quarter section basis are not directly additive because these flows will be subject to attenuation due to travel time and storage effects as water flows downstream.

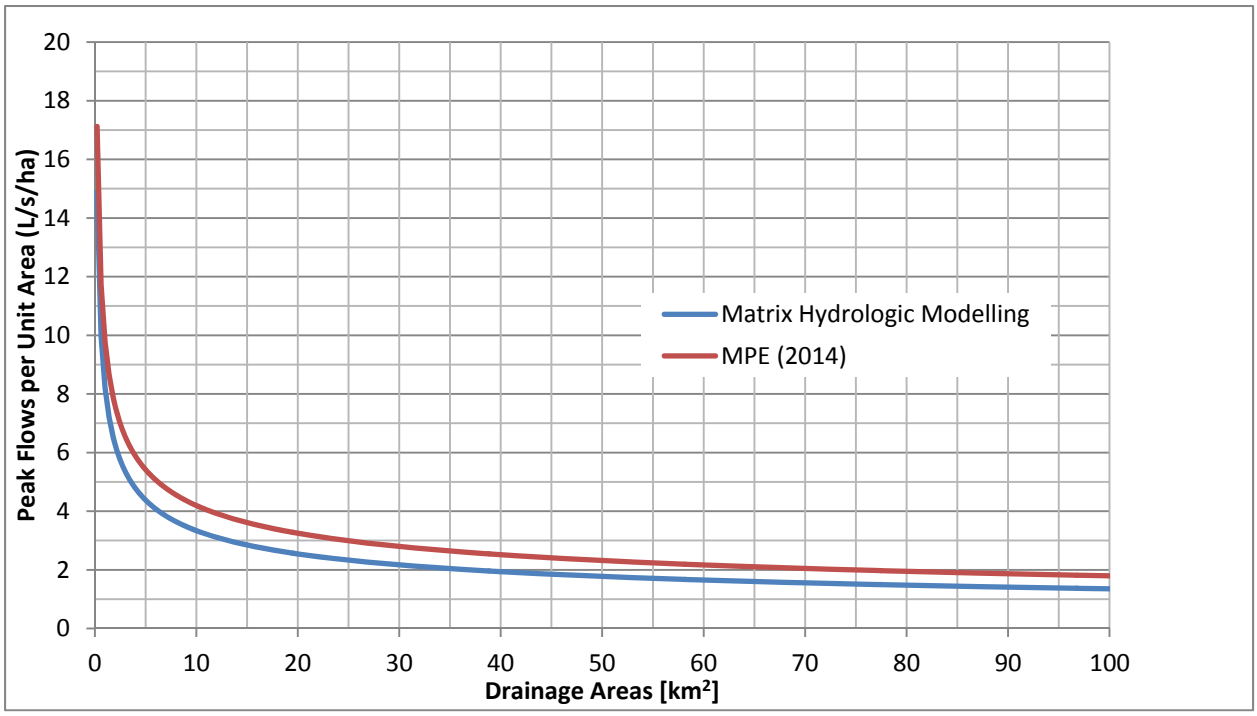

FIGURE 2 Peak Flow per Unite Area Variation with Drainage Area

From Figure 2, it is also evident that the hydrologic modelling results completed in this study provide lower peak flows per unit area than the equation developed in the MPE (2014) report using regional flow analysis.

In a similar fashion, using SCS hydrology CN Method, the 1:5-year pre-development flow rates from a typical full section and quarter section of land area, were determined to vary from 1.8 to 3.5 L/s/ha, respectively. This calculation is based on a 24-hour duration rainfall of 56 mm and a CN value of 60.

5.1.5 Hydraulic and Morphologic Characteristics of Receiving Watercourses / Water Bodies

5.1.5.1 Piper Creek

Matrix conducted a desktop review of the available information on the hydraulic and morphologic characteristics of Piper Creek, the Red Deer River, and the existing ravines. Piper Creek and Waskasoo Creek both run through the City before joining together near 49th Street and Spruce Drive. The urban reaches of both of these creeks are subject to flooding and erosion. Release rates from the SWM facilities draining into Piper Creek should be determined based on a balance between the safe operation of the SWM facilities (e.g., minimizing clogging of the flow control structures and thus reducing flooding

risk in the downstream developments) and maintaining the existing ecology of the creek without increasing erosion and flooding potential in the downstream reaches.

5.1.5.2 Ravines and Wetlands

In addition to the above-mentioned criteria, ecology, water quality, and water quantity in the ravines and wetlands must be considered when determining allowable release rates into these water bodies. Altering flow characteristics by allowing more or less water into their systems may affect sustainability of the ravines and wetlands in the long term. Treated stormwater from adjacent SWM facilities will only be discharged into the wetlands for maintaining their functionality. All applicable regulatory requirements must be satisfied during the planning phase of the future developments, and the necessary permits and approvals shall be in place before development begins.

5.1.5.3 Red Deer River

Based on a preliminary review, the Red Deer River reach through the City is about 75 m wide at mean flow conditions. Given the size and conveyance capacity of the Red Deer River reach, the effect of the discharges through the engineered outfalls on the hydraulic and morphologic characteristic of the river will be limited to the immediate vicinity of the outfall structures. Also, the volume of water discharging through various outfalls will be minor compared to the flows in the river during rainfall events and flood events because the total drainage area serviced by these stormwater outfalls is much smaller than the total drainage area of the river at the outfall locations. Any potential adverse effects on the river hydraulics and morphology in the immediate vicinity of the outfalls can be mitigated by carrying out detailed assessment during the design stage and by implementing appropriate methods, controls, and structures as needed. Water from the SWM facilities in the new developments will be conveyed through storm sewer pipes to the Red Deer River and as a result there will be no adverse effects on the surrounding natural environment. The Red Deer River is less sensitive to stormwater related impacts as compared to the Piper Creek watershed or other water bodies. Consequently, a higher release rate can be justified for the study area draining to the Red Deer River, within the acceptable range, as indicated on Figure 2, for a given drainage area.

