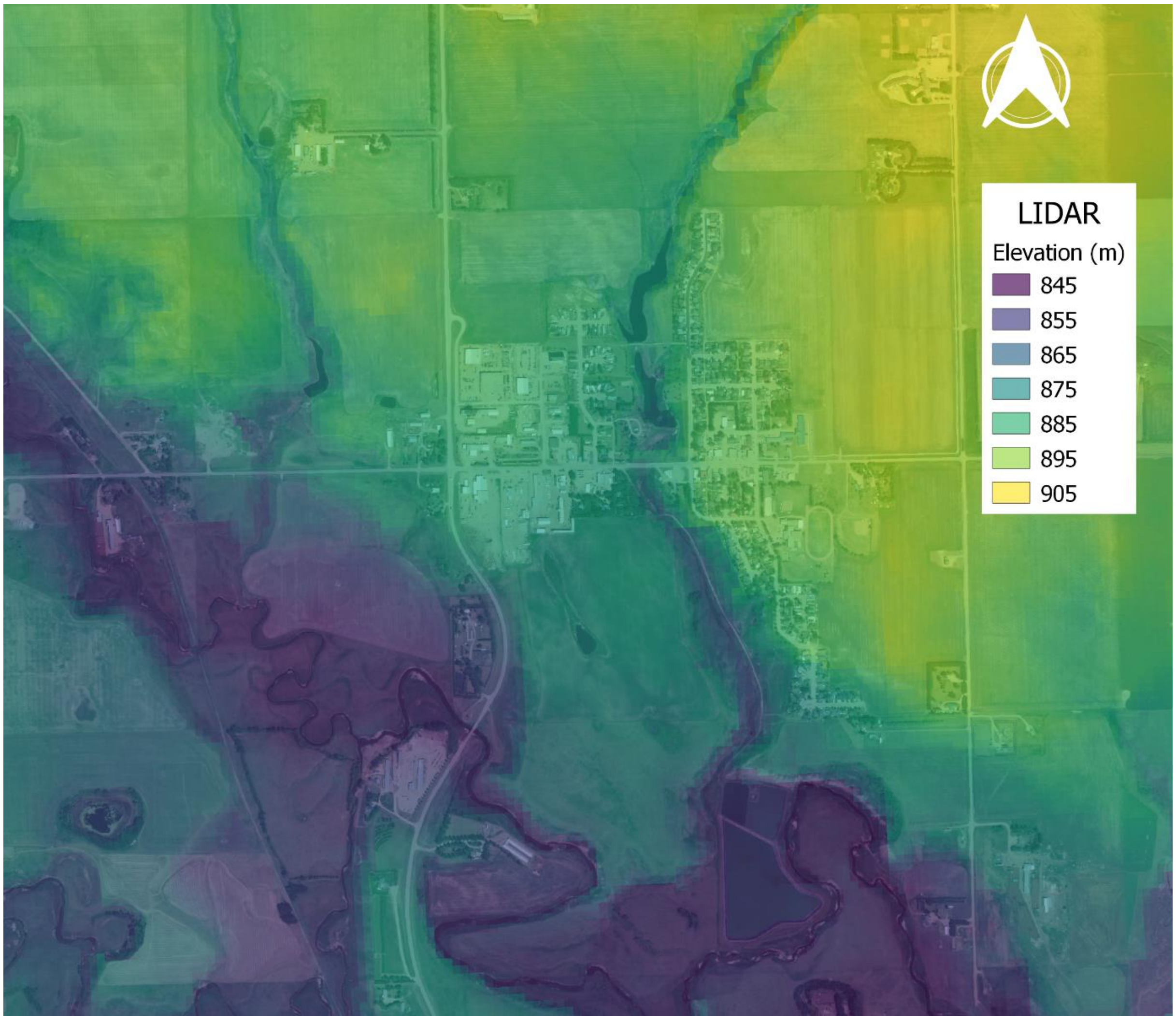

Figure 5-2: Topography within the Study Area

5.2.1.1 Upstream Drainage Patterns

There are permanent water bodies upstream of Linden along the Kneehills Creek tributary caused by other dam structures within the coulee. Typically, this water course would be ephemeral in nature, but the dams create permanent water bodies holding water throughout the year. However, upstream flow that drains through Linden to the coulee is overland sheet flow across predominately agricultural lands. There is no evidence of existing ephemeral or seasonal drainage courses conveying upstream runoff through the Village. The runoff flowing through Linden from upstream lands appears to be sheet flow in nature.

5.2.1.2 Downstream Receiving Water Body

The downstream receiving water course is ultimately Kneehills Creek. The majority of the community first drains to the coulee in the middle of the community before reaching Kneehills Creek to the south. Some portions of the community closer to Kneehills Creek drain directly to the water course.

There are existing wetlands south of Courtney Way which likely intercept some of the runoff coming from the industrial properties along the south side of Central Ave. No biophysical assessment has been completed on the wetlands to determine their class or if they are seasonal or permanent; however, based on LiDAR data, these would spill south towards Kneehills Creek.

5.2.2 Existing Stormwater Infrastructure

The existing stormwater infrastructure within Linden includes catch basins, outfall structures, manholes, storm sewers, culverts, and drainage ditches. The largest culvert in the Village crosses Central Ave and drains the coulee water course and is a recorded bridge file structure (BF #06593-1.) with Alberta Transportation (AT). Additionally, the storm sewer along Central Ave on the west side of Linden discharges directly into the bridge sized culvert. Currently, there are no specific stormwater management facilities (SWMF) (i.e. dry ponds or wet ponds); however, the coulee reservoir works as a pseudo-management facility to attenuate runoff reaching Kneehills Creek. The coulee reservoir would also provide some water quality treatment as sediments settle to the bottom, but no specific water quality treatment exists in the Village.

The underground infrastructure is primarily located in the largest developed areas of Linden (i.e. the downtown commercial area). Drainage ditches are used in the outer area of the built community and help transition flow from rural roadway cross sections to the underground infrastructure or to bypass around built neighbourhoods.

Most of Linden employs curb and gutter along the roadways to help convey runoff towards the catch basins and control overland flow towards receiving water bodies. Areas that do not have curb and gutter or well defined ditches have been noted to pool and hold water, including 6th St NW. Additionally, locations where curb and gutter are lost, flow reaching natural lands have experienced erosion concerns.

Aside from the minor system, there appears to be a lack of major overland drainage pathways, especially designated emergency overland escape routes. Major flows that would be directed to catch basins at the cul-de-sacs along Picci Court, Centre St S, and Linview Road do not have drainage easements for flow in excess of catch basin capacities and would spill across private property towards the coulee.

An overview of the existing stormwater infrastructure is shown in Figure 5-3; a full plate drawing can be found in Appendix C (Figure ST1A/ST1B).

Figure 5-3: Existing Stormwater Infrastructure in Linden

5.2.2.1 Existing Flooding Concerns

The Village has noted, that generally, the stormwater infrastructure within Linden operates adequately for storm events. However, the townhouses along 5th St NW have been noted to experience localized flooding during more intense storm events. This localized flooding has occurred more frequently in recent years. Flow concentrates at the rear of the lots and travels south along the backyards and then east towards 5th St NW around the townhouses. The cause of the drainage concern was evaluated by CIMA+ in 2020 and reported in a memo (November 2020).

The drainage infrastructure also has been noted to have concerns during spring freshet and snow melt. Snow melt from upstream agricultural lands can discharge large volumes of water towards the community and poorly defined drainage pathways to upstream stormwater infrastructure (i.e. concrete swales, culverts, and catch basins) can cause runoff to flow through private property towards the coulee. Snow and ice accumulation near storm inlets can reduce the capacity of the drainage system during spring freshet and exacerbate the overland runoff issue. Additionally, ice accumulation at the base of the concrete swales can cause safety concerns for pedestrians and vehicular traffic.

A similar issue has been noted to occur along Courtney Way during spring runoff. The industrial lands to the west of Courtney Way drain from north to south and west to east towards the coulee and Kneehills Creek. The runoff from industrial lands is conveyed through overland flow and portions of the flow discharge across Courtney Way and through further private property before reaching the coulee. Currently, there is no drainage infrastructure in place to intercept this runoff and redirect it around the private property.

The outlet of the storm sewer system at the northwest corner of the intersection of Central Ave and 1st St NW has been noted to freeze and become blocked due to a build up of ice and snow. The current configuration of the outlet structure shows that it is countersunk and has reduced capacity even under normal operating conditions. Due to the blockage of the outlet during the winter and spring, the storm sewer often surcharges and spills through the manhole and catch basins upstream of the outlet and drains through the overland major network.

There is the inherent risk of flooding due to Kneehills Creek itself; however, the creeks alignment is just south of the Village boundary near existing urban reserve lands. No existing flood hazard map has been undertaken for Kneehills Creek within the vicinity of Linden; however, much of the current development is located on the terrace above the creek. Similarly, no flood hazard map has been completed for the tributary to Kneehills Creek that flows through the middle of Linden, though development is currently located on the terrace above the coulee.

5.2.2.2 Major Hydraulic Structures

As noted in Section 5.2.2, there is the presence of a bridge sized culvert under Central Ave. The bridge file number for the culvert is 06593-1. Additionally, there is a standard bridge that crosses Kneehills Creek along Highway 806 near the southwest corner of the Village boundary; the bridge file number for the standard deck bridge is 02236-1. The bridges are registered with Alberta Transportation and further information can be obtained with the above structure numbers.

5.2.3 Reservoir

The reservoir in the center of the Village is not included in the scope of the analysis. The Village has not identified any current concerns with the condition and operation of the reservoir. Additionally, the elevation of the reservoir is lower than community infrastructure, including the spill elevation of the dams. Although the reservoir appears to be operating adequately, an independent condition assessment is recommended to ensure the structural stability of the two earthen dams.

Failure of the dam structures would cause a significant volume of water and debris to flow towards the bridge sized culvert crossing Central Ave which could block the culvert or damage the culvert/road base. However, inundation locations within the coulee are unlikely to significantly change.

5.2.4 Catchment Delineation

The study area was delineated into various catchments based on LiDAR data, a desktop review, computer software, and site confirmation. LiDAR data supplied from AltaLIS was used to create a digital elevation model (DEM) of Linden and the surrounding lands. A combination of high quality LiDAR (2 meter grid) within the immediate vicinity of the Village and lower quality LiDAR (25 meter grid) for the surrounding lands was used in the computer software analysis. Other hard boundaries were confirmed via a desktop review, such as roadways, and a field confirmation for culverts crossing the roadways was completed to confirm and finalize the catchments.

The results of the catchment delineation are shown in Figure 5-4; a full plate drawing can be found in Appendix C (Figure ST2).

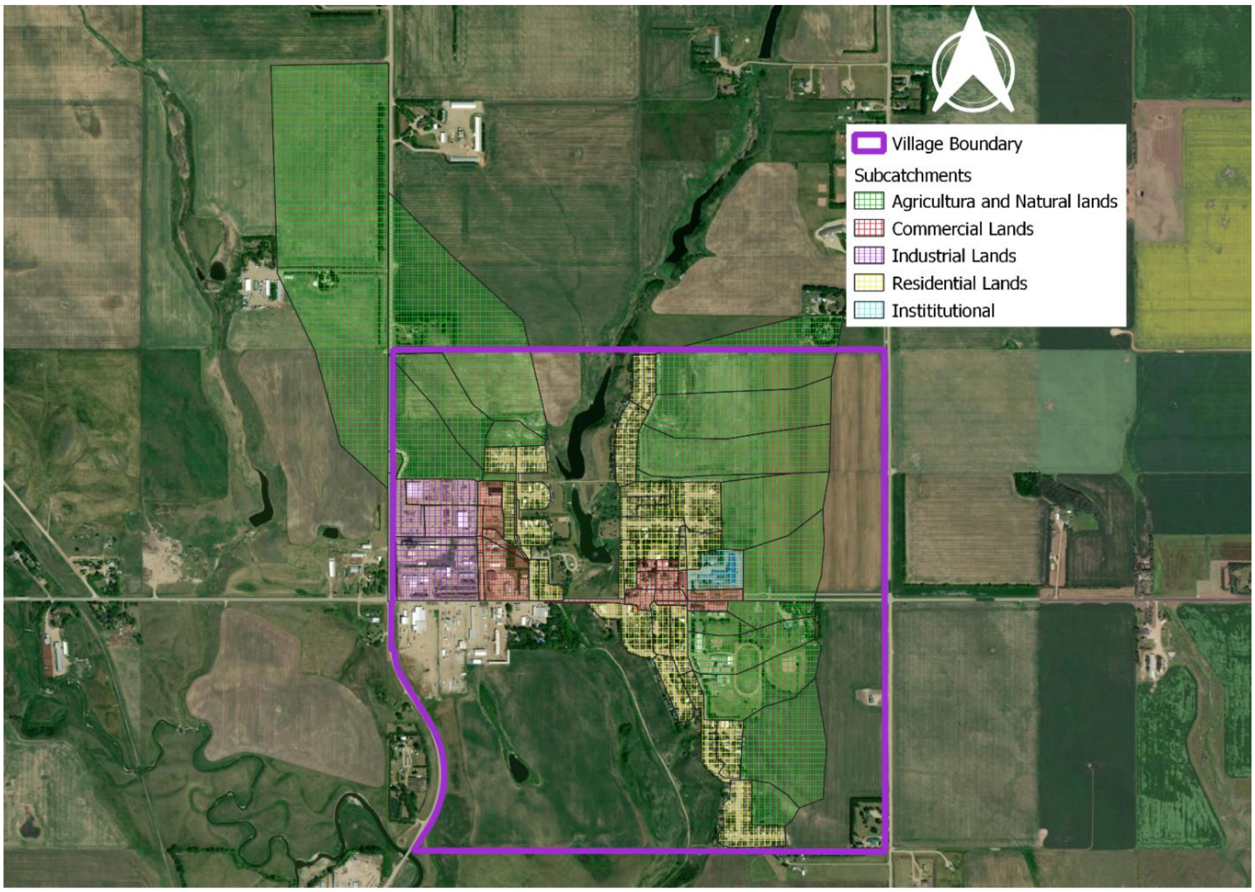

Figure 5-4: Drainage Boundary and Sub-Catchments within Linden

5.2.4.1 Computational Software

PCSWMM's built in analysis tool in conjunction with site visits and a desktop review were used to delineate the catchment areas for Linden. The tool uses a digital elevation model (DEM) raster file and a user input for average sub-basin size to develop overland flow paths. The sub-basins can be combined to determine the total catchment area.

The LiDAR data obtained from AltaLIS was used as the input DEM file. The average sub-basin size used in the model delineation process was 5 hectares. Based on the site visit and desktop review the sub-basins were combined to accurately depict the likely sub-catchments within Linden and where each sub-catchment enters the drainage network.

5.3 Asset Inventory

The existing pipe network in Linden incorporates both at grade pipes (culverts) and below grade pipes (underground storm sewer). Information regarding the storm sewer pipe material and diameters can be found in Table 5-1 and Table 5-2, respectively. Information regarding culvert materials and diameters can be found in Table 5-3 and Table 5-4, respectively.

Table 5-1: Storm Sewer Pipe Materials

Pipe Material	Length (m)	Percentage
PVC	1,630	64.1%
Concrete	779	30.6%
Steel	13	0.5%
PE	120	4.8%
Total	**2,542 m**	

Table 5-2: Storm Sewer Pipe Diameters

Pipe Diameter (mm)	Length (m)	Percentage
200	26	1.1%
250	77	3.0%
300	1,038	40.8%
375	102	4.0%
400	227	8.9%
450	264	10.4%
500	179	7.0%
525	215	8.5%
600	164	6.5%
750	219	8.6%
800	31	1.2%
Total	**2,542 m**	

Table 5-3: Culvert Pipe Material

Pipe Material	Length (m)	Percentage
CSP	487	100.0%
Total	**487 m**	

Table 5-4: Culvert Pipe Diameters

Pipe Diameter (mm)	Length (m)	Percentage
375	28	5.7%
400	91	18.7%
450	132	27.1%
600	117	24.0%
750	26	5.3%
800	13	2.7%
1,500	80	16.5%
Total	**487 m**	

In addition to the storm pipes and culverts, there are 40 catch basins, 23 storm manholes, and 12 storm outfalls in Linden. The catch basins are generally Type K2 inlets and there are a few grated top manholes based on an imagery review.

5.4 Hydrologic Assessment

A hydrologic assessment using PCSWMM was completed to model the runoff from the catchments. The hydrologic parameters are based on the LiDAR data (slopes, catchment area, and flow lengths) and industry standards for prairie lands (infiltration, depression storage, Manning's roughness coefficient, etc.). The infiltration is assumed to be based on clay subsoils, which are predominate in the prairie landscapes. If future geotechnical investigations are completed, more detailed and accurate infiltration parameters can be obtained for the site. Information regarding the typical industry standards for prairie lands are based on the City of Calgary stormwater guidelines (2011), which outline the infiltration parameters, depression storage, and Manning's roughness coefficient. Imperviousness and flow routing were based on the LiDAR data, aerial imagery, and the site visit.

5.4.1 IDF Data

To complete the hydrologic analysis, precipitation data is required. The precipitation data used for the Village of Linden comes from the Environment Canada weather station in Drumheller (station ID 30221LG). Data from Drumheller is used since it is relatively close to Linden and has a similar climate. IDF curve data from the climate station is shown in Figure 5-5 and additional data is provided in Appendix H. The IDF data is based on precipitation data from 2005 to 2017 and is statistically fitted with the Gumbel method.

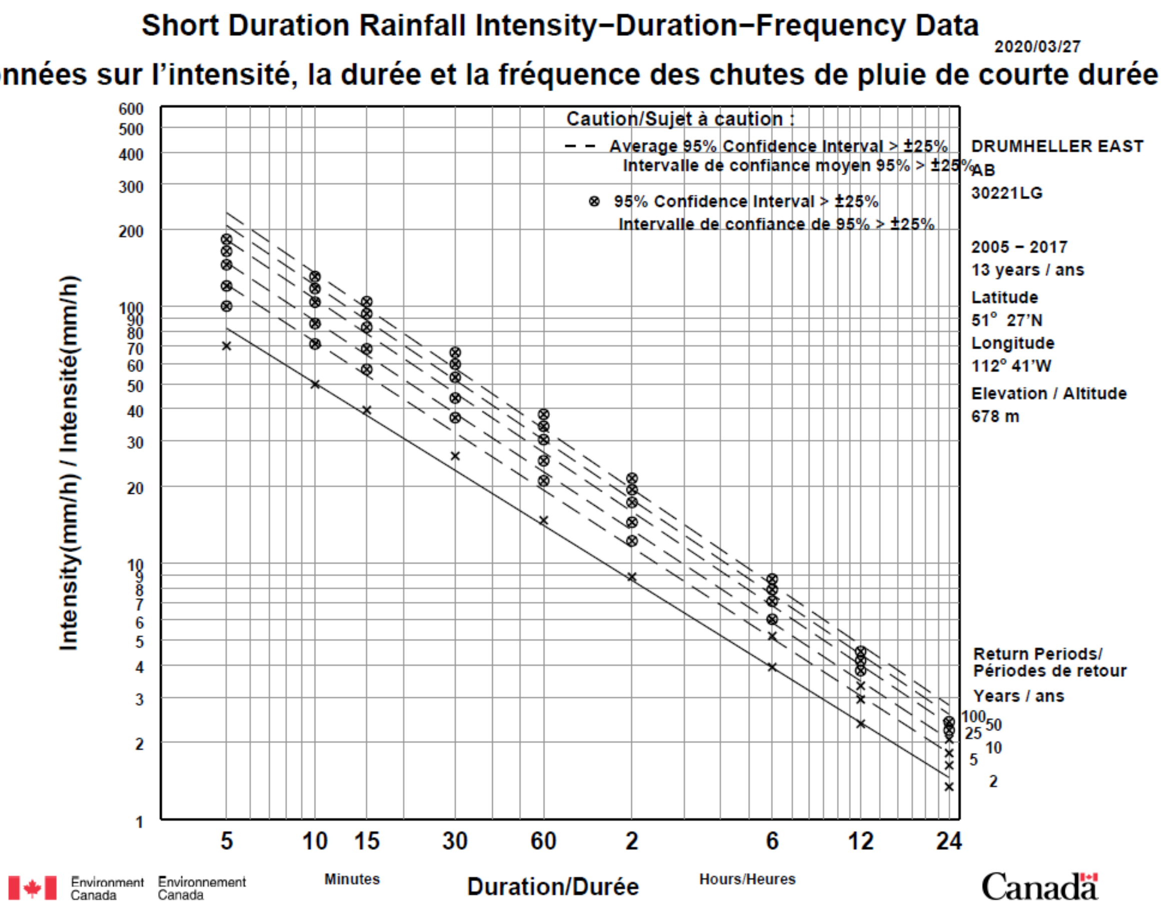

Figure 5-5: IDF Data from Drumheller East Station

Further information about the IDF parameters and design storm generation is provided in Section 5.4.3.

5.4.2 Pre-Development Runoff (Existing Conditions)

To provide guidance for future development an existing hydrologic assessment must be completed to determine what is currently occurring. Future development unit area release rates (UARR) will be determined based on the pre-development flows and existing condition of the drainage network. AEP recommends a streamflow record analysis for estimating initial hydrologic runoff (2001). Without any streamflow records readily available in the vicinity of Linden, a comparative basin analysis was completed. In addition to the pre-development runoff analysis, an investigation to identify current constraints governing development also need to be completed.

5.4.2.1 Comparative Basins

AEP recommends analyzing pre-development flows through stream gauges where possible (2001). Kneehills Creek downstream of the Village of Linden boundary is not gauged, so no local records are available; however, there is a gauging station approximately 40 kilometers downstream of Linden. A comparative basin technique was employed to estimate the pre-development runoff in Linden using the data set from the downstream gauging station.

A comparative basin technique generally utilizes data from a similar gauged drainage basin, where land use, topography, and basin size are similar. In this case, the exact same drainage basin will be analyzed, but only the lands upstream of Linden need to be used in the analysis for the peak flows.

The comparative basin technique was completed using data obtained from Kneehills Creek downstream of Linden. The gauging station from the Water Survey of Canada is called “Kneehills Creek near Drumheller” (gauge number 05CE002). The station has been observing data since 1921 through to the present day.

Since Linden drains into Kneehills Creek and all the flow reaches the gauging station, only a single station analysis was completed. Previous studies completed nearby Linden have also completed a flow-frequency analysis using only the single station (Northwest Hydraulic Consultants, 2007 & 2008). Information for the gauging station is summarized in Table 5-5.

Table 5-5: Stream Gauge Information

Station ID	Name	Drainage Area (km²)	Record Period (Years)
05CE002	Kneehills Creek near Drumheller	2,430	1921-2018

To complete the comparative basin technique, the following equation is used:

$$Q_p = Q_w \left(\frac{A_p}{A_w}\right)^{0.5}$$

Where Q_p is the desired project flow rate, Q_w is the comparative watershed flow rate, A_p is the project catchment area, and A_w is the comparative watershed catchment area. The exponent of 0.5 accounts for routing differences in the varying sized basins; generating high flow rates for smaller project basins and smaller flow rates for larger project basins. The exponent coefficient was based on previous studies completed on Kneehills Creek in Carbon, approximately 28 km downstream of Linden (Northwest Hydraulic Consultants, 2007). The comparative watershed flow rate, Q_w, is obtained from a statistical analysis of the raw data from the WSC website. The statistical 1:100-year flow rate for the comparative watershed is used to determine the 1:100-year flow rate for Kneehills Creek at Linden, shown in Table 5-6. The drainage area at Linden is estimated to be 1,655 km². The drainage area was estimated using 25-meter gridded LiDAR data and PCSWMM built in water shed delineation tool.

Table 5-6: Comparative Basins 1:100-Year Discharge

Station Name	Statistical 1:100-Year Discharge (m^3/s)	Statistical Fit	Statistical 1:100-Year Discharge for Linden (m^3/s)
Kneehills Creek near Drumheller	283	Log Pearson III	234

The resulting 1:100-year discharge rate can be converted into a UARR by normalizing the flow with the drainage area. The resulting UARR for Linden is 1.40 L/s/ha. The UARR is representative of drainage basin as a whole. Small areas within the basin, though, such as the steep portion near the valley, would likely runoff at a higher rate than the overall UARR. It is recommended that future stormwater management facilities release water at the targeted 1.40 L/s/ha rate; however, developments in abnormal topography could be analyzed on a case by case basis to determine an appropriate UARR for the site.

5.4.2.2 Identification of Governing Constraints

Future development should adhere to a maximum release rate from the site. Generally, this value would be based on data from Kneehills Creek (1.40 L/s/ha); however, depending on the location of the development, existing downstream infrastructure may have a lower capacity and would represent the governing constraint for release rates.

Possible constraints include drainage channels, culverts, or existing storm trunks.

Capacity of downstream drainage paths would need to be completed as part of future Master Drainage Plans (MDP) or Staged Master Drainage Plans (SMDP).

5.4.3 Storm Events

Analysis of the stormwater system is based on design storm events and a continuous simulation. The design storm events use data from Environment Canada from a climate station in Drumheller, discussed in Section 5.4.1. The resulting coefficients for the storm event are shown in Table 5-7.

Table 5-7:Rainfall Intensity Coefficients for the Drumheller East Station

Storm Event	IDF Coefficient	
	a	b
1:2-Year	14	0.712
1:5-year	19.2	0.743
1:100-year	33.3	0.781

The parameters in Table 5-7 correspond to the following equation

$$i = \frac{a}{(t)^b}$$

Where *i* is the rainfall intensity in mm/hr;

t is the duration; and

a & b are constants found in Table 5-7.

The IDF data was converted to a hyetograph using a storm duration of 24-hours, a time to peak ratio of 0.3, and a rain interval of 5 minutes. A 5 minute rain interval ensures that the peak intensity of the storms are captured. The design storm events analyses includes:

- 1:2-year storm
- 1:5-year storm
- 1:100-year storm

Generally, the storm sewer and drainage system should be able to convey the 1:5-year storm events. However, at a minimum, the sewer system should be able to convey the 1:2-year storm. The 1:100-year storm event will exceed the capacity of the sewer system, but should be safely conveyed through the overland ditch system and streets so as not to cause damage to building structures.

The design storm event hyetographs are shown in Figure 5-6.

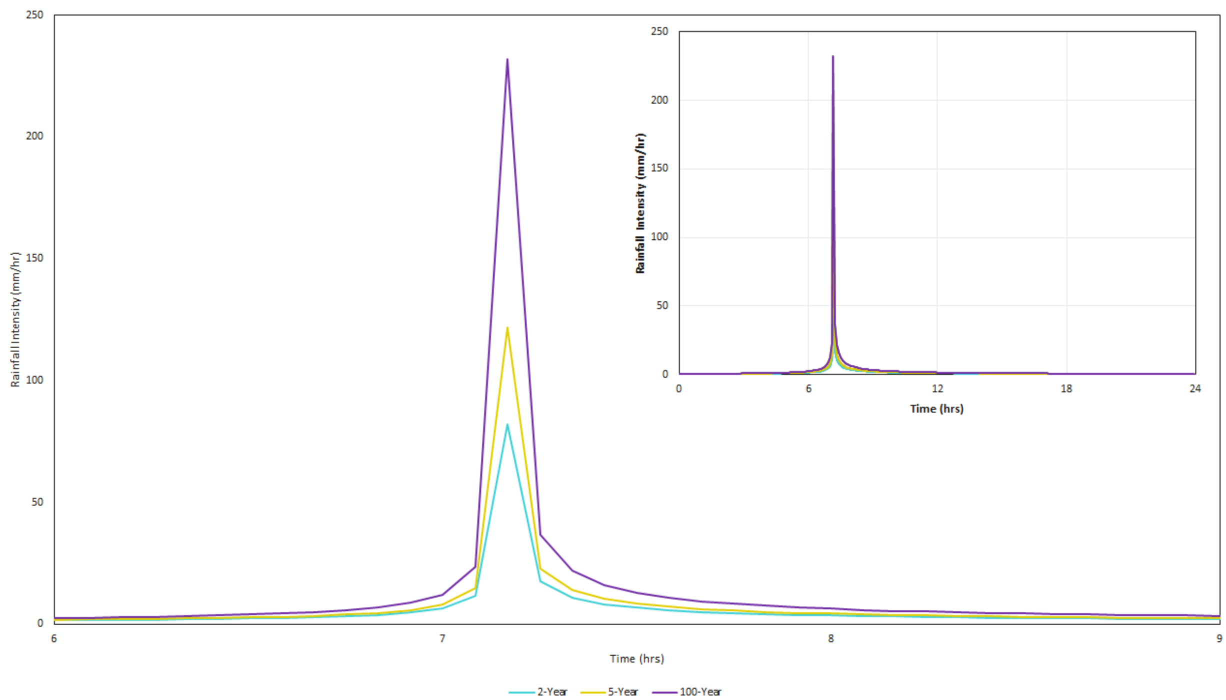

Figure 5-6: Design Storm Event Hyetographs

To analyze how the storm system behaves through time, the impacts of antecedent events, and snow melt, a continuous simulation was also completed. Continuous simulations require climatic data (precipitation, temperature, etc.) over a long period of time. Currently, limited data sets exist, however, the City of Calgary has published data from 1960 to 2014. The continuous simulation data is obtained from the Calgary international airport meteorological station and outlined in the City of Calgary stormwater guidelines. No adjustments were made to the precipitation data. Other factors including wind speed, snow melt, aerial depletion, soil conductivity were assumed using Southern Alberta industry standards. During the continuous simulation, evaporation rates were based on temporal averages, shown in Table 5-8, and are representative of Southern Alberta. To analyze the impacts of snow melt, especially from lands upstream of Linden, the continuous simulation included snowpack build-up. The impacts of reduced infiltration and depression storage due to the snowpack and frozen ground are accounted for through a temporal adjustment, shown in Table 5-9.

Table 5-8:Monthly Evaporation Rates (mm/month)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
3.0	10.9	34.6	72.1	112.0	137.1	154.7	124.1	67.2	30.6	8.1	2.2

Table 5-9: Adjustment Multipliers for Soil Conductivity and Depression Storage for Each Month

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0.1	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.1

5.4.4 Post-Development Changes

At the present time, the development locations identified in Linden are predominately residential. The scale of development is relatively minor at this time (Figure 5-11). Generally, stormwater management facilities are to have a minimum footprint of 2 ha; however, this size is greater than proposed development areas. The Village can explore regional stormwater ponds

Future development will cause an increase in imperviousness and the amount of runoff during storm events. Future development could also impact existing flow routing paths and will likely decrease overland flow lengths.

5.4.5 Catchment Runoff

Runoff from the upstream agricultural lands are limited and for the most part nonexistent during rain events. The local depression storage and local pooling areas provide enough storage to prevent runoff from reaching the Village during storm events. The runoff from these lands that eventually reach the Village are generally generated during the spring freshet.

Runoff from the upstream agricultural lands is directed through or around the Village through the use of drainage ditches, concrete swales, culverts, and catch basins. The hydraulic performance of this infrastructure is discussed further in Section 5.5. However, as noted by the Village, spring freshet has been noted to overwhelm the drainage system and cause overland flow to discharge across private property. The analysis in Section 5.5, will examine the system based on maximum hydraulic efficiency; however, the system may have reduced capacity due to snow and ice accumulation during spring freshet. Maintenance efforts for the drainage infrastructure that helps convey upstream catchment runoff is most important during the times of snow melt.

Runoff from the Village itself is not impacted by the snow melt. Due to the imperviousness in Linden, the peak flows occur during the high intensity rain events from the continuous simulation and design storm events. The hydraulic performance of the stormwater network in Linden is discuss further in Section 5.5.

5.5 Hydraulic Analysis

The capacity of the drainage network, including the storm sewers, ditches, and culverts throughout Linden were modelled with computer simulations. The information for the drainage infrastructure was obtained from record drawings and site survey (i.e. inverts, pipe sizes, ditch cross-sections, etc.). The sub-catchments were routed directly into the drainage network at the nearest and most applicable nodes in the hydraulic network. Beyond the depression storage provided in the hydrologic parameters, no detention was provided for the flow before entering the drainage network.

Since portions of Linden drain above ground without defined overland networks (i.e. curbed roads, swales, etc.) the flow would likely congregate into localized pools or puddles before reaching the drainage network. This was not explicitly captured in the model and the performance of the drainage network in the model may not fully represent the actual conditions in the field. Additionally, it was assumed that the network would have maximum hydraulic capacity (i.e. no blockages, silt accumulation, etc.).

5.5.1 Current Drainage Network Performance

The current drainage system in the model notes concerns during the minor storm events (1:2-year and 1:5-year storms) and the major storm event (1:100-year).

During the 1:2-year storm event there is minimal flooding; however, the system should be able to handle this storm event without surcharging. The surface inundation occurs at the intersection of 1st St NW and 2nd Ave NE and the intersection of 6th St NW and Central Ave. The surcharge to surface noted at 6th St NW and Central Ave is due to the industrial lands being routed towards the grated top manhole at the intersection; however, flow paths in the field might slow or prevent flow from reaching the manhole in a timely manner. The only location that reported a substantial surface inundation volume (i.e. greater than 20 m^3) in the 1:2-year storm event was the catch basin at the intersection of 1st St NW and 2nd Ave NE. This small storm sewer section captures a significant amount of urban runoff from 2nd Ave NE, which overwhelms the sewer capacity. However, the overland spill location is immediately across the street and discharges directly into the coulee.

During the 1:5-year storm event, the ponding at the intersection of 1st St NW and 2nd Ave NE and the intersection of 6th St NW and Central Ave increase in volume. There is additional surface ponding noted along 6th St NW where the ditch network enters the storm system, the field catch basin behind 1st St NW (approximately 417 1st St NW), the cul-de-sac at Centre St S, and the cul-de-sac at Linview Road. The capacity of the storm sewer along 6th St NW can not support peak flows and backs up to the ditch causing surcharge at the intersection of 6th St NW and 1st Ave NW. The exceedance of the pipe capacity along 6th St NW further exacerbates the surcharge volume noted at the grated top manhole at 6th St NW and Central Ave. The storm sewer along 1st St NW between 5th Ave and 3rd Ave collects the urban runoff from this area and also from upstream lands through a catch basin behind 417 1st St NW. The pipe capacity of the sewer is met through the urban contributing lands and backwater escapes through catch basin into the agricultural lands behind the houses. Similar to the catch basin at the intersection of 1st St NW and 2nd Ave NE, the small sewers at the Centre St S and Linview Road cul-de-sacs can not convey the runoff reaching the catch basins. Ponding during the 1:5-year storm event is estimated to be:

- 23 m^3 at the intersection of 6th St NW and 1st Ave NW
- 77 m^3 at the intersection of 6th St NW and Central Ave
- 13 m^3 at the field catch basin behind 417 1st St NW
- 123 m^3 at the intersection of 1st St NW and 2nd Ave
- 22 m^3 at the cul-de-sac of Centre St S
- 53 m^3 at the cul-de-sac of Linview Road

The location of pipes experiencing surcharge during the 1:5-year storm are shown in Figure 5-7.

Figure 5-7: Storm Sewer Capacities During the 1:5-Year Storm Event

During the 1:100-year storm event, flooding occurs at multiple junctions in the storm sewer; however, this is expected. During large storm events, the major drainage system should help convey flow towards the outlet locations. Although Linden employs curb and gutter, there is no designated overland escape route throughout parts of the Village. Additionally, there is a low point in the lane behind 1st St SE / Centre St S south of Central Ave that would hold runoff in a large event. Generally, overland flow follows the topography of Linden towards the coulee, and in some locations a proper major system is in place, but there are significant portions of the Village that flow does not have a designated pathway out to the coulee. This is most noticeable at the cul-de-sacs, where there is no overland flow escape above the catch basins, rather flow would escape through an undefined path across private property before reaching the coulee. Other areas where overland flow escapes to the coulee at the end of curb and gutter systems have been noted to experience erosion and require remediation work. Due to the lack of a designed overland system, this could cause localized flooding or damage to certain areas of the Village. To better understand the impacts of overland flow, an integrated 1D-2D model was completed.

5.5.1.1 Integrated 1D-2D Model

To better understand the impacts of the flooding noted in the 1:100-year storm event, an integrated 1D-2D model was created. The model incorporates a 2D mesh which is connected to the junction nodes in the 1D PCSWMM model. When flooding occurs in the 1D model, the surcharging volume enters the 2D network to better understand flow paths. The 2D network is created with the DEM raster developed from the LiDAR data. The 1:100-year storm was used because it is the governing storm for the urban sub catchments and provides higher overland flow throughout much of Linden.

The 2D model employs a 5-meter hexagonal grid that is connected with all adjacent cells so that flow can propagate in a two-dimensional nature. The elevation of each 2D cell grid is based on a three-point average within the cells. The results of the 1:100-year storm event 2D model are shown in Figure 5-8; a full plate drawing can be found in Appendix C (Figure ST3A/ST3B).

