DRAFT WAPITI WATERSHED SOURCE WATER RISK ASSESSMENT

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PROJECT TEAM

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Risk Assessment Background for Identified Hazards

What is a Source Water Protection Plan?

Although contaminated water may seem like a 19th century problem, water quality is still a major issue today even in countries using advanced technology to monitor and treat water (Hrudey & Hrudey, 2019). The potential for contaminated water increases greatly when water is not provided via a water treatment plant but rather accessed for recreation through private systems. A Source Water Protection Plan improves even further the safety of water that comes from a water treatment plant and simultaneously improves water quality in the environment and the uses associated with this.

The multi-barrier approach comprises of six core elements: source water protection; effective water treatment; secure water distribution system; water quality monitoring (at source, treatment plant, and tap); operator training and an emergency response procedure. Central to the multi-barrier approach is the assessment and management of the risks to water safety that can be addressed by each barrier (Dunn, Harris, Cook, & Prystajecky, 2014). Source Water

Source Water Protection Plan Development: how it was done.

The project team consisted of both those who work primarily in the water field and may be considered water experts as well as those who did not. This diversity was intentional so that the project team had a broader range of values and understanding involved in the risk assessment, thereby increasing its robustness through contributory expertise, which is "the capacity and skill to interact with participants within a field of relevance" (Bosholm & Prutzer, 2017). The reader is recommended to (Bosholm & Prutzer, 2017) for a discussion of expertise and water management.

Potential hazards to source water in the Wapiti Watershed were identified and then assessed for risk. Below is the assessment completed by the project team for the identified hazards. All hazards were assessed for risk based on the likelihood of a particular hazard occurring **AND** it affecting water. The severity was assessed in the case that a hazard occurred **AND** impacted water what was the level of the impact.

The scale used for assessing risk is found in Table 1. Scale used for risk assessment and the risk assessment is found in Table 2. Risk assessment for identified hazards to source water in the Wapiti Watershed. For each hazard, the intensity of the event was assumed to be normal. If a catastrophic event occurs, the severity for the risk assessment would be much higher. The rationale for the risk assessment is found in Risk Assessment Summary.

Why a Wapiti Watershed Source Water Protection Plan

The reason for undertaking a Source Water Protection Plan is the need to proactively manage the critical water resource in this watershed. Addressing potential issues before they occur can prevent serious economic impacts, protect aquatic life and manage conflict (Redd & Kalimantan, 2010). Source water protection also aligns with the 3 goals of Alberta's *Water for Life* Strategy: 1) safe, secure drinking water; 2) healthy aquatic ecosystems, and 3) reliable supplies for a sustainable economy. Specific to the Wapiti Watershed, the Wapiti River Water Management Plan Steering Committee recommended that a watershed scale management plan, of which a Source Water Protection Plan is one type, be undertaken as a complement to the Water Conservation Objectives (Wapiti River Water Management Plan Steering Committee, 2019).

The Scope of the Plan

Scope of source water is both human health and ecosystem health (Dunn, Harris, Cook, & Prystajecky, 2014). For this plan, the entirety of the watershed was considered, and source water was defined as follows. All water in the Alberta portion of the Wapiti Watershed (Appendix A) that is accessed by humans for use. This can entail drinking water withdrawals, industrial withdrawals and recreational use among others.

Cumulative Effects

Currently there is a great emphasis among all industries and levels of government to improve their management practices. Subsequently, we see a decreasing risk associated with the individual instance of each hazard identified. Nevertheless, there is substantial risk present due to the cumulative, additive nature of all these hazards. Moreover, it is very difficult to define and assess the potential interactive and additive effects of so many different contaminants from so many different sources (Villanueva, et al., 2014; Van der Brink, et al., 2019). Any single cutblock, field, pipeline or lawn is likely to have an insignificant effect on the source water of the watershed, but the sum of every cutblock, every field, every pipeline and every lawn has a significant impact. Although the risk of individual activities may not appear to be all that great it is critical to place this within the context of an ever-increasingly developed watershed with a broad range of stressors.