5.2 Allowable Release Rates

The stormwater drainage plan will maintain existing drainage patterns and pre-development flow rates, wherever possible. Based on the review of existing drainage patterns, assessment of findings of previous reports and hydrologic modelling of pre-development conditions in the current study area, the outfalls from the SWM facilities will be located on the following:

- Piper Creek
- existing ravines
- Red Deer River

A review of the findings of the pre-development flow rates obtained from computer modelling of the existing conditions and regional flow analysis, clearly indicate that release rates up to 10 L/s/ha from a typical quarter section can be justified for sizing the stormwater infrastructure. Based on a review of the physical features of the receiving watercourses and downstream flooding situations, Matrix proposed lower release rates, depending on the discharge locations.

The following factors were considered in determining release rates from the SWM facilities:

- hydraulic and morphologic conditions of receiving watercourses/water bodies
- flooding potential of downstream areas
- cost-effectiveness of stormwater infrastructure (without affecting natural environment)
- effective drawdown capability of SWM facilities to accommodate runoff from consecutive rainfall events
- considering hydraulic capacity restrictions of the downstream drainage structure and natural watercourses, including Waskasoo Creek
- considering appropriate mitigation measures around outfall structure
- currently adopted release rates by the City and nearby municipalities for similar watercourses

As discussed in Sections 2 and 4.1.3.1, up to 38% of the land area may not be actively contributing to runoff, resulting in an effective drainage area of 108 km^2 of Piper Creek at its confluence with Waskasoo Creek. Using this effective drainage area and Yaremko (1992) estimated 1:100-year peak flow of 44 m^3/s results in a peak flow per unit area of 4.0 L/s/ha. The City currently uses a peak flow unit rate of 3.6 L/s/ha during a 100-year 24-hour storm event for sizing the stormwater infrastructure that drains into Piper Creek.

In this study, for land areas draining through outfalls directly into the Red Deer River, 3.5 L/s/ha and 9.0 L/s/ha allowable release rates are recommended for the 1:5-year and 1:100-year storm events, respectively. Similarly, for land areas draining into the Red Deer River via Piper Creek and the ravines 1.8 and 3.6 L/s/ha allowable release rates are recommended for the 1:5-year and 1:100-year storm events, respectively. This recommendation is based on hydrologic modelling and analysis of pre-development flow rates, and the hydraulic and morphologic characteristics of the Red Deer River, Piper Creek, and several tributary ravines that receive runoff from the study area.

Based on the information and rationale provided above, the recommended allowable 1:100-year and 1:5-year release rates for various sub-watersheds are summarized in Table 6 below.

TABLE 6 Allowable Release Rate Summary

Land Area	1:100-year Release Rate (L/s/ha)	1:5-year Release Rate (L/s/ha)
Draining directly through outfalls into Piper Creek	3.6 L/s/ha	1.8 L/s/ha
Draining directly through outfalls into Ravines/Wetlands	3.6 L/s/ha	1.8 L/s/ha
Draining directly through outfalls into the Red Deer River	9.0 L/s/ha	3.5 L/s/ha

In order to achieve the allowable release rates (and treat the stormwater to meet AEP water quality requirements), all stormwater flows from the future developed areas will be routed through SWM ponds before being discharged into Red Deer River, Piper Creek, or any of the tributary ravines. Appropriate mitigation measures at each outfall location will be incorporated to minimize any adverse effect to receiving water bodies. The allowable release rates are used to determine the opening sizes of outflow control devices (such as orifices) and also the storage requirements for the 100-year storm for each SWM facility.

6 PROPOSED MASTER DRAINAGE PLAN

Proposed drainage catchments have been developed for the study area, with consideration for offsite areas that will require a drainage path through the study area. As specified in the terms of the study, SWM facilities are being considered for each quarter section individually. The exception to this is where the City has indicated that future roads are to cross quarter sections diagonally. In these cases SWM facilities have been identified on each side of the diagonal roadway. These facilities will service subcatchments of similar size to quarter sections.

Map 3 details the storm basin area to each receiving watercourse considered for the current project. In addition, the drainage area for Red Deer River is divided into two areas identified as Outlets 1 and 2 as these areas are distinctly separated by a ravine. Storm basin areas considered in this study, including area in and outside of the study area are detailed in Table 7. A total of 46 subcatchments were defined and assessed within the study area.

TABLE 7 Storm Basin Areas Considered

Storm Basin	Within Study Area (ha)	Offsite Area (ha)	Total Drainage Area* (ha)
Red Deer River Outlet 1	736.0	796.8	1,532.8
Red Deer River Outlet 2	84.1	21.0	105.1
Ravine 1	273.2	344.6	617.8
Ravine 2	60.0	0.0	60.0
Piper Creek	521.3	738.6	1,259.9

*The areas considered to Piper Creek and Red Deer River include only the portion of the storm drainage basins that flow through the study area.

Typically flow is from east to west in this area, while development is progressing from the west. As offsite areas currently drain through the study area, accommodations will need to be made to collect overland flow from the east. Further discussion of the interim options is provided in the following sections.

As shown on Map 2 and previously discussed, there are numerous wetlands within the study area. Any impacts to wetlands will require a Water Act approval and appropriate compensation. Wetlands that are thought to be permanent or semi-permanent are shown on the drainage plans (Map 4 sheets 1-5). These wetlands are likely to be considered more valuable and therefore could incur higher compensation costs. Where interaction between a SWM facility and a wetland is unavoidable, SWM facilities are shown adjacent to these locations, specifically the larger wetlands. Only treated stormwater will be released, which will ensure the wetlands' functionality is maintained.

A sufficient buffer is to be maintained between the natural wetlands and SWM facilities located adjacent to such wetlands, and forebays will also be required upstream of each wetland to further mitigate potential water quality impacts. Any additional mitigation or compensation for affected or lost wetlands or use of wetlands as SWM facilities will be incorporated during the planning phase of the future developments following all regulatory requirements.

6.1 Post-development Drainage Patterns

6.1.1 Piper Creek

The City has previously experienced flooding problems associated with Piper Creek and Waskasoo Creek running through the City and as such we are proposing to reduce the catchment area to Piper Creek as much as feasible. Within the study area, runoff from Sections 1 and 12 will be conveyed south to 19th Street and then west to Piper Creek. Runoff from lands north of 39th Street will be conveyed to Red Deer River to reduce flood risks in downstream developments along Piper Creek and Waskasoo Creek, and to attempt to best accommodate development phasing in some sections (e.g., SW13). External (offsite) drainage areas include Sections 5 through 8 and portions of Sections 4 and 9. According to the Wastewater System Study (Stantec, 2013), Section 1 is only 50% developable. The remainder of this catchment is slated for residential development.