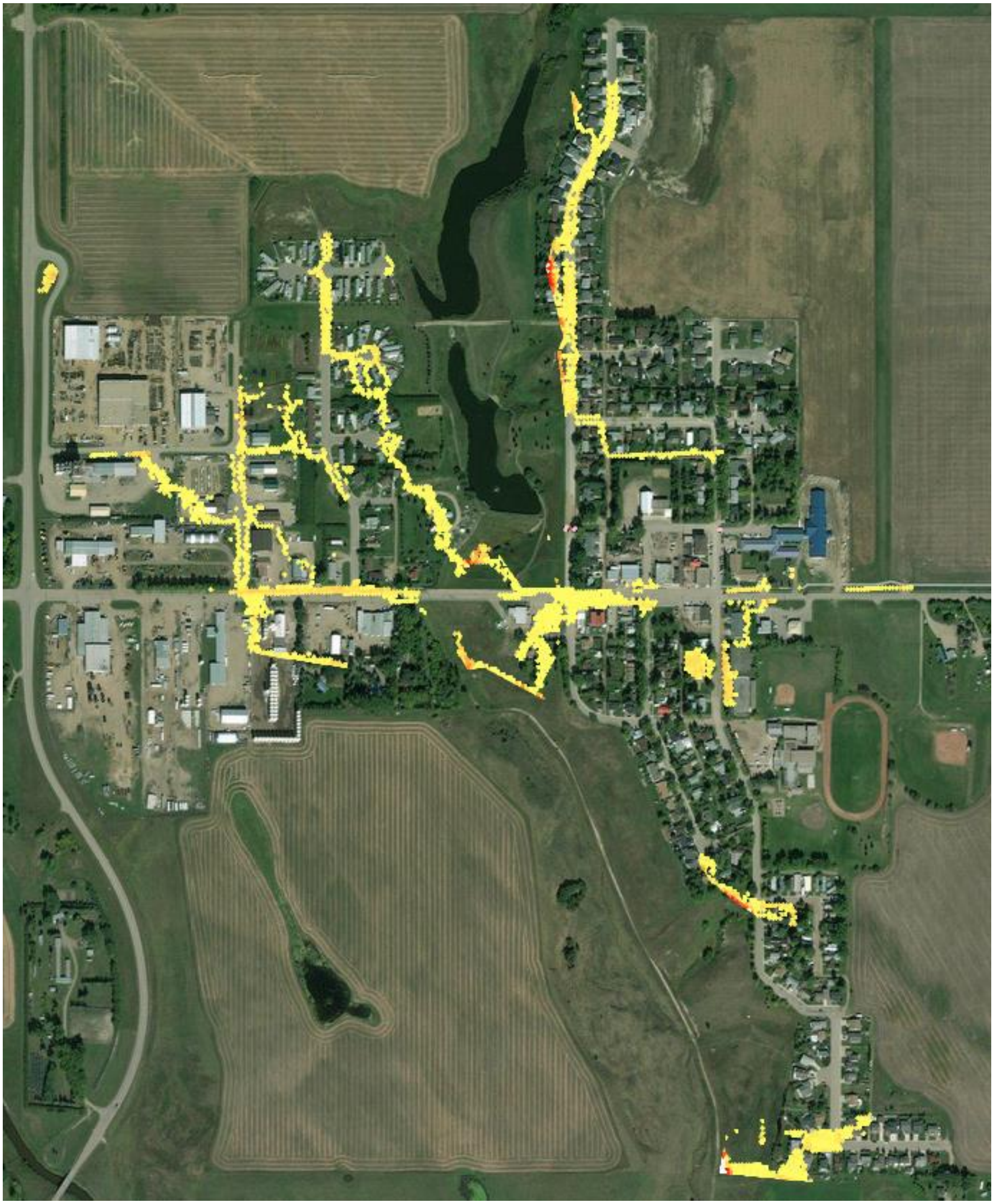

Figure 5-8: Maximum Overland Flow Depths Computed in the 2D PCSWMM Model for the 1:100-Year Storm Event

The overland flow depths shown in Figure 5-8 are provided as a gradient between yellow and red. The yellow cells represent a maximum depth of 0.05 m and the red cells represent a maximum depth of 1.0 m.

Figure 5-8 shows the overland flow paths during the 1:100-year storm event and these paths would also flow during smaller events when flooding occurs. The flooding during the 1:2-year storm at 1St NW and 2nd Ave N can be seen to spill across 1st St NW towards the coulee. Surcharging from the 6th St NW ditch appears to cross the road and spill towards the townhouses on 5th St NW. Surcharging from the grated top manhole at the intersection of 6th St NW and Central Ave generally flows to east along Central Ave towards the bridge file culvert. Other spill locations at cul-de-sacs show flow crossing private property towards the coulee. The 2D model also highlights the low point in the lane behind 1st St SE / Centre St S / Central Ave. Flooding during the 1:5-year storm event is likely to be in the same location as delineated in Figure 5-8, but with less volume.

Although the model suggests flow conglomerates in private property along 1st St NW, this is likely caused by the cell size (5 meters) and the elevation sampling process. It is more likely that flow would continue south along the curb and gutter before spilling towards the coulee where the curb and gutter and.

5.5.2 Impacts of Kneehills Creek and Tributaries

Generally, there is an inherent risk with storm outfalls discharging along the banks of a water course. If the water course is at an elevated level it will cause backwater effects through the storm systems and limit capacity of the systems. However, the developed area within Linden is significantly higher than the tributary flowing through the coulee and Kneehills Creek. Flood elevations within these water courses should have minimal impacts on the storm drainage network.

5.6 Areas of Concern for Overland Flow Routing

There are several areas within Linden that have poor overland flow drainage routes. If the Village is satisfied with the current level of service and the drainage patterns with Linden, then the areas of concern listed below may not be addressed. Generally, overland escape routes should not occur through private property to avoid damaging structures and prevent lawsuits against the municipality.

Additionally, any upgrades to the system should adhere to the current AEP standards and due to the existing conditions throughout the Village, it may be difficult to meet the requirements without regrading significant portions of the Village's overland drainage system. Regrading the overland drainage system can be cost prohibitive and construction could impact private property.

The simplest way to maintain / improve the performance of the current system and ensure that the maximum hydraulic capacity of the network is available during storm events, is to complete regular maintenance of the storm infrastructure. This includes removing silt build up from culverts and catch basins, mowing of ditches, and clearing debris near outfall structures. However, large storm events would produce flows in excess of storm sewer capacity, the following locations are noted to require some additional work to improve overland drainage during large events.

- Townhouses on 5th St NW
- Courtney Way
- Emergency escapes from cul-de-sacs
    - Picci Court

  - Centre St S
  - Linview Road
- Drainage channel at north end of 6th St NW
- 6th St NW
- Field catch basin near 417 1st St NW
  - Predominately occurs during spring freshet
- Drainage channel through trailer park off of 1st SE
  - Predominately occurs during spring freshet
- Lane behind 1st St SE / Centre St S / Central Ave
- Access into Diamond Café off of 1st St SW

Most of the above projects could be completed with a drainage easement and drainage channel / swale sized to accommodate the flow through a prescribed route towards the coulee. However, land availability and constructability are more challenging in some locations than others. Upgrades to 6th St NW (i.e. curb and gutter) or regrading along the gravel edges of the roadway could help improve the overland drainage function.

If overland escapes from areas that experience spring freshet concerns are not desirable, upstream storage could be examined to provided attenuation and grading work could promote flow towards the current drainage infrastructure.

5.7 Stormwater Projects

The following are stormwater projects are prepared based on the findings of the stormwater models and input from the Village.

Generally, the infrastructure appears to be in a fair condition and should be replaced when other sub-surface or road projects are completed in the vicinity of stormwater infrastructure. Pipe diameters should not decrease in size unless sufficient slope can be provided to maintain similar capacity to upstream larger diameter pipes. There is one section of storm sewer in Linden that pipe diameters decrease, along 1st Ave N at 1a St NW. This area was noted as being in surcharge in the 1:5-year storm event (Figure 5-7). Additionally, CCTV captured along the storm sewer on 1st Ave N found a second pipe intercepting the storm sewer, shown in Figure 5-9. The storm sewer along Central Ave between Centre St N and 1st St NW is also noted to be surcharging during the 1:5-year storm event and should be upgraded; this upgrade would also address the poor outfall structure noted by the Village staff. Additionally, the CCTV inspection completed in the Village noted a concrete blockage along the 1st St NE storm sewer immediately south of Central Ave. The concrete blockage is shown in Figure 5-10. Linden staff investigated this manhole in March 2021 and found that the line has been abandoned and a new connection to the adjacent manhole has been created. The storm sewer is noted as surcharging in the model; however, the system does not surcharge to surface (i.e. cause surface inundation).

The remaining projects pertain to the overland drainage system in Linden and reducing flooding concerns caused by storm events and/or spring freshet.

Figure 5-9: Second Pipe Intercepting the Storm Sewer on 1st Ave N

Figure 5-10: Concrete Blockage in the Storm Sewer Along 1st St NE

5.7.1 EX SW1 – Upgrade Storm Along Central Ave

Project Description

Reconstruct the storm sewer along Central Ave between Centre St and 1st St NW, including a new outfall structure.

Project Rationale

Currently, the storm sewer can not convey the 1:5-year storm event without surcharging. Additionally, the outfall is currently countersunk and performs poorly during the winter and spring causing water to surcharge to the surface.

Project Details

- 150 m of new 450 mm PVC pipe
- New 450 mm concrete outfall structure

Project Cost

Engineering	$	35,000.00
Implementation	$	150,000.00
Contingency	$	40,000.00
Total	**$**	**225,000.00**

5.7.2 EX SW2 – Upgrade Storm Along 1st Ave N

Project Description

Upgrade the section of 525 mm pipe to 750 mm diameter pipe, excluding the outfall pipe, and replace the section of 750 mm diameter pipe that has the other utility line intercepting it.

Project Rationale

The 525 mm has reduced capacity compared to the upstream 750 mm diameter pipe and modelled to surcharge in the 1:5-year event. The outfall pipe, also a 525 mm, does have appropriate capacity due to the steep slope of the pipe. The section of existing 750 mm diameter pipe that has the intruding utility line needs to be regraded and new pipe installed to avoid the intrusion and maximize capacity.

Project Details

+ 110 m of new 750 mm PVC Pipe

Project Cost

Engineering	$	20,000.00
Implementation	$	100,000.00
Contingency	$	30,000.00
Total	**$**	**150,000.00**

5.7.3 EX SW3 – Overland Diversion Around 5th St NW Townhouses

Project Description

Obtain a drainage easement and construct a swale around the rear of lots of the townhouses and provide an overland drainage route to the 5th St NW roadway.

Project Rationale

The drainage swale will redirect the water through a designated path to the major system on 5th St NW. The drainage easement will ensure Village access and limit future construction within the swale.

Project Details

+ Drainage easement acquisition
+ 125 m of new drainage swale construction

Project Cost

Engineering	$	15,000.00
Implementation	$	35,000.00
Contingency	$	15,000.00
Total	**$**	**65,000.00**

5.7.4 EX SW4 – Regrading and Berm Around Field Catch Basin (417 1st St NW)

Project Description

Regrading around the current field catch basin and construction of earthen berm to attenuate runoff volume and increase flow to the catch basin. Possible extension of the storm sewer to a new catch basin if regrading to current catch basin is unfeasible.

Project Rationale

Currently, upstream runoff bypasses the field catch basin and flows as overland sheet flow through private property towards 1st St NW during spring freshet. Regrading around the catch basin would promote capture and the earthen berm would attenuate flow and allow it to enter the catch basin

Project Details

+ 100 m of new earthen berm
+ Regrading around existing catch basin
+ Possible 50 m of new 300 mm PVC pipe and catch basin

Project Cost

Engineering	$	15,000.00
Implementation	$	50,000.00
Contingency	$	20,000.00
Total	**$**	**85,000.00**

5.7.5 EX SW5 – Ditch and Inlet Upgrade at Trailer Park

Project Description

Construction of new catch basin and upgraded ditch to capture upstream runoff.

Project Rationale

Currently, the existing Type K2 catch basin becomes overwhelmed with runoff from spring freshet. Upgrading the catch basin to a Type C and allowing head buildup will improve hydraulic capacity of the system.

Project Details

+ 1 new catch basin structure
+ 50 m of ditch upgrades

Project Cost

Engineering	$	15,000.00
Implementation	$	35,000.00
Contingency	$	15,000.00
Total	**$**	**65,000.00**

5.7.6 EX SW6 – Coulee Dam Inspection

Project Description

Engineering inspection of the dam structures responsible for the coulee reservoirs.

Project Rationale

It is unclear the last time the dams have been inspected to determine their structural stability.

Project Details

- 1 new engineering report assessing the dams' stability

Project Cost

Engineering	$	50,000.00
Implementation	$	0.00
Contingency	$	0.00
Total	**$**	**50,000.00**

5.7.6.1 Project Update

This project has been ongoing since April as part of the emergency works for the coulee dam.

5.7.7 EX SW7 – 2nd Ave N Overland Escape Erosion Protection

Project Description

Erosion protection and energy dissipation for overland runoff crossing 1st St NW.

Project Rationale

Overland flow currently spills across the roadway and down coulee. Erosion protection and energy dissipation near the roadway could disperse the flow evenly to promote sheet flow further downstream.

Project Details

- Class I rip rap erosion protection mat

Project Cost

Engineering	$	15,000.00
Implementation	$	25,000.00
Contingency	$	10,000.00
Total	**$**	**50,000.00**

5.7.8 Additional Projects

In addition to the projects reported above, the Village should consider obtaining drainage easements for emergency escapes from the cul-de-sacs in the Village and overland drainage routes through Courtney Way and the Diamond Café site. The existing drainage channel at the north end of 6th St NW appears to function adequately; however, having water spill to the back of curb on 5th St NW poses an erosion concern. Upgrades to the swale are recommended as development further occurs along 5th St NW and are discussed in Section 5.10.2.

Regrading on private property may be required in order to drain the low area in the lane behind 1st St SE / Centre St S / Central Ave. The extension of the Central Ave storm sewer (Section 5.7.1) to include a grated top manhole in the lane may provide a slight improvement to the area. Although pooling will still occur, a drainage relief point will be provided, and water will not be forced to pool and infiltrate.

Upgrades to 6th St NW, including the construction of curb and gutter would improve overland drainage routes; however, this work would also trigger upgrades to the storm sewer system since water would access the sewer quicker than current conditions and closer to the modelled results. Upgrades to the 6th St NW sewer system is discussed in Section 5.10.1.

5.8 Future Development and Development Standards

The following section addresses the impact of development and outlines the recommended requirements for designing future stormwater infrastructure. The requirements for future development must, at a minimum, follow the stormwater regulations developed by AEP. It is recommended that future developments also follow the CSA W204:19 (Flood Resilient Design of New Residential Communities) standards wherever possible.

The projected growth in Linden is based on the current land use map which outlines some minor residential development. The residential development is expected to continue off of 5th St NW, north of Picci Court and 5th Ave N east of 1st St NW. The current land use map is shown in Figure 5-11.

Figure 5-11: Land Use Map for Linden

5.8.1 Future Stormwater Management

There are multiple ways to address the stormwater increase caused by future development. Stormwater management on site would need to address the water quantity and restrict flows, and possibly volumes, to pre-development levels. Additionally, the water quality must be treated before discharging to the existing drainage system. To address the water quantity and quality, the following options are appropriate alternatives.

+ LID Practices
+ Storm Ponds
+ Constructed Wetlands

At the present time, there are no volume control targets prescribed by AEP for the Kneehills Creek watershed. Since no volume targets are in place, storm ponds may be the more appealing alternative to treat stormwater runoff; however, LID practices and wetlands could provide more resiliency to the system. Future site investigations would be required to determine what LID practices are suitable for the developments and if whole developments could be serviced through LID practices alone or if storm ponds would also be necessary.

Drainage upstream of any developments would also need to be maintained after development. The future developments would need to convey upstream flow through the development; however, this flow should not be incorporated in the sizing of any LID or storm pond infrastructure. The upstream flow should be contained to its own drainage network through the development. If the upstream flow is incorporated into the stormwater management system, the sizing of the stormwater management infrastructure could significantly increase.

5.8.2 Minor and Major System

Future development should employ the dual drainage system, that consists of below ground pipes (minor system) for more frequent events and overland escape routes (major system) for extreme events.

5.8.2.1 Major System

The major stormwater drainage system includes all overland drainage routes, such as swales, ditches, roads, and storage facilities. The major system facilitates flow when the minor (piped) system is beyond capacity; because of this, the major system is designed for infrequent extreme rainfall events that exceed the capacity of the minor system. Failure to adequately plan and design the major system can cause flooding and damage to public and private property during an extreme event.

Designing for the major system is required to follow Alberta Environment guidelines. In addition to the guidelines, a useful summary of the design standards has been prepared as part of the current AEP Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems (2013, Part 5). These documents outline all the requirements for stormwater management in Alberta; however, a few of the most pertinent guidelines regarding the major system are also listed below:

+ The major drainage system is to be designed to safely convey a one in 100-year rainfall event. This includes the sizing requirements of any stormwater management facilities.
+ The grading of development is required to ensure a continuous escape route for stormwater, often via streets. Adjacent properties to the flow must be protected from flooding.
+ The maximum depth of flow at curbside gutters should be less than 0.3 m.
+ Standing water at low points (trap lows) should be less than 0.5 m.
+ Velocities and flow depths for the major system, including gutters and swales, shall not exceed the values outlined in Table 5-10.
+ Sufficient freeboard must be provided between the water level along the major system and building elevations.

Table 5-10: Permissible Flow Depths and Velocity

Water Velocity (m/s)	Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

5.8.2.2 Minor System

The minor drainage system includes all the underground piping system that facilitate transport of stormwater quickly and efficiently below its design capacity. Similar to the major system, the design guidelines for the minor system must follow Alberta Environment Guidelines; the minor system requirements can be found in the publications mentioned above.

Pertinent design guidelines for the minor system include:

- The minor system should be designed to carry the peak flow resulting from a 1:5-year rainfall event (typically 70 L/s/ha).
- Storm system must be designed as a separate entity from the sanitary system.
- Storm sewer pipe shall be designed to convey the design flow with the hydraulic grade-line below the pipe crown. During detailed design of the drainage system, the hydraulic grade-line during the one in 100-year event must be acceptable. Surcharging to the surface should not be allowed. Inlet control devices (ICD) may be required to control flows into the piped system.
- Minimum depth of cover to the pipe crown should be 1.2 m.

It is recommended that the minor system be sized to handle a flow rate of 70 L/s/ha. In steeper areas, where traplow storage is limited, the minor system capacity should be increased to 80-120 L/s/ha depending on storage availability and site imperviousness.

5.8.3 Design Storm Events

It is recommended that future developments use precipitation data from the nearby Drumheller gauging station. The Drumheller East climate station is maintained by Environment Canada (station ID 30221LG) and has been collecting data since 2005. Drumheller is approximately 55 kilometers to the southeast of Linden and has a similar climate.

The IDF curve data from the Drumheller station is reported in Section 5.4.1. Additionally, the IDF data can be found in the Environment Canada file in Appendix H.

5.8.4 Stormwater Quality

The current requirement for stormwater quality is to provide a minimum of 85% removal of total suspended solids (TSS) for particle sizes greater than 75 µm prior to discharge (AEP, 2001). This stormwater quality requirement will be provided by the SWMF servicing the subject area. The minimum detention time for the storm ponds is 24 hours. By controlling and treating all runoff generated by the more frequent events, represented by the water quality design event, the desired objectives should be achievable. The water quality storm event should follow Alberta Environment's guidelines of a 25 mm event.

Increased water quality targets for downstream water bodies can be implemented by increasing the minimum percent removal of TSS or reducing the particle sizes. It is recommended that if increased water quality targets are to be set, the particle size be reduced before increasing the minimum percent removal of TSS. Additional quality control can be achieved by implementing oil and grit separators (OGS), normally upstream of the pond or near the source of runoff.

5.8.5 Best Management Practices

A sediment forebay is recommended for wet ponds. Sizing and detail design of the forebay will have to be provided in the SWMF report, to be provided during subdivision design.

Direct runoff of stormwater from impervious surfaces, such as asphalt, to receiving waters can increase stream temperatures beyond the habitual limits of aquatic organisms. Fish species and aquatic invertebrates have temperature preferences that may be exceeded during periods of stormwater runoff. Vegetation around the storm ponds is recommended to help reduce the temperature of effluent stormwater. Other BMPs include implementation of lot level controls, outlet cooling, or SWMF configuration design to limit open areas of water.

Salt used on local roadways as de-icer in winter months can have a significant impact on stormwater quality during periods of snowmelt. Salt concentrations can have a negative impact on wildlife, freshwater ecosystems, vegetation, and soils. It is recommended that a salt management plan for the storage and use of road salts follows Environment Canada's Code of Practice for the Environmental Management of Road Salts.

5.8.5.1 LID and Source Control

Controlling stormwater at the source is an effective way to reduce the demands on SWMFs and properly designed source controls can completely replace the need for SWMFs. These Low Impact Designs (LID) try to replicate pre-development hydrology, water budget, and provide water quality treatment through natural processes. Replicating the water budget is effective at meeting volume controls on stormwater. Further investigation would be required to determine the applicability and extent of LID design within the study area, especially identifying locations with permeable soils and the hydrogeological processes. A useful document outlining LID and other source control practices can be found in the City of Calgary's *Stormwater Source Control Practices Handbook* (2007).

The handbook outlines the various types of designs, source controls, and their applicability; however, a few of recommended practices are listed below:

+ All roof drainage from single family homes and garages to be directed away from hard surface and towards landscaped areas prior to draining to streets or lanes. Rain barrels can also be used to intercept runoff.
+ Absorbent landscapes with a minimum of 300 mm of topsoil.
+ Vegetated swales.

5.8.5.2 Erosion Protection

The effect of increased runoff, even those controlled, could also cause increased erosion downstream of development. Although SWMF attenuate the flow and keep them below a prescribed flow rate, duration of flow can still cause erosion problems in the channels downstream of a SWMF. Further studies at the time of development will need to examine the erosion impacts and channel stability of downstream reaches and devise solutions to prevent erosion if necessary. Volume control can be considered as an option to assist in alleviating erosion concerns; however, an erosion assessment should still be undertaken during subdivision detailed design.

If future developments discharge directly to a watercourse (i.e. Kneehills Creek or a tributary), it is recommended that erosion protection measures are put in place to protect the outfall from high flow velocity exiting the pipe system and also erosion from the watercourse itself in the case of Kneehills Creek. A combination of rip rap and natural vegetation along the channel banks should be used. Orientation of the outfall structure could also assist.

5.8.6 Upstream Discharge

New developments should be constructed so that incoming flow from upstream catchments can safely pass through the development. The offsite flows can be directed around the development of through the development; however, the 1:100-year flow rates need to be accommodated. Since the majority of the upstream land is agricultural in nature, peak flow rates may be experienced in spring freshet due to snow melt. The drainage infrastructure may need to be sized for snow melt conditions and the hydraulic capacity may need to account for reductions due to snow and ice accumulation.

5.9 Future Drainage Network Performance

The future drainage system is modelled based on the land use map (Figure 5-11). The development north of Picci Court on 5th St NW should include a minor system capable of draining 70 L/s/ha. This would be completed through a new storm system. The 70 L/s/ha should account for possible upstream flows from future development to the west. The current land use map shows urban reserve; however, if this is projected to be developed in the future, its flows should be accounted for in the sewer system.

Development off of 5th Ave N adjacent to 1st St NW would drain to the existing storm sewer system crossing 1st St NW. The inclusion of the additional development causes the existing storm sewer to surcharge to the surface during the minor storm events (1:2-year and 1:5-year storms). It is recommended that the storm sewer be upgraded alongside the new construction. At a minimum, the storm sewer should be upsized to a 450 mm diameter pipe; however, similar to above, the storm sewer should be sized to accommodate future development upstream to the east. The upstream lands are shown as urban reserve; however, if this is projected to be developed in the future, it's flows should be accounted for in the sewer system. Overland emergency escape routes from the new development will drain towards 1st St NW and then south along 1st St NW on the existing drainage path. If large areas of future development follows the overland flow paths towards 1st St NW, the existing pathway may become overwhelmed and exceed provincial requirements and/or cause flooding concerns.

Preliminary pond sizing for the approximately 8 ha development north of Picci Court is in the range of 3,000 to 5,000 m³ of active storage volume. This corresponds to a storm pond roughly 0.4 to 0.5 ha in size. Storage volumes were estimated using PCSWMM software and Figure 4-3 from the City of Calgary *Stormwater Management and Design Manual*.

5.10 Future Stormwater Projects

If upgrades to the industrial development in the northwest occurs and runoff is provided with quicker access to the storm sewer than currently available (i.e., slow routing to the grated top manhole at 6th St NW and Central Ave), the storm sewer on Central Ave should be upgraded.

Similarly, areas that are upgraded to curb and gutter should be accounted for in the sewer pipe capacity (70 L/s/ha) to determine if pipe upgrades are triggered.

Stormwater management facilities should be constructed alongside new development. However, to avoid many small SWMFs, a larger pond should be constructed (greater than 2 ha). If areas of limited development size or phasing makes it impossible for a larger single pond, it is recommended that each development include an OGS for water quality treatment. Although large SWMF may not be doable, it is recommended that downstream developments have oversized storm sewers to accommodate future upstream development. Cost sharing of upsized pipes may be needed to promote development, but rate of return for the Village may take a long time.

5.10.1 FT SW1 – 6th St NW and Central Ave Sewer Upgrade

Project Description

Reconstruct the storm sewer along 6th St NW and Central Ave.

Project Rationale

Currently, the storm sewer can not handle the modelled 1:5-year storm event without surcharging. Due to the long travel time for a portion of land to enter the grated top manhole at the intersection of 6th St NW and Central Ave, the surcharging might not currently be noticed. However, future upgrades to 6th St NW, including the construction of curb and gutter will improve inlet efficiency and the sewer will require upgrading.

Project Details

+ 350 m of new 525 mm PVC pipe
+ 5 new manhole structures

Project Cost

Engineering	$	30,000.00
Implementation	$	270,000.00
Contingency	$	50,000.00
Total	**$**	**350,000.00**

5.10.2 FT SW2 – Diversion Swale Around Picci Court and Culvert Underneath Roadway

Project Description

Dedicated drainage swale to accommodate upstream runoff and culvert to convey the flow across 5th St NW.

Project Rationale

As further development occurs north of Picci Court, providing an appropriate drainage path for upstream lands to safely reach the coulee reservoir is required. The construction of a single dedicated drainage ditch around Picci Court and the inclusion of twin culverts across 5th St NW will convey runoff from upstream lands and the runoff from the culvert crossing Highway 806 at Service Road.

Project Details

+ 300 m of new/upgraded ditch construction
+ Twin 900 mm culverts

Project Cost

Engineering	$	20,000.00
Implementation	$	85,000.00
Contingency	$	25,000.00
Total	**$**	**130,000.00**

5.10.3 Additional Projects

Upgrades are required for the storm sewer across 1st St NW at 5th Ave. The existing storm sewer across 1st St NW at 5th Ave does not have capacity for additional flows. With future development, the pipe will need to be upsized. Depending on the future growth and projected timeline, this pipe could be upsized for different build out scenarios The current land use plan suggests a minimal amount of development (approximately 12 lots); however, the Village has noted that the owner of the land proposes to develop the remaining quarter section. Phasing of the development should be discussed with the Village to understand timing of development (i.e., start time, full built out time, etc.). If minor development only is proposed, the existing storm sewer could be upgraded to convey peak flows. However, if major development is anticipated, a SWMF will be required and conveyance through the existing storm pipe will need to be examined based on the proposed stormwater management plan (i.e., overland escape route from the SWMF, upsized storm pipes, 1:500-year storage, etc.). Flow attenuation to pre-development peak flows and water quality treatment will need to be provided regardless of an interim solution.

Further projects like the construction of the SWMF will be the responsibility of developers. However, due to the impracticality of constructing many small SWMFs, a single larger SWMF may be warranted for development and each development pays its portion of contributing land. It is recommended that a maximum of one SWMF should be provided per quarter section. The concern with this option is that the developer takes risk in development timing and return on their investment to construct a SWMF.

5.11 Climate Change

A climate change scenario was completed to try to better understand how the drainage system may behave in the future. The climate scenario allowed for a comparison of the existing performance of the system versus a potential climatic future performance of the drainage system.

The climate change scenario was completed using the IDF CC Tool 4.0 (Schardong et al., 2018). The tool allows the user to select an existing climate station or predict an IDF for an ungauged location. Since the existing models utilized data from the Drumheller 30221LG station, that existing station was chosen. The years of record used in the IDF development were chosen to be within the immediate future, 2020-2050. The climatic scenario chosen was the RCP 4.5 which is one of three options in the tool and represents a moderate climate change severity. The RCP 2.6 represents the lowest severity and RCP 8.5 represents the highest severity. The RCP 4.5 stands for the Representative Concentration Pathway where radiative forcing peaks at 4.5 W/m^2 by the year 2100 (Schardong et al., 2018). Finally, the last two inputs by the user are the climate model and the IDF statistical representation. For the climate model the CanESM2 model was chosen which is developed by the Canadian Centre for Climate Modelling and Analysis and is the only Canadian option available. The distribution of the IDF curve uses the generalized extreme value (GEV) distribution. The resulting IDF coefficients for the climate scenario are provided in Table 5-11.

Table 5-11: Rainfall Intensity Coefficients for Future Climatic Scenario

Storm Event	IDF Coefficient		
	A	B	C
1:5-year	26.7	0.059	0.780
1:100-year	83.7	0.139	0.892

The parameters in Table 5-11 correspond to the following equation

$$i = \frac{A}{(t + B)^C}$$

Where *i* is the rainfall intensity in mm/hr;

t is the duration; and

A, B, & C are constants found in Table 5-11

Storm models were completed for minor (1:5-year) and major (1:100-year) storm events. The storm events modelled were 24 hours in duration and used a timestep of 5 minutes to account for the highest intensity portion of the synthetic storm. A Chicago distribution was used to create the hyetograph shape; the Chicago distribution is a robust synthetic storm event that is used across many climatic regions and common for use in engineering analysis. The rainfall hyetographs for these storms are shown in Figure 5-12.

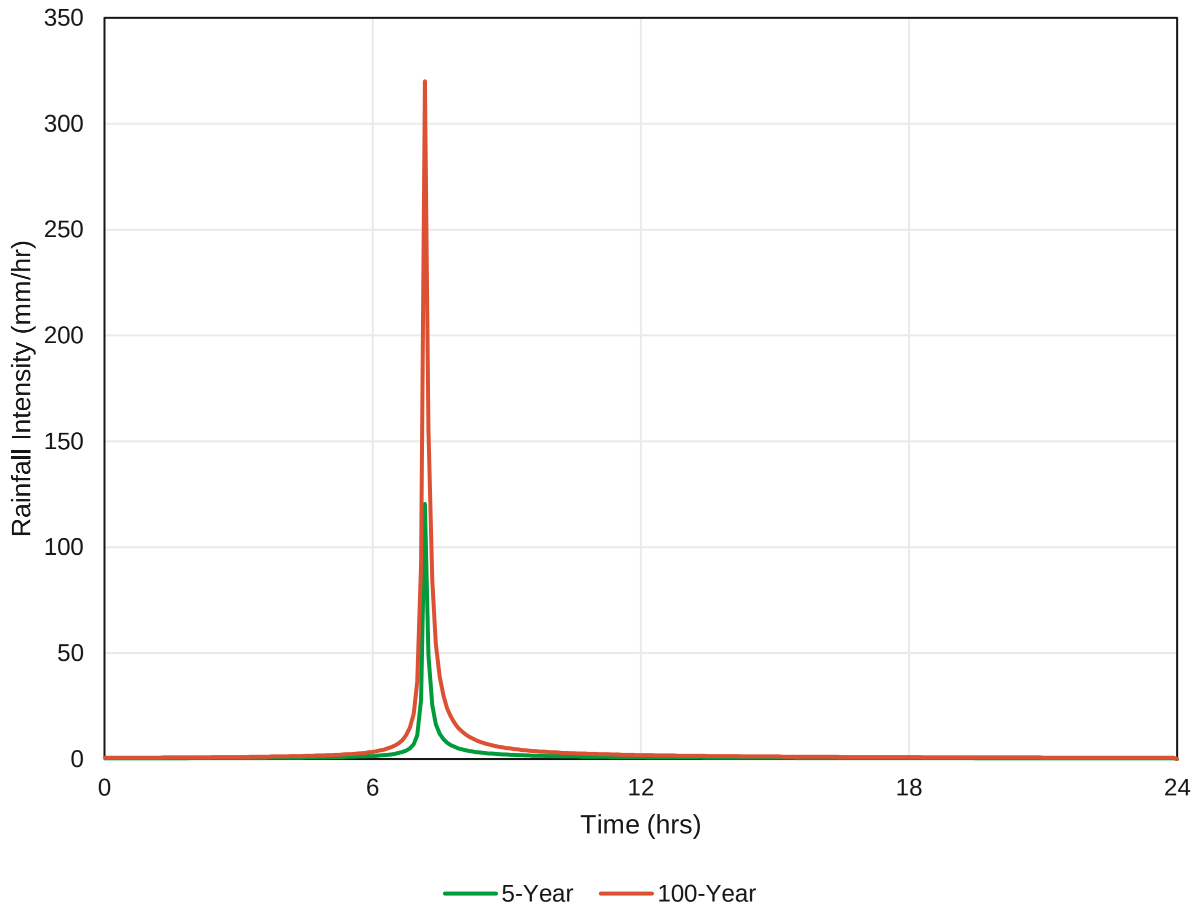

Figure 5-12: Climate Scenario Storm Event Hyetographs

The results of the climate change scenario showed an increase in surcharging and flooding in both the 1:5-year and 1:100-year storm events with respect to the current events. During the 1:5-year storm event, the ponding occurs in the same locations as currently, but with greater volume.

- 125 m³ at the intersection of 6th St NW and 1st Ave NW
- 153 m³ at the intersection of 6th St NW and Central Ave
- 19 m³ at the field catch basin behind 417 1st St NW
- 190 m³ at the intersection of 1st St NW and 2nd Ave
- 32 m³ at the cul-de-sac of Centre St S
- 89 m³ at the cul-de-sac of Linview Road

During the 1:100-year future climate scenario, significant flooding increases occur throughout the Village. Due to the increase in storm intensity, the runoff from the upstream agricultural lands increases substantially and causes flooding to occur along the highway ditches and further increases surface inundation at the manholes and catch basins in the community. To analyze the impacts of the increased flow and the flooding occurring under the climate scenario, a 2D model was completed to help forecast flood prone areas. The 2D model was set up in the same fashion described in Section 5.5.1.1. The results of the 1:100-year future climate scenario with the 2D overland mesh are shown in Figure 5-13.

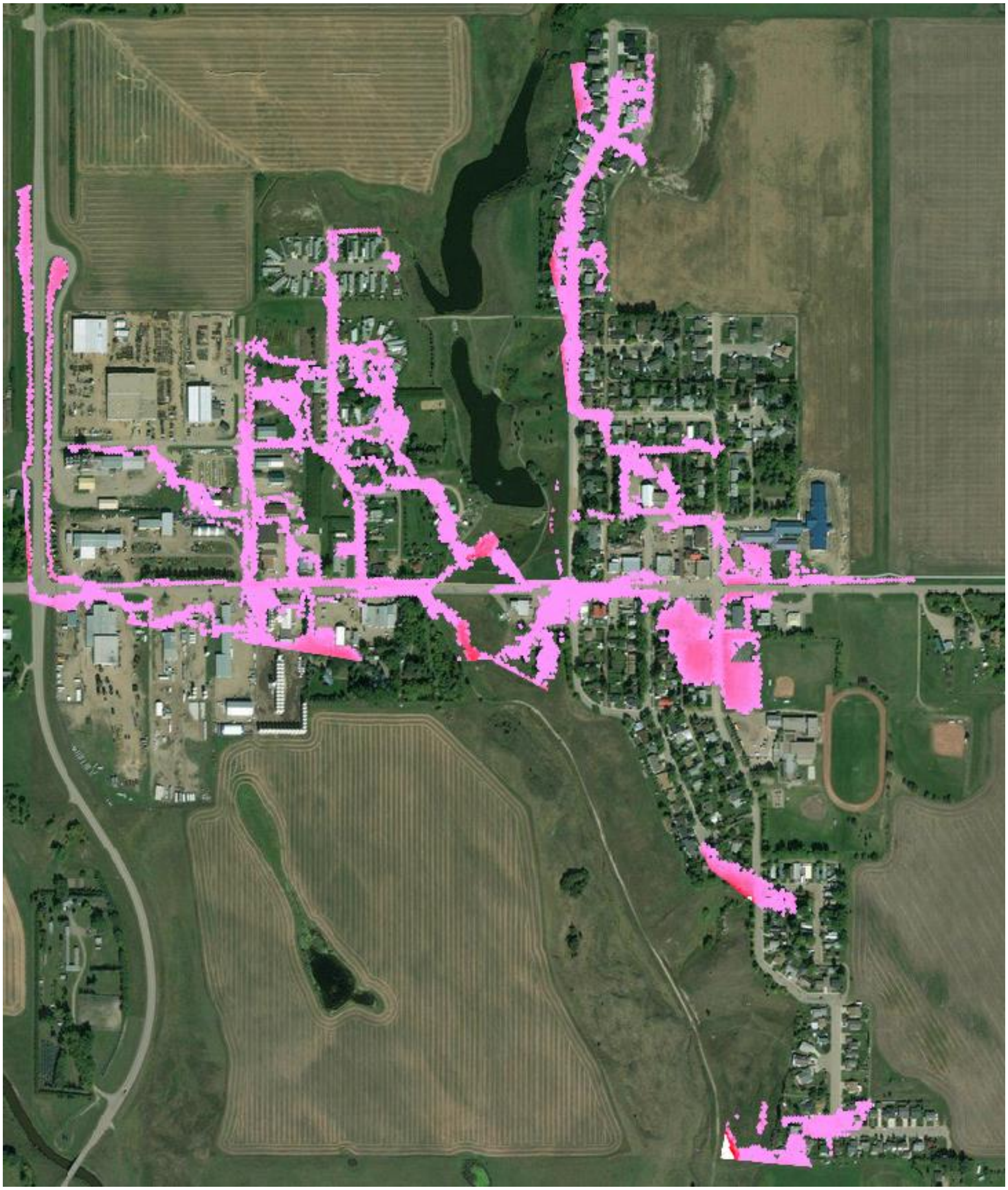

Figure 5-13: Maximum Overland Flow Depths Computed in the 2D PCSWMM Model for the Future Climate Scenario

The overland flow depths shown in Figure 5-13 are provided as a gradient between pink and red. The pink cells represent a maximum depth of 0.05 m and the red cells represent a maximum depth of 2.0 m.