A study commissioned by Alberta Environment and Parks provides an effective management tool for understanding the potential for cumulative effects. Inventory and Evaluation of Non-Point Pollution Sources in the Wapiti River Basin (Hutchison Environmental Sciences Ltd., 2018) explores the potential for contaminants to be transported off the landscape and into source water by examining factors such as topography, soil characteristics and drainage density. Through a detailed modelling exercise, a model for the cumulative export of contaminants from the landscape into the water has been developed. A few key maps are presented in Appendix B. In Appendix C, there are maps of management priority that have added land use, i.e.., human activity, to the mix to identify those areas where we can do the most to reduce contaminants from reaching source water. This study can be found at www.mightypeacewatershedalliance.org/projects/wapiti-watershed-source-water-protection-plan/.

Ultimately, the cumulative effect of all identified hazards presents the greatest risk to source water in the Wapiti Watershed.

Climate Change

A watershed modelling exercise conducted by the Pacific Climate Impacts Consortium on the Pine River Watershed, which is similar to the Wapiti River Watershed, provides a scenario for climate change in the Wapiti Watershed (Schnorbus, Bennett, & Berland, 2011). This scenario indicates that the Wapiti Watershed is unlikely to see much change in its hydrology due to climate change in the next 25 years. However, a multi-barrier is prudent in terms of climate change because it helps to address uncertainty in future conditions. As noted by Bosholm & Prutzer (Bosholm & Prutzer, 2017), adaptation will become increasingly important as climate change affects our water resources, thereby elevating the utility of the multi-barrier approach that includes source water protection planning.

This Document

This document represents the work of hazard identification and risk assessment and not a Source Water Protection Plan. After engagement has been done on the hazards and risks, the project team will review

the input. Once a risk assessment has been finalized, then work will begin on mitigative strategies which are the final component of the Source Water Protection Plan. This is when practices and policies are recommended that will afford protection to source waters throughout the Wapiti Watershed.

Hazards Ranked as the Highest Risk

Table 1 Relative Risk Ranking Table of Highest 3 Risk Rankings for Identified Hazards

Number	Hazard
	Cumulative Effects
1	Illegal dumping into wastewater systems
21	Temporary Harvest Roads
25	Forest fires (not controlled)
16	Manure disposal
43	Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)
59	Crossings/culverts/ditches (this more of a pathway)
74	Stormwater (pathway)
77	Flooding
2	Illegal dumping rest of watershed
4	Development
5	Wildlife faeces
6	Wildlife pathogens
9	Application of chemicals for weeds
11	BC portion of watershed
12	Feedlots/confined feeding operations

13	Application of chemicals
17	Ditching/draining
20	Cutblocks (includes normal operation, runoff, etc.)
42	Erosion caused by OHVs
45	Boat operation leading to incidental discharge and emissions
47	Recreational development (new & existing)
49	Sediment from rural properties
50	Runoff in stormwater management systems
53	Improper Hazardous waste disposal
56	Highway 40 Bridge Spill
57	Road salt/de-icer application
60	Trucking (primarily Transportation of Dangerous Goods)
61	Construction
62	Petroleum from vehicles day to day operation
63	Calcium application for dust control
65	Railway oil/grease/fuel leakage
67	De-icing at GP airport
70	Stormwater (pathway)
78	Bank slumping
79	Discharges (treated wastewater intentional releases)

Risk Assessment of all Hazards

Table 2 Risk Assessment Rating Matrix

Likelihood		
The probability of a hazard occurring and affecting water.	1	most unlikely
	2	unlikely
	4	possible
	8	probable
	16	almost certain
Severity		
The level of impact on source water due to occurrence.	1	insignificant
	2	minor
	4	moderate
	8	severe
	16	catastrophic
Certainty		
The team's confidence in their assessment.	1	very uncertain
	2	uncertain
	4	perhaps
	8	certain
	16	very certain

Table 3 Categorized Risk Assessment Table for the Wapiti Watershed of all Identified Hazards