Permanent or semi-permanent wetlands have been identified in SE1, SW1, NE1 and NW12 and SW12. SWM facilities have been proposed adjacent to each of these to minimize compensation requirements by allowing treated stormwater to flow into these wetlands, while maintaining as much natural functionality as possible. A sufficient buffer distance is be maintained between SWM facilities and the wetlands. Forebays will also be required upstream of each wetland to further mitigate potential water quality impacts.

Trunk sewers are proposed along Township Road 381 (between Sections 1 and 12) and 19th Street; each, conveying flow west to 20th Avenue. A trunk sewer will flow south along 20th Avenue to 19th Street and then west along 19th Street to Piper Creek.

While there may be opportunities to convey flows from external areas southerly and around the current study area (refer to Functional Servicing Study Figure 5.10), flows from the external areas have been accounted for in the trunk sewer sizing.

6.1.1.1 19th Street Outlet Sewer

The Functional Servicing Study indicated that an outlet sewer along 19th Street to Piper Creek was not desirable due to a required 18 m of cover near 30th Avenue. As an alternative the Functional Servicing Study recommended an outlet sewer detouring around the Solid Waste Disposal Facility.

Upon review, it has been determined that an outlet sewer along 19th Street could be constructed with a maximum cover of less than 13 m while still meeting minimum cover in the upstream areas and maintaining minimum slope throughout the sewer system. Map 5 shows the anticipated profile along 19th Street and provides some insight into the amount of cut required. By pursuing this route instead of the previously proposed route the City would realize a savings of 2.0 km of trunk sewer.

Location constraints for the 19th Street trunk include: existing four-lane roadway; berm, landscaping, and trail on portion of the north boulevard; a large wetland in Section 34 (on the south side of 19th Street); and a new water trunk main in the boulevard on the north side of 19th Street between 40th and 49th. It is desirable to have the trunk main discharge into Piper Creek upstream (south of) the 19th Street culvert, as this culvert acts as a flow restriction for large storm events helping to prevent flooding of downtown Red Deer. A culvert capacity assessment is recommended during the detailed design phase to ensure that this outflow does not cause undue flood risk upstream of 19th Street.

Existing culverts under 19th Street connect Section 1 and Section 36. There is an existing pond within SW ¼ 36 that is fed by the flow conveyed through these culverts. As such, construction should proceed in a manor than maintains drainage to south of 19th Street as required.

6.1.2 Red Deer River

The first and main outlet to Red Deer River will use the existing trunk sewer on Northland Drive downstream of 30th Avenue. Runoff from lands north of 39th Street and south of Ravine 1 is conveyed to Red Deer Outlet 1. While the divide between the Red Deer River and Piper Creek catchments has been moved to convey more flow northerly (relative to the Functional Servicing Study), a significant increase in lands draining directly to the ravines will decrease the resultant flow to the existing trunk sewer on Northlands Drive.

Similar to the external areas draining into the Piper Creek catchment, ditches along Range Roads may be required to convey flow to inlets at the trunk sewers.

SWM facility locations shown on the drainage plan maps are based on existing topographic data. The exception is Section 13 in which the development plans indicate ponds to be located as follows:

- NW13 - southwest corner
- SW13 - northwest corner and southwest corner.

A second outlet to Red Deer River is proposed between the two ravines in the northern portion of the study area. This outlet primarily services Section NW35; however, accommodations have been made for an external area to the north in case this area cannot be conveyed to the ravines downstream of the study area.

The existing storm sewer on 30th Avenue, north of 67th Street, has been sized to accept flows from the future Emerson development and high school site within SW26.

6.1.2.1 Ravine Crossing

The proposed trunk sewer along the future Northland Drive will cross a ravine approximately 400 m east of the 30th Avenue intersection. A wildlife crossing is anticipated as part of the future road works at this location. Due to the proposed configuration of the future road, it will not be feasible for the trunk sewer to pass over the wildlife crossing. As such, the trunk sewer will need to be constructed below the ravine. There is sufficient fall between the base of the ravine and the existing downstream trunk sewer that an inverted siphon will not be required. Plan and profile of the conceptual crossing design is provided on Map 6.

6.1.3 Ravines

Conveying runoff to the ravines provides both environmental benefits and a cost effective method of controlling and conveying stormwater. Ravines provide habitat and connectivity for wildlife. Maintaining flow to these areas is required to sustaining the viability of these areas. In addition, ravines function as natural drainage infrastructure. As such, utilizing the existing conveyance capacity reduces the amount of engineered infrastructure required.

Runoff from lands immediately adjacent to the ravines within the study area will be outlet to the ravines downstream of the proposed SWM facilities. Flow to the ravines will be conveyed via individual outlets and not concentrated via trunk sewers. This will reduce infrastructure requirements and impacts to the ravine conditions.

The man-made wetland within NW26 has been slated for use as a SWM facility to serve NW26 development (the Evergreen neighbourhood). Much of the lands in NW26 are within the ravine catchment. Construction of the Evergreen neighbourhood began in 2016. The development's SWM

facility has been designed with a primary outlet pipe connecting to the existing trunk main on 30th Avenue, which outlets to the Red Deer River. A secondary outlet has been provided to the north, into the existing ravine, allowing for a slow release of water into the ravine to mimic pre-development conditions.

6.2 Hydrologic and Hydraulic Modelling

Hydrologic and hydraulic modelling using PCSWMM software was carried out for sizing SWM facilities and associated drainage infrastructure. Detailed designs of these facilities will be completed and submitted by developers for approval at a later stage, as development progresses. The hydraulic model was also used to provide preliminary sizing requirements for the trunk sewer system downstream of the SWM facilities.