As can be seen in Figure 5-13, the flooding throughout Linden increases under the climate change scenario. On the west side of Linden, the flooding is shown to generally follow the roadway network, except for in the vicinity of the townhouses on 5th St NW, where flow congregates from the properties on the east side of 6th St NW. The lack of escape routes from the Picci Court cul-de-sacs are also highlighted in the model. South of Central Ave, drainage moves in a southeasterly direction to Courtney Way. The boundary of the 2D mess causes the build up of surface water at Courtney Way; however, the flow path highlights the importance of a drainage route around the street.

On the east side of the coulee, the increase in flooding generally follows the same pathways but in greater volume. Overland flow appears to spill across the Mennonite church property from southeast to northwest towards 2nd Ave. The overland flow path along the rear lane of 2nd Ave highlights its importance for overland major drainage through the center of the Village. Once again, the lane behind 1st St SE / Centre St S / Central Ave accumulates significant depth of water before spilling. Additional runoff from the agricultural lands shows the general inundation area near the field catch basin behind 417 1st St NW.

5.12 Closing

The stormwater analysis undertaken was to evaluate the current system performance and help provide guidance for future projects and developments within the Village of Linden. In lieu of any existing watershed management plans, master drainage plans, or stormwater management plans, the analysis acts as a planning level document and can help guide future stormwater initiatives within Linden.

The models completed with PCSWMM identified current locations within Linden that would likely experience localized flooding during regular and infrequent storm events. Under normal flow conditions, it appears that the majority of the stormwater network in Linden is adequately sized to prevent surcharging to the surface, with the exception of some surface ponding at the intersection of 1st St NW and 2nd Ave NE and the intersection of 6th St NW and Central Ave during the 1:2-year storm event. During the 1:5-year storm event, ponding begins to occur at the intersections of 6th St NW and 1st Ave NW, 6th St NW and Central Ave, and 1st St NW and 2nd Ave. Additional surcharge in the 1:5-year storm event also occurs at the cul-de-sacs of Centre St S and Linview Road, and the field catch basin behind 417 1st St NW. During larger flow events, the lack of a properly designed overland major drainage network could cause drainage to cross private property as flows escape to the coulee. The overland drainage routing is impacted in both the major storm events and during snow melt in the spring.

Future development within Linden will need to adhere to the current stormwater requirements from AEP (2001) and meet the CSA W204:19 standards wherever possible. To provide guidance for the future stormwater infrastructure, a comparative basin technique was used with data from Kneehills Creek survey station downstream of Linden. The analysis provides a target UARR for future development and the UARR is representative of the drainage basin as a whole. Small areas within the basin, though, such as the steep portion near the escarpment, would likely runoff at a higher rate than the overall UARR. Future development based on the current land use map (Figure 5-11) shows some minor residential growth. Any stormwater management facilities for these small areas may be impractical to construct; however, at a minimum, an OGS should be installed on any new sewer system. Stormwater management facilities, such as storm ponds, should have a minimum size of approximately 2 ha for operations and maintenance purposes, but based on development scale, a regional pond may be warranted.

A climate change analysis was completed based on moderate projections over the future 30 years to identify potential concerns. The results of the analysis showed an increase in surcharge to the drainage system during the minor storm events. In the major storm event, increased runoff exacerbates the existing flooding areas and increases flooding risks throughout the community. Overland flow paths through Linden remain the same; however, the flow conveyed through the streets and overland increases significantly. Overland flow routes (major system) may need to be addressed in both the current and possible future climate scenario to ensure that flow from large storm events are routed to the appropriate locations within Linden and limit impact to private property. The flooding and inundation maps completed show that flow is generally limited to the streets, but spills across private property near the townhouses on 5th St NW and at the escapes from the cul-de-sacs. Additionally, the lane behind 1st St SE / Centre St S / Central Ave is currently a large traplow without any designed escape for water aside from infiltration. However, no detailed survey was completed to ensure that building elevations have an appropriate freeboard beyond the flow depths or spill elevations.

5.12.1 Recommendations

The following recommendations are based on information from record drawings, LiDAR data, field survey completed in 2020, and the results of the hydrologic/hydraulic models under normal flow conditions.

- Regular inspection and maintenance need to be completed to ensure that the stormwater system is operating at its maximum hydraulic capacity. This includes the maintenance of catch basins, manholes, culvert, ditches, and outfalls. Areas of special attention include:
  - Field catch basin at the rear of 417 1st St NW
  - Catch basin and drainage ditch at the trailer park on 1st St SE
  - Ice accumulation at concrete swales
  - Ditch connection to the minor system on 6th St NW
- Minor developments that drain to the coulee reservoir may not need attenuation storage volume due to impractical size and that the coulee reservoir will provide some attenuation. However, OGS structures should be constructed upstream of the sewer outfalls to provide water quality treatment. Using the coulee reservoir as attenuation would need to be confirmed by the developer under the Water Act and Environmental Protection and Enhancement Act.

  - Larger developments will need to attenuate stormwater runoff through an on-site stormwater management facility (i.e. storm pond).
- An overland escape route is maintained across 1st St NW from 2nd Ave NE to prevent significant pooling at the intersection.
  - This includes limiting curb on the west side of 1st St NW and possible erosion and protection works adjacent to the roadway where water spills into the coulee.
- Ephemeral wetlands or drainage pockets within the Village boundary are recommended to be maintained as they provide attenuation and storage and lessen flooding impacts.
  - Currently no information or inventory is available within the vicinity of Linden for wetlands. It is recommended that a biophysical assessment of the area be completed before any future development occurs
- It is recommended that future development adheres to a UARR of 1.40 L/s/ha. This is based on the comparative basin technique using gauged stream flow along Kneehills Creek downstream of Linden.
- It is recommended that future stormwater analysis is completed using the IDF data from Environment Canada station in Drumheller (station ID 30221LG).
- It is recommended that LID practices be incorporated as much as possible in the future development to achieve possible future water volume targets.
- If spring freshets are a major concern, it is recommended that a future study be completed to identify local hydrologic parameters, culvert capacity reduction, downstream boundary conditions, etc.
- If underground utilities are being upgraded adjacent to stormwater systems, the storm sewer network should be upgraded in conjunction with the adjacent underground work.

Overland drainage is a known challenge for existing communities constructed prior to the dual drainage stormwater collection systems. Addressing overland grades can be challenging in a retroactive upgrade.

- Major overland drainage routes should be identified and possible upgrades to occur through a staged effort. Implementing the dual drainage system may be a significant undertaking and require large resources. Creating new overland drainage pathways may have consequential impacts to existing land and structures.
  - Generally, overland escape routes should not occur through private property to avoid damaging structures and prevent lawsuits against the municipality. Existing lot grading and overland drainage paths through private property is not the responsibility of the Village due to the standards at the time of construction. New construction or redevelopment in the Village will require stormwater management reports (SWMR) to ensure new problems are not created or existing problems are not exacerbated.

- Any upgrades to the major drainage system would need to meet current AEP standards and due to the existing conditions throughout the Village, it may be difficult or impractical to meet the requirements without regrading significant portions of the Village's overland drainage system. Regrading the overland drainage system can be cost prohibitive and construction could impact private property.
- The Village could begin to explore the acquisition of drainage easements from current low points that cross private property before reaching the coulee to accommodate major flow events. However, existing major drainage and overland routes that go between two private landowners are not the explicit responsibility of the Village. Although the Village could work with landowners to resolve the issue, overland drainage can require significant grading requirements to lots or new infrastructure (i.e. ditches, berms, etc.) that would require easements for maintenance.

5.13 References

Alberta Environment Protection (AEP). (2001). *Stormwater Management Guidelines for the Province of Alberta.*

Alberta Environment and Parks. (2013). *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*.

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City of Calgary. (2007). *Stormwater Source Control Practices Handbook*.

City of Calgary. (2011). *Stormwater Management and Design Manual.*

LGN Consulting Engineering Ltd. (December 16, 2012). *Stormwater Management to Mitigate Drainage Issues – Village of Linden, Alberta*.

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Red Deer River Watershed Alliance. (2009). K*neehills Subwatershed – Red Deer River State of the Watershed Report*.

Schardong, A., Gaur, A., Simonovic, S. P., & Sasndink, D. (2018). *Computerized Tool for the Development of Intensity-Duration-Frequency Curves Under a Changing Climate*.

6. Roads Assessment

6.1 Introduction and Background

CIMA+ performed a visual assessment of the roads for the Village of Lindens to provide decision makers and Village staff with a current understanding of the road conditions, recommendations for rehabilitation and improvements, and provide priority and cost insights for future capital planning.

The scope of this section of the report includes:

+ Collection of condition assessments of existing paved roads, curbs and gutter, and sidewalks.
+ Analyze the collected data and establish a road rating system to rate the condition of each roadway.
+ Review and analyze any geometric issues with the existing road infrastructure and provide recommendations for improvement.
+ Analyze the collected data to determine the proposed repair and enhancements.
+ Recommend a priority-based schedule for road repairs and enhancements.

Currently the Village of Linden maintains approximately 7.125km of paved roadways that vary in age, condition, and pavement structure/construction standards. Bridges and culverts are not included in the scope of this assessment.

The visual assessment of the roadways, curbs and gutters, and sidewalks was conducted in October 2020. The following sections provide further information regarding the methodology developed, details pertaining to each roadway element, and provides recommendations for improvements.

6.2 Methodology

There are various methods and techniques used throughout industry when undertaking pavement condition assessments. CIMA has combined two common commonly used methods to ensure that roadways were being assessed both quantitively and qualitatively.

Each paved road segment was assessed based on two observational criteria:

+ Visual distress manifestation.
+ Experienced ride comfort.

CIMA created a Pavement Condition Rating evaluation based off the commonly used Flexible Pavement Condition Rating Form (FHWA, 1998) method for identifying specific pavement defects on the asphalt surface, their severity, and their frequency of occurrence as a proportion to the overall road area in order to establish the distress manifestation classification – this was used for the quantitative portion of the evaluation.

The pavement condition rating for flexible pavements provides a set standard for the roadways to be assessed against critical end of life cycle pavement manifestations and the ride comfort rating provides a qualitative base for user perception regardless of the pavements visual distress appearance – for the qualitative evaluation.

6.2.1 Distress Manifestation

This component of the pavement evaluation involved the collection of quantitative visual data related to the condition of the pavement surface, defined by the types and frequency of pavement distresses present. Distresses are defined as the manifestations of pavement surface defects resulting from construction quality, the damaging effects of traffic, the environment, and their interaction. Pavement distresses can include a broad variety of surface defects, deformations, patching and potholes, and cracking.

This data was collected manually through the pavement condition inspections performed through a windshield survey. For each distress type present the severity and extent are recorded on the Roads Assessment Inspection forms (Appendix G).

The Distress Manifestation Criteria provides a visually comparative quantitative method which evaluates two critical criteria related to pavement condition integrity which are:

+ Severity of Distress (SI)
+ Density of Distress (DI)

These parameters are the core inputs for how the pavement condition is assessed and given a numerical value. CIMA used the modified (FWHA 1998) Pavement Condition Rating (PCR) which is a deductive approach with each pavement starting with a score of 100. For asphalt surfaces both the SI and DI were rated on a scale of 0.25 to 1.25 which refer to very low to very severe for SI and few to throughout for DI respectively. Each category of surface distortion was then given a weight of between 2.5 and 15 in terms of how it consequentially impacts the pavements lifespan.

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)					Deduct Points
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout	
								<10%	10-20%	20-40%	40-80%	>80%	
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25	
Surface Defects	Raveling & loss of surface aggregate	15											0
	Flushing/Bleeding	2.5											0
Surface Deformations	Rippling, Shoving, Corrugations	5											0
	Rutting	10											0
Patching and Potholes	Potholes	15											0
	Patch/Patch Deterioration	5											0
Cracking: Longitudinal Wheel Track	Single and Multiple	15											0
Transverse	Half, full, and multiple	10											0
Centerline	Single and Multiple	5											0
Pavement Edge	Single and Multiple	5											0
Alligator Cracking		5											0
Block Cracking		7.5											0
												Total Deduct	0
												PCR (100-deduct)	100

Figure 6-1 CIMA Roads Assessment Inspection Sheet - PCR

The equation for calculating the PCR is:

$$Deduct\ Points = Weight\ x\ SI\ x\ DI$$

$$Pavement\ Condition\ Rating = (100 - \Sigma\ deduct\ points)$$

Examples of these types of distresses are provided in the figure below.

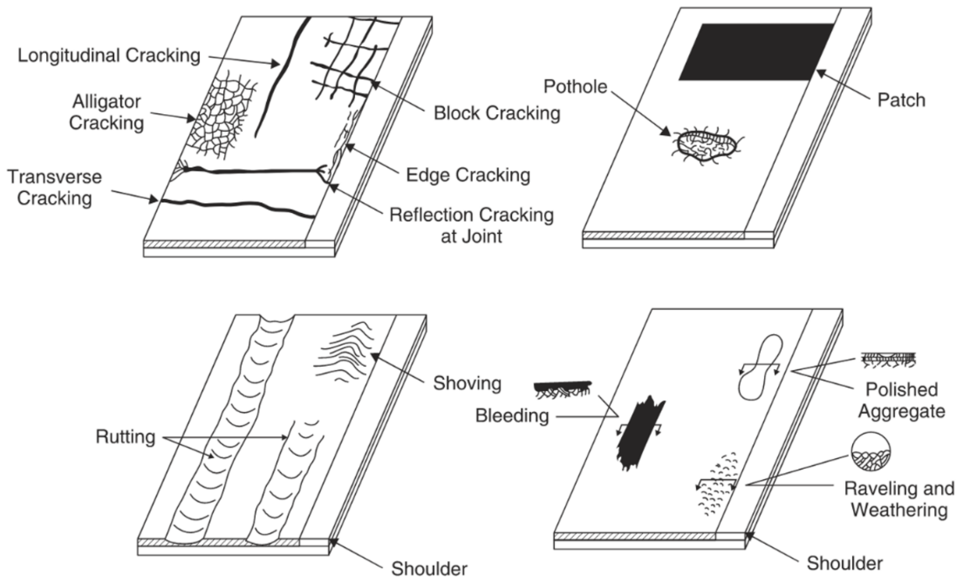

Figure 6-2 Examples of Pavement Distresses

(Papagiannakis, A. T., and Eyad Masad. Pavement design and materials. Hoboken, N.J: John Wiley, 2008. Print.)

Refer to the example Road Condition Assessment Inspection forms in Appendix G for further details.

The numerical value generated by the PCR then relates to the pavement condition as described in the table below.

Table 6-1 Pavement Condition Rating Scale

Pavement Condition Rating (PCR)	Condition
0-30	**Very Poor to Poor**
30-50	**Poor to Fair**
50-75	**Fair**
75-90	**Good**
90-100	**Excellent / New (full structure)**

A PCR of 100 would indicate a perfectly constructed new roadway (from shoulder to shoulder) that has not experienced any deterioration or damage. As the pavement experiences distresses and damages the PCR score reflects this through the calculations described above. As the PCR score is the metric used to determine the pavements assessed condition, the condition can then be extrapolated in terms of priority of repairs. The relationship between PCR and priority of rehabilitation is explained in Table 6-5: Rehabilitation Priority below.

6.2.2 Ride Comfort Rating (RCR)

The Ride Comfort Rating (RCR) was evaluated for each section of paved roadway and provides a qualitative assessment of road segments based on the inspector's judgment of select criteria while driving at the posted speed limit. The RCR is rated using the scale presented in Table 6-2 below.

Table 6-2 Ride Comfort Rating Scale

Ride Comfort Rating (at posted speed limit)										
10	9	8	7	6	5	4	3	2	1	0
Excellent		Good		Fair			Poor		Very Poor	

A Ride Comfort Rating (RCR) was established for each section of paved roadway evaluated. The RCR was evaluated subjectively by a driver travelling at the posted speed and scoring the ride comfort on a scale from 0 to 10.

Table 6-3 Ride Comfort Rating (RCR)

Numerical Value	Condition	Description
10-9	Excellent	New pavement (base structure and asphalt). Very Smooth and stable with negligible surface distortions
8-7	Good	Mostly smooth and stable with minor surface distortions
6-5	Fair	Comfortable with intermittent surface distortions
4-3	Poor	Uncomfortable with frequent surface distortions
2-1	Very Poor	Uncomfortable with continual surface distortions

A rating of 10 would indicate a smooth and stable road with no discomfort (newly constructed pavement) to the rider, while a rating of 0 would indicate a very rough and deteriorated road with potential and safety concerns.

6.3 Summary of Observations and Results

The Village of Linden contains approximately 7.125km of flexible asphalt roads. Overall, the pavement condition of the roads network is in satisfactory condition. A few main roads were found to be in poor condition and need of prioritized rehabilitation however that only accounts for 11.4% of the entire roads network. Approximately 26.4% of the roads network was determined to be in poor to fair condition. Lastly, 62.3% of the roads network was judged to be in fair to good condition.

Summary of the condition assessment in Table 6-4 below.

Table 6-4 Condition Assessment Summary

Pavement Condition Rating (PCR)	Condition	Number of Segments	Approx. Roadway Length (m)	Proportion of Village Road Network (%)
0-30	Very Poor to Poor	7	810	11.4%
30-50	Poor to Fair	8	1,880	26.4%
50-75	Fair	14	2,415	33.9%
75-90	Good	8	2,020	28.4%
90-100	Excellent / New Road	0	0	0.0%

Appendix D provides the roads assessment inspection details for all 37 of the Villages road segments evaluated. Recommendations for the priority of rehabilitation of the identified roads are based on the PCR value and ride comfort.

6.4 Prioritization and Approach

The prioritization ranking was developed as follows:

+ High Priority (PCR = very poor to poor) – Upgrade over the next 0-3 years required to correct stability, safety, and/or drainage issues.
+ Medium Priority (PCR = poor to fair) – Plan to upgrade in 3-5 years as budgets allow. Depending on pavement distress type and severity, pavement service life could substantially be extended through appropriate pavement maintenance (crack sealing, patching, and chip sealing). Monitor pavement condition for potentially accelerated deterioration.
+ Low Priority (PCR = fair to good) – Upgrade after lower rated roads only if identified by soils and materials investigating or site inspections (monitor roads and note condition in 5 years). Service life could substantially be extended through proactive pavement maintenance techniques. Monitor pavement condition for future planning.
+ Not required (PCR = excellent) – upgrades and maintenance repairs should not be required. However, best practice would involve at least some level of monitoring.

Table 6-5 Rehabilitation Priority

Repair Priority	Estimated Repair Timing	PCR	Map Color Code
High	**Immediate (0-3years)**	**0-30**	
Medium	**Repair 3-5years**	**30-50**	
Low – service life extension	**5-10 years**	**50-75**	
Low – long term planning	**10+ years**	**75-90**	
Not Required	**15+ years**	**90-100**	

Other Priority Consideration

It should be noted that these priorities are derived from the visual condition of assessment and ride comfort. The Village of Linden should not only prioritize the upgrades based on the above criteria, but also by offsetting the cost with underground utility upgrades, traffic volumes, population growth, and the perceived needs of the residents.

6.5 General Recommendations

It is anticipated that the surface rehabilitation will consist primarily of mill and overlay. However, spot base repairs and crack repairs may be necessary depending on the roadway condition and budgetary constraints.

A typical approach to rehabilitation on roadways is to remove the aging surface layer(s) through cold milling and then replace the removed material with new Hot Mix Asphalt Concrete (HMAC) Pavement. To recommend pavement structure details (asphalt thickness, base course, subbase, geotextile, etc.) further investigations are required such as performing a traffic count analysis and a geotechnical review of soil conditions.

The approach noted above is generally required for high priority areas.

Table 6-6 High Priority Repair Approaches

High Priority – Very Poor to Poor	
Pavement	**Resurface/Overlay**
	Full Depth Reconstruction

Maintenance treatment options to extend the service life of pavements include:

Table 6-7 Medium to Low Priority Repair Approaches

Maintenance Treatment Options (Medium to Low Priority)	
Pavement	**Manual Patching**
	Machine Patching
	Spray Patching
	Gout and seal Cracks
	Chip Seal

6.6 Priority Roads Projects

A list of projects and cost estimates has been created for the roads that have been rated as very poor to poor condition. The identified projects are assuming full curb to curb road replacement for the length of the street. Any overlap with potential water or wastewater projects could reduce the cost of construction and should be cross-referenced to maximize budgetary efficiency.

Table 6-8 summarizes the road sections rated as very poor to poor in need of high priority rehabilitation.

Table 6-8 Road Sections Rated as Severe

Road	From	To	Segment ID	Material	Approx. Length (m)	Approx. Width (m)	Approx. Area (m^2)	Ride Comfort Rating	Pavement Condition Rating (PCR)	Percentage of Network
Centre St N	Central Ave E	1 Ave N	24	Asphalt	95	10	950	**3**	**20.5**	1%
4 Ave SE (Private)	1 St SE	Road End	36	Asphalt	185	10	1850	**1**	**20.8**	3%
1 Ave S	Centre St S	1 St SE	31	Asphalt	100	10	1000	**3**	**22**	1%
Centre St S	Central Ave W	1 Ave S	29	Asphalt	160	10	1600	**3**	**22.3**	2%
Central Ave E	Centre St N	1 St NE	6	Asphalt	100	25	2500	**3**	**22.8**	1%
Central Ave W	1a St NW	Centre St N	5	Asphalt	60	20.5	1230	**3**	**20.8**	1%
Central Ave W	1 St NW	1a St NW	4	Asphalt	110	20.5	2255	**3**	**20.8**	2%

Detailed descriptions of these road segments, recommended strategy, and costs are outlined in the following section.

6.6.1 R1 - Centre St N from Central Ave E to 1 Ave N

Project Description

Mill and overlay Centre St N from Central Ave E to 1 Ave N due to severe rating.

Project Rationale

This segment of roadway was found to be in very poor condition and is showing signs of wear and damage due to the old age and seasonal freeze-thaw process. There are several transverse and longitudinal cracks and potholes (some of which have been filled recently) and significant edge deterioration. The pavement also showed rutting and patches in several areas. There are several businesses in this area which would also contribute to the noted failures within the road due to heavy loads travelling daily.

Project Details

+ Mill and overlay 950 m^2 of roadway with potential spot base repairs

Project Cost

Engineering	$	15,000.00
Implementation	$	95,000.00
Contingency	$	35,000.00
Total	**$**	**145,000.00**

Figure 6-3 - Road Photo October 7, 2020

6.6.2 R2 - Centre St S from Central Ave W to 1 Ave S

Project Description

Mill and overlay Centre St S from Central Ave W to 1 Ave S due to severe rating.

Project Rationale

This segment of roadway was found to be in very poor condition and is severely deteriorated and damaged likely due to the old age and the seasonal freeze-thaw process. The pavement surface is very severely raveled/loss of surface aggregate, longitudinal cracks, potholes (some of which have been filled recently), and significant edge deterioration. The pavement also showed rutting and patches in several areas.

Project Details

+ Mill and overlay 1600 m^2 of roadway

Project Cost

Engineering	$	25,000.00
Implementation	$	160,000.00
Contingency	$	55,000.00
Total	**$**	**240,000.00**

Figure 6-4 - Road Photo October 7, 2020

6.6.3 R3 - Central Ave E from Centre St N to 1 St NE

Project Description

Mill and overlay for minimum rehabilitation. Potentially reconstruct full road structure with the use of geotextile depending on geotechnical soil conditions. Central Ave E from Centre St N to 1 St NE due to severe rating.

Project Rationale

This segment of roadway was found to be in poor condition and is showing signs of wear and damage due to the old age, the seasonal freeze-thaw process, and repeated heavy loading. The pavement surface is experiencing loss of surface aggregate, there are several longitudinal cracks, and potholes which appear to have been filled recently. The pavement also showed rutting and patching in several areas.

Project Details

+ Mill and overlay 1850 m^2 of roadway with potential section base repairs for rutting

Project Cost

Engineering	$	30,000.00
Implementation	$	185,000.00
Contingency	$	65,000.00
Total	**$**	**280,000.00**

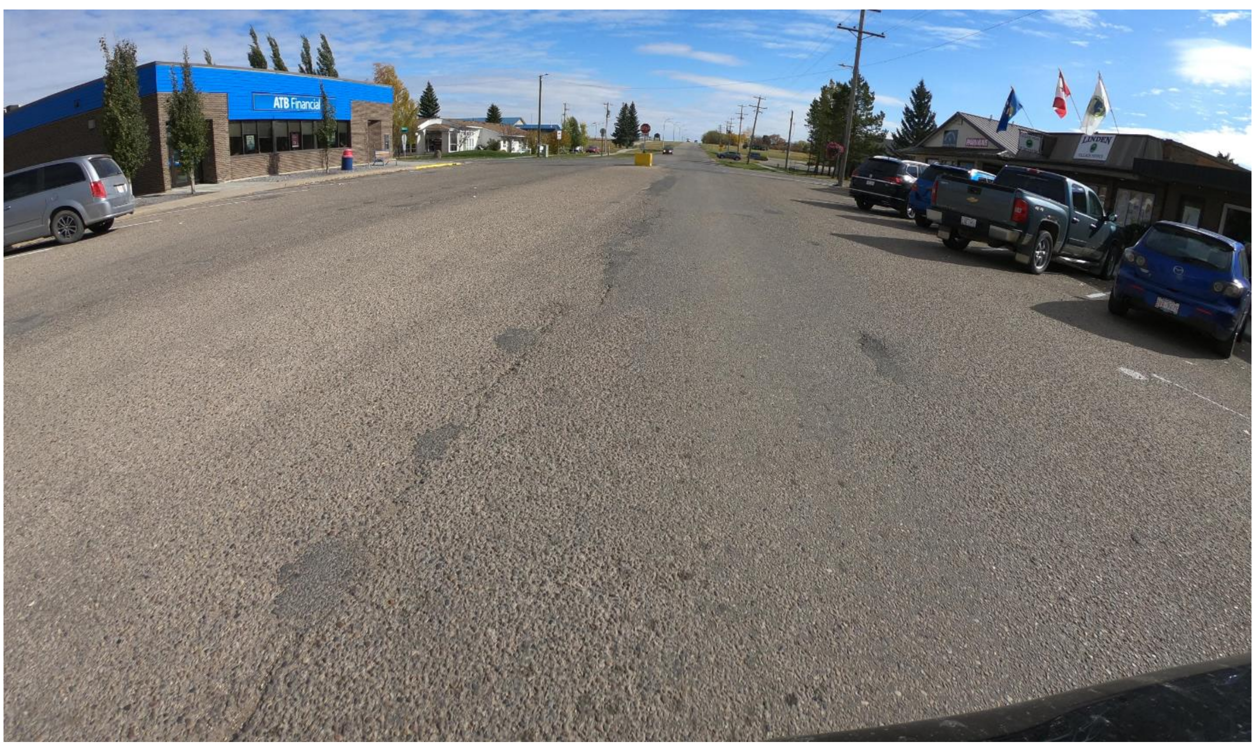

Figure 6-5 - Road Photo October 7, 2020

6.6.4 R4 - Central Ave W from 1 St NW to Centre St N

Project Description

Mill and overlay for minimum rehabilitation. Potentially reconstruct full road structure with the use of geotextile depending on geotechnical soil conditions. Central Ave E from Centre St N to 1 St NE due to severe rating.

Project Rationale

This segment of roadway was found to be in poor condition and is showing signs of wear and damage due to the old age, the seasonal freeze-thaw process, and repeated heavy loading. The pavement surface is experiencing loss of surface aggregate, there are several longitudinal cracks, and potholes (which appear to have been filled recently). The pavement also showed rutting and patching in several areas.

Project Details

+ Mill and overlay 3485 m^2 of roadway

Project Cost

Engineering	$	50,000.00
Implementation	$	350,000.00
Contingency	$	120,000.00
Total	**$**	**520,000.00**

Figure 6-6 - Road Photo October 7, 2020

6.6.5 R5 – 1 Ave S from Centre St S to 1 St SE

Project Description

Mill and overlay 1 Ave S from Centre St S to 1 St SE due to severe rating.

Project Rationale

This segment of roadway was found to be in very poor condition and is severely deteriorated and damaged due to the old age and the seasonal freeze-thaw process. The pavement surface is very severely raveled/loss of surface aggregate, longitudinal cracks, potholes (some of which have been filled recently), and significant edge deterioration. The pavement also showed rutting and shoving in various patches.

Project Details

+ Mill and overlay 1000 m^2 of roadway with potential section base repairs for rutting and patches

Project Cost

Engineering	$	15,000.00
Implementation	$	100,000.00
Contingency	$	35,000.00
Total	**$**	**150,000.00**

Figure 6-7 - Road Photo October 7, 2020

6.6.6

6.6.6 R6 – Central Ave from 1 St SE to RR254

Project Description

Mill and overlay Central Ave from 1 St SE to RR254 due to poor rating and planned future development.

Project Rationale

This segment of roadway was found to be in poor condition and is moderately deteriorated and damaged due to the old age and the seasonal freeze-thaw process. The pavement surface is severely raveled/loss of surface aggregate, longitudinal cracks, potholes (some of which have been filled recently), and significant edge deterioration. The pavement also showed rutting and shoving in various patches.

Project Details

+ Mill and overlay 6600 m^2 of roadway

Project Cost

Engineering	$	100,000.00
Implementation	$	660,000.00
Contingency	$	200,000.00
Total	**$**	**960,000.00**

6.7 Supplementary Pavement Failure Hierarchy Information

The following figure is provided as supplementary information to help the Village of Linden with further understanding failure hierarchies and potential distress manifestations. It is important to note that multiple variables are present all the time in the world, and the cause and effect links presented below should be viewed as probable cause.

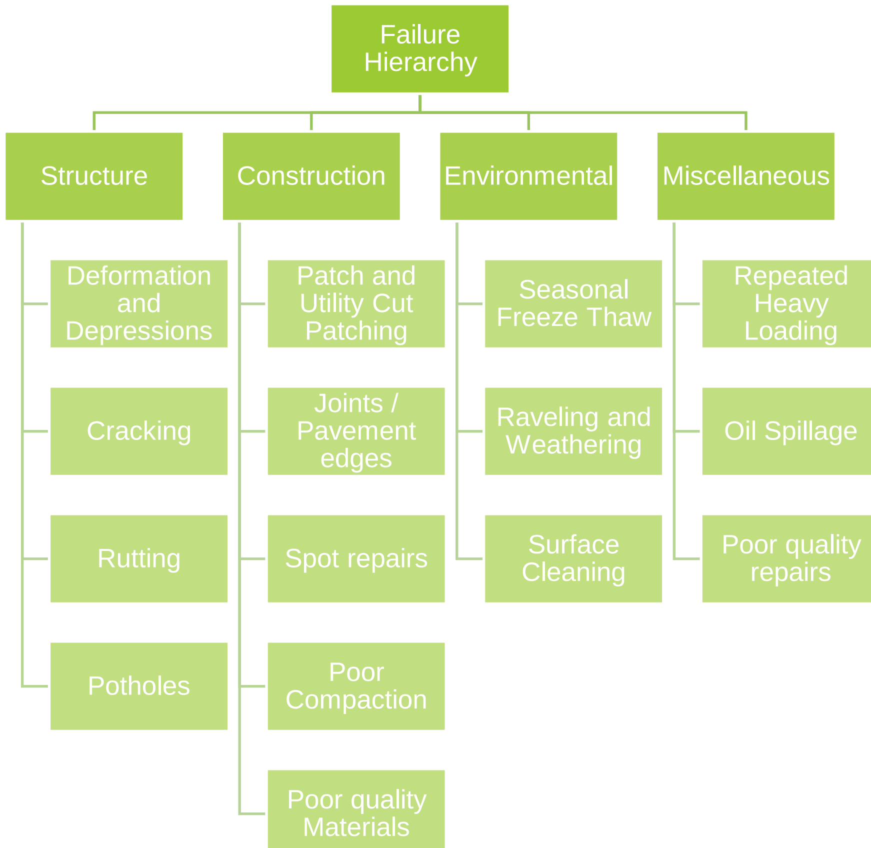

Figure 6-8 - Failure Hierarchy

6.8 Curbs and Gutters, and Sidewalks

Concrete works such as curbs and gutters, and sidewalks were evaluated at a high level on their perceived visual condition. Visual condition was determined based on defects or deformities such as concrete spalling, heaving, cracking, or tree root intrusion and then classified under good, minor, moderate, or severe. A similar approach of using the severity of abnormality and density was used, however in order to be efficient with inspections the inspector used their overall judgement on the condition as marking down every distortion would be too time intensive.

The condition of the curbs and gutters and sidewalks appeared to vary significantly throughout the Village with no obvious correlation to the pavement condition. Overall, the majority of concrete appeared to be in the moderate to minor condition rating with smaller sections in either severe or good condition. The sidewalks appeared to be fall more into the moderate and severe categories. The curbs and gutters were generally in moderate or minor condition. The inspector did note that multiple sections of sidewalks and curbs and gutters have been redone on various road segments making it challenging to classify (i.e. section of new concrete beside moderately or minor rated concrete, and how should then be classified).

CIMA recommends that the concrete works be upgraded during roads and other upgrade programs to for efficiency and economics.

For detailed information regarding concrete condition in specific road segments please refer to Appendix G Road Assessment Key.

6.9 Limitations of Visual Inspections

+ Sun angle and shade - illumination is of utmost importance during pavement conditions assessments for obvious reasons. The vertical and horizontal sun angles significantly effect surface defect visibility. Furthermore, trees and buildings casting shade can also make it difficult to identify features.
+ Parked Vehicles / Objects obstructing view (seasonal foliage, debris) - parts of roadways may not be visible due to parked vehicles or other obstacles placed on pavements. There may also be environmental variables at play such as seasonal leaf's, and erosion and sediment. This may cause surface features to be missed and result in not being accounted for.
+ Surface Wetness: To the casual observer a slightly wet surface may aid in visually spotting cracking as even small hairline cracks can be observed. Conversely, a very wet road surface such as obtained during or shortly after a rainstorm camouflages all but severe cracking. Furthermore, after a precipitation event cracked pavement will hold water in the surrounding pavement for longer, causing visual variations from the normal.

The limitations discussed above may cause features to not be accounted for, misclassified, or even over exaggerated. Furthermore, as pavements are continually being stressed, new defects may be present from the time this inspection was performed. Therefore, visual pavement evaluations are subjective and although inspectors use their best judgement, results may vary.