	Hazard				
#	General/Other	Likelihood	Severity	Risk	Certainty
1	Illegal dumping into wastewater systems	4	16	64	16
2	Illegal dumping rest of watershed	16	1	16	8
3	Deleterious substances	8	1	8	4
4	Development	16	1	16	8
5	Wildlife faeces	16	1	16	8
6	Wildlife pathogens	8	2	16	8
7	Active Landfills (includes operations, fires and leachate)	4	2	8	8
8	Inactive/abandoned landfills	4	2	8	4
9	Application of chemicals for weeds	8	2	16	4
10	Invasives/weeds	2	1	2	4
11	BC portion of watershed	8	2	16	1

	Land disposal (from drilling or waste treatment sludge)	2	1	2	8

	Agriculture	Likelihood	Severity	Risk	Certainty
12	Feedlots/confined feeding operations	8	2	16	4
13	Application of chemicals	16	1	16	8
14	Storage of chemicals	4	1	4	8
15	Livestock grazing	8	1	8	2
16	Manure disposal	16	2	32	4
17	Ditching/draining	16	1	16	8
18	Land clearing/tree location	8	1	8	4
19	Garbage burning	1	1	1	4

	Forestry	Likelihood	Severity	Risk	Certainty
20	Cutblocks (includes normal operation, runoff, etc.)	16	1	16	8
21	Temporary Harvest Roads	16	4	64	8
22	Wood storage yards	2	1	2	8
23	Spills	2	1	2	8
24	Rutting	4	1	4	8
25	Forest fires (not controlled)	8	8	64	4
26	Fire-fighting chemical	4	2	8	4
27	Herbicide	2	1	2	8
28	Camps	2	1	2	8
29	Mountain Pine Beetle/pests	1	1	1	8

	Oil & Gas	Likelihood	Severity	Risk	Certainty
30	Pipeline releases	2	4	8	4
31	Surface spills	2	1	2	8
32	Subsurface spills (casing failures)	1	1	1	1
33	Air emissions/flaring	1	1	1	2
34	Suspended wells and pipelines	1	1	1	8
35	Linear disturbance incl seismic lines and pipelines (pathway)	4	1	4	4
36	Pads	2	1	2	4
37	Water access infrastructure	2	2	4	4
38	Herbicide spraying	4	2	8	8
39	Camps	2	1	2	4
40	Sumps new	1	1	1	8
41	sumps old	4	2	8	4

	Recreational	Likelihood	Severity	Risk	Certainty
42	Erosion caused by OHVs	16	1	16	8

43	Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)	16	2	32	8
44	Unauthorized boat launches	4	2	8	4
45	Boat operation leading to incidental discharge and emissions	16	1	16	8
46	Sediment due to wake or boat disturbing channel	8	1	8	8
47	Recreational development (new & existing)	8	2	16	8
48	Parks outhouses	2	2	4	8
	Rural - residential properties not agricultural and not in subdivisions	**Likelihood**	**Severity**	**Risk**	**Certainty**
49	Sediment from rural properties	16	1	16	8
50	Runoff in stormwater management systems	16	1	16	16
51	Spill of Hazardous materials (lawnmower, recreational vehicles, chainsaws, etc.	1	1	1	16
52	Garbage burning (both barrel and otherwise)	1	1	1	16
53	Improper Hazardous waste disposal	8	2	16	8
54	Water wells	2	4	8	1
55	Septic systems/private systems	2	2	4	4
	Transportation	**Likelihood**	**Severity**	**Risk**	**Certainty**
56	Highway 40 Bridge Spill	2	8	16	8
57	Road salt/de-icer application	16	1	16	8
58	Road salt storage (includes snow dump)	2	2	4	4
59	Crossings/culverts/ditches (this more of a pathway)	16	2	32	4
60	Trucking (primarily Transportation of Dangerous Goods)	2	8	16	8
61	Construction	16	1	16	8
62	Petroleum from vehicles day to day operation	16	1	16	4
63	Calcium application for dust control	16	1	16	4
64	Railway spills				
65	Railway oil/grease/fuel leakage	16	1	16	8
66	Creosote Ties				
67	De-icing at GP airport	16	1	16	8
68	Tarmac run-off	4	1	4	8
	Urban	**Likelihood**	**Severity**	**Risk**	**Certainty**
69	Institutional/commercial/industrial	4	2	8	1
70	Stormwater (pathway)	~~8~~	2	16	2
71	Yard care	4	2	8	4