6.3 Methods

The stormwater modelling software PCSWMM, was used to assess the hydrologic response of the catchments and associated hydraulic response of the proposed drainage system during various design rainfall events. The model was used to determine the required storage volume at each proposed SWM facility to suitably control 100-year event flows to allowable peak rates. Each pond's stage-storage-discharge characteristics were determined along with the major system infrastructure, including the trunk sewer system. To understand the hydraulic functionality of the proposed drainage system and to evaluate proposed SWM facilities, the following method was used to conduct the hydraulic modelling:

- delineating subcatchment areas and determining various physical and modelling parameters for developing the stormwater model
- determining required stage-storage-discharge requirements at each proposed pond such that peak outflows are less than or equal to previously determined pre-development flow rates
- conducting a PCSWMM combined hydrologic and hydraulic analysis of catchments and their related SWM system using a 1:100-year, 24-hour SCS Type 2 rainfall distribution (Appendix A)
    - The model was used to determine the storage requirements and the adequacy of the SWM facilities and the conveyance system.
    - This design rainfall event governs the sizing of the ponds since it has the maximum rainfall depth in comparison to other design rainfall events selected for assessing the performance of the proposed drainage system.
- conducting a PCSWMM combined hydrologic and hydraulic analysis of the entire SWM system using several design rainfall events including the 5, 10, 25 and 50-year, 4-hour Chicago distribution

(Appendix A) to assess the hydraulic functionality of the proposed drainage system during minor system events.

6.4 Trunk Sewer Design

A conceptual design of the trunk sewer system was completed using the developed PCSWMM model. The trunk sewer system has been designed based on City guidelines for minimum cover and AEP guidelines for minimum slope. Sewers have been sized to convey the 100-year outflows from the modelled SWM facilities. Map 7 provides the proposed sewer sizes and slopes as well as manhole inverts throughout the study area.

6.5 Summary of Modelling Results

As mentioned above, SWM facilities were typically designed for each quarter section individually. In cases where the City has indicated that future roads are to cross quarter sections, SWM facilities have been identified on each side of the diagonal roadway. These facilities will service subcatchments of similar size to quarter sections. Using the developed PCSWMM model, SWM facilities have been sized to control peak outflows to less than or equal to the approved release rates.

The proposed SWM ponds have been sized to provide storage for up to the 100-year design storm. A comparison of the allowable release rates with the modelled outflows from the SWM facilities during 1:100 design rainfall event indicates that modelled outflows are very similar to allowable release rates.

Peak outflows from the facilities in the Piper Creek and Ravine catchments for a 5-year, 4-hour storm event are very similar to what would have occurred under natural conditions from a small basin such as one the size of a quarter section. Total peak outflow was compared to total pre-development peak flows at each outlet location to the receiving water body. As shown in Table 8, the total peak flows at the outlets are less than the existing flows for both the 100-year, 24-hour and 5-year, 4-hour event peak outflows, with the exception of the 5-year, 4-hour storm at the Red Deer 2 outlet that is slightly higher than the estimated pre-development peak flow. The SWM modelling completed for this planning level study included a circular orifice at each facility. During detailed design, configuration of the orifice (e.g., consideration of rectangular shape instead of a circular orifice) can be evaluated to control flows to equal or less than pre-development rates.

TABLE 8 Summary of Modelling Results at the Outlets in Red Deer River and Piper Creek

Catchment Outlet	Total Contributing Area (ha)	100-year		5-year	
		Modelled Peak Flow (m^3/s)	Allowable Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Allowable Peak Flow (m^3/s)
Red Deer 1	1,650	14.1	14.9	5.7	5.8
Red Deer 2	105	0.87	0.95	0.43	0.37
Piper Creek	1,260	4.4	4.5	1.9	2.3

Tables 9 to 11 show the physical attributes of the SWM facilities such as surface area at normal water level, high water level, and freeboard elevation (0.6 m of freeboard) for each SWM pond in the Red Deer, Piper, and ravine catchments respectively and summary of modelling results for the 100-year, 24-hour design rainfall event. In a similar fashion, summary of modelling results for other design rainfall events are included in Appendix B. Digital model files are included in Appendix C. A table summarizing the pipe details for the main trunk sections is also included in Appendix B.

TABLE 9 Summary of Modelling Results of Stormwater Ponds draining to the Red Deer River (100-year and 5-year return period)

Pond ID	Drainage Area (ha)	Normal Surface Area (ha)	High Water Level Surface (ha)	Freeboard Surface Area (ha)	High Water Level (m)	Normal Water Level (m)	Maximum Allowable Release Rate (m^3/s)	100-year Peak Outflows (m^3/s)	Max Volume (1,000 m^3)	Orifice Size (m)	5-year Peak Outflows (m^3/s)
1	62.4	1.3	2.3	3.1	912.8	911.3	0.56	0.54	24.4	0.480	0.27
2	31.2	0.7	1.0	1.2	908.8	907.3	0.28	0.29	12.2	0.350	0.15
2A	31.2	0.7	1.0	1.2	907.7	906.2	0.28	0.29	12.2	0.350	0.15
3	70.6	1.8	2.4	2.6	919.9	918.5	0.64	0.60	27.8	0.525	0.26
4	21.9	0.5	0.8	0.9	908.5	907.1	0.20	0.18	8.9	0.280	0.10
5	46.4	1.1	1.5	1.7	907.4	906.0	0.42	0.41	18.4	0.420	0.19
6	59.1	1.4	1.9	2.1	904.5	903.1	0.53	0.51	23.2	0.475	0.24
7	66.3	1.7	2.2	2.5	897.1	895.7	0.60	0.55	26.4	0.500	0.24
8	67.8	1.7	2.2	2.5	895.0	893.6	0.61	0.56	27.0	0.500	0.25
9	68.3	1.7	2.2	2.5	884.9	883.5	0.61	0.56	27.2	0.500	0.25
10	84.2	2.0	2.6	2.8	875.0	873.6	0.76	0.79	31.9	0.600	0.32
11	55.4	1.4	1.9	2.1	882.6	881.2	0.50	0.47	22.0	0.460	0.22
20	41.6	1.0	1.4	1.6	877.4	876.0	0.37	0.33	17.0	0.375	0.16
21	42.5	1.0	1.4	1.6	879.8	878.3	0.38	0.33	17.4	0.375	0.17
23	21.0	0.5	0.7	0.9	879.2	877.8	0.19	0.21	8.1	0.300	0.11
28	265.9	6.2	7.1	7.5	918.8	917.3	2.39	2.26	98.5	1.050	0.66
29	97.0	2.4	3.0	3.2	960.3	958.9	0.87	0.84	37.5	0.620	0.33
33	104.9	2.4	3.0	3.2	938.5	937.0	0.94	0.95	39.8	0.650	0.38
34	80.7	1.9	2.5	2.7	925.0	923.6	0.73	0.716	31.2	0.565	0.30
35	97.1	2.4	3.0	3.2	917.1	915.7	0.87	0.84	37.5	0.620	0.33
36	151.2	3.5	4.3	4.6	907.9	906.4	1.36	1.32	57.0	0.780	0.46
13	71.3	1.8	2.4	2.6	882.5	881.1	0.64	0.56	28.7	0.500	0.25
16	42.2	1.0	1.4	1.6	880.4	878.9	0.38	0.33	17.3	0.375	0.16
17	74.9	1.8	2.4	2.6	892.0	890.5	0.67	0.58	30.3	0.500	0.27