A

Appendix A
Water Infrastructure Figures

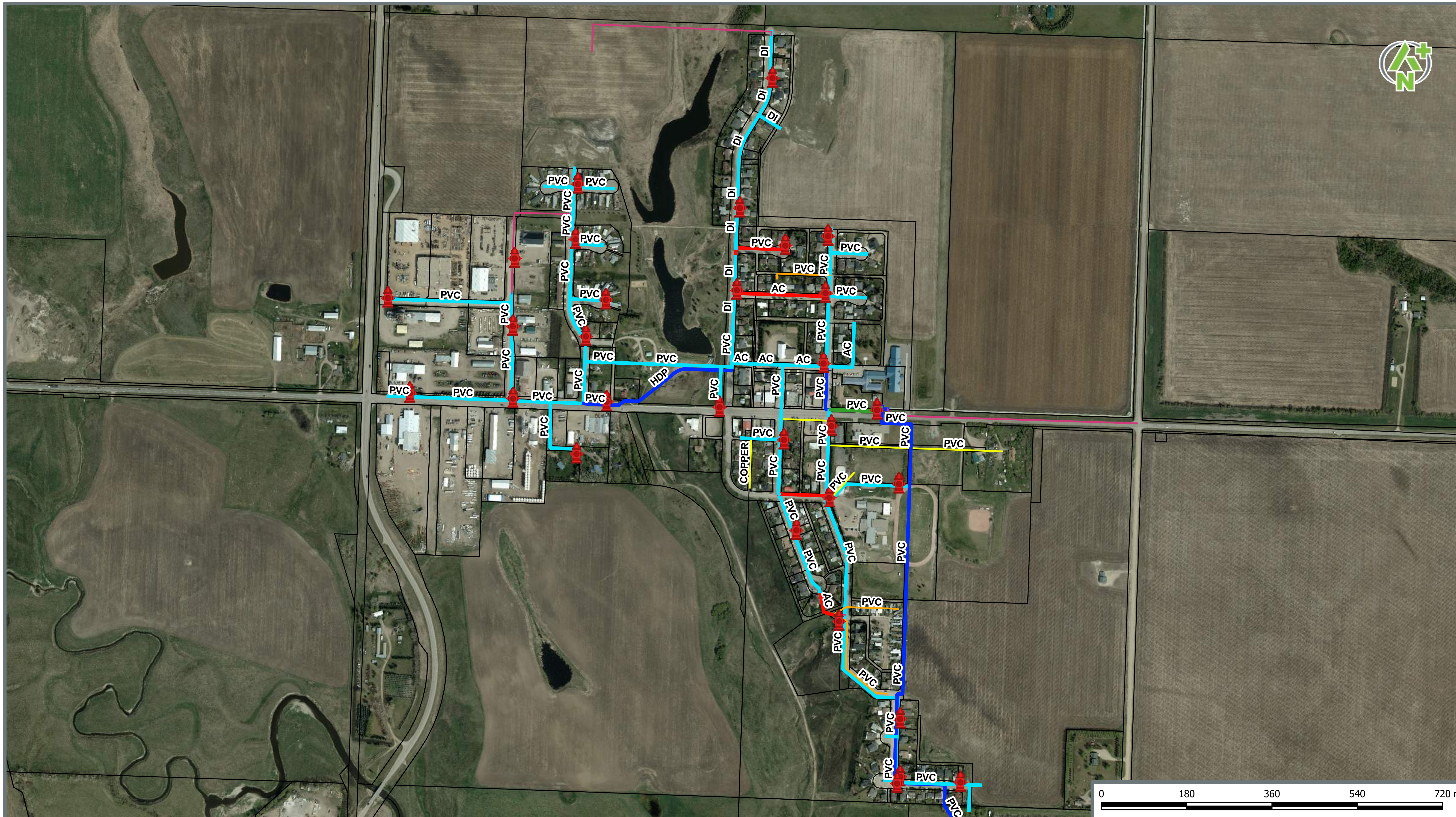

Figure W1 - Existing Water System

Scale 1:7,500

CIMA+

25mm Pipe
50mm Pipe
100mm Pipe
150mm Pipe
200mm Pipe
250mm Pipe
Water Hydrants

PREPARED FOR VILLAGE OF LINDEN UMP 2021

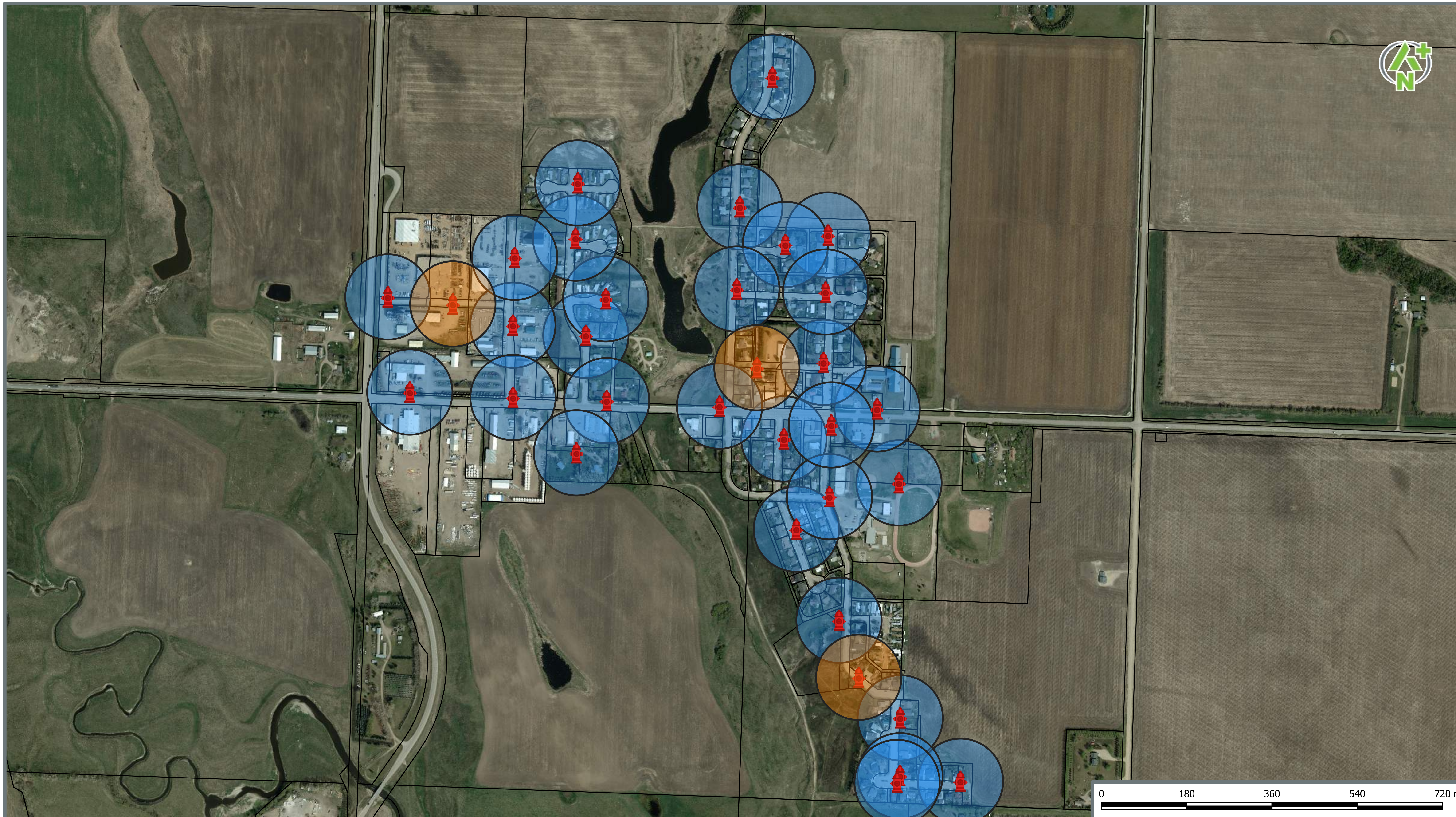

Figure W2 - Hydrant Spacing Assessment

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Existing Hydrant Spacing
Proposed Hydrant Spacing

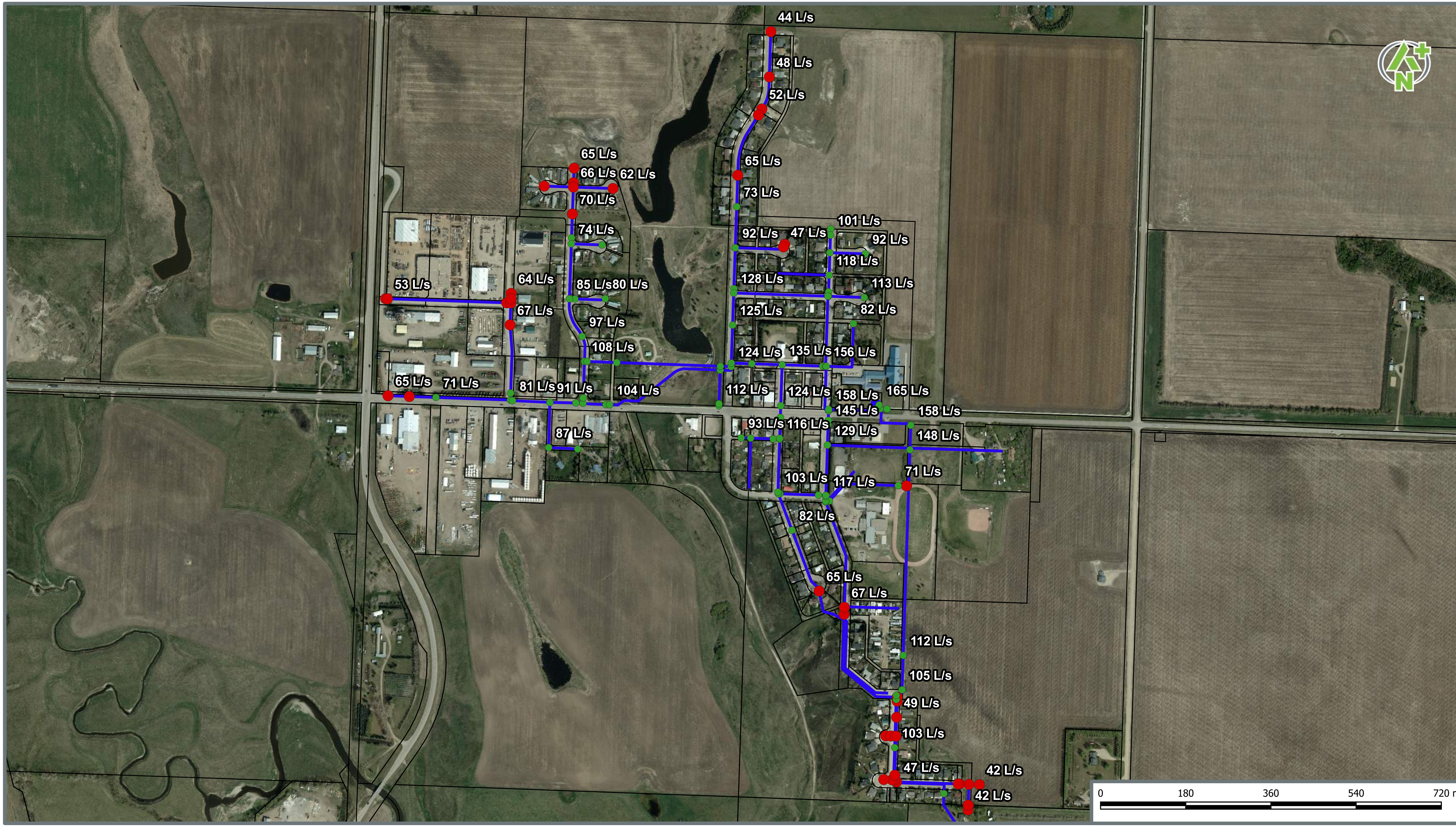

Figure W3 - Existing System Model Results (MDD+FF)

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

> 70 L/s Available Fire Flow

< 70 L/s Available Fire Flow

Existing Water Pipes

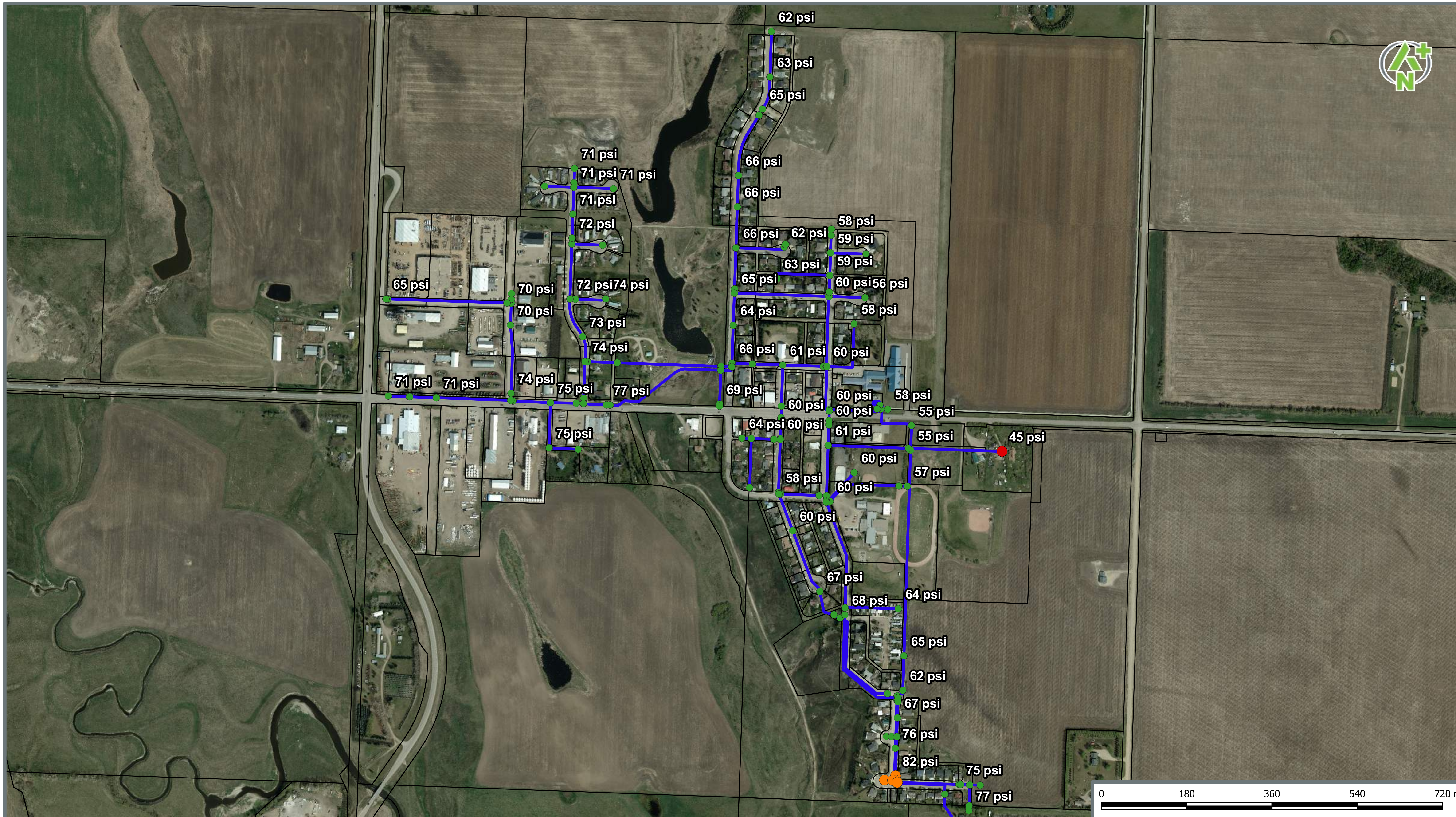

Figure W4 - Existing System Model Results (PHD)

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- <50 psi
- 50 psi - 80 psi
- >80 psi
- Water Lines

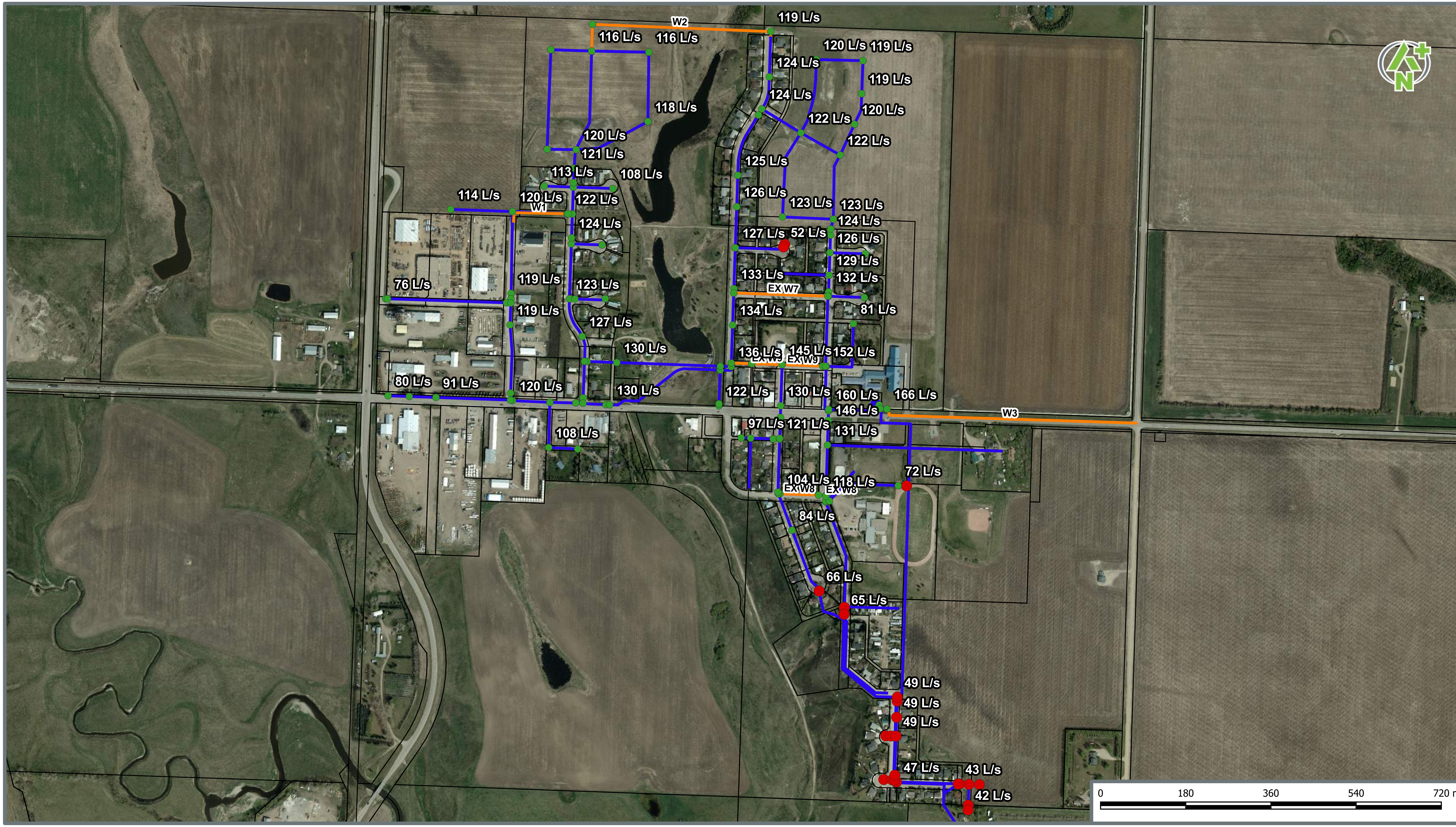

Figure W5 - 20 Year Model Results (MDD+FF)

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

> 70 L/s Available Fire Flow
< 70 L/s Available Fire Flow
Existing Water Pipes
Water Projects

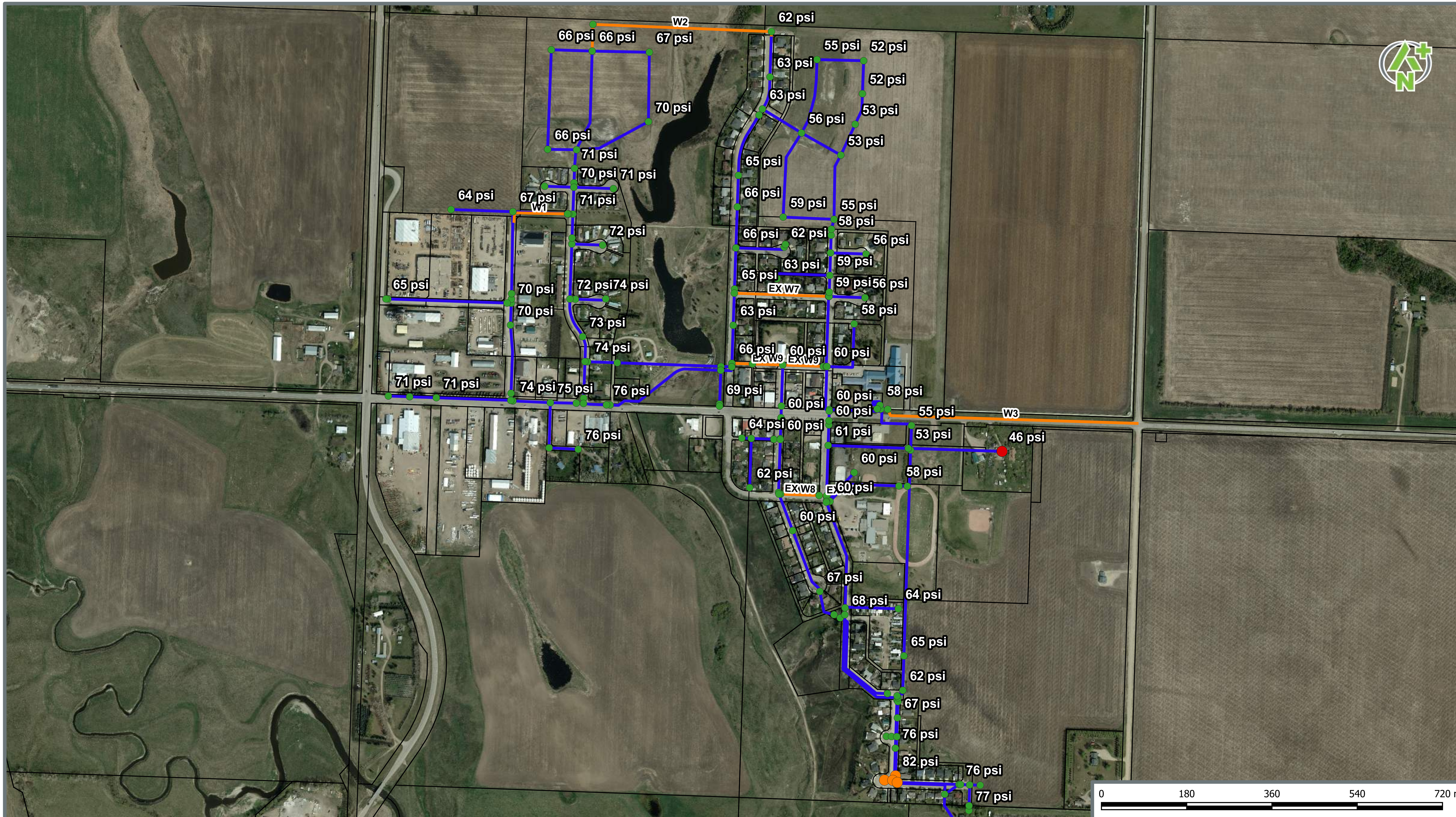

Figure W6 - 20 Year Model Results (PHD)

Scale 1:7,500

CIMA+

- <50 psi
- 50 psi - 80 psi
- >80 psi
- 20 Year Pipes
- Water Projects

PREPARED FOR VILLAGE OF LINDEN UMP 2021

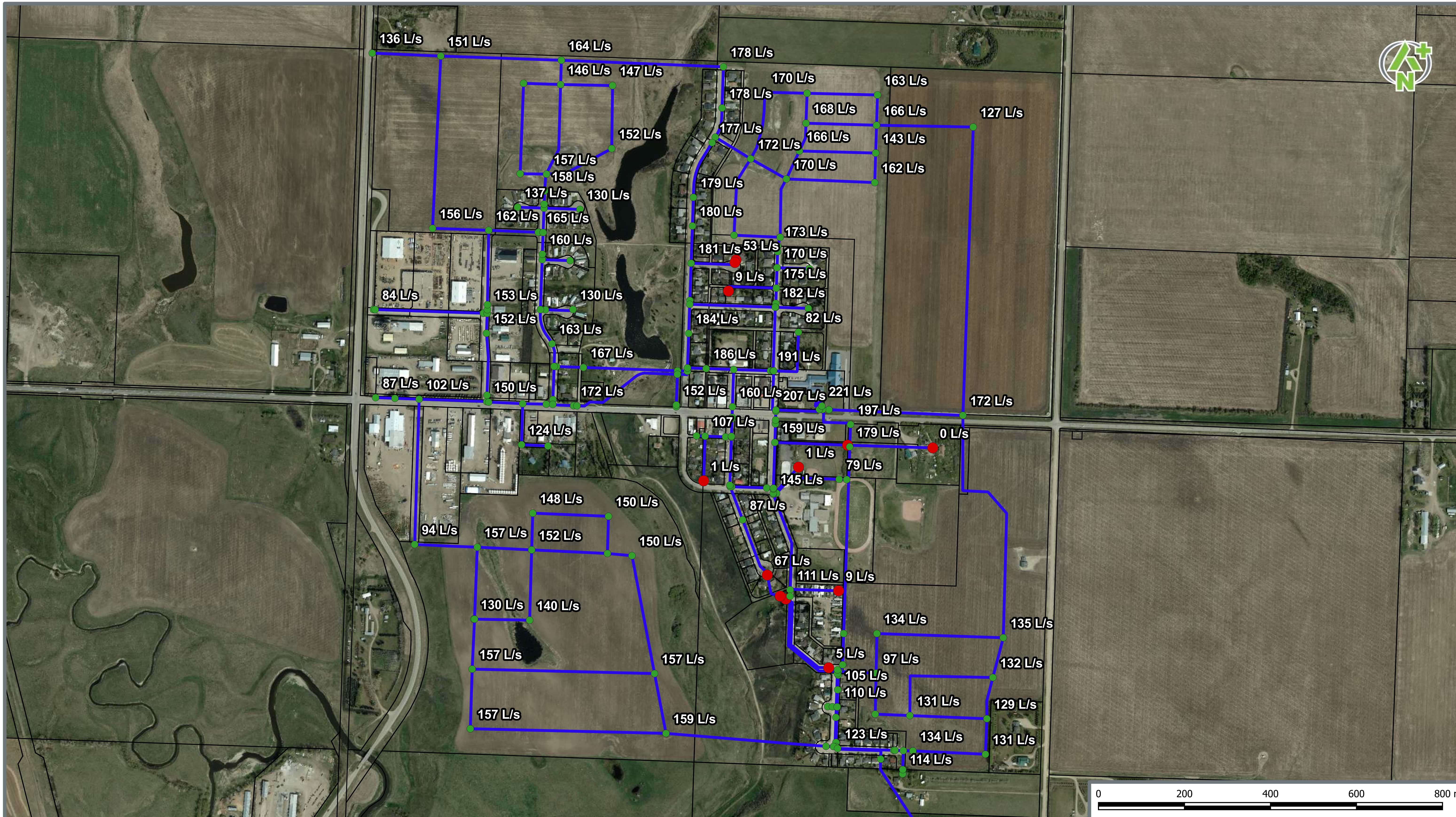

Figure W7 - Future System Model Results (MDD+FF)

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- > 70 L/s Available Fire Flow
- < 70 L/s Available Fire Flow
- Existing Water Pipes

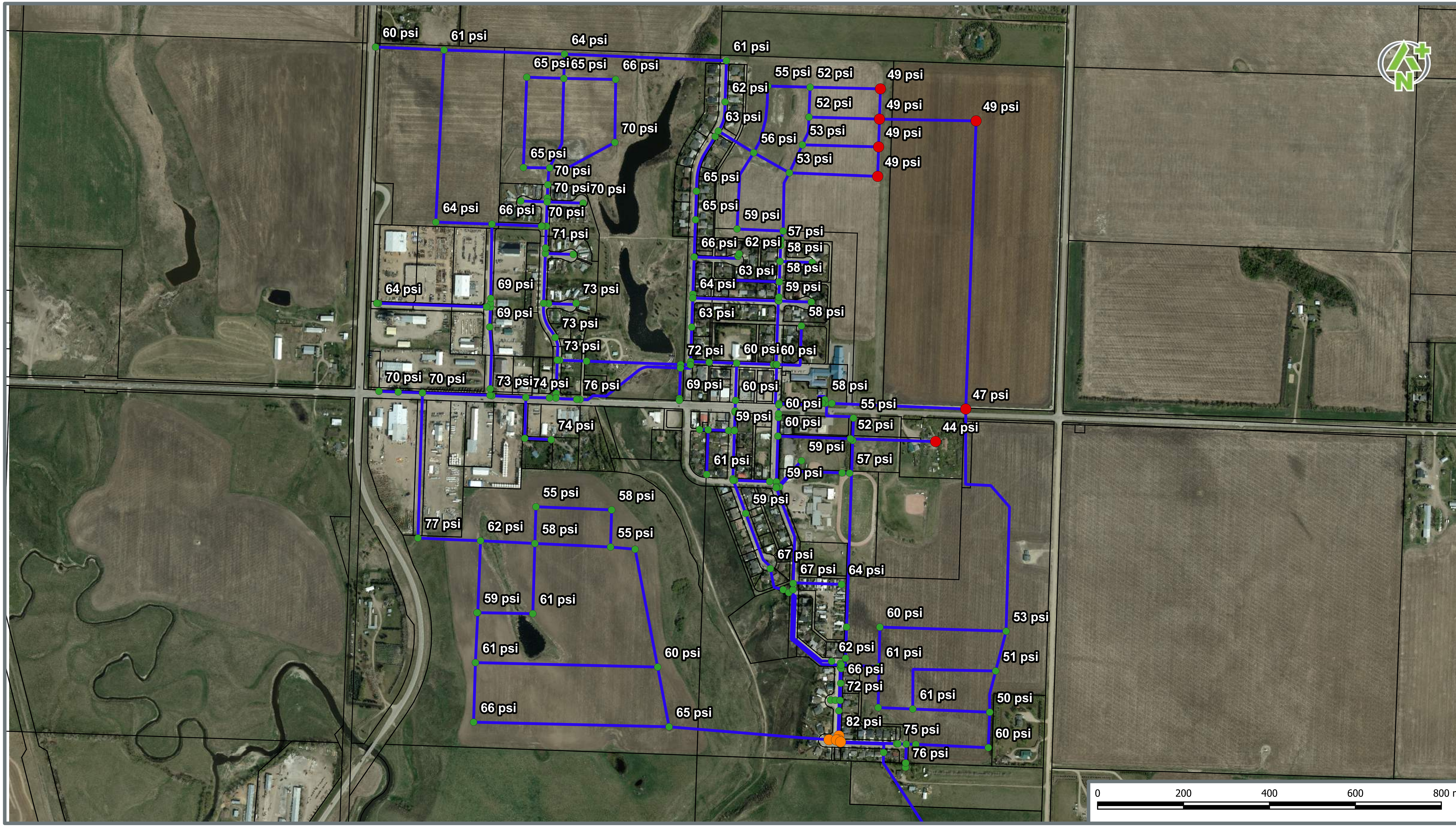

Figure W8 - Future System Model Results (PHD)

Scale 1:7,500

PREPARED FOR VILLAGE OF LINDEN UMP 2021

<50 psi
50 psi - 80 psi
>80 psi
Water Lines

B

Appendix B
Sanitary Infrastructure Figures

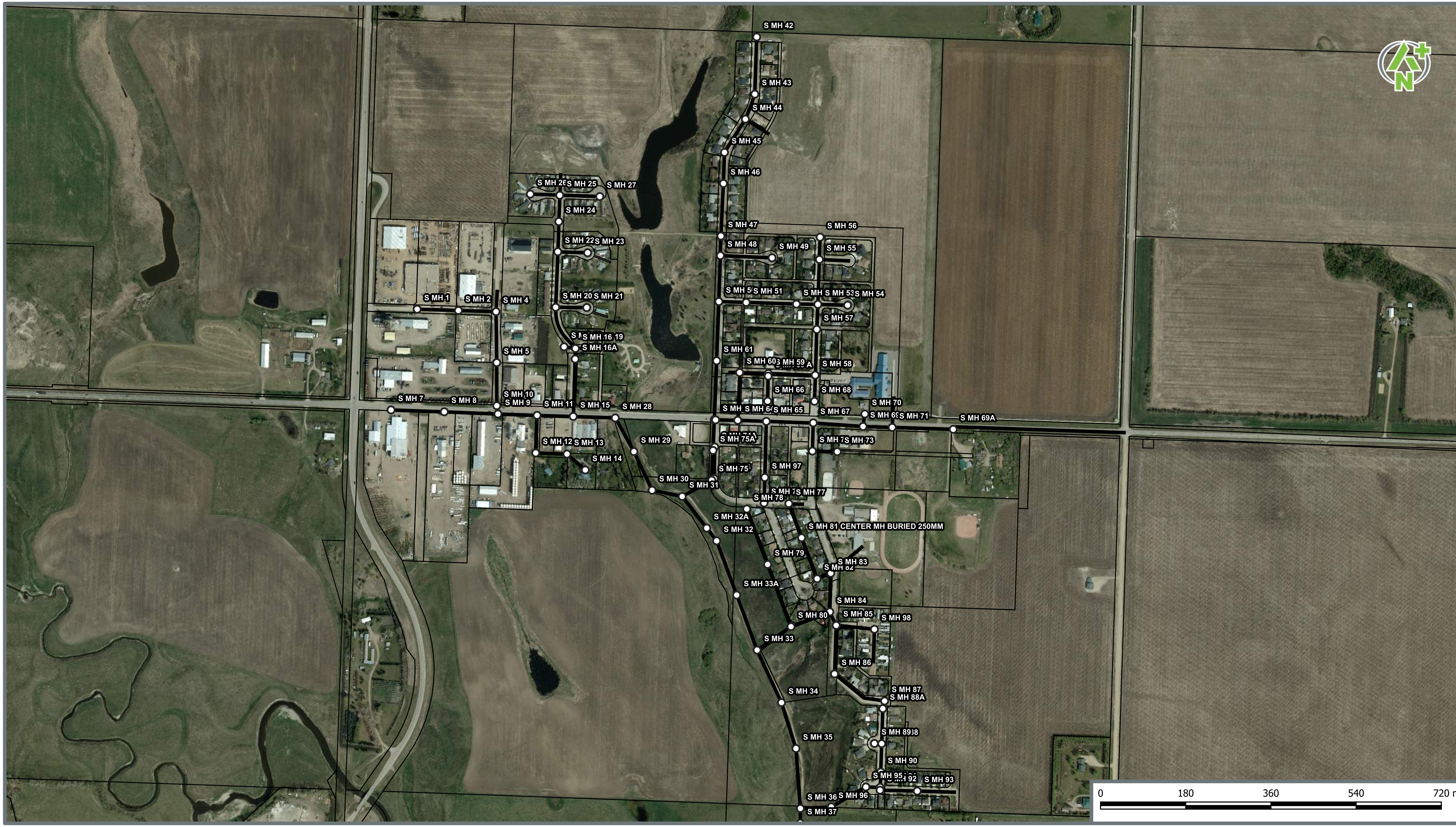

Figure S1 - Existing Sanitary System (Manhole Names)

Scale 1:7,500

Existing Manholes

Existing Sanitary Pipes

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Figure S2 - Existing Sanitary System (Manhole Names and Lagoon)

Scale 1:3,000

CIMA+

Existing Manholes

Existing Sanitary Pipes

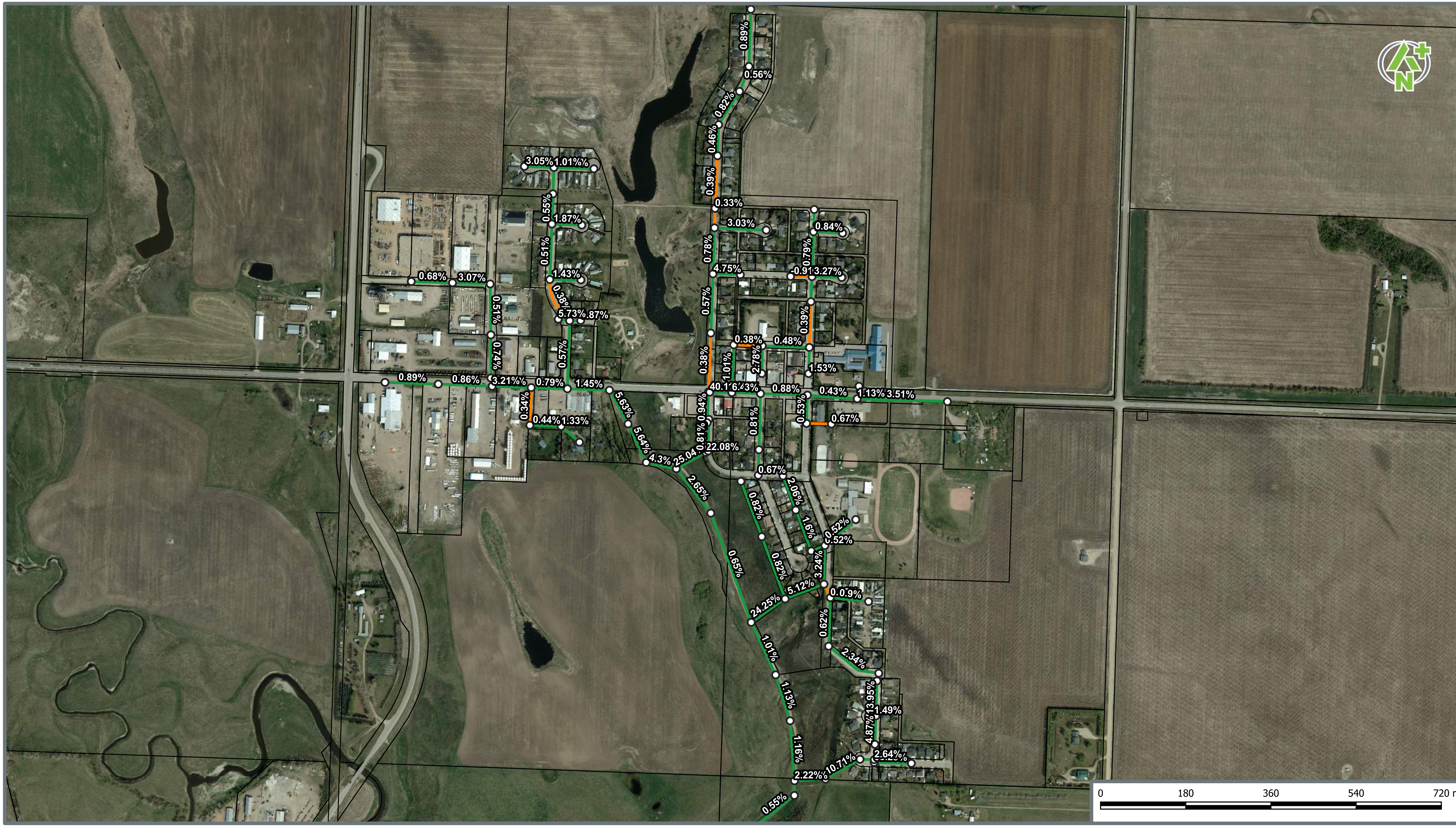

Figure S3 - Pipe Slopes of Sanitary Lines

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- Existing Manholes
- Greater Than Minimum Slope
- Does Not Meet Minimum Slope
- Negative Slope