	Water/Wastewater infrastructure	Likelihood	Severity	Risk	Certainty
72	Boat hitting water intake	1	1	1	4
73	Lagoons (breach or failure)	2	2	4	4
74	Stormwater (pathway)	16	2	32	4
75	Camp wastewater	2	1	2	8
76	Drought	2	1	2	4
77	Flooding	16	2	32	4
78	Bank slumping	8	2	16	4
79	Discharges (treated wastewater intentional releases)	16	1	16	8

*Fields that are empty reflect hazards for which insufficient information or expertise was available to make an assessment

Risk Assessment Summary

General

1. Illegal dumping into wastewater systems

The County of Grande Prairie had to close and remediate their Sportsplex pond as recently as May 23, 2019 due to illegal dumping of Industrial Oil into a curbside drain (County of Grande Prairie No. 1, 2019). Although treatment can prevent events from reaching source water, there is the possibility that illegal dumping could cause the failure of the treatment system and subsequently lead to a system failure and large release of untreated wastewater to source water.

The likelihood of this occurring is possible and the severity is assessed as high.

2. Illegal dumping rest of watershed

An annual clean up of the dunes area south-east of Grande Prairie removes many tonnes each year; 18.9 Tonnes in 2016 and 11.35 Tonnes in 2017 (Alberta Environment and Parks, pers. comm.). Although there is regular clean-up and general compliance is with littering regulations is thought to be better, the volume which stills occur is a hazard. Most substances that are illegally dumped will not make their way into source water and negatively impact source water.

The likelihood is almost certain and the severity is insignificant.

3. Deleterious substances

This category does not include industrial activities, nor illegal activities but substances introduced to water through normal, routine and legal actions.

The likelihood of this hazard is probable and the severity is insignificant.

4. Development

Altering a landscape from historic state to developed, involves many changes including soil disturbance, vegetation removal or replacement and topography changes. These activities combine to create a new state in which the export of nutrients, such a phosphorous and nitrogen, sediment and pollutants at this location are more readily exported to nearby water courses (Hutchison Environmental Sciences Ltd., 2018; Vigiak, Malago, Bouraoui, Grizzetti, & Weissteiner, 2016).

The likelihood is almost certain and the severity is insignificant.

5. Wildlife faeces

The introduction of fecally-derived contaminants into source water by wildlife occurs globally and presents a health risk to humans through a variety of pathways (Zahedi, Paparini, Jian, Robertson, & Ryan, 2016). Additionally, (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of wildlife faeces contaminant of source water by exacerbating the potential impact.

The likelihood is almost certain and the severity is insignificant.

6. Wildlife pathogens

There is much greater uncertainty with understanding the potential for wildlife pathogens that are not transmitted through urine or faeces, even there is still much to be understood regarding fecally-derived

contaminants (Zahedi, Paparini, Jian, Robertson, & Ryan, 2016). (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk. Just recently, a moose in Montana was found infected with Chronic Wasting Disease and Wildlife Management Specialist have posited one pathway as the release of prions from a dead infected animal into the water (Montana Public Radio, 2019). There are many wildlife pathogens that could potentially contaminate source water; some are already endemic for instance *Giardia*, and some, including whirling disease, are not yet known to be present in the Wapiti Watershed but their arrival is plausible.

The likelihood is probable and the severity is minor.

7. Active Landfills (includes operations, fires and leachate)

Landfill fires both create and release a range of toxins into the environment introducing contaminants into the surrounding area (Vassiliadou, et al., 2009; Weichenthal, et al., 2015). Contaminants released by the fire may make their way into the water via leaching, surface water runoff or through the air. Generally, very toxic compounds such as PCBs and heavy metals are expected from a landfill fire, however, nitrogen and changes in pH and conductivity have also been documented (Øygard, Måge, Gjengedal, & Svane, 2005).