Note: [1]Allowable release rates: 1:100-year 9 L/s/ha, 1:5-year 3.5 L/s/ha.

TABLE 10 Summary of Modelling Results of Stormwater Ponds draining to Piper Creek (100-year and 5-year return period)

Pond ID	Drainage Area (ha)	Normal Surface Area (ha)	High Water Level Surface (ha)	Freeboard Surface Area (ha)	High Water Level (m)	Normal Water Level (m)	Maximum Allowable Release Rate (m^3/s)	100-year Peak Outflows (m^3/s)	Max Volume (1000 m^3)	Orifice Size (m)	5-year Peak Outflows (m^3/s)
1	65.8	1.9	2.5	2.7	898.2	896.7	0.59	0.23	32.0	0.310	0.11
2	65.8	1.9	2.5	2.7	899.9	898.4	0.59	0.23	32.0	0.310	0.114
3	38.0	1.1	1.5	1.7	898.2	896.7	0.34	0.13	18.7	0.235	0.07
4	59.8	1.8	2.3	2.5	900.1	898.7	0.54	0.21	29.1	0.300	0.11
5	26.1	0.7	1.0	1.2	898.9	897.4	0.23	0.09	12.9	0.191	0.05
6	62.8	1.8	2.3	2.5	898.8	897.3	0.57	0.23	30.3	0.310	0.12
7	68.9	2.0	2.6	2.8	900.1	898.7	0.62	0.24	33.4	0.320	0.12
8	63.8	1.8	2.4	2.6	903.5	902.1	0.57	0.23	30.9	0.310	0.12
9	70.3	2.0	2.6	2.8	903.8	902.3	0.63	0.25	34.1	0.320	0.12
13	111.3	3.3	4.0	4.3	924.4	923.0	1.00	0.40	53.4	0.410	0.18
14	263.0	7.9	8.9	9.4	902.9	901.4	2.37	0.91	123.9	0.635	0.31
16	262.0	8.0	9.0	9.5	908.2	906.8	2.36	0.90	123.6	0.635	0.31
17	102.2	3.3	4.0	4.3	944.6	943.3	0.92	0.33	50.1	0.380	0.15

Notes: [1]Allowable release rates: 1:100-year 3.6 L/s/ha, 1:5-year 1.8 L/s/ha

TABLE 11 Summary of Modelling Results of Ravine Stormwater Ponds (100-year and 5-year return period)

Pond ID	Drainage Area (ha)	Normal Surface Area (ha)	High Water Level Surface (ha)	Freeboard Surface Area (ha)	High Water Level (m)	Normal Water Level (m)	Maximum Allowable Release Rate (m^3/s)	100-year Peak Outflows (m^3/s)	Max Volume (1000 m^3)	Orifice Size (m)	5-year Peak Outflows (m^3/s)
RV-15	59.3	1.8	2.3	2.5	890.9	889.5	0.53	0.21	28.8	0.300	0.10
RV-16	58.5	1.8	2.3	2.5	877.9	876.5	0.53	0.21	28.4	0.300	0.10
RV-17	24.1	0.7	1.0	1.2	879.7	878.3	0.22	0.09	11.7	0.200	0.05
RV-22	20.3	0.6	0.9	1.0	879.7	878.3	0.18	0.07	10.0	0.170	0.04
RV-18	50.7	1.5	2.0	2.2	882.8	881.4	0.46	0.17	24.9	0.270	0.09
RV-21	9.4	0.2	0.4	0.5	883.7	882.3	0.08	0.04	4.6	0.120	0.02
RV-23	172.3	5.5	6.4	6.8	901.4	900.0	1.55	0.61	81.8	0.525	0.23
RV-24	172.3	5.5	6.4	6.8	904.9	903.5	1.55	0.61	81.8	0.525	0.23

Note: [1]Allowable release rates: 1:100-year 3.6 L/s/ha, 1:5-year 1.8 L/s/ha

7 IMPLEMENTATION PLAN

The developed MDP can be used as a guiding document in development stages within the Greater East Hill area. The proposed volume requirements for SWM facilities were sized without considering any BMPs in place. However, it is recommended that BMPs including low impact development features suitable for the Red Deer area and deemed acceptable by the City be considered, designed, and implemented during detailed design stages. BMPs can be adapted from Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems, Part 5 - Stormwater Management Guidelines (ESRD 2013) and will include SWM methods that retain as much of the natural runoff characteristics and infiltration components of the undeveloped system as possible.

In addition, appropriate regulatory requirements for conserving the natural environment and wetlands, and also a compensation plan for any lost wetlands or use of wetlands as SWM facilities need to be identified and fulfilled at the detail design phase of the individual developments before proceeding with the implementation of the drainage plan.

Appropriate geotechnical investigation needs to be completed during the planning stage of future development to determine design parameters for the construction of all the proposed ponds. Relevant environmental and engineering studies also need to be completed at the planning stage to address any environmental, regulatory concerns and to identify and mitigate any potential issues affecting developments.