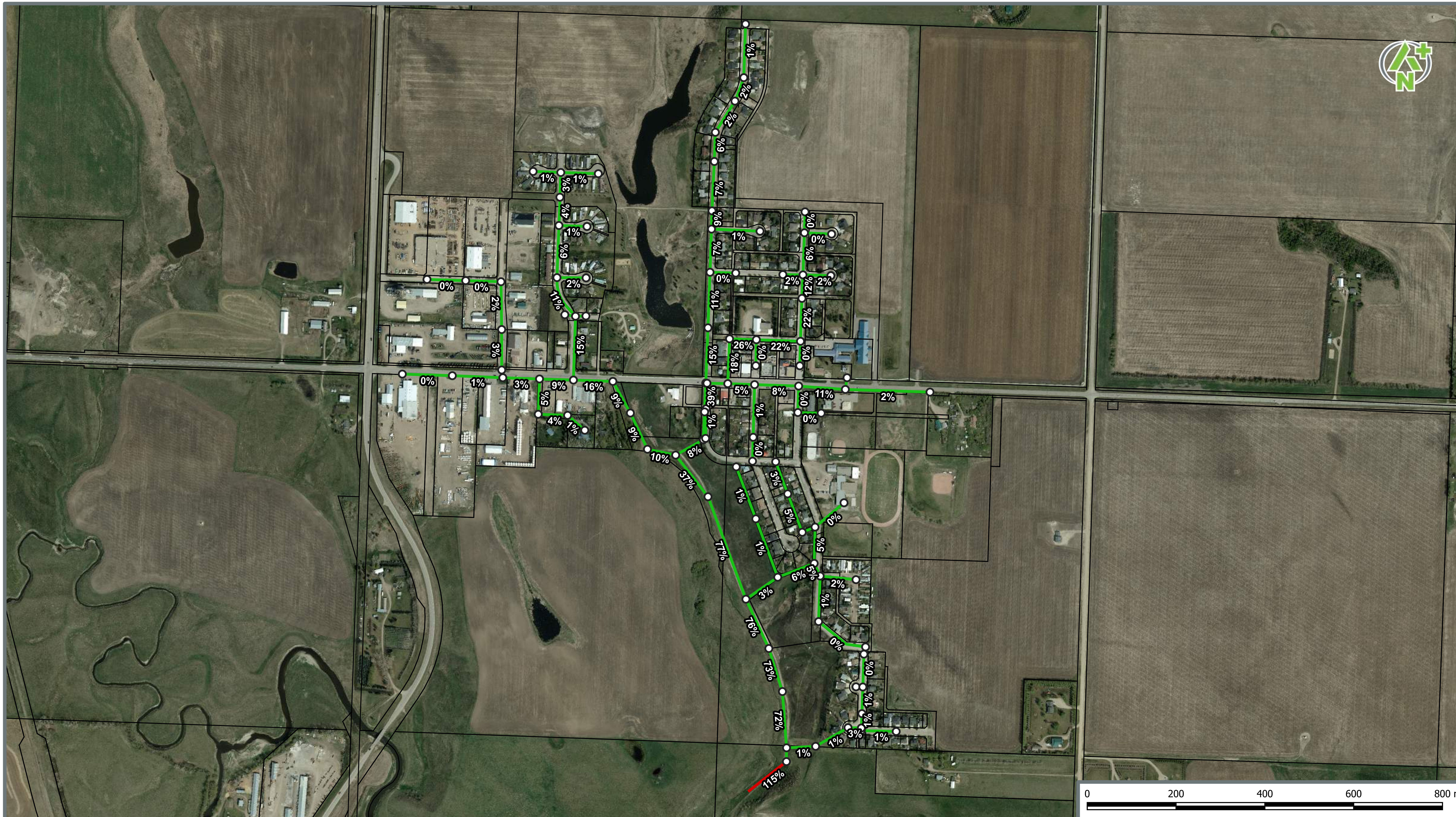

Figure S4 - Existing System Model Results (Percentage of Pipe Capacity vs Flow)

Scale 1:8,000

- Existing Manholes
- Pipe Capacity of 0% to 86%
- Pipe Capacity >86% and <100%
- Pipe Capacity >100%

PREPARED FOR VILLAGE OF LINDEN UMP 2021

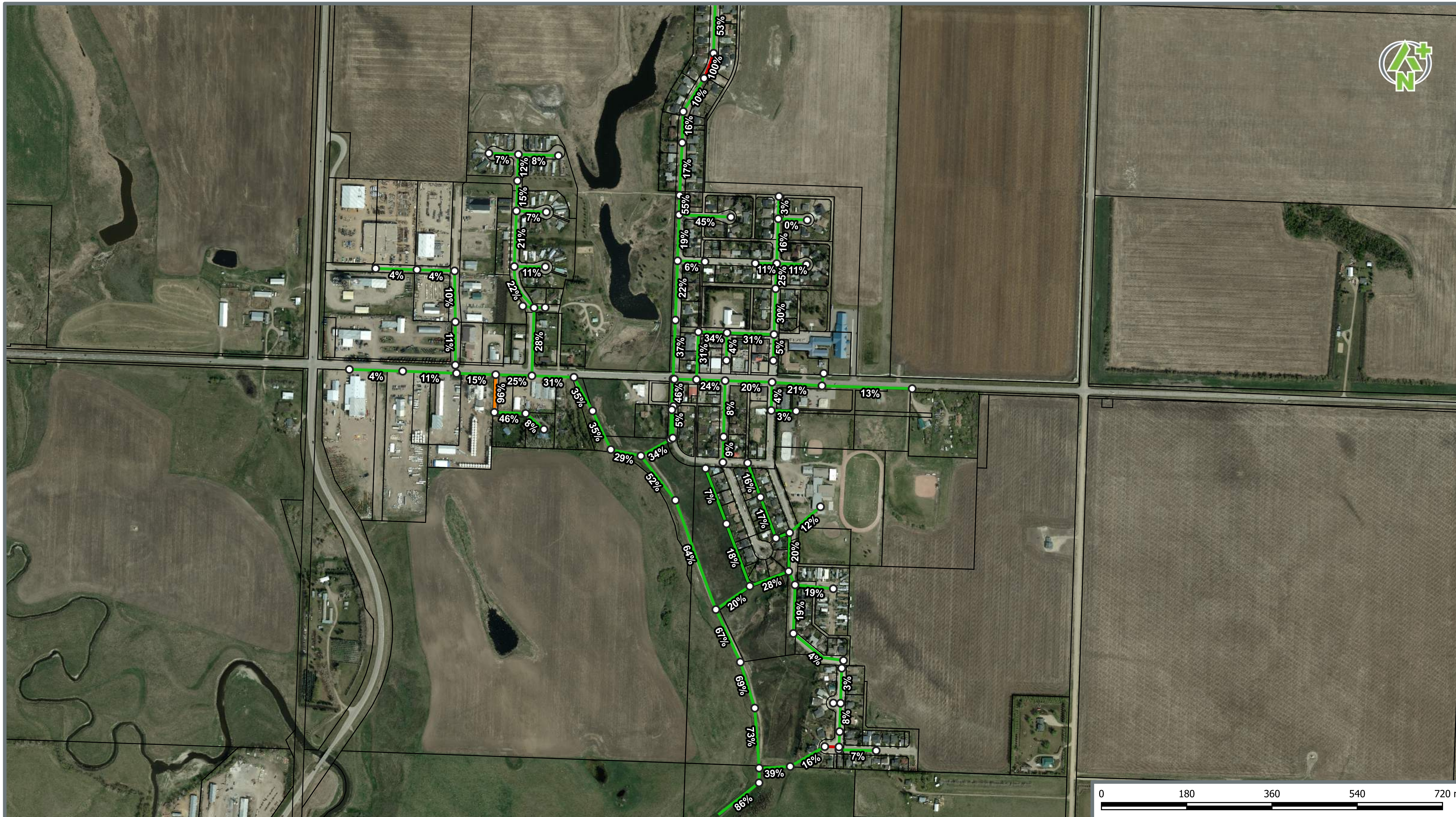

Figure S5 - Existing System Model Results (Percentage of Hydraulic Grade Line vs Pipe Depth)

Scale 1:7,500

- Existing Manholes
- HGL of 0%-90% of Pipe
- HGL of 90%-100% of Pipe
- HGL of >100% of Pipe

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

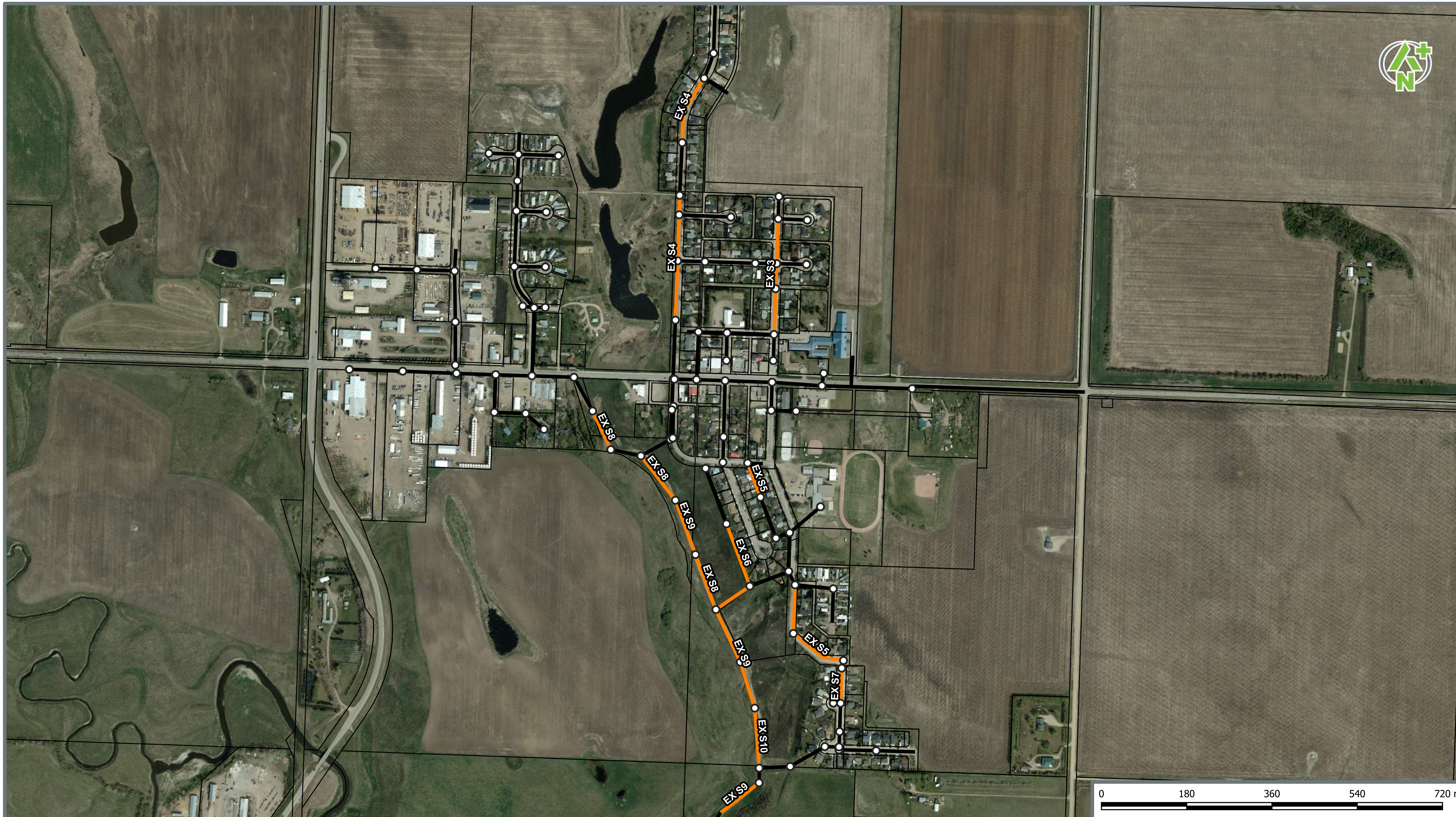

Figure S6 - Existing System Proposed Upgrades

Scale 1:7,500

CIMA+

Existing Manholes
Proposed Upgrades
Sanitary Lines

PREPARED FOR VILLAGE OF LINDEN UMP 2021

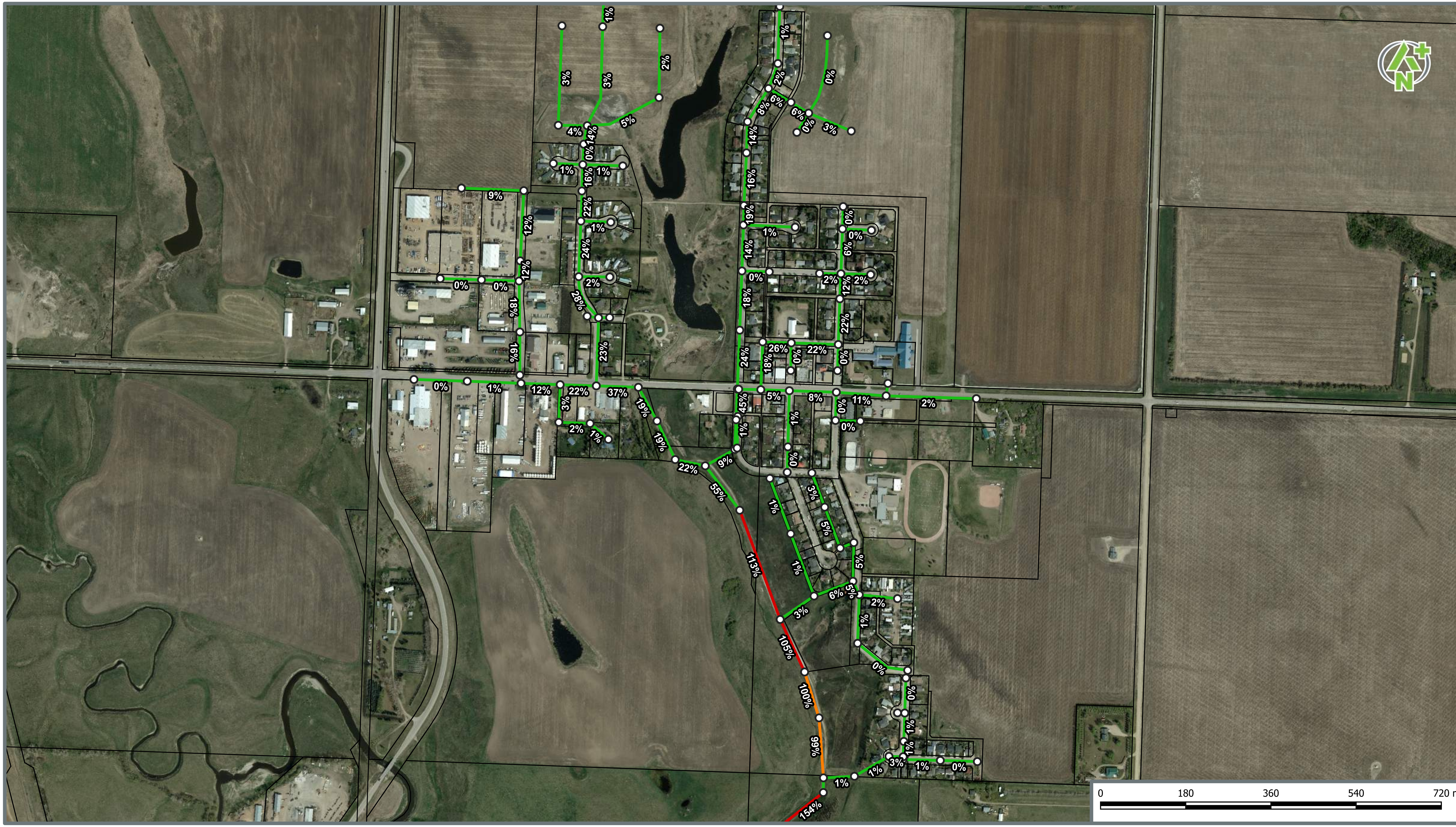

Figure S7 - 20 Year System Model Results - Original Pipes (Percentage of Pipe Capacity vs Flow)

Scale 1:4,000

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Existing Manholes
Pipe Capacity of 0% to 86%
Pipe Capacity >86% and <100%
Pipe Capacity >100%

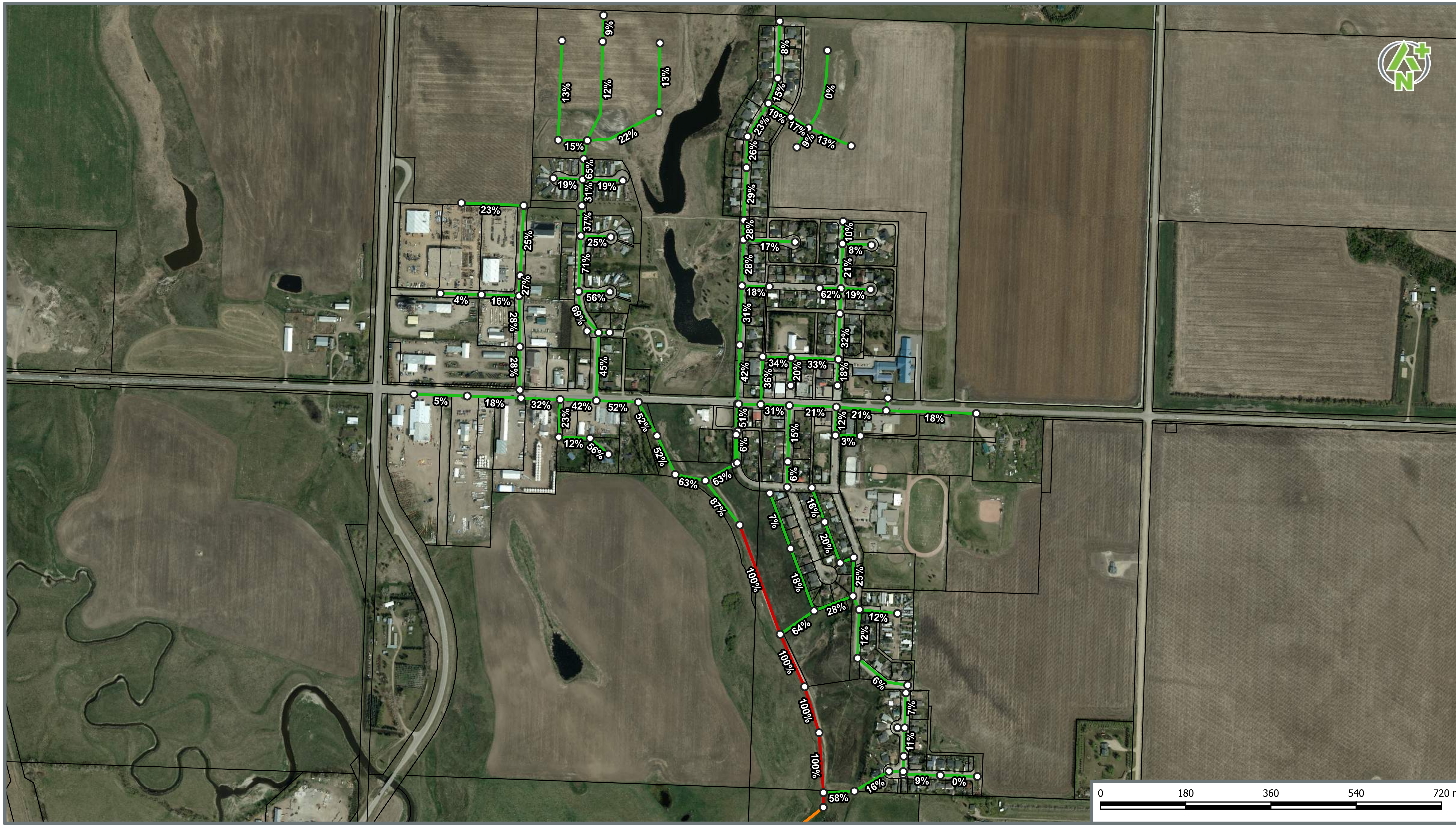

Figure S8 - 20 Year System Model Results - Original Pipes (Percentage of Hydraulic Grade Line vs Pipe Depth)

Scale 1:7,500

- Existing Manholes
- HGL of 0%-90% of Pipe
- HGL of 90%-100% of Pipe
- HGL of >100% of Pipe

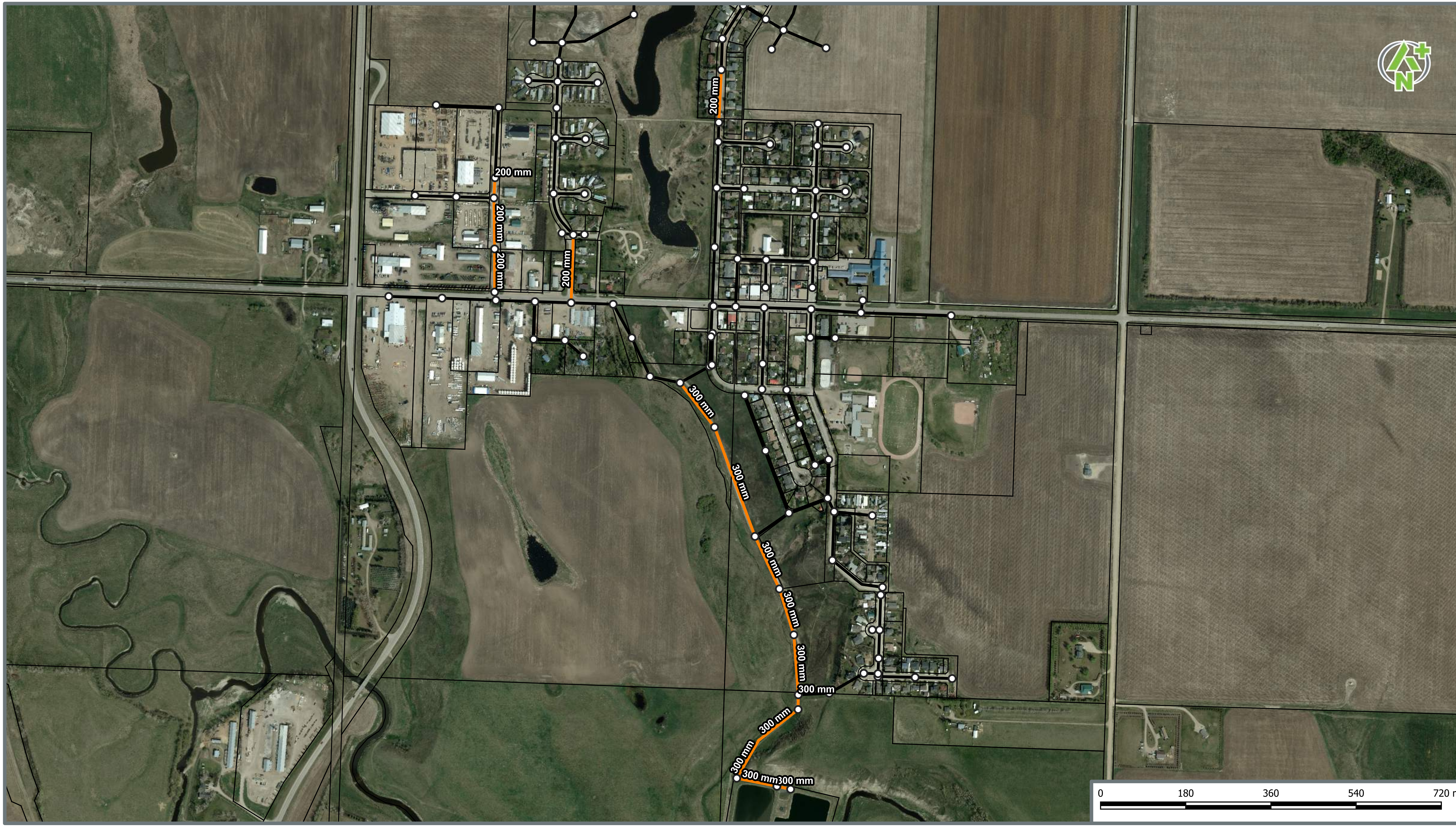

Figure S9 - 20 Year System Proposed Upgrades

Scale 1:7,500

CIMA+

Existing Manholes
Proposed Upgrades
Sanitary Lines

PREPARED FOR VILLAGE OF LINDEN UMP 2021

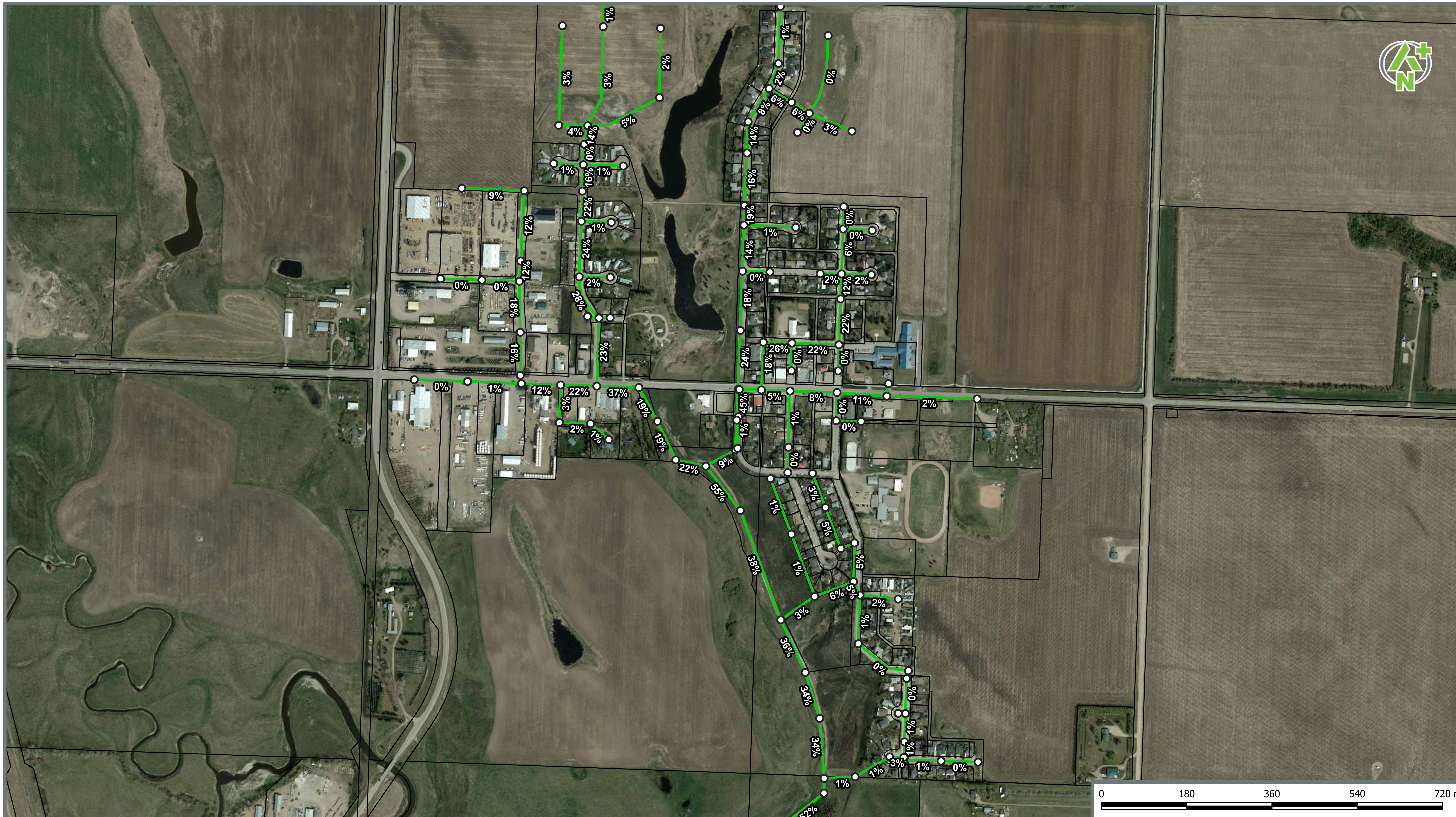

Figure S10 - 20 Year System Model Results - Upgraded Pipes (Percentage of Pipe Capacity vs Flow)

Scale 1:7,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- Existing Manholes
- Pipe Capacity of 0% to 86%
- Pipe Capacity >86% and <100%
- Pipe Capacity >100%

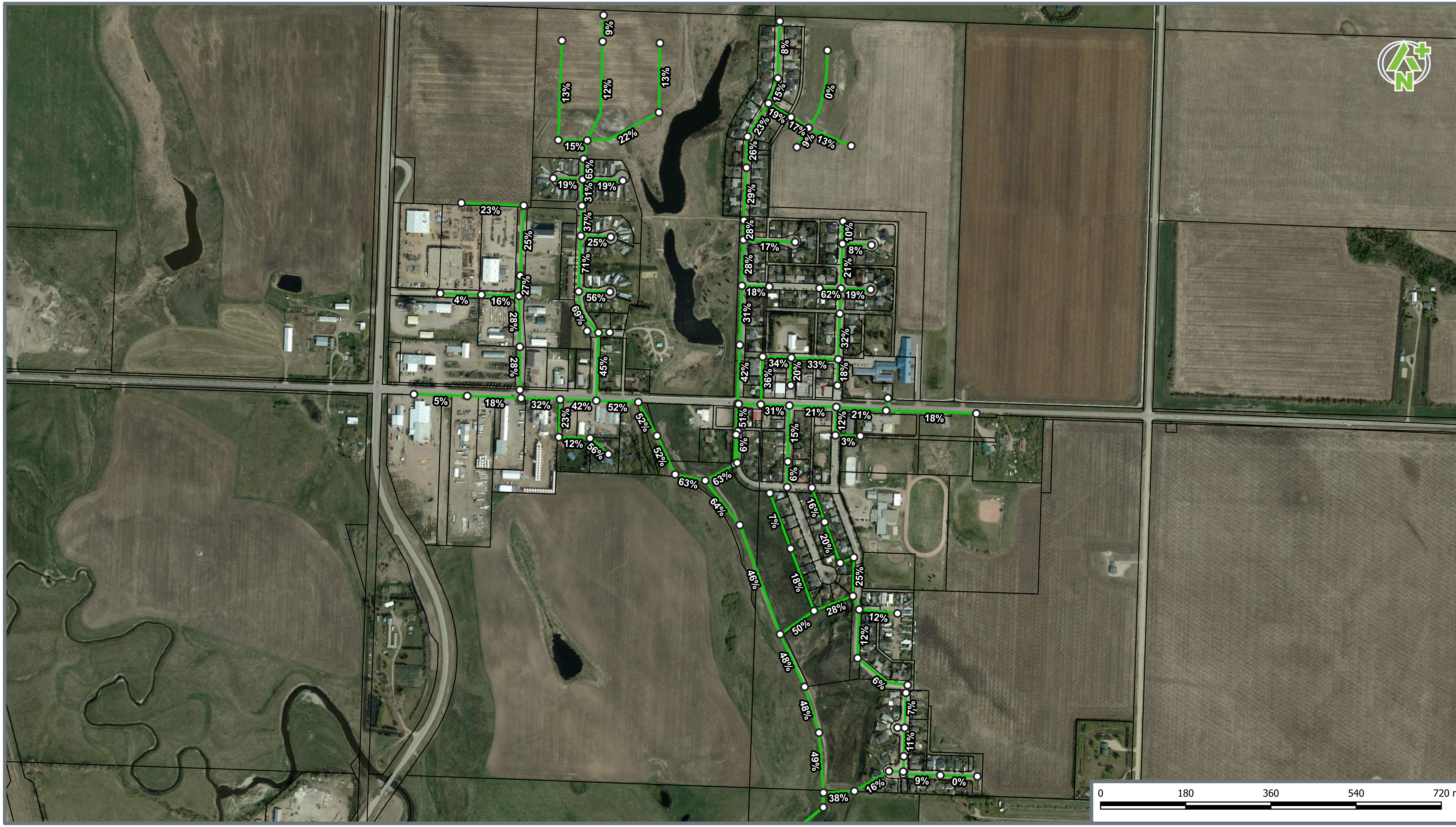

Figure S11 - 20 Year System Model Results - Upgraded Pipes (Percentage of Hydraulic Grade Line vs Pipe Depth)

Scale 1:7,500

CIMA+

Existing Manholes
HGL of 0%-90% of Pipe
HGL of 90%-100% of Pipe
HGL of >100% of Pipe

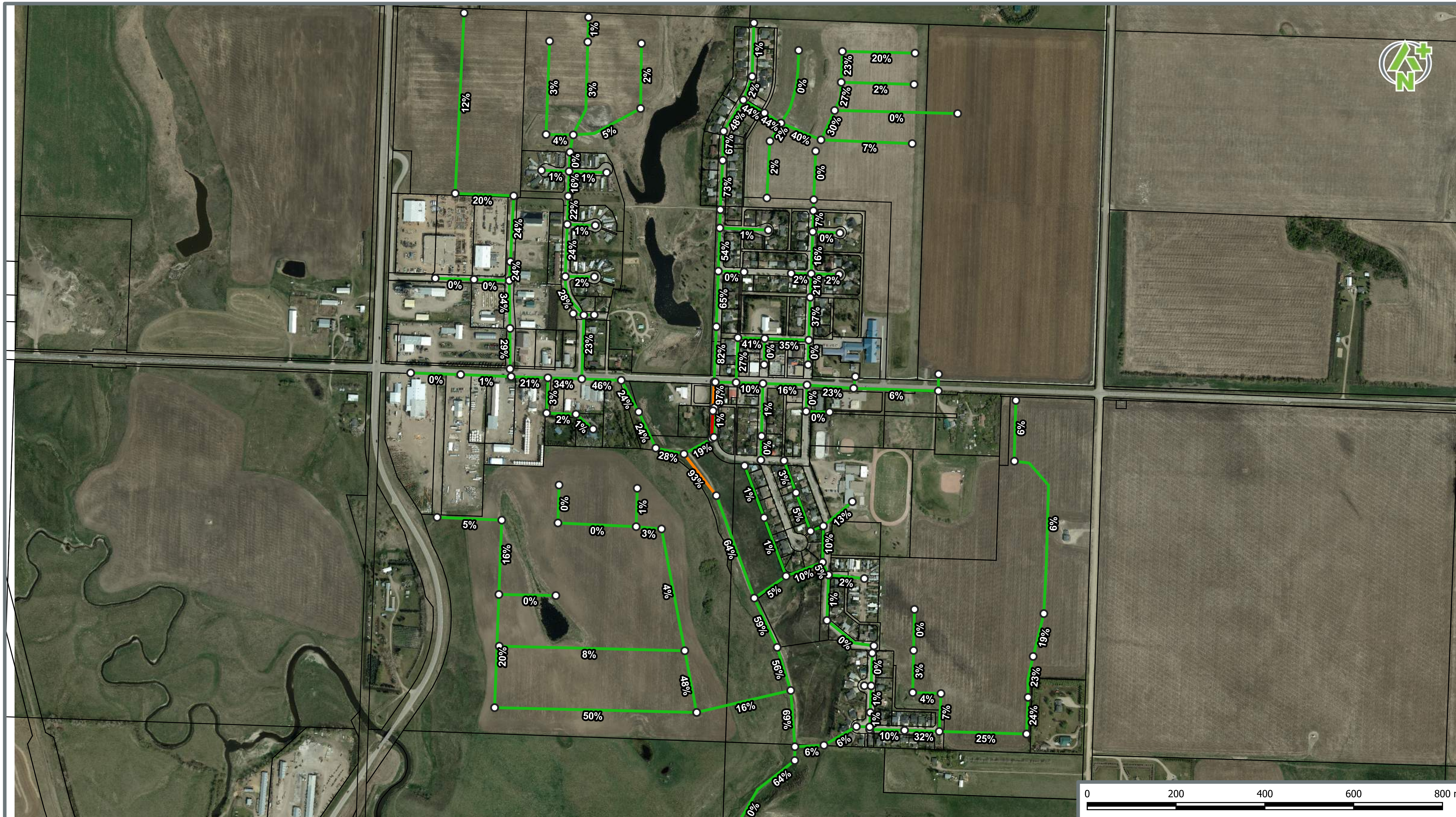

Figure S12 - Full Buildout System Model Results (Percentage of Pipe Capacity vs Flow)

Scale 1:8,000

- Existing Manholes
- Pipe Capacity of 0% to 86%
- Pipe Capacity >86% and <100%
- Pipe Capacity >100%