Likelihood is possible and the severity is minor

8. Inactive/abandoned landfills

An inventory of active and inactive landfills was undertaken in 1982 (MacLaren lansearch Lavalin, 1982)and records landfills in the Wapiti Watershed. The report acknowledges that some industrial landfills and some inactive landfills may have been missed. The landfills at Grande Prairie (E-11-71-06-W6) and Beaverlodge (N-3-72-10-W6) were identified as a priority 1 site in their screening because the landfill contacted the water table and was in permeable soils close to wells, respectively. See Appendix A for listing of landfill status in the Wapiti Watershed. The Help End Landfill Pollution project (Alberta Environment, 1988) built upon this by identifying and tracking the status of industrial landfills. See Appendix B for a redacted list of landfills in the Wapiti Watershed drawn from this report.

The likelihood is possible and the impact is minor.

9. Application of chemicals for weeds

Spraying for weeds happens in urban settings, parks, rural properties and in general where weeds become a problem. A study based in Alberta suggested that the transport mechanism for glyphosate, a pesticide often considered not to migrate, is dust and that indeed glyphosate does migrate (Humprhies, Byrtus, & Anderson, 2005). The concern for source water is not only for the individual chemicals that may migrate into source waters but also the interactions between the range of chemicals applied. The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014).

There is a concern for long term chronic effects, however, the short-term, acute affects are anticipated to be low, particularly as application practices improve.

The likelihood is probable and the severity is minor.

10. Invasives/weeds

Invasive plant species and weeds are problematic in that they alter plant communities, thus affecting how water moves through the ecosystem, nutrient cycling and the stability of soils. The ecohydrologic function of systems has been linked to the presence of novel or invasive species which then create issues such as flooding, increased nutrient export and soil erosion (see for instance (Fitch, Adams, & Hale, Riparian Health Assessment for Streams and Small Rivers - Field Workbook. Second Edition., 2009) & (Williams, et al., 2020)

The likelihood is unlikely and the severity is insignificant

11. Watershed portion in British Columbia

The Upper Wapiti Watershed, upstream of Pinto Creek, contributes 80% of the flows in the Wapiti River (Kerkhoven, 2014). Not only water quantity but water quality is dependent on what occurs in the British Columbia portion of the watershed. Managing across provincial boundaries can be challenging and this uncertainty is part of the hazard identified. Additionally, there are no communities on the British Columbia and therefore no regular monitoring of water quality associated with drinking water plants or recreational areas. Wapiti Lake, the source of the Wapiti River, is in a provincial park and subject to this management. These challenges due to jurisdiction in undertaking integrated Source Water Protection Planning has been identified in a range of situations (Bosholm & Prutzer, 2017).

The likelihood is probable and the impact is minor.

Agriculture

12. Feedlots/confined feeding operations

A case study of Swedish Water Management professionals revealed a discrepancy among them both on how to assess and to mitigate the risks associated with animal husbandry (Bosholm & Prutzer, 2017).

The likelihood is probable and the severity is minor.

13. Application of chemicals

A study that examined reducing nitrogen pollution in surface by changing agricultural practices found that this approach can reduce nitrogen loading but is also expensive for the producer (Centner, Houston, Keeler, & Fuchs, 1999). The more challenging component of chemical application is understanding the interactions of the full suite of chemicals being used. The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014).

The likelihood is almost certain and the severity is insignificant.

14. Storage of chemicals

If chemicals are improperly stored or an accidental release occurs, source waters may be impacted. Generally, large amounts of chemicals are not stockpiled on site but purchased shortly before application. Depending the phase (i.e.., solid, liquid) and location on the landscape this contaminant has a very different pathway for contaminating source water. Conservation Ontario, the mandated organization for watershed planning and source water protection in Ontario, identifies all storage of chemicals as a significant risk (Conservation Ontario, 2018).

Improving management practices among producers are reducing this risk.

The likelihood is possible and the severity is insignificant.

15. Livestock grazing

Dunn et al. (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of livestock grazing contribution to contamination as it is unlikely to be detected. However, improving agricultural practices (see for instance (Fitch, Adams, & O'Shaughnessy, Caring for th the Gren Zone: Riparian Areas and Grazing Management - Third Edition, 2003)) suggest that any contamination incidents will be small in quantity or duration.