The consideration and implementation of low impact development (LID) features including source control and BMPs at the development stage is highly recommended. These features will reduce peak flows and reduce total runoff volumes and thereby will also reduce pollutant loadings. In addition, the footprint and storage volume requirements will be reduced for the catchment areas where LID features are implemented. The location and footprint for each SWM facility provided in this report can be considered as a guide only and any details presented herein may be modified or changed as further information and data become available. While exact locations and sizes of pipes and ponds will be designed in the future, their intended functions will remain as described herein.

8 REGULATORY APPLICATIONS

This MDP was required as per Section 3.7 in *Water Act* Approval No. 00356040-00-00, as amended. The purpose of the MDP is to have a single report that studies how drainage from individual developments works together, rather than having individual submissions that may not consider nearby developments. Therefore, AEP will issue a new approval for the development area.

The City will need to prepare and submit a *Water Act* application to AEP for the new development area. An application for registration under the *Environmental Protection and Enhancement Act* is not required.

Water Boundaries will be submitted by individual developers (as development proceeds) for assessment under *Public Lands Act* for determination of Crown-claimable wetlands.

The following regulatory requirements may apply to the development area:

- Current City of Red Deer Design Guidelines
- Current AEP Stormwater Management Standards and Guidelines
- The Code of Practice for Outfall Structures on Water Bodies
- *Public Lands Act*
- *Fisheries Act*
- *Navigable Waters Protection Act*
- *Migratory Birds Act*

Developers will be responsible for preparing and acquiring required approvals, authorizations, or permissions from the appropriate regulatory agencies. The following three options exist for developers:

1. Avoid all wetlands, in which case no Approvals under the *Water Act* or *Public Lands Act* are required.

2. Impact any or all wetlands, which will require an Approval under the *Water Act* and *Public Lands Act* and adherence to wetland replacement requirements in accordance with the *Alberta Wetland Mitigation Directive* (AEP 2017).

3. Incorporate some wetlands into the SWM system, in which case an Approval to divert stormwater into those wetlands will be required under the *Water Act* and likely the *Public Lands Act* (if the wetlands identified to receive stormwater are either semi-permanent or permanent wetlands); however, if these wetlands are designed according to the guidelines outlined in *General Design Guidelines for a Constructed 'Habitat' Wetland – Grasslands Natural Region* (AT 2014), each of these designed stormwater wetlands could serve as partial wetland replacement in accordance with the *Alberta Wetland Mitigation Directive* (AEP 2017)

9 CONCLUSIONS

This MDP addresses the drainage design criteria and SWM requirements for the East Hill area of the City of Red Deer. This includes determining the allowable release rates from future development areas draining to Red Deer River, Piper Creek, and various ravines, as well as providing adequate storage and treatment for stormwater flows before being discharged and planning for trunk storm sewer systems to convey stormwater to respective outfalls. In addition to a land area of 1,670 ha located within the study area, surface water runoff from an additional offsite area of 2,610 ha flows through the study area before draining into Piper Creek and the Red Deer River. As a result, the storm drainage boundary considered in the current study includes a total land area of 4,280 ha. As these offsite areas currently drain through the study area, accommodations of flows have been made to collect overland flow from the east into the proposed storm drainage system.

Stormwater flows from the future developed areas will be routed through SWM ponds before being discharged into Red Deer River, Piper Creek, or any of the tributary ravines. As the study area is located on multiple watersheds, different release rates are proposed based on outlet locations. The recommended allowable release rates are provided in Table 12.

TABLE 12 Allowable Release Rate Summary

Land Area	1:100-year Release Rate (L/s/ha)	1:5-year Release Rate (L/s/ha)
Draining directly through outfalls into Piper Creek	3.6	1.8
Draining directly through outfalls into Ravines/Wetlands	3.6	1.8
Draining directly through outfalls into the Red Deer River	9.0	3.5

These release rates are recommended based on the findings of the pre-development flow analysis and desktop review of the hydraulic and morphologic characteristics of the Red Deer River, Piper Creek, and any of the tributary ravines that receive runoff from the study area. Appropriate mitigation measures at each outfall location will be incorporated to minimize any adverse effect to receiving water bodies.

A PCSWMM model has been developed for the post-development conditions including SWM facilities, orifices sized to control peak outflows to less than or equal to the approved release rates, and a trunk sewer system to convey outflows to designated outlet locations. The detailed results of this modelling are provided in digital format along with this report.

A comparison of the allowable release rates with the modelled outflows from the SWM facilities during 1:100-year design rainfall event indicates that modelled outflows are very similar to allowable release rates. The modelling results during a 5-year, 4-hour storm event indicate that the peak outflows from the facilities in the Piper Creek and Ravine catchments are very similar to what would have occurred under natural conditions from a small basin such as one the size of a quarter section; however, the modelled outflows from the ponds in the Red Deer catchments during a 5-year design storm event are on average 10% higher than the allowable release rates on an individual pond basis. Total peak flows through all the outfalls are less than the total allowable flows for the 100-year, 24-hour event; however, during a 5-year, 4-hour design storm event, total outflows through all the outfalls except the Red Deer 2 outlet are less than the allowable flows. The peak outflow through the Red Deer 2 outlet is about 15% higher than allowable.

The SWM modelling completed for this planning level study included a circular orifice at each facility. During the detailed design, configuration of the orifice (e.g., consideration of rectangular shape instead of a circular orifice) can be evaluated to reduce the outflow from each facility to be equalled or less than the allowable rates during the 5-year, 4-hour storm event.

Wetlands are located throughout the study area. A desktop wetland assessment was conducted to identify and tentatively classify wetlands within the study area that may be affected by future

developments. Proposed SWM facilities have been aligned with the locations of select semi-permanent and permanent wetlands, where feasible, to reduce future wetland replacement obligations. The use of wetlands as SWM facilities should be avoided where possible. If unavoidable, they must adhere to specific design specifications, including sufficient buffers between SWM facilities and wetlands and forebays upstream of wetlands. Appropriate mitigation and compensation will be incorporated during the planning stage of future developments. ER should be placed on all wetlands that are not affected by the developments. Wetland impact assessments and a plan for the protection of wetlands should be included as a part of SWM plan as development progresses. SWM facilities were typically designed for each quarter section individually. In cases where the City has indicated that future roads are to cross quarter sections, SWM facilities have been identified on each side of the diagonal roadway. These facilities will service subcatchments of similar size to quarter sections.