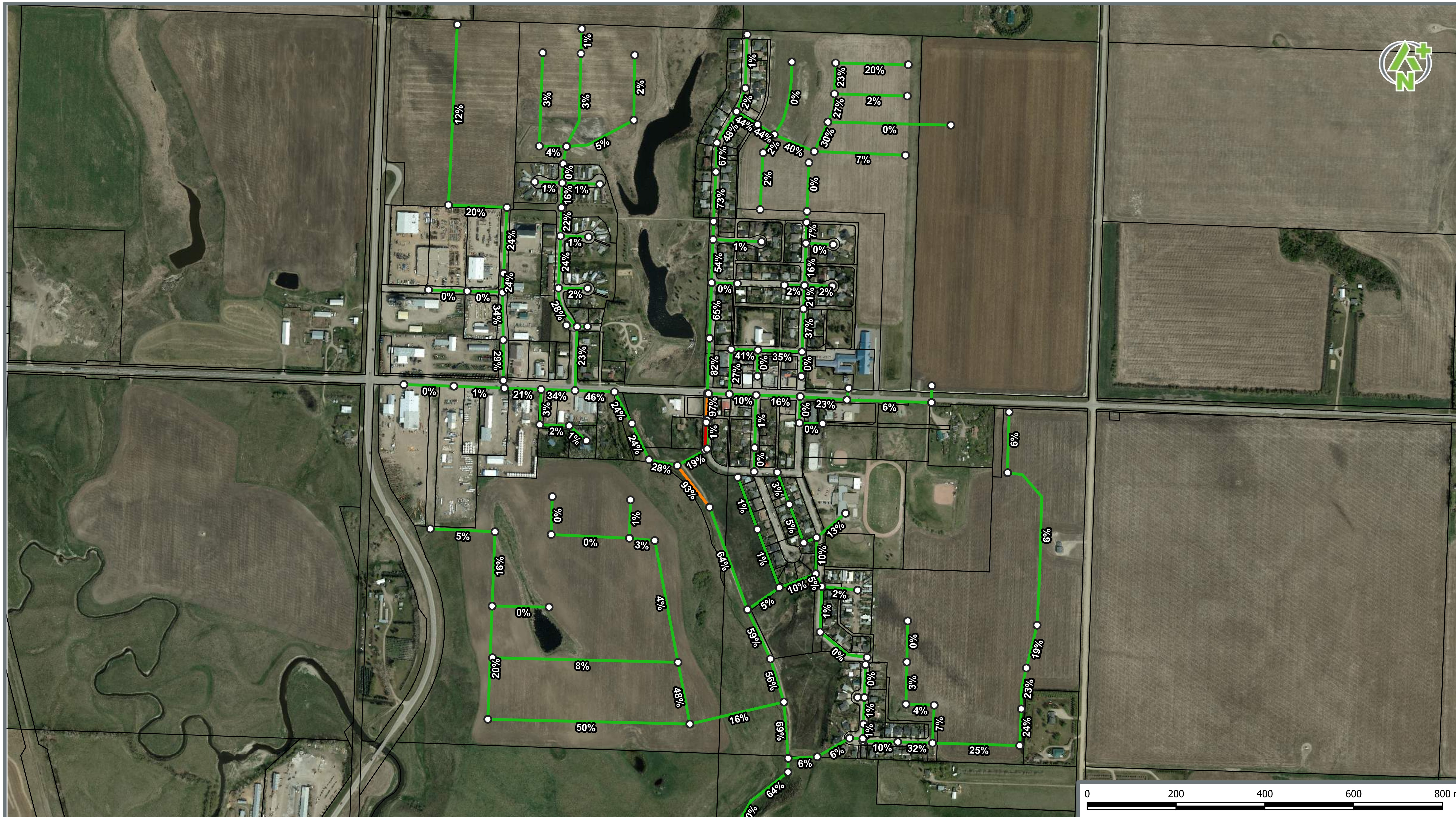

Figure S13 - Full Buildout System Model Results (Percentage of Hydraulic Grade Line vs Pipe Depth)

Scale 1:8,000

- Existing Manholes
- HGL of 0%-90% of Pipe
- HGL of 90%-100% of Pipe
- HGL of >100% of Pipe

PREPARED FOR VILLAGE OF LINDEN UMP 2021

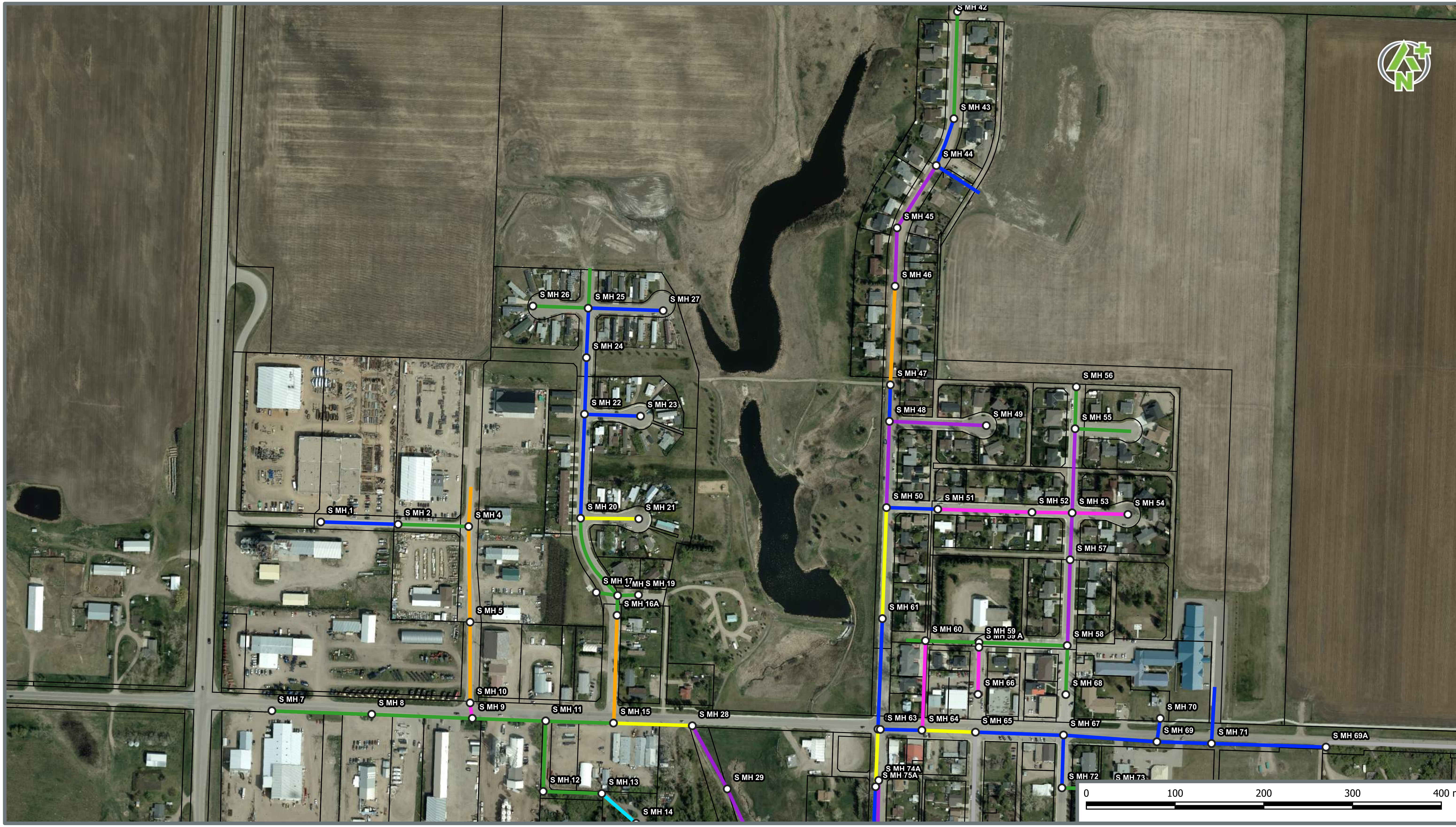

Figure S14A - CCTV Results

Scale 1:4,000

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Existing Manholes
Good Condition
Operational / Maintenance Issues
Minor Issues (Sags, Ovaling)
Moderate Issues (Sags, Ovaling)
Moderate Lining Repairs
Severe Lining Repairs
Moderate (Requires Replacement)
Severe (Requires Replacement)
Not Surveyed

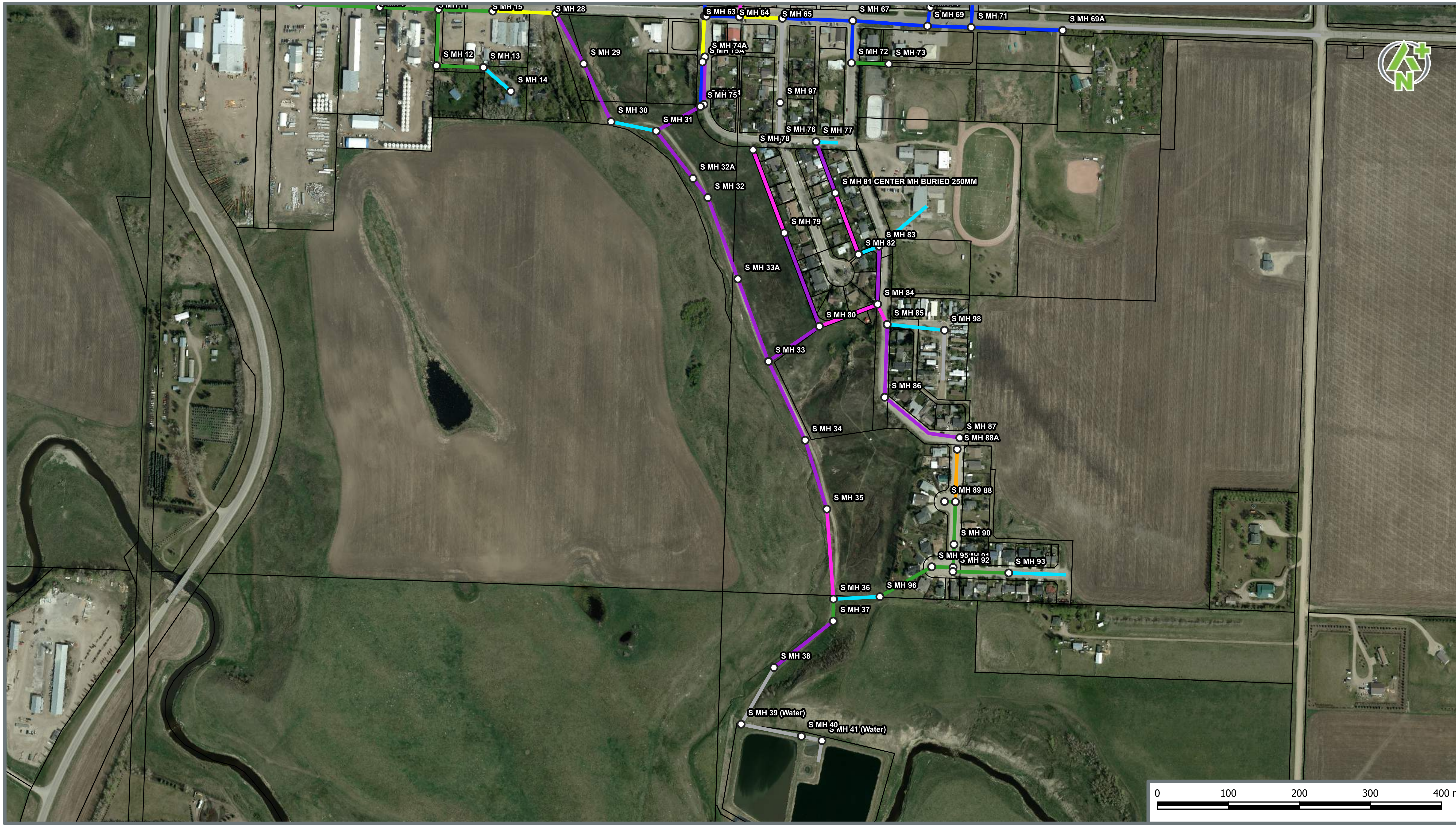

Figure S14B - CCTV Results

Scale 1:5,000

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- Existing Manholes
- Good Condition
- Operational / Maintenance Issues
- Minor Issues (Sags, Ovaling)
- Moderate Issues (Sags, Ovaling)
- Moderate Lining Repairs
- Severe Lining Repairs
- Moderate (Requires Replacement)
- Severe (Requires Replacement)
- Not Surveyed

C

Appendix C
Storm Infrastructure Figures

Figure ST1A - Existing Storm System

Scale 1:4,000

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Storm Manholes	375 mm Culverts	750 mm Culverts	375 mm Storm Pipes	750 mm Storm Pipes
Catchbasins	400 mm Culverts	1500 mm Culverts	450 mm Storm Pipes	
Outfalls	450 mm Culverts	250 mm Storm Pipes	525 mm Storm Pipes	
	600 mm Culverts	300 mm Storm Pipes	600 mm Storm Pipes	

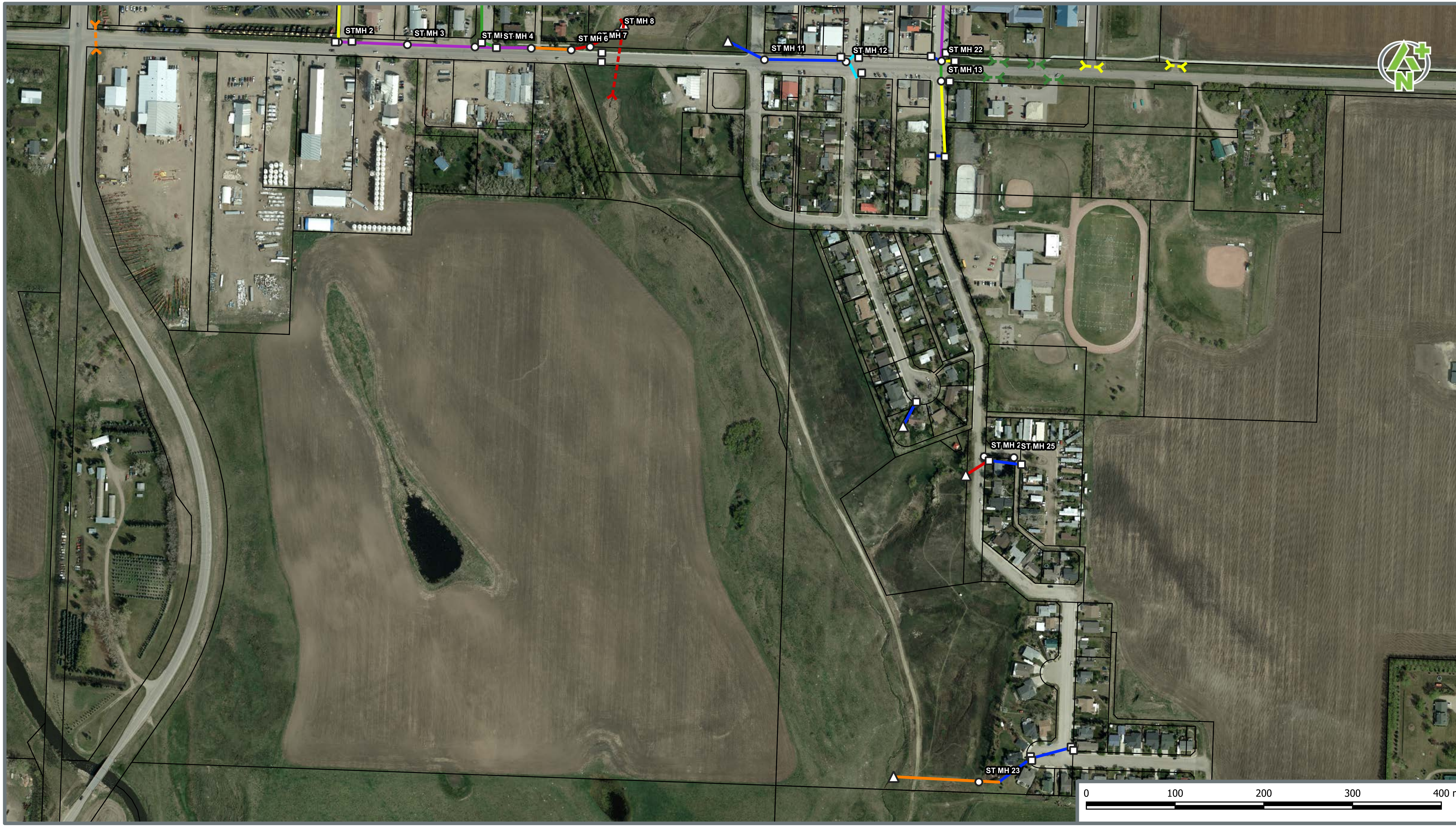

Figure ST1B - Existing Storm System

Scale 1:4,000

○	Storm Manholes	375 mm Culverts	750 mm Culverts	375 mm Storm Pipes	750 mm Storm Pipes
□	Catchbasins	400 mm Culverts	1500 mm Culverts	450 mm Storm Pipes	
△	Outfalls	450 mm Culverts	250 mm Storm Pipes	525 mm Storm Pipes	
		600 mm Culverts	300 mm Storm Pipes	600 mm Storm Pipes	

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

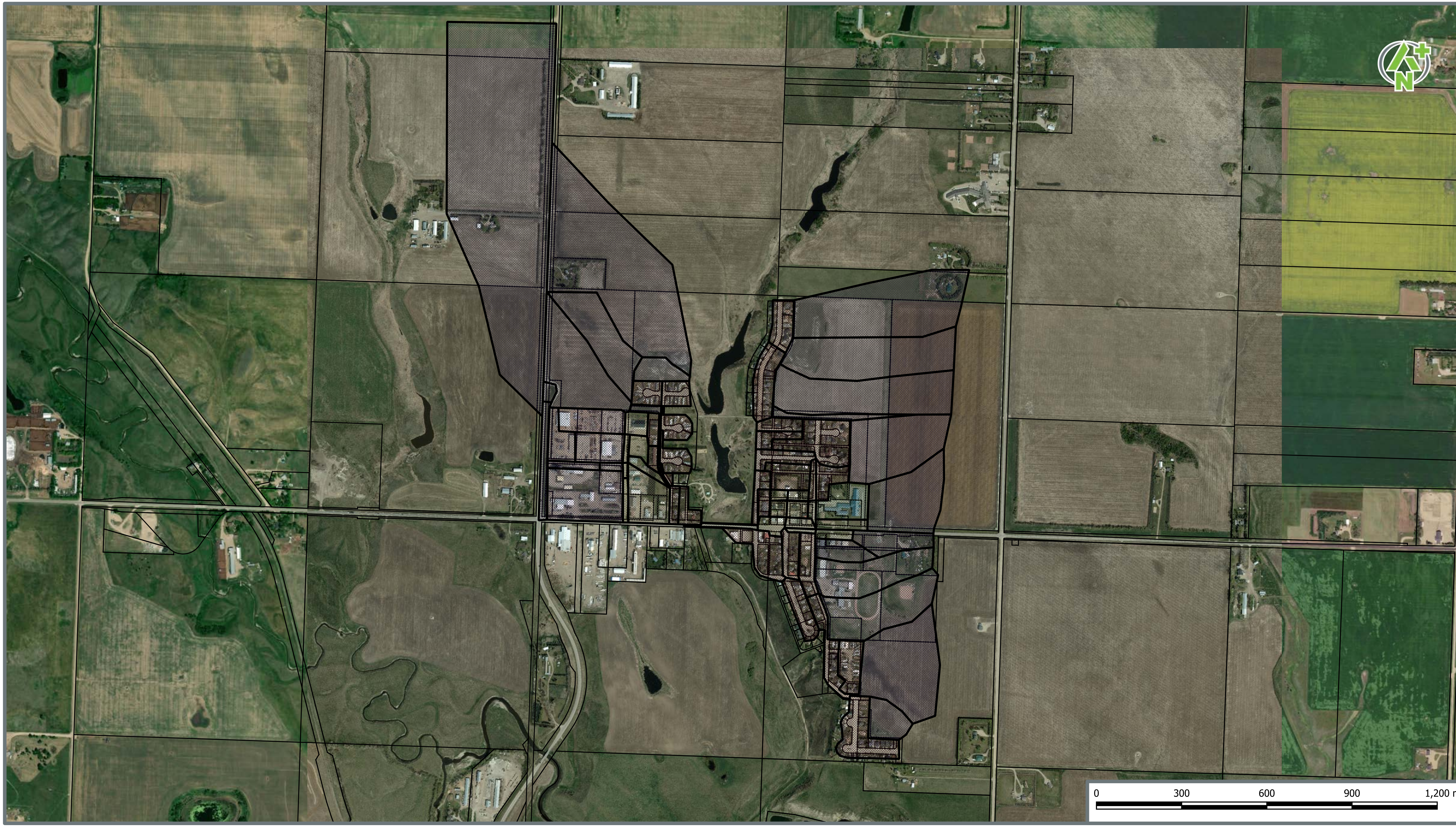

Figure ST2 - Storm System Drainage Boundary

Scale 1:12,500

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Agricultural and Natural Lands
Commercial Lands
Industrial lands
Residential Lands
Instititutional Lands

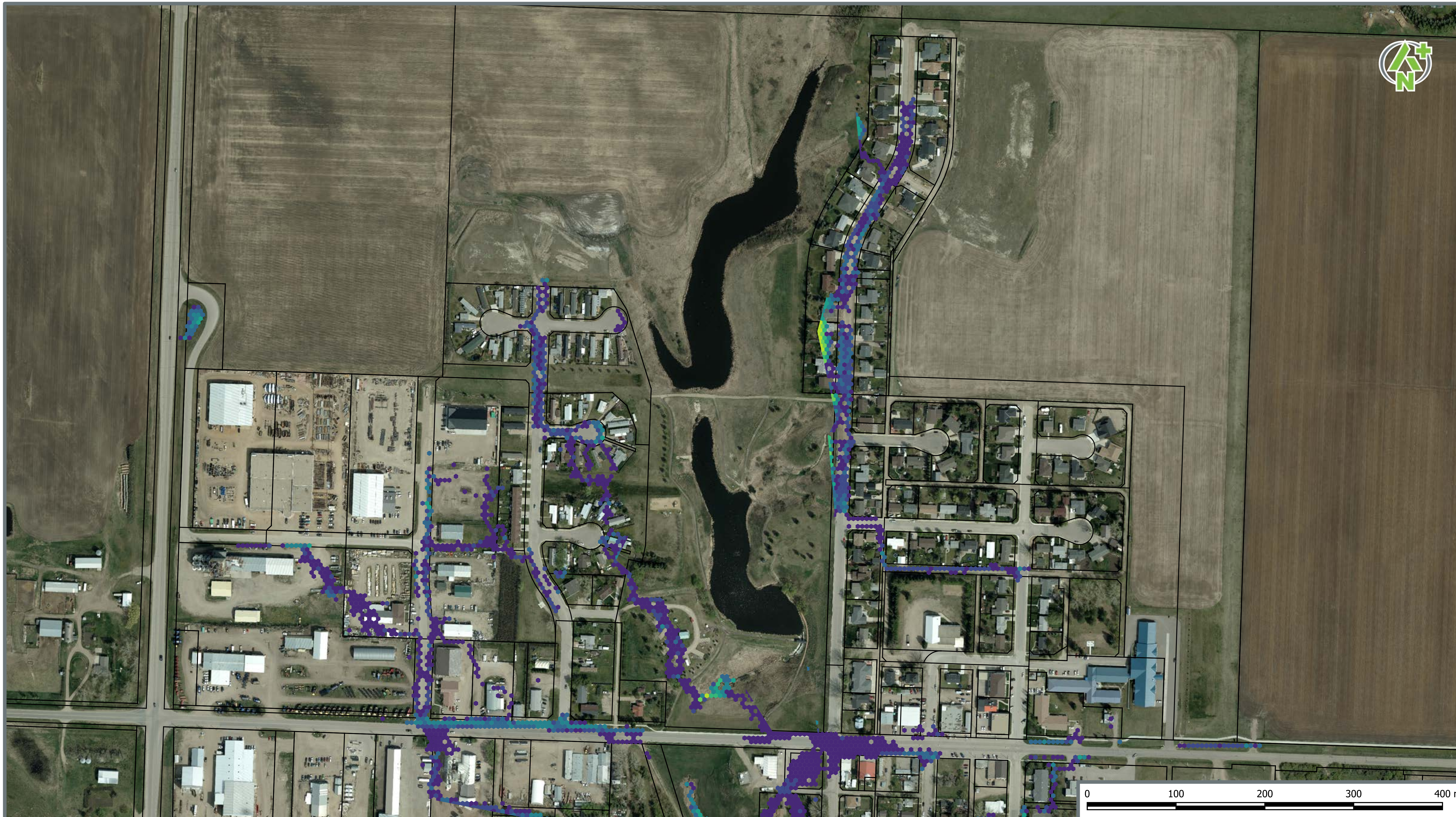

Figure ST3A - Storm System Model Results (2D Simulation, 1:100 Year Storm Event)

Scale 1:4,000

2D Cells Showing Max Water Depth (m)

0 - 0.02
0.02 - 0.05
0.05 - 0.11
0.11 - 0.2
0.2 - 0.37
0.37 - 0.52
0.52 - 0.74
0.74 - 1.37
1.37 - 1.6

PREPARED FOR VILLAGE OF LINDEN UMP 2021

Figure ST3B - Storm System Model Results (2D Simulation, 1:100 Year Storm Event)

Scale 1:4,000

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

2D Cells Showing Max Water Depth (m)

0 - 0.02
0.02 - 0.05
0.05 - 0.11
0.11 - 0.2
0.2 - 0.37
0.37 - 0.52
0.52 - 0.74
0.74 - 1.37
1.37 - 1.6

D

Appendix D
Road Assessment Figures

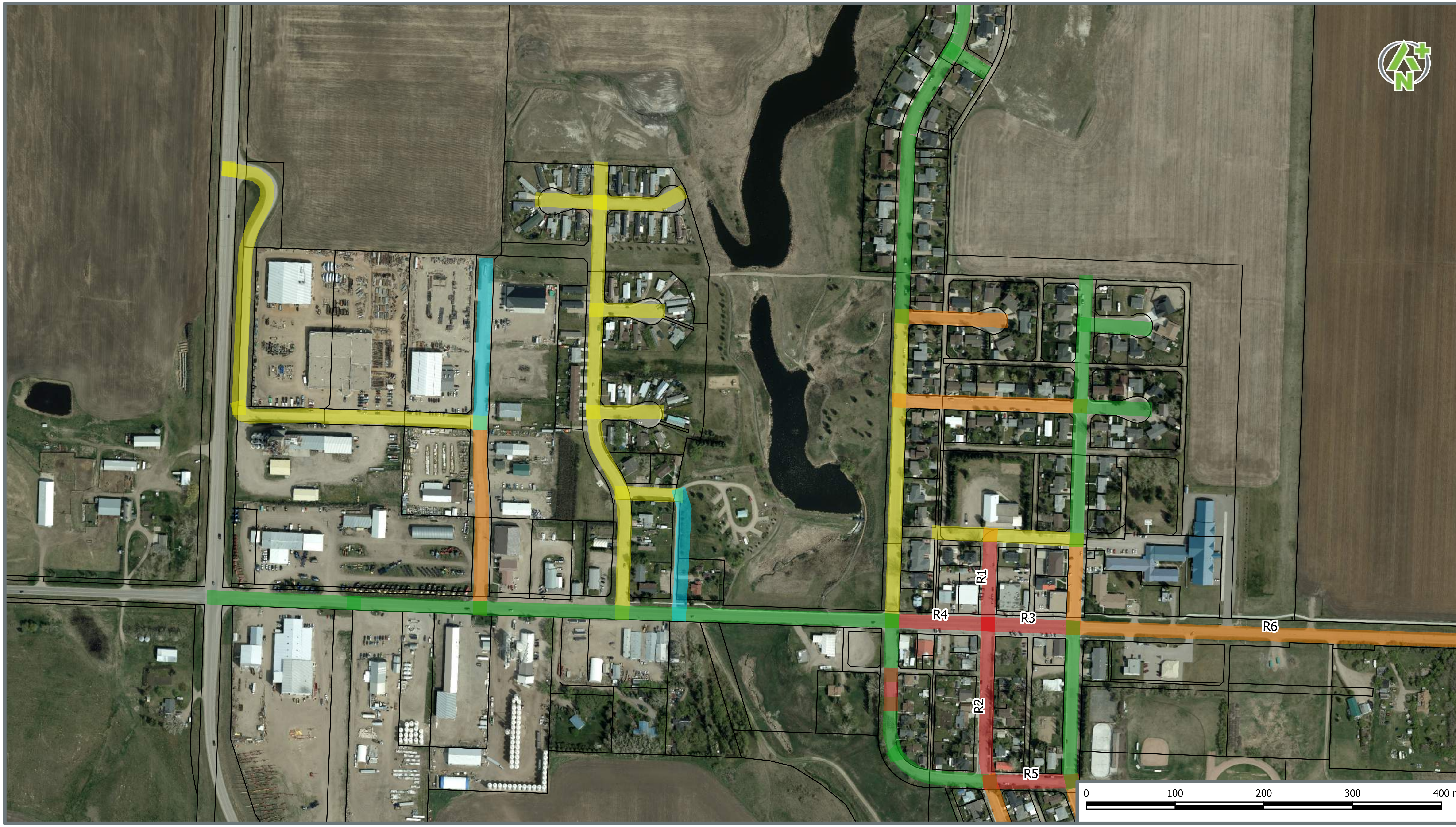

Figure R1 - Roads Condition Assessment

Scale 1:4,000

CIMA+

PREPARED FOR VILLAGE OF LINDEN UMP 2021

- Good
- Fair
- Poor to Fair
- Very Poor to Poor

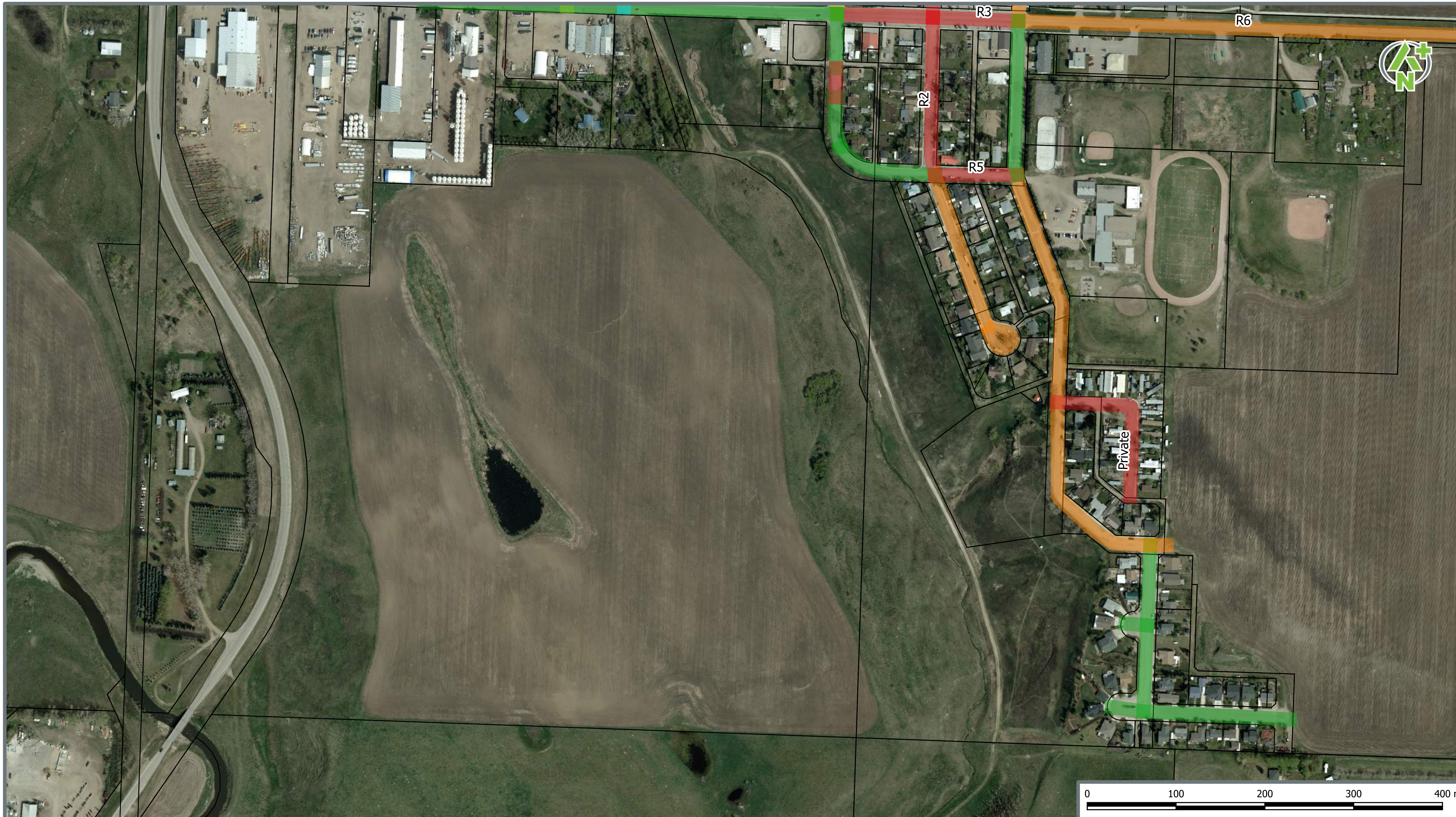

Figure R2 - Roads Condition Assessment

Scale 1:4,000

- Good
- Fair
- Poor to Fair
- Very Poor to Poor

PREPARED FOR VILLAGE OF LINDEN UMP 2021

E

Appendix E
SFE Hydrant Flow Tests

Final Report for
CIMA+

Attn: **Jamie Purdy, C.E.T. -** Senior Technician / Infrastructure

Linden, Alberta
Fire Hydrant Flow Testing
October 2020

Prepared and submitted by:

SFE Global
10707 - 181th Street
Edmonton, Alberta T5S 1N3
Phone (780) 461-0171 Fax (780) 443-4613
Toll Free: 1-877-293-0173

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British Columbia Head Office
#201 – 26641 Fraser Hwy
Aldergrove, British Columbia V4W 3L1
Ph (604) 856-2220 *Fx* (604) 856-3003

November 27, 2020

Jamie Purdy, C.E.T.
Senior Technician / Infrastructure

CIMA +
300, 6815 - 8 Street NE
Calgary, Alberta
T2E 7H7

FINAL REPORT: 2020 Fire Hydrant Flow Testing, Linden, Alberta

Dear Mr. Purdy;

Please find enclosed SFE's Final Report for the above mentioned project. If you have any questions, comments or concerns, please do not hesitate to contact us at your earliest convenience.

Thank you for having SFE conduct this work on your behalf. We are appreciative of the opportunity to work with you and your team on this project. We look forward to working together again in the near future.

Sincerely,
SFE Global

Kevin McMillan
Vice President
(780) 461-0171
Kevin.McMillan@sfeglobal.com
www.sfeglobal.com

1. Executive Summary

This report provides details of the hydrant fire flow testing conducted in Linden, Alberta. SFE Global was retained by CIMA+ under the direction of Mr. Jamie Purdy, C.E.T.. Kevin McMillan represented SFE Global as Project Manager during this project.

As requested, SFE conducted five fire hydrant fire flow tests on October 27th, 2020. The flow hydrants and test hydrants were indicated to SFE by maps supplied by the client. The fire flow tests were conducted according to National Fire Protection Association (NFPA) 291 standards.

2. Summary of Testing

SFE Technicians met representatives of the Village of Linden on-site to perform testing. The testing plan was discussed and location maps reviewed by all participants.

Testing Equipment

Testing was performed on flow hydrants utilizing a Hydro Flow Products 2-1/2" Hose Monster system with integral de-chlorinator. These are fixed pitot devices to measure flow, de-chlorinate and diffuse in one process. The benefit of this system is the ability to provide repeatable results and manage discharge water conditions.

The configuration for the Hose Monster System consisted of one 2-1/2" hose monster on the Flow hydrant 2-1/2" port. To digitally log pressure on the residual hydrant SFE Technicians installed one (2) Telog HPR hydrant pressure loggers. This device was set to ten second logging intervals and one second sampling intervals. Each interval logs the minimum, maximum and average pressure for that time stamp.

Testing Procedure

The client selected all flow and residual hydrants for each test. SFE Technicians installed flow testing equipment on each flow hydrant and residual pressure measurement equipment on the residual hydrant.

The tests were performed by recording system static pressure then flowing the hydrant until fire pumps activated and flow and pressure stabilized. Residual and pitot(flow) pressures were then obtained. Upon closure of the flow hydrant, static pressure was obtained to determine actual fire pump static pressure. Total flow and extrapolated flow to 20 psi residual pressure are calculated with all pumps running and using fire pump static pressure.

Flow testing summary sheets are included in Appendix I.

3. Data

The testing reports included in Appendix I contain all test results and photos. All pressure readings are in psi and all flow values are reported in IGPM. All hydrants were returned to as found condition upon completion of testing.