The likelihood is probable and the severity is insignificant.

16. Manure Disposal

Dunn et al. (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of manure disposal contributing to contamination as it is unlikely to be detected. According to the Government of Alberta, the Wapiti Watershed mostly has lower ranking on the Manure Production Index ((Government of Alberta, 2020).

The likelihood is almost certain and the severity is minor

17. Ditching/draining

A pilot project in Van Buren County, Michigan targeted and paid agricultural land managers to use conservation practices that would reduce the impacts of runoff on downstream water to instead of taxing them for runoff produced (Kerr, Meersman, Fuller, & Fales, 2016). Monitoring and modelling demonstrated how the agricultural use changes the rate of sediment export.

The likelihood is almost certain and the severity is insignificant.

18. Land clearing/tree location

Riparian zones have become a mantra of Beneficial Management Practices (see for instance (Fitch, Adams, & O'Shaughnessy, Caring for th the Gren Zone: Riparian Areas and Grazing Management - Third Edition, 2003; Johnson & Wilby, 2015)) and have a demonstrated benefit to water quality. The improvements to water quality include nutrient reduction, contaminant reduction and sediment retention ((Vigiak, Malago, Bouraoui, Grizzetti, & Weissteiner, 2016).

Land clearing has continued to increase agriculturally productive lands and to facilitate ever larger equipment.

The likelihood is probable and the severity is insignificant.

19. Garbage burning

Although the practice has seen a decline, this still occurs and the contaminants and their pathway to source water would be similar to those of landfills fires. Refer to (Øygard, Måge, Gjengedal, & Svane, 2005) and (Vassiliadou, et al., 2009) for a discussion.

The likelihood is most unlikely and the severity is insignificant.

Forestry

20. Cutblocks (includes normal operation, runoff, change in land cover, etc.)

Changes in hydrology, nutrient and sediment export due to forestry operations are well-documented and for many parameters runoff coefficients have been determined (Donahue, 2013). As in many sectors, continuously improving management practices are reducing most of the risk associated with this hazard. However, there is a large area affected by forestry which poses a chronic stressor and this can be demonstrated in modelling (Hutchison Environmental Sciences Ltd., 2018). Moreover, land use changes can interact synergistically with natural phenomena to impact water quality (Walker, Girard, Alford, & Walters, 2019).

The likelihood is almost certain and the severity is insignificant.

21. Temporary Forest Roads

Roads are an important part of forestry operations and these roads are a source of sediment (Farias, Medeiros, Navarro-Hevia, & de Araujo, 2019; Anderson, 2019) and potentially other contaminants that are on the roadway. Weyerhaeuser's goal is to reclaim and replant these roads within 3 years of construction.

The likelihood is almost certain and the severity is insignificant

22. Wood storage yards

Areas cleared to be lay down yards produce more sediment as well as exporting some nitrogen and phosphorus in runoff events (Donahue, 2013). The location of these yards is critical as only 15% to 20% of unpaved roads in forested areas deliver 90% of the sediment to streams (Anderson, 2019). There is potential for hydrocarbons, petroleum products and heavy metals associated with vehicles (Suryawanshi, Rajaram, Bhanarkar, & Chalapati, 2016) to be transported into water.

The likelihood is unlikely and the severity is insignificant.

23. Spills

Industrial and commercial activity creates the possibility for a spill to occur by concentrating substances in high concentrations (i.e., fuel, pesticides, grease, etc.). Improving management practices are reducing the risk associated with this hazard.

The likelihood is unlikely and the severity is insignificant.

24. Rutting

Rutting that occurs during forestry operations is a recognized impact and much work has been done on reducing rutting and the associated impacts, for example see (Poltorak, Labelle, & Jaeger, 2018).

The likelihood is possible and the severity is insignificant.

25. Forest fires (not controlled)

There is a growing body of work detailing the susceptibility of source water in Alberta to forest fires (Bladon, Emelko, Silins, & Stone, 2014; Silins, et al., 2016), including some analysis indicating risk for Grande Prairie in the Wapiti Watershed (Robinne, et al., 2019).