10 RECOMMENDATIONS

All SWM facilities shall be equipped with a forebay and permanent pool and will be sized to accommodate storm runoff volume during a 100-year, 24-hour design rainfall events and will be configured to enhance and improve water quality and to remove at least 85% of suspended sediment greater than 75 micron in size.

The proposed trunk sewer along the future Northland Drive will cross a ravine approximately 400 m east of the 30th Avenue intersection. A wildlife crossing is anticipated as part of the future road works at this location. Due to the proposed configuration of the future road, it will not be feasible for the trunk sewer to pass over the wildlife crossing. As such, the trunk sewer will need to be constructed below the ravine. There is sufficient fall between the base of the ravine and the existing downstream trunk sewer that an inverted siphon will not be required. Alternative options of constructing this crossing need to be further assessed at the planning stage.

Appropriate geotechnical investigation needs to be completed during the planning stage of future development to determine design parameters for the construction of all the proposed ponds. Relevant environmental and engineering studies also need to be completed at the planning stage to address any environmental, regulatory concerns and to identify and mitigate any potential issues affecting developments.

The consideration and implementation of LID features including source control and BMPs at the development stage is highly recommended. These features will reduce peak flows, total runoff volumes and thereby will also reduce pollutant loadings. In addition, the footprint and storage volume requirements will be reduced for the catchment areas where LID features are implemented. The location and footprint for each SWM facility provided in this report can be considered as a guide only and any details presented herein may be modified or changed as further information and data become available. While exact locations and sizes of pipes and ponds will be designed in the future, their intended functions will remain as described herein.

It is recommended that this MDP be adopted as a framework for developments within the basin and be submitted to AEP for approval under the *Water Act*.

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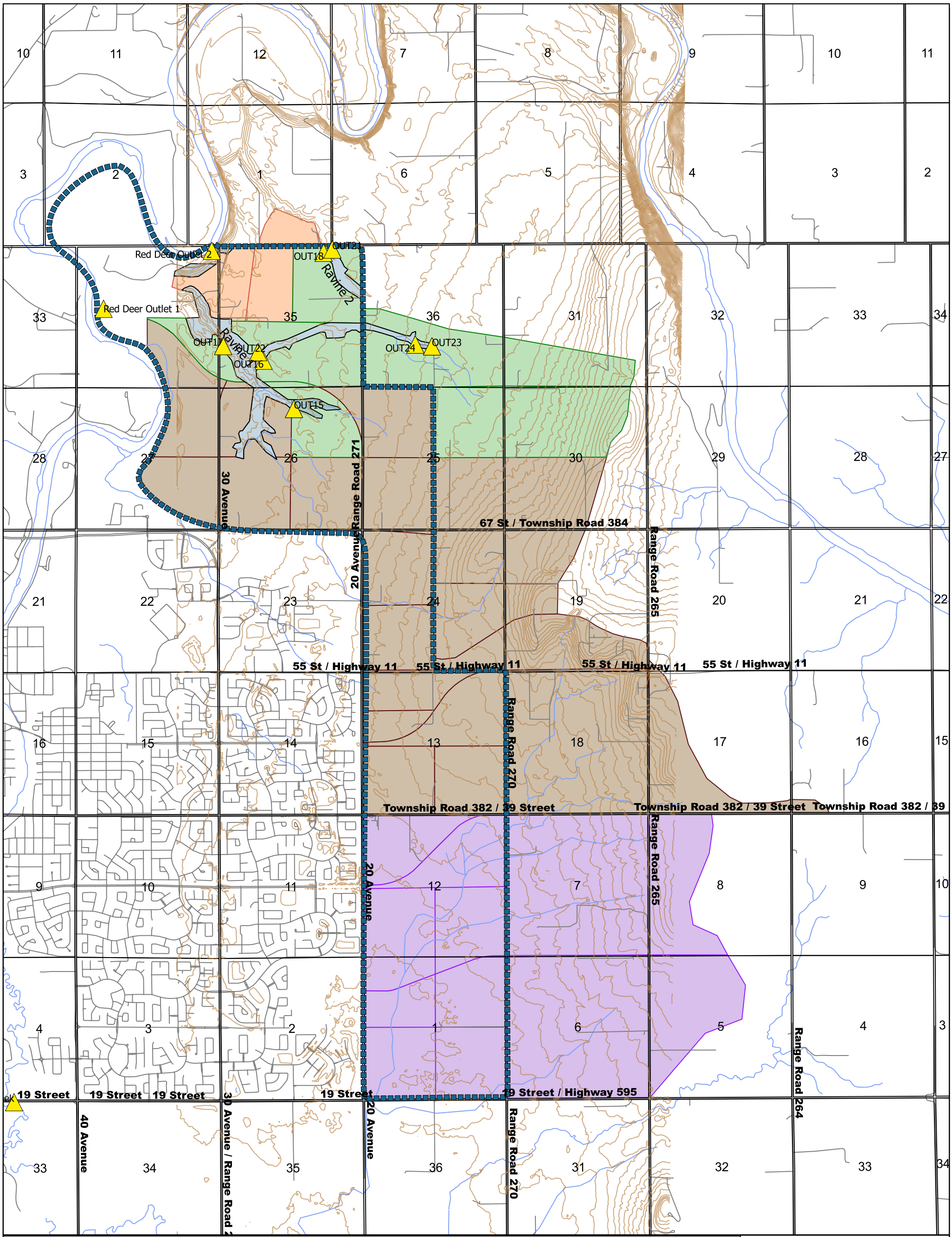