4. Safety

A pre-job safety inspection and meeting was conducted by SFE personnel, and the following potential hazards were identified:

- Need for Personal Protective Equipment
- Working with water under pressure
- Pedestrian and vehicular traffic conditions
- Safe operation and shut down of fire hydrants
- COVID-19 Precautions

This project was conducted in accordance with the WCB and OSHA safety standards as documented in SFE's Safety Procedures Manual. The SFE crew reviewed the work to be completed and safety requirements at a tail-gate safety meeting held prior to commencing work.

Report End
November 2020

SFE Global
Project A20-159

Appendix I

Test Results

Final Report

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	System Pressure	Water Plant
Project Location:	Linden, AB	Hyd 2 - #/Port Size		System Pressure	Central Ave and 4th Street
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: System Pressure   Test :   of   Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi

Flow Summary (igpm)	
Flow 1-1	
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	0
Flow @ 20 psi	#NUM!

Notes:

System Pressure 1

GPS 51.5907 -113.4821

Flow Hydrant 2

GPS

System Pressure 2

GPS 51.5908 -113.4902

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	Flow Hyd 1 Addr	5th St and 300 Picci Ct.
Project Location:	Linden, AB	Hyd 2 - #/Port Size		Flow Hyd 2 Addr	
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	200 Picci Ct.
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: 1 Test : 1 of 5 Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi
11:10	11:12	9				75	28	75

Flow Summary (igpm)	
Flow 1-1	420
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	420
Flow @ 20 psi	457

Notes: Residual hydrant hard to turn.
Starting static pressure 70 psi.

Flow Hydrant 1

GPS 51.5949 -113.4914

Flow Hydrant 2

GPS

Residual Hydrant

GPS 51.5938 -113.4914

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	Flow Hyd 1 Addr	Central Ave Linden Ag
Project Location:	Linden, AB	Hyd 2 - #/Port Size		Flow Hyd 2 Addr	
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	Central Ave and 6th St.
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: 2 Test : 2 of 5 Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi
11:29	11:31	10.5				84	37	84

Flow Summary (igpm)	
Flow 1-1	457
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	457
Flow @ 20 psi	540

Notes:
Starting static pressure 74 psi.

Flow Hydrant 1

GPS 51.5908 -113.4962

Flow Hydrant 2

GPS

Residual Hydrant

GPS 51.5908 -113.4931

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	Flow Hyd 1 Addr	505 1st St.
Project Location:	Linden, AB	Hyd 2 - #/Port Size		Flow Hyd 2 Addr	
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	413 1st St.
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: 3   Test : 3 of 5   Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi
11:53	11:55	8				67	40	67

Flow Summary (igpm)	
Flow 1-1	404
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	404
Flow @ 20 psi	545

Notes: Chosen residual hydrant siezed, picked alternate.
Starting static pressure 66 psi.

Flow Hydrant 1

GPS 51.5971 -113.4856

Flow Hydrant 2

GPS

Residual Hydrant

GPS 51.5945 -113.4866

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	Flow Hyd 1 Addr	180 Centre St.
Project Location:	Linden, AB	Hyd 2 - #/Port Size		Flow Hyd 2 Addr	
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	Hockey Rink
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: 4 Test : 4 of 5 Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi
12:11	12:12	10				62	37	60

Flow Summary (igpm)	
Flow 1-1	444
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	444
Flow @ 20 psi	588

Notes: Chosen residual hydrant hard to turn.
Starting static pressure 60 psi.

Flow Hydrant 1

GPS 51.5884 -113.4844

Flow Hydrant 2

GPS

Residual Hydrant

GPS 51.5892 -113.4834

Final Report

Fire Flow Test Report

Client Name:	CIMA+	Hyd 1 - #/Port Size	2-1/2"	Flow Hyd 1 Addr	509 Linview Rd.
Project Location:	Linden, AB	Hyd 2 - #/Port Size		Flow Hyd 2 Addr	
SFE Project #:	A20-159	Hyd 1 - Pito Types	2-1/2" HM	Resid Hyd Addr.	221 Linview Rd.
SFE Technicians:	KM/NS	Hyd 2 - Pito Types		Fire Pump Status	Auto
		Test Procedure	NFPA 291	(circle one)	Force On

Test ID: 5 Test : 5 of 5 Date: 27-Oct-20

		Flow Hyd 1		Flow Hyd 2		Residual Hydrant		
Start Time	End Time	Port 1-1 psi	Port 1-2 psi	Port 2-1 psi	Port 2-2 psi	Static psi	Residual psi	Static psi
12:26	12:28	8				80	31	80

Flow Summary (igpm)	
Flow 1-1	404
Flow 1-2	
Flow 2-1	
Flow 2-2	
Total Flow	404
Flow @ 20 psi	451

Notes:

Starting static pressure 78 psi.

Flow Hydrant 1

GPS 51.5838 -113.479

Flow Hydrant 2

GPS

Residual Hydrant

GPS 51.5838 -113.4811

F

Appendix F
CCTV Assessment

G

Appendix G
Road Assessment Key

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 Ave NW **From:** 5 St NW **To:** Gravel Alley

Segment ID: 37 **Length (m):** ~55m **Width (m):** ~8m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5			X					X		
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking – Longitudinal	Single and Multiple	15		X				X				
Cracking – Transverse	Half, full, and multiple	10				X					X	
Cracking – Centerline	Single and Multiple	5			X					X		
Cracking – Pavement Edge	Single and Multiple	5				X					X	
Cracking – Alligator Cracking		5										
Cracking – Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS					N/A
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 4 Ave SE **From:** 1 St SE **To:** Road End

Segment ID: 36 **Length (m):** ~185m **Width (m):** ~8-10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15					X					X
Surface Defects		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5					X					X
Surface Deformations		Rutting	10				X					X	
Patching and Potholes		Potholes	15					X					X
Patching and Potholes		Patch/Patch Deterioration	5				X						X
Cracking	Longitudinal	Single and Multiple	15										
Cracking	Transverse	Half, full, and multiple	10				X					X	
Cracking	Centerline	Single and Multiple	5										
Cracking	Pavement Edge	Single and Multiple	5			X						X	
Cracking	Alligator Cracking		5				X					X	
Cracking	Block Cracking		7.5					X				X	
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Monowalk on both sides of road
CURBS AND GUTTER				X	C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Linview Rd **From:** Linview Dr **To:** Linview Rd

Segment ID: 35 **Length (m):** ~350m **Width (m):** ~8-12m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15			X					X		
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15			X				X			
	Patch/Patch Deterioration	5		X					X			
Cracking: Longitudinal	Single and Multiple	15			X				X			
Cracking: Transverse	Half, full, and multiple	10			X				X			
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5										
Cracking	Alligator Cracking	5										
Cracking	Block Cracking	7.5			X					X		
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on west side of road
CURBS AND GUTTER			X		C&G sections

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020
Evaluated By: CIMA+

Road Name: 1 St SE
From: Branch Out
To: Linview Dr

Segment ID: 34
Length (m): ~230m
Width (m): ~8-12m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5			X					X		
	Rutting	10			X					X		
Patching and Potholes	Potholes	15			X				X			
	Patch/Patch Deterioration	5					X					X
Cracking: Longitudinal	Single and Multiple	15			X				X			
Cracking: Transverse	Half, full, and multiple	10				X						X
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5			X					X		
Cracking: Alligator Cracking		5			X			X				
Cracking: Block Cracking		7.5				X					X	
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Condition: Minor	Condition: Moderate	Condition: Severe	Notes
SIDEWALKS			X		Monowalk on west side of road
CURBS AND GUTTER			X		C&G sections

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St SE **From:** 1 Ave S **To:** Branch Out

Segment ID: 33 **Length (m):** ~265m **Width (m):** ~8m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15			X					X		
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10			X				X			
Patching and Potholes	Potholes	15					X			X		
	Patch/Patch Deterioration	5					X				X	
Cracking – Longitudinal	Single and Multiple	15			X				X			
Cracking – Transverse	Half, full, and multiple	10	X					X				
Cracking – Centerline	Single and Multiple	5										
Cracking – Pavement Edge	Single and Multiple	5			X					X		
Cracking	Alligator Cracking	5										
Cracking	Block Cracking	7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on west side of road
CURBS AND GUTTER			X		C&G sections

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St SE **From:** Central Ave E **To:** 1 Ave S

Segment ID: 32 **Length (m):** ~170m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15			X					X		
		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10										
Patching and Potholes		Potholes	15				X			X			
		Patch/Patch Deterioration	5				X					X	
Cracking	Longitudinal	Single and Multiple	15										
	Transverse	Half, full, and multiple	10			X				X			
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5			X						X	
	Alligator Cracking		5										
	Block Cracking		7.5										
												Total Deduct	

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Monowalk on west side of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 Ave S **From:** Centre St S **To:** 1 St SE

Segment ID: 31 **Length (m):** ~100m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
Surface Defects	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5				X					X	
Surface Deformations	Rutting	10				X					X	
Patching and Potholes	Potholes	15					X					X
Patching and Potholes	Patch/Patch Deterioration	5					X					X
Cracking - Longitudinal	Single and Multiple	15										
Cracking - Transverse	Half, full, and multiple	10				X					X	
Cracking - Centerline	Single and Multiple	5				X					X	
Cracking - Pavement Edge	Single and Multiple	5					X					X
Cracking	Alligator Cracking	5				X					X	
Cracking	Block Cracking	7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Separate walk on north side of road
CURBS AND GUTTER				X	C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Centre St S **From:** 1 Ave S **To:** Road End

Segment ID: 30 **Length (m):** ~265m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5			X					X		
	Rutting	10										
Patching and Potholes	Potholes	15			X					X		
	Patch/Patch Deterioration	5				X					X	
Cracking – Longitudinal	Single and Multiple	15			X					X		
Cracking – Transverse	Half, full, and multiple	10			X					X		
Cracking – Centerline	Single and Multiple	5					X					X
Cracking – Pavement Edge	Single and Multiple	5					X					X
Cracking – Alligator Cracking		5										
Cracking – Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk and separate on E/W sides of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Centre St S **From:** Central Ave W **To:** 1 Ave S

Segment ID: 29 **Length (m):** ~160m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10			X					X		
Patching and Potholes	Potholes	15				X					X	
	Patch/Patch Deterioration	5				X					X	
Cracking – Longitudinal	Single and Multiple	15				X					X	
Cracking – Transverse	Half, full, and multiple	10				X					X	
Cracking – Centerline	Single and Multiple	5					X					X
Cracking – Pavement Edge	Single and Multiple	5					X					X
Cracking – Alligator Cracking		5										
Cracking – Block Cracking		7.5				X					X	
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk and separate on E/W sides of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St SW **From:** Central Ave W **To:** Centre St S

Segment ID: 28 **Length (m):** ~255m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15			X					X		
		Flushing/Bleeding	2.5			X					X		
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10										
Patching and Potholes		Potholes	15			X			X				
		Patch/Patch Deterioration	5		X					X			
Cracking	Longitudinal	Single and Multiple	15			X					X		
	Transverse	Half, full, and multiple	10			X					X		
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5				X						
	Alligator Cracking		5										
	Block Cracking		7.5										

Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Monowalk on N/E sides of road
CURBS AND GUTTER				X	C&G section

CIMA+

Village of Linden
Roads Assessment - Inspections

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Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NE **From:** 2 Ave N **To:** Road End

Segment ID: 27 **Length (m):** ~145m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15		X						X		
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15			X				X			
	Patch/Patch Deterioration	5					X				X	
Cracking – Longitudinal	Single and Multiple	15		X					X			
Cracking – Transverse	Half, full, and multiple	10		X				X				
Cracking – Centerline	Single and Multiple	5										
Cracking – Pavement Edge	Single and Multiple	5					X					X
Cracking – Alligator Cracking		5										
Cracking – Block Cracking		7.5										
											Total Deduct	

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Monowalk on both sides of road
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NE **From:** 1 Ave N **To:** 2 Ave N

Segment ID: 26 **Length (m):** ~150m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15		X						X		
		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10										
Patching and Potholes		Potholes	15			X			X				
		Patch/Patch Deterioration	5					X				X	
Cracking	Longitudinal	Single and Multiple	15		X					X			
	Transverse	Half, full, and multiple	10		X				X				
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5					X					X
	Alligator Cracking		5										
	Block Cracking		7.5										
													Total Deduct
													PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Monowalk on both sides of road
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NE **From:** Central Ave W **To:** 1 Ave N

Segment ID: 25 **Length (m):** ~95m **Width (m):** ~10-20m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects		Raveling & loss of surface aggregate	15					X					X
		Flushing/Bleeding	2.5			X					X		
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10				X					X	
Patching and Potholes		Potholes	15			X					X		
		Patch/Patch Deterioration	5				X					X	
Cracking	Longitudinal	Single and Multiple	15			X					X		
	Transverse	Half, full, and multiple	10		X					X			
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5				X					X	
	Alligator Cracking		5										
	Block Cracking		7.5										
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Monowalk on both sides of road
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Centre St N **From:** Central Ave W **To:** 1 Ave N

Segment ID: 24 **Length (m):** ~95m **Width (m):** ~10-11.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10				X					X	
Patching and Potholes	Potholes	15					X					X
	Patch/Patch Deterioration	5				X					X	
Cracking: Longitudinal	Single and Multiple	15				X					X	
Cracking: Transverse	Half, full, and multiple	10				X					X	
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5				X					X	
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5				X					X	
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Monowalk on east side of road
CURBS AND GUTTER			X		C&G on east side of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 Ave N **From:** Centre St N **To:** 1 St NE

Segment ID: 23 **Length (m):** ~120m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects		Raveling & loss of surface aggregate	15					X					X
		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10		X				X				
Patching and Potholes		Potholes	15			X			X				
		Patch/Patch Deterioration	5			X				X			
Cracking	Longitudinal	Single and Multiple	15			X				X			
	Transverse	Half, full, and multiple	10		X					X			
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5			X					X		
		Alligator Cracking	5										
		Block Cracking	7.5										
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on north side of road
CURBS AND GUTTER			X		C&G on both sides of road

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Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 2 Ave N **From:** 1 St NW **To:** Road End

Segment ID: 22 **Length (m):** ~275m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
Surface Defects	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5		X					X			
Surface Deformations	Rutting	10										
Patching and Potholes	Potholes	15			X				X			
Patching and Potholes	Patch/Patch Deterioration	5					X					X
Cracking - Longitudinal	Single and Multiple	15				X					X	
Cracking - Transverse	Half, full, and multiple	10			X					X		
Cracking - Centerline	Single and Multiple	5										
Cracking - Pavement Edge	Single and Multiple	5				X					X	
Cracking - Alligator Cracking		5			X				X			
Cracking - Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on both sides of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 3 Ave N **From:** 1 St NW **To:** Road End

Segment ID: 21 **Length (m):** ~100m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15					X					X
Surface Defects		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5		X					X			
Surface Deformations		Rutting	10										
Patching and Potholes		Potholes	15			X				X			
Patching and Potholes		Patch/Patch Deterioration	5					X					X
Cracking	Longitudinal	Single and Multiple	15				X					X	
Cracking	Transverse	Half, full, and multiple	10			X				X			
Cracking	Centerline	Single and Multiple	5										
Cracking	Pavement Edge	Single and Multiple	5				X					X	
Cracking	Alligator Cracking		5			X					X		
Cracking	Block Cracking		7.5										
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Monowalk on both sides of road
CURBS AND GUTTER				X	C&G on both sides of road

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Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NW **From:** 3 Ave N **To:** Road End

Segment ID: 20 **Length (m):** ~480m **Width (m):** ~11.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15		X						X		
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5					X					X
Cracking: Longitudinal	Single and Multiple	15	X					X				
Cracking: Transverse	Half, full, and multiple	10		X				X				
Cracking: Centerline	Single and Multiple	5		X				X				
Cracking: Pavement Edge	Single and Multiple	5										
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS	X				Monowalk on east side of road
CURBS AND GUTTER	X				C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NW **From:** 1 Ave N **To:** 3 Ave N

Segment ID: 19 **Length (m):** ~95m **Width (m):** ~11.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15		X							X	
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5		X					X			
Cracking - Longitudinal	Single and Multiple	15			X							X
Cracking - Transverse	Half, full, and multiple	10			X						X	
Cracking - Centerline	Single and Multiple	5			X						X	
Cracking - Pavement Edge	Single and Multiple	5										
Cracking - Alligator Cracking		5										
Cracking - Block Cracking		7.5										
											Total Deduct	

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on east side of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 St NW **From:** Central Ave W **To:** 1 Ave N

Segment ID: 18 **Length (m):** ~250m **Width (m):** ~11.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15		X							X	
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking – Longitudinal	Single and Multiple	15			X							X
Cracking – Transverse	Half, full, and multiple	10			X						X	
Cracking – Centerline	Single and Multiple	5			X						X	
Cracking – Pavement Edge	Single and Multiple	5										
Cracking – Alligator Cracking		5										
Cracking – Block Cracking		7.5										
											Total Deduct	

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Monowalk on east side of road
CURBS AND GUTTER			X		C&G on both sides of road

CIMA+

Village of Linden

Roads Assessment - Inspections

FILE: L070-C04-00343
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Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 1 Ave NW **From:** 6 St NW **To:** Highway 806

Segment ID: 17 **Length (m):** ~575m **Width (m):** ~8m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15					X					X
Surface Defects		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
Surface Deformations		Rutting	10										
Patching and Potholes		Potholes	15										
Patching and Potholes		Patch/Patch Deterioration	5										
Cracking	Longitudinal	Single and Multiple	15		X				X				
Cracking	Transverse	Half, full, and multiple	10				X				X		
Cracking	Centerline	Single and Multiple	5	X							X		
Cracking	Pavement Edge	Single and Multiple	5										
Cracking	Alligator Cracking		5										
Cracking	Block Cracking		7.5										

Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS					N/A
CURBS AND GUTTER					N/A

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 6 St NW **From:** Central Ave W **To:** Road End

Segment ID: 16 **Length (m):** ~210m **Width (m):** 8-10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15			X			X				
	Patch/Patch Deterioration	5				X					X	
Cracking Longitudinal	Single and Multiple	15										
Transverse	Half, full, and multiple	10				X				X		
Centerline	Single and Multiple	5										
Pavement Edge	Single and Multiple	5					X					X
Alligator Cracking		5										
Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS					N/A
CURBS AND GUTTER					N/A

CIMA+

Village of Linden

Roads Assessment - Inspections

FILE: L070-C04-00343
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Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Picci Ct 400 **From:** 5 St NW **To:** Cul-de-sac

Segment ID: 15 **Length (m):** ~60m **Width (m):** Cul-de-sac

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking: Longitudinal	Single and Multiple	15				X				X		
Transverse	Half, full, and multiple	10				X		X				
Centerline	Single and Multiple	5			X			X				
Pavement Edge	Single and Multiple	5										
	Alligator Cracking	5										
	Block Cracking	7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Monowalk
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Picci Ct 300 **From:** 5 St NW **To:** Cul-de-sac

Segment ID: 14 **Length (m):** ~85m **Width (m):** Cul-de-sac

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking: Longitudinal	Single and Multiple	15				X			X			
Cracking: Transverse	Half, full, and multiple	10				X			X			
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5										
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Monowalk
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Picci Ct 200 **From:** 5 St NW **To:** Cul-de-sac

Segment ID: 13 **Length (m):** ~60m **Width (m):** Cul-de-sac

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking: Longitudinal	Single and Multiple	15										
Cracking: Transverse	Half, full, and multiple	10				X			X			
Cracking: Centerline	Single and Multiple	5			X					X		
Cracking: Pavement Edge	Single and Multiple	5										
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Mono, east side of road
CURBS AND GUTTER		X			C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Picci Ct 100 **From:** 5 St NW **To:** Cul-de-sac

Segment ID: 12 **Length (m):** ~60m **Width (m):** Cul-de-sac

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few <10%	Intermitent 10-20%	Frequent 20-40%	Extensive 40-80%	Throughout >80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking: Longitudinal	Single and Multiple	15										
Cracking: Transverse	Half, full, and multiple	10			X				X			
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5			X						X	
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Mono, east side of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 5 St NW **From:** Picci Ct 200 **To:** Road End

Segment ID: 11 **Length (m):** ~170m **Width (m):** ~10.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	**15**				X						X
	Flushing/Bleeding	**2.5**										
Surface Deformations	Rippling, Shoving, Corrugations	**5**										
	Rutting	**10**										
Patching and Potholes	Potholes	**15**										
	Patch/Patch Deterioration	**5**				X		X				
Cracking – Longitudinal	Single and Multiple	**15**			X					X		
Cracking – Transverse	Half, full, and multiple	**10**				X				X		
Cracking – Centerline	Single and Multiple	**5**			X					X		
Cracking – Pavement Edge	Single and Multiple	**5**			X					X		
Cracking	Alligator Cracking	**5**										
Cracking	Block Cracking	**7.5**										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS				X	Mono, east side of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 5 St NW **From:** Picci Ct 100 **To:** Picci Ct 200

Segment ID: 10 **Length (m):** ~115m **Width (m):** ~10.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
	CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
	Surface Defects	Raveling & loss of surface aggregate	15				X						X
		Flushing/Bleeding	2.5										
	Surface Deformations	Rippling, Shoving, Corrugations	5										
		Rutting	10										
	Patching and Potholes	Potholes	15			X			X				
		Patch/Patch Deterioration	5		X				X				
Cracking	Longitudinal	Single and Multiple	15	X						X			
	Transverse	Half, full, and multiple	10				X				X		
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5		X					X			
	Alligator Cracking		5										
	Block Cracking		7.5										

Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Mono, east side of road
CURBS AND GUTTER			X		C&G on both sides of road

Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 5 St NW **From:** 1 Ave NW **To:** Picci Ct 100

Segment ID: 9 **Length (m):** ~120m **Width (m):** ~10.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5		X							X	
Cracking: Longitudinal	Single and Multiple	15			X				X			
Cracking: Transverse	Half, full, and multiple	10			X						X	
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5										
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Mono, east side of road
CURBS AND GUTTER			X		C&G on both sides of road

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Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: 5 St NW **From:** Central Ave W **To:** 1 Ave NW

Segment ID: 8 **Length (m):** ~140m **Width (m):** ~10.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15				X						X
		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10		X				X				
Patching and Potholes		Potholes	15			X			X				
		Patch/Patch Deterioration	5										
Cracking	Longitudinal	Single and Multiple	15			X					X		
	Transverse	Half, full, and multiple	10			X				X			
	Centerline	Single and Multiple	5			X				X			
	Pavement Edge	Single and Multiple	5										
	Alligator Cracking		5										
	Block Cracking		7.5										
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Mono, East side of road - minor condition
CURBS AND GUTTER			X		Small C&G section - minor condition

CIMA+

Village of Linden
Roads Assessment - Inspections

FILE: L070-C04-00343
2/12/2021
7

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave E **From:** 1 St NE **To:** Range Road 254

Segment ID: 7 **Length (m):** ~650m **Width (m):** ~10m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10				X					X	
Patching and Potholes	Potholes	15			X						X	
	Patch/Patch Deterioration	5				X						X
Cracking: Longitudinal	Single and Multiple	15		X					X			
Cracking: Transverse	Half, full, and multiple	10			X					X		
Cracking: Centerline	Single and Multiple	5				X					X	
Cracking: Pavement Edge	Single and Multiple	5				X					X	
Cracking	Alligator Cracking	5	X					X				
Cracking	Block Cracking	7.5			X				X			
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS	X				Separate, north side of road - good condition
CURBS AND GUTTER		X			Small C&G section - minor condition

CIMA+

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave E **From:** Centre St N **To:** 1 St NE

Segment ID: 6 **Length (m):** ~100m **Width (m):** ~25m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	**DESCRIPTION**	**Weight**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**0.25**	**0.5**	**0.75**	**1**	**1.25**
Surface Defects	Raveling & loss of surface aggregate	15				X						X
	Flushing/Bleeding	2.5		X					X			
Surface Deformations	Rippling, Shoving, Corrugations	5			X					X		
	Rutting	10				X					X	
Patching and Potholes	Potholes	15					X					X
	Patch/Patch Deterioration	5				X					X	
Cracking – Longitudinal	Single and Multiple	15				X						X
Cracking – Transverse	Half, full, and multiple	10			X			X				
Cracking – Centerline	Single and Multiple	5				X					X	
Cracking – Pavement Edge	Single and Multiple	5			X					X		
Cracking	Alligator Cracking	5										
Cracking	Block Cracking	7.5				X					X	
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS			X		Mono, both sides of road - Moderate condition
CURBS AND GUTTER			X		C&G both sides of road - Moderate condition

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave W **From:** 1a St NW **To:** Centre St N

Segment ID: 5 **Length (m):** ~60m **Width (m):** Varies from ~14-20.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15					X					X
		Flushing/Bleeding	2.5		X						X		
Surface Deformations		Rippling, Shoving, Corrugations	5				X					X	
		Rutting	10				X					X	
Patching and Potholes		Potholes	15					X					X
		Patch/Patch Deterioration	5				X						X
Cracking	Longitudinal	Single and Multiple	15				X						X
	Transverse	Half, full, and multiple	10			X					X		
	Centerline	Single and Multiple	5			X					X		
	Pavement Edge	Single and Multiple	5										
	Alligator Cracking		5										
	Block Cracking		7.5			X				X			
													Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Mono, north side of road - Minor
CURBS AND GUTTER			X		C&G both sides of road - Moderate damage

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave W **From:** 1 St NW **To:** 1a St NW

Segment ID: 4 **Length (m):** ~110m **Width (m):** Varies from ~14-20.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15					X					X
	Flushing/Bleeding	2.5		X						X		
Surface Deformations	Rippling, Shoving, Corrugations	5				X					X	
	Rutting	10				X					X	
Patching and Potholes	Potholes	15					X					X
	Patch/Patch Deterioration	5				X						X
Cracking – Longitudinal	Single and Multiple	15				X						X
Cracking – Transverse	Half, full, and multiple	10			X					X		
Cracking – Centerline	Single and Multiple	5			X					X		
Cracking – Pavement Edge	Single and Multiple	5										
Cracking	Alligator Cracking	5										
Cracking	Block Cracking	7.5			X				X			
												Total Deduct

PCR (100-deduct)

SIDEWALKS, CURBS & GUTTER	Condition: Good	Minor	Moderate	Severe	Notes
SIDEWALKS		X			Mono, north side of road - minor displacements
CURBS AND GUTTER		X			C&G both sides of road - minor damage

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave W **From:** 5 St NW **To:** 1 Ave NW

Segment ID: 3 **Length (m):** ~60m **Width (m):** ~12.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15		X						X		
	Flushing/Bleeding	2.5		X						X		
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5	X					X				
Cracking: Longitudinal	Single and Multiple	15										
Cracking: Transverse	Half, full, and multiple	10										
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5										
Cracking	Alligator Cracking	5										
Cracking	Block Cracking	7.5										
												Total Deduct

PCR (100-deduct)

Village of Linden

Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave W **From:** 6 St NW **To:** 5 St NW

Segment ID: 2 **Length (m):** ~165m **Width (m):** ~12.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through			Severity of Distress (SI)					Density of Distress (DI)				
			Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
								<10%	10-20%	20-40%	40-80%	>80%
CATEGORY	DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects	Raveling & loss of surface aggregate	15		X							X	
	Flushing/Bleeding	2.5										
Surface Deformations	Rippling, Shoving, Corrugations	5										
	Rutting	10										
Patching and Potholes	Potholes	15										
	Patch/Patch Deterioration	5										
Cracking: Longitudinal	Single and Multiple	15										
Cracking: Transverse	Half, full, and multiple	10			X			X				
Cracking: Centerline	Single and Multiple	5										
Cracking: Pavement Edge	Single and Multiple	5										
Cracking: Alligator Cracking		5										
Cracking: Block Cracking		7.5										
											Total Deduct	

PCR (100-deduct)

FILE: L070-C04-00343
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Village of Linden
Roads Assessment - Inspections

Date: October 7th, 2020 **Evaluated By:** CIMA+

Road Name: Central Ave W **From:** Highway 806 **To:** 6 St NW

Segment ID: 1 **Length (m):** ~300m **Width (m):** ~12.5m

1st Drive Through	Ride Comfort Rating (at posted speed limit)										
	10	9	8	7	6	5	4	3	2	1	0
	Excellent		Good		Fair			Poor		Very Poor	

2nd Drive Through				Severity of Distress (SI)					Density of Distress (DI)				
				Very Low	Low	Moderate	Severe	Very Severe	Few	Intermitent	Frequent	Extensive	Throughout
									<10%	10-20%	20-40%	40-80%	>80%
CATEGORY		DESCRIPTION	Weight	0.25	0.5	0.75	1	1.25	0.25	0.5	0.75	1	1.25
Surface Defects		Raveling & loss of surface aggregate	15				X						X
		Flushing/Bleeding	2.5										
Surface Deformations		Rippling, Shoving, Corrugations	5										
		Rutting	10										
Patching and Potholes		Potholes	15										
		Patch/Patch Deterioration	5										
Cracking	Longitudinal	Single and Multiple	15		X						X		
	Transverse	Half, full, and multiple	10				X				X		
	Centerline	Single and Multiple	5										
	Pavement Edge	Single and Multiple	5		X					X			
	Alligator Cracking		5										
	Block Cracking		7.5										
													Total Deduct

PCR (100-deduct)

Roads Assessment Master Sheet

Pavement Condition Rating	Condition	Color Code
0-30	Very Poor to Poor	
30-50	Poor to Fair	
50-75	Fair	
75-90	Good	
90-100	Excellent / New Road	

Central Ave

Road	From	To	Segment ID	Material	Approx. Length (m)	Approx. Width (m)	Approx. Area (m^2)	Ride Comfort Rating	Pavement Condition Rating (PCR)	Percentage of Network	Sidewalks	Curb and Gutter (C&G)
Centre St N	Central Ave E	1 Ave N	24	Asphalt	95.0	10.0	950	**3**	**20.5**	1%	Severe	Moderate
4 Ave SE (branch out)	1 St SE	Road End	36	Asphalt	185.0	10.0	1850	**1**	**20.8**	3%	Severe	Severe
1 Ave S	Centre St S	1 St SE	31	Asphalt	100.0	10.0	1000	**3**	**22.0**	1%	Moderate	Severe
Centre St S	Central Ave W	1 Ave S	29	Asphalt	160.0	10.0	1600	**3**	**22.3**	2%	Moderate	Moderate
Central Ave E	Centre St N	1 St NE	6	Asphalt	100.0	25.0	2500	**3**	**22.8**	1%	Moderate	Moderate
Central Ave W	1a St NW	Centre St N	5	Asphalt	60.0	20.5	1230	**3**	**20.8**	1%	Minor	Moderate
Central Ave W	1 St NW	1a St NW	4	Asphalt	110.0	20.5	2255	**3**	**20.8**	2%	Minor	Minor
1 St SE	4 Ave SE (Branch Out)	Linview Dr	34	Asphalt	230.0	10.0	2300	**5**	**40.3**	3%	Moderate	Moderate
Centre St S	1 Ave S	Road End	30	Asphalt	265.0	10.0	2650	**4**	**44.5**	4%	Moderate	Moderate
Central Ave E	1 St NE	Range Road 254	7	Asphalt	650.0	10.0	6500	**3**	**45**	9%	Good	Minor
2 Ave N	1 St NW	1 St NE	22	Asphalt	275.0	10.0	2750	**6**	**47.5**	4%	Moderate	Moderate
3 Ave NE	1 St NW	Road End	21	Asphalt	100.0	10.0	1000	**6**	**48.3**	1%	Severe	Severe
1 St NE	Central Ave E	1 Ave N	25	Asphalt	95.0	20.0	1900	**7**	**48.6**	1%	Minor	Minor
6 St NW	Central Ave W	Road End	16	Asphalt	210.0	8.0	1680	**6**	**62.8**	3%	N/A	N/A
1 Ave NW	5 St NW	Gravel Alley (Campground)	37	Asphalt	55.0	8.0	440	**7**	**63.3**	1%	N/A	Moderate
1 St SE	1 Ave S	4 Ave SE (Branch Out)	33	Asphalt	265.0	8.0	2120	**6**	**66.8**	4%	Moderate	Moderate
5 St NW	Picci Ct 200	Picci Ct 300/400	11	Asphalt	170.0	10.5	1785	**7**	**66.8**	2%	Severe	Moderate
Picci Ct 100	5 St NW	Cul-de-sac	12	Asphalt	60.0	20.0	1200	**7**	**66.8**	1%	Severe	Moderate
1 Ave N	1 St NW	1 St NE	23	Asphalt	120.0	10.0	1200	**6**	**67.8**	2%	Moderate	Moderate
5 St NW	Central Ave W	1 Ave NW	8	Asphalt	140.0	10.5	1470	**7**	**70.5**	2%	Minor	Moderate
5 St NW	1 Ave NW	Picci Ct 100	9	Asphalt	120.0	10.5	1260	**7**	**72.5**	2%	Moderate	Moderate
1 St NW	1 Ave N	3 Ave NE	19	Asphalt	95.0	11.5	1092.5	**7**	**72.8**	1%	Moderate	Moderate
1 Ave NW	6 St NW	Highway 806	17	Asphalt	575.0	8.0	4600	**6**	**73.0**	8%	N/A	N/A
Picci Ct 400	5 St NW	Cul-de-sac	15	Asphalt	60.0	20.0	1200	**7**	**73.3**	1%	Minor	Minor
Central Ave W	Highway 806	6 St NW	1	Asphalt	300.0	12.5	3750	**9**	**73.5**	4%	N/A	Good
1 St NW	Central Ave W	1 Ave N	18	Asphalt	250.0	11.5	2875	**7**	**73.8**	4%	Moderate	Moderate
5 St NW	Picci Ct 100	Picci Ct 200	10	Asphalt	115.0	10.5	1207.5	**8**	**73.8**	2%	Severe	Moderate
Picci Ct 300	5 St NW	Cul-de-sac	14	Asphalt	85.0	20.0	1700	**7**	**75.0**	1%	Minor	Minor
Picci Ct 200	5 St NW	Cul-de-sac	13	Asphalt	60.0	20.0	1200	**8**	**75.0**	1%	Minor	Minor
1 St NE	2 Ave N	Road End	27	Asphalt	145.0	10.0	1450	**6**	**75.8**	2%	Minor	Minor
1 St SE	Linview Dr	Road End	35	Asphalt	350.0	10.0	3500	**6**	**76.9**	5%	Moderate	Moderate
1 St SE	Central Ave E	1 Ave S	32	Asphalt	170.0	10.0	1700	**6**	**77.3**	2%	Severe	Moderate
1 St SW	Central Ave W	Centre St S	28	Asphalt	255.0	10.0	2550	**4**	**77.625**	4%	Severe	Severe
1 St NE	1 Ave N	2 Ave N	26	Asphalt	150.0	10.0	1500	**6**	**78.0**	2%	Minor	Minor
1 St NW	3 Ave NE	Road End	20	Asphalt	480.0	11.5	5520	**9**	**87.0**	7%	Good	Good
Central Ave W	6 St NW	5 St NW	2	Asphalt	165.0	12.5	2063	**9**	**92.5**	2%	N/A	Good
Central Ave W	5 St NW	1 St NW	3	Asphalt	305.0	12.5	3813	**9**	**94.5**	4%	Good	Good
Courtney Way	Central Ave W	Road End	GR1	Gravel	140	6	770	N/A	N/A		N/A	N/A
5 Ave NW	1 St NW	Road End	GR2	Asphalt/Gravel	35	10	350	N/A	N/A		N/A	Minor
1a St NW	Central Ave W	1 Ave N	GR3	Gravel	125	35.5	4438	N/A	**N/A**		N/A	N/A
6 St NW	1 Ave NW	Road End	GR4	Gravel	170	8	1360	N/A	**N/A**		N/A	N/A

* When varies then used larger dimension

H

Appendix H
IDF Curves

Drumheller IDF Data March 27, 2020 (v.3.10).txt
Environment and Climate Change Canada
Environnement et Changement climatique Canada

Short Duration Rainfall Intensity-Duration-Frequency Data
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

Gumbel - Method of moments/Méthode des moments

2020/03/27

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DRUMHELLER EAST AB 30221LG

Latitude: 51 27'N Longitude: 112 41'W Elevation/Altitude: 678 m

Years/Années : 2005 - 2017 # Years/Années : 13

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Table 1 : Annual Maximum (mm)/Maximum annuel (mm)

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Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
2005	1.6	2.4	2.8	4.8	5.4	8.0	15.6	23.6	36.0
2006	6.2	10.8	13.4	16.8	18.2	18.2	18.2	23.6	26.6
2007	8.2	15.4	19.8	20.4	20.4	20.4	25.0	25.2	26.2
2008	5.1	6.2	6.8	10.2	12.3	13.1	20.0	24.9	26.1
2009	5.3	8.7	11.1	13.9	15.5	17.9	22.0	32.0	39.6
2010	3.2	4.0	4.6	7.0	10.6	12.8	19.4	24.8	33.0
2011	4.9	7.0	8.6	11.5	12.3	16.7	16.7	22.6	22.8
2012	9.7	13.8	17.1	24.4	31.1	33.3	46.7	47.1	47.1
2013	6.2	9.0	9.9	10.3	10.7	14.5	23.5	28.7	39.6
2014	13.0	15.7	16.3	20.6	21.6	23.8	29.2	30.0	33.5
2015	6.1	6.3	8.9	11.6	11.6	13.7	23.1	26.9	27.2
2016	6.8	9.2	10.9	21.2	24.7	33.6	34.6	44.8	45.2
2017	5.8	7.9	8.5	10.1	11.3	19.8	30.6	30.6	32.0
# Yrs. Années	13	13	13	13	13	13	13	13	13
Mean Moyenne	6.3	9.0	10.7	14.1	15.8	18.9	25.0	29.6	33.5
Std. Dev. Écart-type	2.8	4.1	4.9	6.1	7.1	7.6	8.6	7.8	7.7
Skew. Dissymétrie	0.88	0.35	0.36	0.30	0.81	0.97	1.45	1.59	0.45
Kurtosis	5.39	3.16	3.32	2.66	3.95	4.14	5.84	5.20	2.85

*-99.9 Indicates Missing Data/Données manquantes

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Table 2a : Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

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Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	5.8	8.4	10.0	12.1	13.7	15.2	13
10 min	8.3	11.9	14.3	17.3	19.6	21.8	13
15 min	9.9	14.2	17.1	20.7	23.4	26.1	13
30 min	13.1	18.4	22.0	26.5	29.8	33.1	13
1 h	14.7	20.9	25.0	30.2	34.1	38.0	13
2 h	17.7	24.4	28.8	34.4	38.6	42.7	13
6 h	23.6	31.2	36.2	42.5	47.3	51.9	13
12 h	28.3	35.2	39.8	45.6	49.9	54.2	13
24 h	32.2	39.0	43.5	49.2	53.5	57.7	13

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Table 2b :

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	70.2	100.3	120.2	145.4	164.1	182.6	13
	+/- 17.0	+/- 28.6	+/- 38.7	+/- 52.1	+/- 62.4	+/- 72.7	13
10 min	49.7	71.4	85.8	103.9	117.4	130.8	13
	+/- 12.3	+/- 20.6	+/- 27.9	+/- 37.6	+/- 45.0	+/- 52.4	13
15 min	39.4	56.8	68.4	82.9	93.7	104.4	13
	+/- 9.8	+/- 16.5	+/- 22.3	+/- 30.1	+/- 36.0	+/- 42.0	13
30 min	26.1	36.8	43.9	52.9	59.6	66.2	13
	+/- 6.1	+/- 10.2	+/- 13.8	+/- 18.6	+/- 22.2	+/- 25.9	13
1 h	14.7	20.9	25.0	30.2	34.1	38.0	13
	+/- 3.5	+/- 5.9	+/- 8.0	+/- 10.8	+/- 12.9	+/- 15.1	13
2 h	8.8	12.2	14.4	17.2	19.3	21.4	13
	+/- 1.9	+/- 3.2	+/- 4.3	+/- 5.8	+/- 7.0	+/- 8.1	13
6 h	3.9	5.2	6.0	7.1	7.9	8.7	13
	+/- 0.7	+/- 1.2	+/- 1.6	+/- 2.2	+/- 2.6	+/- 3.1	13
12 h	2.4	2.9	3.3	3.8	4.2	4.5	13
	+/- 0.3	+/- 0.5	+/- 0.7	+/- 1.0	+/- 1.2	+/- 1.4	13
24 h	1.3	1.6	1.8	2.1	2.2	2.4	13
	+/- 0.2	+/- 0.3	+/- 0.4	+/- 0.5	+/- 0.6	+/- 0.7	13

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Table 3 : Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
T = Rainfall duration (h) / Durée de la pluie (h)

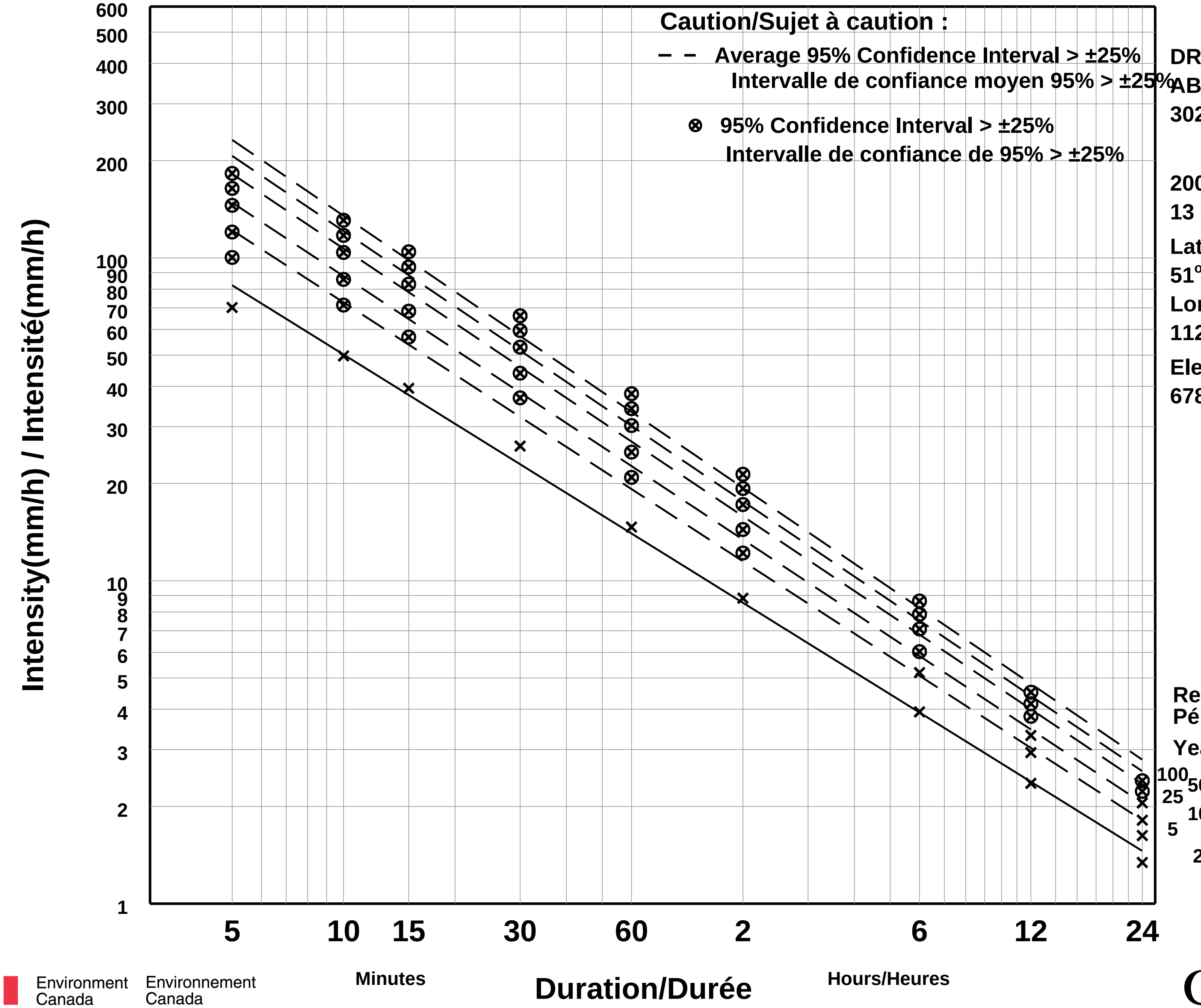
****

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	24.1	34.2	41.0	49.5	55.8	62.1
Std. Dev. /Écart-type (RR)	24.3	35.0	42.1	51.0	57.7	64.3
Std. Error/Erreur-type	4.8	8.4	11.0	14.3	16.7	19.2
Coefficient (A)	14.0	19.2	22.7	27.0	30.2	33.3
Exponent/Exposant (B)	-0.712	-0.743	-0.756	-0.768	-0.775	-0.781
Mean % Error/% erreur moyenne	5.9	8.0	9.0	9.9	10.4	10.9

Short Duration Rainfall Intensity−Duration−Frequency Data

2020/03/27

Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée



DRUMHELLER EAST
AB
30221LG

2005 − 2017
13 years / ans

Latitude
51° 27'N
Longitude
112° 41'W
Elevation / Altitude
678 m

Return Periods/
Périodes de retour
Years / ans

Environment Canada Environnement Canada

Canada

Appendix I
5, 10, 15, 20 Year Capital Plans

Village of Linden 5 Year Capital Plan

Project	Description	Notes	Cost
2022			
EX W1	Pump Station Operational Issues Investigation	Note - Partly completed as of 2021	$ 15,000.00
EX W2	Pump 1 ARV Piping Replacement and Rebuild		$ 25,000.00
EX W3	Old Generator Decomissioning	Note - Partly completed as of 2021	$ 30,000.00
EX W4	Reservoir North Cell Investigation and Repairs		$ 40,000.00
EX S1	Lagoon Sludge Survey	Sludge survey will determine extent of cleaning required, for now it is assumed anaerobic cells will need to be cleaned	$ 22,000.00
EX S3	CIPP Lining Program: 1st St NE		$ 55,000.00
EX S7	Repair Defective Service 203 Linview Dr	Costs may be responsibility of builder	$ 30,000.00
EX S8	Lagoon Trunk Line - Immediate Action		$ 95,000.00
EX SW4	Overland Diversion Around 5th St NW Townhouse		$ 65,000.00
EX SW7	Coulee Dam Inspection		$ 50,000.00
Total for 2022			**$ 427,000.00**
2023			
EX S2	Lagoon Sludge Cleaning	Price and scope of work dependant on results of lagoon survey. Highest anticipated cost used, likely to be lower	$ 100,000.00
EX S9	Lagoon Trunk Line - Near Future Action		$ 156,000.00
EX W5	Hydrant Investigation and Maintenance/Repair Program	Price and scope of work dependant on results of investigation. Highest anticipated cost used, likely to be lower	$ 150,000.00
EX S4	CIPP Lining Program - 1st St NW		$ 75,000.00
S1	Trunk Main Flow Monitor		$ 20,000.00
Total for 2023			**$ 501,000.00**
2024			
UP1	Unified Project 1 - Centre Ave 1st St to Centre St		$ 660,000.00
Total for 2024			**$ 660,000.00**
2025			
EX S5	CIPP Lining Program - 1st St SE		$ 115,000.00
EX S6	CIPP Lining Program - Alley Behind Centre St SE		$ 85,000.00
EX SW2	Upgrade Storm Along 1st Ave N		$ 150,000.00
Total for 2025			**$ 350,000.00**
2026			
EX S10	Lagoon Trunk Line - Future Action		$ 30,000.00
R3	Central Ave E from Centre St N to 1 St NE		$ 280,000.00
EX SW5	Regrading and Berm Around Field Catch Basin (417 1st St NW)		$ 85,000.00
Total for 2026			**$ 365,000.00**

Village of Linden 10 Year Capital Plan			
Project	**Description**	**Notes**	**Cost**
		2022	
EX W1	Pump Station Operational Issues Investigation	Note - Partly completed as of 2021	$ 15,000.00
EX W2	Pump 1 ARV Piping Replacement and Rebuild		$ 25,000.00
EX W3	Old Generator Decomissioning	Note - Partly completed as of 2021	$ 30,000.00
EX W4	Reservoir North Cell Investigation and Repairs		$ 40,000.00
EX S1	Lagoon Sludge Survey	Sludge survey will determine extent of cleaning required, for now it is assumed anaerobic cells will need to be cleaned	$ 22,000.00
EX S3	CIPP Lining Program: 1st St NE		$ 55,000.00
EX S7	Repair Defective Service 203 Linview Dr	Costs may be responsibility of builder	$ 30,000.00
EX S8	Lagoon Trunk Line - Immediate Action		$ 95,000.00
EX SW4	Overland Diversion Around 5th St NW Townhouse		$ 65,000.00
EX SW7	Coulee Dam Inspection		$ 50,000.00
Total for 2022			**$ 427,000.00**
		2023	
EX S2	Lagoon Sludge Cleaning	Price and scope of work dependant on results of lagoon survey. Highest anticipated cost used, likely to be lower	$ 100,000.00
EX S9	Lagoon Trunk Line - Near Future Action		$ 156,000.00
EX W5	Hydrant Investigation and Maintenance/Repair Program	Price and scope of work dependant on results of investigation. Highest anticipated cost used, likely to be lower	$ 150,000.00
EX S4	CIPP Lining Program - 1st St NW		$ 75,000.00
S1	Trunk Main Flow Monitor		$ 20,000.00
Total for 2023			**$ 501,000.00**
		2024	
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 1 of UP1, half of project	$ 330,000.00
Total for 2024			**$ 330,000.00**
		2025	
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 2 of UP 1, half of project	$ 330,000.00
Total for 2025			**$ 330,000.00**
		2026	
EX S5	CIPP Lining Program - 1st St SE		$ 115,000.00
EX S6	CIPP Lining Program - Alley Behind Centre St SE		$ 85,000.00
EX SW2	Upgrade Storm Along 1st Ave N		$ 150,000.00
Total for 2026			**$ 350,000.00**
		2027	
EX S10	Lagoon Trunk Line - Future Action		$ 30,000.00
R3	Central Ave E from Centre St N to 1 St NE		$ 280,000.00
EX SW5	Regrading and Berm Around Field Catch Basin (417 1st St NW)		$ 85,000.00
Total for 2027			**$ 395,000.00**
		2028	
UP2	Unified Project 2 - 1 Ave S (Centre St S to 1st St SE)		$ 200,000.00
R1	Centre St N from Central Ave E to 1 Ave		$ 145,000.00
Total for 2028			**$ 345,000.00**
		2029	
EX W6	Small Diameter, AC and DI Pipe Replacement (2nd Ave NE)		$ 240,000.00
EX W7	Small Diameter, AC and DI Pipe Replacement (1st Ave S)		$ 105,000.00
EX SW 6	Ditch and Inlet Upgrade at Trailer Park		$ 65,000.00
Total for 2029			**$ 410,000.00**
		2029	
R2	Centre St S from Central Ave W to 1 Ave S		$ 240,000.00
EX W9	New Hydrants Program		$ 70,000.00
EX SW 8	2nd Ave N Overland Escape Erosion Protection		$ 50,000.00
Total for 2030			**$ 360,000.00**
		2031	
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 1)	Phase 1 of UP3, approximately first 200 m	$ 490,000.00
Total for 2031			**$ 490,000.00**

Village of Linden 15 Year Capital Plan

Project	Description	Notes	Cost
2022			
EX W1	Pump Station Operational Issues Investigation	Note - Partly completed as of 2021	$ 15,000.00
EX W2	Pump 1 ARV Piping Replacement and Rebuild		$ 25,000.00
EX W3	Old Generator Decomissioning	Note - Partly completed as of 2021	$ 30,000.00
EX W4	Reservoir North Cell Investigation and Repairs		$ 40,000.00
EX S1	Lagoon Sludge Survey	Sludge survey will determine extent of cleaning required, for now it is assumed anaerobic cells will need to be cleaned	$ 22,000.00
EX S3	CIPP Lining Program: 1st St NE		$ 55,000.00
EX S7	Repair Defective Service 203 Linview Dr	Costs may be responsibility of builder	$ 30,000.00
EX S8	Lagoon Trunk Line - Immediate Action		$ 95,000.00
EX SW3	Overland Diversion Around 5th St NW Townhouse		$ 65,000.00
EX SW6	Coulee Dam Inspection		$ 50,000.00
Total for 2022			**$ 427,000.00**
2023			
EX S2	Lagoon Sludge Cleaning	Price and scope of work dependant on results of lagoon survey. Highest anticipated cost used, likely to be lower	$ 100,000.00
EX S9	Lagoon Trunk Line - Near Future Action		$ 156,000.00
EX W5	Hydrant Investigation and Maintenance/Repair Program	Price and scope of work dependant on results of investigation. Highest anticipated cost used, likely to be lower	$ 150,000.00
EX S4	CIPP Lining Program - 1st St NW		$ 75,000.00
S1	Trunk Main Flow Monitor		$ 20,000.00
Total for 2023			**$ 501,000.00**
2024			
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 1 of UP1, half of project	$ 330,000.00
Total for 2024			**$ 330,000.00**
2025			
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 2 of UP 1, half of project	$ 330,000.00
Total for 2025			**$ 330,000.00**
2026			
EX S5	CIPP Lining Program - 1st St SE		$ 115,000.00
EX S6	CIPP Lining Program - Alley Behind Centre St SE		$ 85,000.00
EX SW2	Upgrade Storm Along 1st Ave N		$ 150,000.00
Total for 2026			**$ 350,000.00**
2027			
EX S10	Lagoon Trunk Line - Future Action		$ 30,000.00
R3	Central Ave E from Centre St N to 1 St NE		$ 280,000.00
EX SW4	Regrading and Berm Around Field Catch Basin (417 1st St NW)		$ 85,000.00
Total for 2027			**$ 395,000.00**
2028			
UP2	Unified Project 2 - 1 Ave S (Centre St S to 1st St SE)		$ 200,000.00
R1	Centre St N from Central Ave E to 1 Ave		$ 145,000.00
Total for 2028			**$ 345,000.00**
2029			
EX W6	Small Diameter, AC and DI Pipe Replacement (2nd Ave NE)		$ 240,000.00
EX W7	Small Diameter, AC and DI Pipe Replacement (1st Ave S)		$ 105,000.00
EX SW 5	Ditch and Inlet Upgrade at Trailer Park		$ 65,000.00
Total for 2029			**$ 410,000.00**
2029			
R2	Centre St S from Central Ave W to 1 Ave S		$ 240,000.00
EX W9	New Hydrants Program		$ 70,000.00
EX SW 7	2nd Ave N Overland Escape Erosion Protection		$ 50,000.00
Total for 2030			**$ 360,000.00**
2031			
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 1)	Phase 1 of UP3, approximately first 200 m	$ 490,000.00
Total for 2031			**$ 490,000.00**
2032			
W1	5th St NW and 6th St NW Cross Connect		$ 95,000.00
W2	1st St NW and 5th St NW Cross Connect		$ 435,000.00
Total for 2032			**$ 530,000.00**
2033			
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 2)	Phase 2 of UP3, approximately next 200 m	$ 490,000.00
Total for 2033			**$ 490,000.00**
2034			
S2	Trunk Main Upgrade	Phase 1 - Approximately half of project	$ 445,000.00
Total for 2034			**$ 445,000.00**
2035			
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 3)	Phase 3 of UP3, approximately next 200 m	$ 490,000.00
Total for 2035			**$ 490,000.00**
2036			
S2	Trunk Main Upgrade	Phase 2 - Approximately half of project	$ 445,000.00
Total for 2036			**$ 445,000.00**

Village of Linden 20 Year Capital Plan			
Project	**Description**	**Notes**	**Cost**
		2022	
EX W1	Pump Station Operational Issues Investigation	Note - Partly completed as of 2021	$ 15,000.00
EX W2	Pump 1 ARV Piping Replacement and Rebuild		$ 25,000.00
EX W3	Old Generator Decomissioning	Note - Partly completed as of 2021	$ 30,000.00
EX W4	Reservoir North Cell Investigation and Repairs		$ 40,000.00
EX S1	Lagoon Sludge Survey	Sludge survey will determine extent of cleaning required, for now it is assumed anaerobic cells will need to be cleaned	$ 22,000.00
EX S3	CIPP Lining Program: 1st St NE		$ 55,000.00
EX S7	Repair Defective Service 203 Linview Dr	Costs may be responsibility of builder	$ 30,000.00
EX S8	Lagoon Trunk Line - Immediate Action		$ 95,000.00
EX SW3	Overland Diversion Around 5th St NW Townhouse		$ 65,000.00
EX SW6	Coulee Dam Inspection		$ 50,000.00
Total for 2022			**$ 427,000.00**
		2023	
EX S2	Lagoon Sludge Cleaning	Price and scope of work dependant on results of lagoon survey. Highest anticipated cost used, likely to be lower	$ 100,000.00
EX S9	Lagoon Trunk Line - Near Future Action		$ 156,000.00
EX W5	Hydrant Investigation and Maintenance/Repair Program	Price and scope of work dependant on results of investigation. Highest anticipated cost used, likely to be lower	$ 150,000.00
EX S4	CIPP Lining Program - 1st St NW		$ 75,000.00
S1	Trunk Main Flow Monitor		$ 20,000.00
Total for 2023			**$ 501,000.00**
		2024	
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 1 of UP1, half of project	$ 330,000.00
Total for 2024			**$ 330,000.00**
		2025	
UP1	Unified Project 1 - Centre Ave 1st St to Centre St	Phase 2 of UP 1, half of project	$ 330,000.00
Total for 2025			**$ 330,000.00**
		2026	
EX S5	CIPP Lining Program - 1st St SE		$ 115,000.00
EX S6	CIPP Lining Program - Alley Behind Centre St SE		$ 85,000.00
EX SW2	Upgrade Storm Along 1st Ave N		$ 150,000.00
Total for 2026			**$ 350,000.00**
		2027	
EX S10	Lagoon Trunk Line - Future Action		$ 30,000.00
R3	Central Ave E from Centre St N to 1 St NE		$ 280,000.00
EX SW4	Regrading and Berm Around Field Catch Basin (417 1st St NW)		$ 85,000.00
Total for 2027			**$ 395,000.00**
		2028	
UP2	Unified Project 2 - 1 Ave S (Centre St S to 1st St SE)		$ 200,000.00
R1	Centre St N from Central Ave E to 1 Ave		$ 145,000.00
Total for 2028			**$ 345,000.00**
		2029	
EX W6	Small Diameter, AC and DI Pipe Replacement (2nd Ave NE)		$ 240,000.00
EX W7	Small Diameter, AC and DI Pipe Replacement (1st Ave S)		$ 105,000.00
EX SW 5	Ditch and Inlet Upgrade at Trailer Park		$ 65,000.00
Total for 2029			**$ 410,000.00**
		2029	
R2	Centre St S from Central Ave W to 1 Ave S		$ 240,000.00
EX W9	New Hydrants Program		$ 70,000.00
EX SW 7	2nd Ave N Overland Escape Erosion Protection		$ 50,000.00
Total for 2030			**$ 360,000.00**
		2031	
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 1)	Phase 1 of UP3, approximately first 200 m	$ 490,000.00
Total for 2031			**$ 490,000.00**
		2032	
W1	5th St NW and 6th St NW Cross Connect		$ 95,000.00
W2	1st St NW and 5th St NW Cross Connect		$ 435,000.00
Total for 2032			**$ 530,000.00**
		2033	
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 2)	Phase 2 of UP3, approximately next 200 m	$ 490,000.00
Total for 2033			**$ 490,000.00**
		2034	
S2	Trunk Main Upgrade	Phase 1 - Approximately half of project	$ 445,000.00
Total for 2034			**$ 445,000.00**
		2035	
UP3	Unified Project 3 - Centre Ave (1st St NE to RR 254, Phase 3)	Phase 3 of UP3, approximately last 200 m	$ 490,000.00
Total for 2035			**$ 490,000.00**
		2036	
S2	Trunk Main Upgrade	Phase 2 - Approximately half of project	$ 445,000.00
Total for 2036			**$ 445,000.00**
		2037	
FT SW1	6th St NW and Central Ave Sewer Upgrade	Complete with S5 - no cost savings, but along same alignment (Phase 1 - Approximately half)	$ 175,000.00
S5	6th St NW Pipe Replacement	Complete with FT SW1 - no cost savings, but along same alignment (Phase 1 - Approximately half)	$ 135,000.00
Total for 2037			**$ 310,000.00**
		2038	
FT SW1	6th St NW and Central Ave Sewer Upgrade	Complete with S5 - no cost savings, but along same alignment (Phase 1 - Approximately half)	$ 175,000.00
S5	6th St NW Pipe Replacement	Complete with FT SW1 - no cost savings, but along same alignment (Phase 1 - Approximately hal	$ 135,000.00
Total for 2038			**$ 310,000.00**
		2039	
FT SW2	Diversion Swale Around Picci Court and Culvert Underneath Roadway		$ 130,000.00
Total for 2039			**$ 130,000.00**
		2040	
S3	1st St NW Pipe Replacement		$ 140,000.00
Total for 2040			**$ 140,000.00**
		2041	
S4	5th St NW Pipe Replacement		$ 145,000.00
Total for 2041			**$ 145,000.00**

J

Appendix J
Remaining CCTV Investigation (Lagoon Trunk Main)

June 23, 2021

Ms. Lynda Vanderwoerd
Chief Administrative Officer
Village of Linden

Subject: Linden Remaining CCTV Inspection

Ms. Vanderwoerd

In June of 2021 the Village of Linden retained Thuro Inc. to finish the CCTV inspection on the remaining sections of the sanitary system in the Village which were not completed last year for the Utility Master Plan (UMP). All remaining pipes have been inspected, and has been subsequently reviewed by CIMA+. The following provides a summary of the results of the review, and recommendations for remediation of deficiencies.

These recommendations should be considered in conjunction with projects established in the UMP. Immediate action items should take precedence, as they occur in the trunk line leading to the lagoon, which is critical infrastructure.

The most common recommendation for repairing damaged pipes is Cured In Place Pipe (CIPP) lining. CIPP is a trenchless repair solution where a resin and felt tube is inserted into the pipe, inflated, and cured so that it attaches to the walls of the pipe. This method can provide structural integrity to significantly damaged pipes, and is significantly more cost effective than outright replacement. In addition to adding structural integrity, it can reduce infiltration and mitigate root intrusion in most cases.

Smaller sections that need repair, or defective services, can be done through spot repairs, where a small section of liner is installed. In the case of services, a section of liner known as a “top hat” repair can be used. However, in general if a pipe had defective sections that required lining, it was recommended to line the full pipe as a form of preventative maintenance. This is because the majority of defects are in aging Vitrified Clay Tile (VCT) pipe, which would be prone to further defects as they continue to age.

300, 6815 – 8 Street NE, Calgary, AB T2E 7H7 CANADA T 403 775-0100 F 403-775-0102
cima.ca

Pipe sections requiring remediation or action have been categorized as follows:

- Immediate Action With Lining Solution – These contain severe defects such as broken or collapsed pipes, exposed soil and extensive fracturing, and should be addressed as soon as possible
- Near Future Action (0-5 Years) With Lining Solution – These contain significant defects such a multiple instances of cracks and fractures, or sever root intrusion and should be addressed within the next 5 years
- Future Action (5-10 Years) With Lining Solution – These contain instances of defects such as cracks and fractures and moderate root intrusion that are not an immediate concern, but should be addressed in the next 5 to 10 years before they become a hazard
- Maintenance Required – These present some level of increased maintenance or other action, such as regular flushing due to sags, more significant cleaning/pigging due to grease buildup or other deposits that aren't easily flushed, or removal of minor intruding roots.

A drawing has been provided which outlines the grading assigned to each inspected pipe.

Immediate Action

The following are the pipe sections that require immediate action. In all cases, CIPP lining of the full pipe is recommended. These items are listed in order of priority.

Manhole From	Manhole To	Defect	Recommendation	Pipe Length (m)
SMH 33A	SMH 33	Broken/collapsing pipe	CIPP full pipe	124
SMH 31	SMH 32A	Broken pipe, holes	CIPP full pipe	86
SMH 29	SMH 30	Broken pipe	CIPP full pipe	104

Figure 1 MH 33A to MH 33

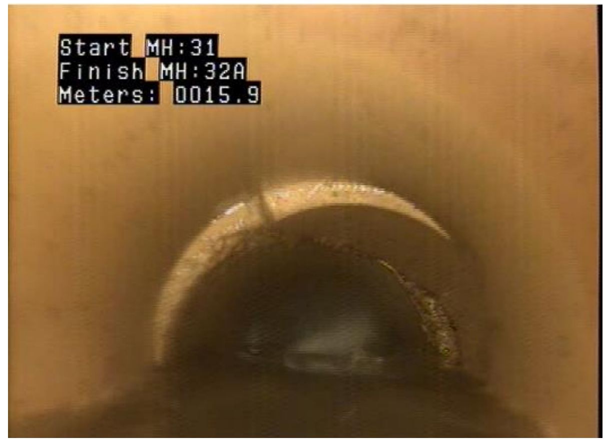


Figure 2 MH 31 to MH 32A

Figure 3 MH 29 to MH 30

Near Future Action

The following are the pipe sections that require action in the next 5 years. In all cases, CIPP lining of the full pipe is recommended, where possible.

Manhole From	Manhole To	Defect	Recommendation	Pipe Length (m)
SMH 32	SMH 33A	Broken/fractured Pipe	CIPP full pipe	125
SMH 33	SMH 34	Broken/fractured Pipe	CIPP full pipe	132
SMH 37	SMH 38	Broken/fractured Pipe	CIPP full pipe	107
SMH 32A	SMH 32	Holes at top, fracturing	CIPP full pipe	30
SMH 34	SMH 35	Broken pipe (can't see it due to water level)*	CIPP full pipe	125

*Camera couldn’t be pulled through pipe end, operator assumed pipe was broken. Could not be confirmed due to water level

Future Action

The following are the pipe sections that require action in the next 5 to 10 years. In all cases, CIPP lining of the full pipe is recommended, where possible.

Manhole From	Manhole To	Defect	Recommendation	Pipe Length (m)
SMH 35	SMH 36	Minor cracks	CIPP	98

Maintenance Required

The following pipe sections require some level of additional maintenance. This generally includes frequent flushing due to pipe sags, more extensive cleaning in the case of grease or gravel deposits, removal of root intrusion, and monitoring/reinspection for worsening defects. Refer to the inspection table for a detailed recommendation.

Manhole From	Manhole To	Defect	Recommendation	Pipe Length (m)
SMH 30	SMH 31	Roots, sag	Monitor, clear roots if they worsen	64
SMH 96	SMH 36	Settled deposits	Flush/pigging	18

Cost Estimates

The following are the estimated costs for the CIPP lining for the Immediate Action, Near Future Action, and Future Action categories. These are high level estimates based on the total pipe lengths for each category, and a unit rate of $250 per meter for CIPP lining, plus 20% contingency.

- Immediate Action
  - Total Length – 315 m
  - Cost - $95,000
- Near Future Action
  - Total Length – 520 m
  - Cost - $156,000
- Future Action
  - Total Length – 98 m
  - Cost - $30,000

Regards,

Jamie Purdy
Lead Technician

JP/jp

cc

Encl.

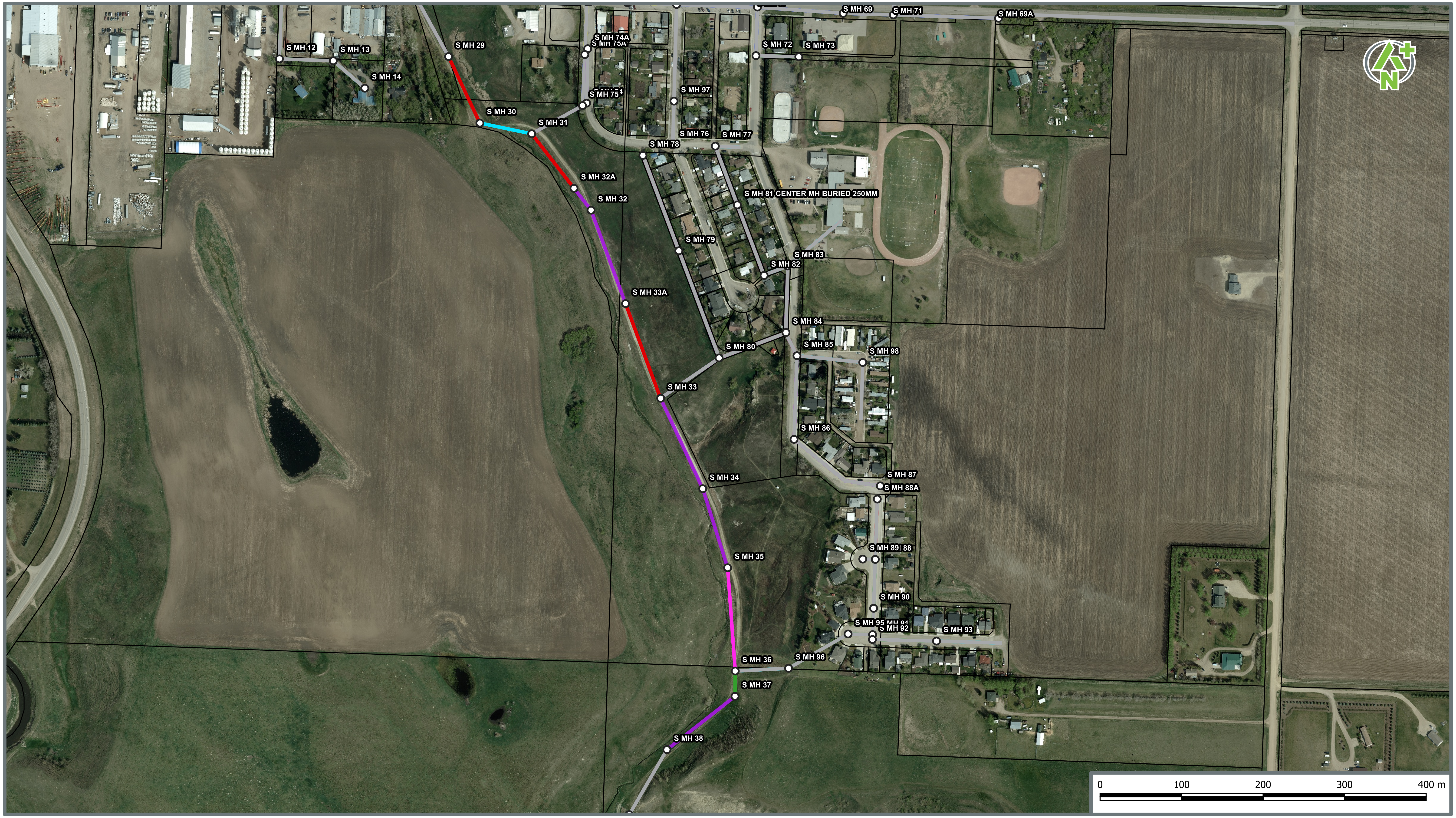


Figure 1 - Remaining CCTV Inspection Results (Sanitary)

Scale 1:3000

- Good Condition
- Operational / Maintenance Issues
- Future Action (5-10 Years) With Lining Solution
- Near Future Action (0-5 Years) With Lining Solution
- Immediate Action With Lining Solution
- Not Surveyed

PREPARED FOR VILLAGE OF LINDEN
JUNE 2021

ThuroInc.
Sewer & Water Professionals

4650 50 Avenue SE | Calgary, AB | T2B 3R4
Ph: (403) 243-0276 | thuro@thuro.ca | www.thuro.ca

VIDEO INSPECTION SUMMARY

Project Information

Client: Cima
Project: Village of Linden
Date: 20-May-21
WO/File: 14257

Video #	Start MH	End MH	Use	Size	Material	Length	Defects
1	29	30	SAN	200	CT	104.5	Large Joint Displace @ 2.1m - Sag 10% @ 17.1m - Sag 10% @ 21.3m - Sag 10% @ 32.1m - Roots 15% @ 54.4m - Sag 10% @ 78.8 - Pipe Broken @ 82.7m - Pipe Broken @ 83.8m - Roots 15% @ 101.4m
2	30	31	SAN	200	CT	63.7	Sag 10% @ 34.4m
3	31	32A	SAN	200	CT	87.5	Hole in pipe @ 10.2m - Hole in pipe @ 10.6m - Hole in pipe @ 11.4 m - Medium Joint Displaced @ 14.6m - Hole in pipe @ 15.5m - Pipe Broken @ 16.0m - Pipe Fracture @ 45.9m - Pipe Fracture @ 79.3m
4	32A	32	SAN	200	CT	30.1	Pipe Crack @ 6.3m -Defective Patch Repair @ 6.7m - Hole in pipe @ 14.5m - Crack in pipe @ 20.4m - Pipe Fracture @ 21.4m - Pipe Crack @ 23.1m - Pipe Crack @ 24.6m - Pipe Crack @ 29.1m
5	32	33A	SAN	200	CT	124.8	Pipe Crack @ 3.8m - Pipe crack @ 7.3m - Pipe crack @ 25.1m - Pipe broken @ 77.2m
6	33	34	SAN	200	CT	122.3	Pipe Crack @ 3.4m - Pipe Broken @ 21.3m - Pipe Fracture @ 57.5m - Pipe Crack @ 107.2m
7	23	23A	SAN	450	CT	65.1	
8	23A	Outlet	SAN	450	CT	32.4	
9	96	36	SAN	250	CT	17.7	
10	24	Outlet	ST	600	CMP	13.6	Unable to pass rocks in line.
11	34	35	SAN	200	CT	120	Pipe Fracture @ 1.0m - Roots 20% @ 71.2m - Pipe Fracture @ 92.0m - Roots 10% @ 93.4m - Roots 10% @ 100.4m - Roots 20% @ 117.0m - Pipe fracture @ 117.3 - Pipe broken @ 120m
12	35	36	SAN	200	CT	97.6	Pipe Crack @ 43.4m - Pipe Fracture @ 73.6m
13	36	37	SAN	200	CT	41.5	

14	37	38	SAN	200	CT	106.4	Pipe Broken @ 33.9m
15	33A	33	SAN	200	CT	123.3	Pipe Crack @ 3.5m - Pipe Crack @ 22.0 - Pipe Crack @ 63.4m - Pipe Broken @ 87.2m -
104R	16	17	ST	525	CMP	32.7	External pipe running through main @ 32.7m
105	16	15	ST	525	PVC	38.7	

All mandrel tests passed

total 1221.9