StudyArea-Matrix

Contours-5m

Roads

Ravines

Watercourse

Proposed Future Catchments

Piper

Ravine

RedDeer1

RedDeer2

Proposed Outlets

N

0 500 1000 1500 m

1:40,000

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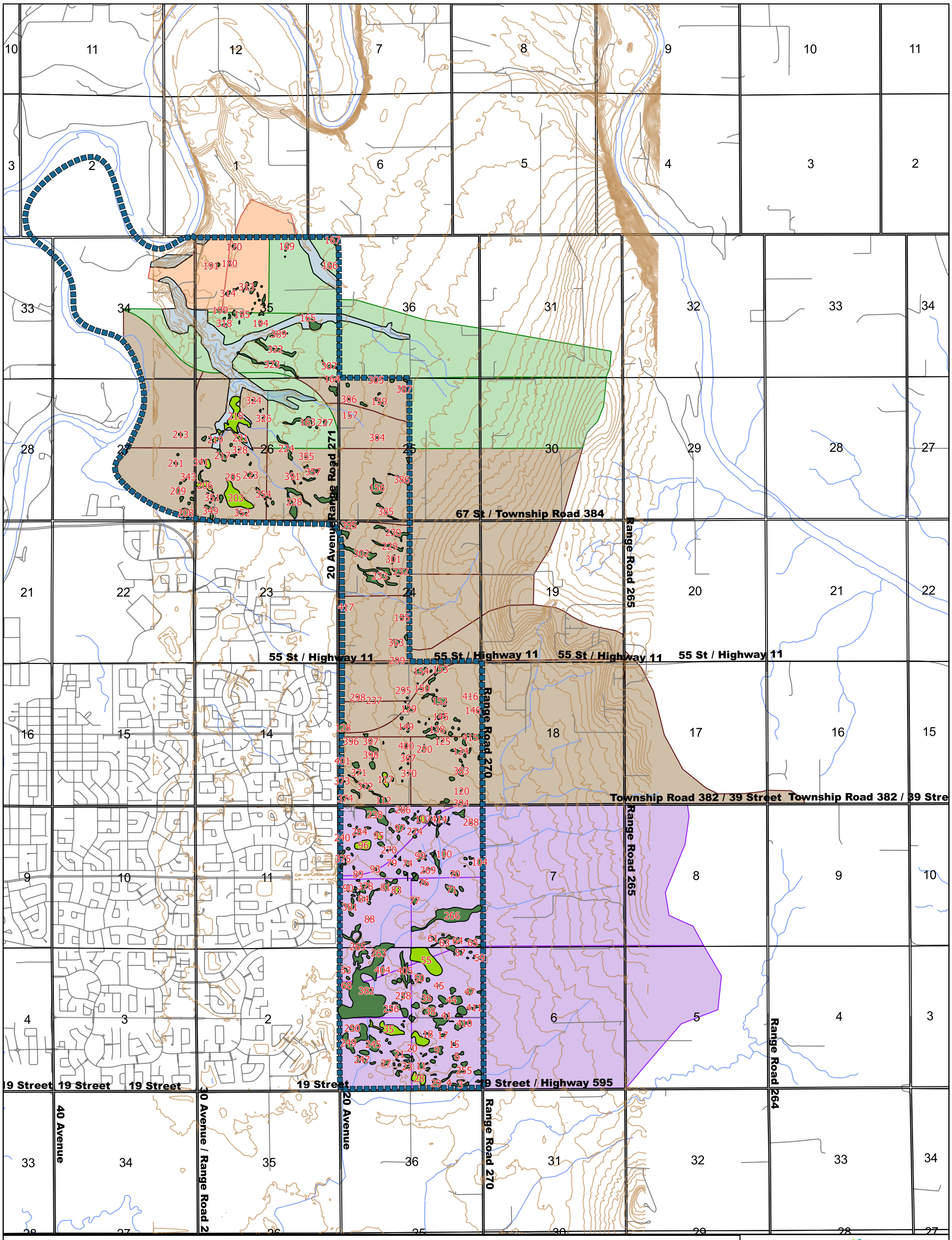
Greater East Hill
Master Drainage Plan
City of Red Deer, Alberta

Matrix Project #23973

Study Area

K. Hofbauer
M. Shome

Map 1


67 St / Township Road 384
55 St / Highway 11
55 St / Highway 11
55 St / Highway 11
55 St / Highway 11
Township Road 382 / 39 Street
Township Road 382 / 39 Stre
19 Street / Highway 595
19 Street
19 Street
19 Street
19 Street
20 Avenue Range Road 271
Range Road 265
Range Road 270
Range Road 265
Range Road 264
Range Road 270
40 Avenue
30 Avenue / Range Road 2
20 Avenue
N
StudyArea-Matrix
Contours-5m
Roads
Ravines
Watercourse
Semi- and Permanent Wetlands
Other Wetlands
Proposed Future Catchments
Piper
Ravine
RedDeer1
RedDeer2
0 500 1000 1500 m
1:40,000
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ENVIRONMENT & ENGINEERING
Greater East Hill
Master Drainage Plan
City of Red Deer, Alberta
Matrix Project #23973
Wetland Areas
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K. Hofbauer
M. Shome
Map 2

186 ha within Study Area
39 ha outside Study Area

Red Deer Oulet 2
Red Deer Outlet 2

OUT21
OUT18
Ravine 2

Ravine 2
43 ha within Study
442 ha outside Study Area

Red Deer Outlet 1

OUT17
Ravine 3
OUT22
OUT24
OUT23
OUT16
OUT15

Ravine 1

Red Deer Outlet 1

683 ha within Study Area
549 ha outside Study Area

30 Avenue
Range Road 271
20 Avenue
67 St / Township Road 384
Range Road 265
55 St / Highway 11
Red Deer Outlet 1
55 St / Highway 11
55 St / Highway 11
456 ha within Study Area
93 ha outside Study Area
Range Road 270
Township Road 382 / 39 Street
Township Road 382 / 39 Street
Township Road 382 / 39
20 Avenue
Range Road 265
Piper Creek
576 ha within Study Area
1143 ha outside Study Area
Range Road 264
19 Street
19 Street
19 Street
19 Street
19 Street / Highway 595
40 Avenue
30 Avenue / Range Road 2
20 Avenue
Range Road 270

StudyArea-Matrix
Predevelopment Subcatchments
Contours-5m
Roads
Ravines
Watercourse

N

0 500 1000 1500 m
1:40,000

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Greater East Hill
Master Drainage Plan
City of Red Deer, Alberta

Matrix Project #23973

Predevelopment Catchment Areas

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M. Shome

Map 3