The severity of the fire and the exact location of the fire within the watershed will determine the severity of the impact.

The likelihood is probable and the severity is minor.

26. Fire fighting chemical

There are two main chemicals used by the Alberta Agriculture and Forestry in fighting wildfires. PHOS-CHECK®LC95a is the fire retardant and "may cause long-term adverse effects in the aquatic environment" according to the Material Safety Data Sheet (Perimeter Solutions, 2019). Likewise, it states to "avoid release to the environment", otherwise no particular impacts are listed.

The Material Safety Data Sheet for the foam agent used, PHOS-CHECK®WD881C, also states to "avoid release to the environment" and that it "may cause long-term adverse effects in the aquatic environment" (Perimeter Solutionsq, 2019). Additionally, there is a LC50 fish (the concentration at which 50% of the organisms exposed to the chemical can be expected to suffer lethal effects) of 17 mg/l (Exposure time: 96 hours for Rainbow Trout). However, this chemical is also listed as readily biodegradable, thus application that avoids watercourses has a lower probability of reaching water unless there is a precipitation event immediately after application.

Alberta Agriculture and Forestry avoid application directly into water bodies (personal communication December 9, 2019) so that the most likely pathway for these constituents to enter water bodies is through drift during application or surface runoff after application. Therefore, it can be expected that there are consistently low levels reaching water bodies after fire fighting operations and this constitutes a chronic stressor on the aquatic ecosystem. Only seldomly, would a large amount of drift or a large precipitation event directly after application constitute an acute stressor.

The likelihood is possible and the severity is minor.

27. Herbicide

The use of herbicide, primarily Glyphosate, to reduce deciduous competition is a common practice in the Wapiti Watershed. A study based in Alberta suggested that the transport mechanism for glyphosate, a pesticide often considered not to migrate, is dust and that indeed glyphosate does migrate (Humprhies, Byrtus, & Anderson, 2005). The concern for source water is not only for the individual chemicals that may migrate into source waters but also the interactions between glyphosate and other chemicals that occur in the water. The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014).

There is a concern for long term chronic effects, however, the short-term, acute affects are anticipated to be low, particularly as application practices improve.

The likelihood is unlikely and the severity is insignificant.

28. Camps

Dunn et al. (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of septic/private systems contaminant contribution. Improving practices reduce the risk of contamination

due to camp wastewater or other chemicals. Camps are managed with ever improving regulation and management practices reducing the risk.

The likelihood is unlikely and the severity is insignificant.

29. Mountain Pine Beetle/pests

Many factors will influence how a Mountain Pine Beetle (*Dendroctonus ponderosae*) or other pest attack could potentially affect surface runoff or groundwater/surface water interactions so that any risk assessment only accounts for a portion of the potential scenarios. A 9 year study in British Columbia found relatively small impacts on hydrology after a Mountain Pine Beetle attack and that hydrology recovered began in the second year (Meyer, et al., 2017). This risk assessment is for the hazard of any infestation or outbreak, of which Mountain Pine Beetle is the most recent example, and does not refer to the forestry harvesting strategies employed to address such an outbreak.

The likelihood is most unlikely and the severity is insignificant.

Oil & Gas

30. Pipeline releases

Pipeline accidents in the United States are on the order of 10^{-3} per kilometer per year for onshore although the annual water contamination rate was only 1.07×10^{-4} accidents per kilometer per year with approximately 9% of spills contaminating water (Belvederesi, Thopmson, & Komers, 2018) . The rate of accidental releases has declined in comparison to the growing network of pipelines and most spills are below 50 barrels in volume

Alberta Energy Regulator has record of approximately 1572 releases in the Wapiti Watershed ranging from 0.015 m^3 to 8500 m^3 from 1976 through 2019 (Alberta Energy Regulator, 2020).

The likelihood is unlikely and the severity is moderate.

31. Surface spills

Hazardous material handling, construction, monitoring and containment practices are improving which reduces the risk of a surface spill.

The likelihood is unlikely and the severity is insignificant.

32. Subsurface spills (casing failures)

The following 2 paragraphs are provided by the Alberta Energy Regulator in response to questions regarding this hazard (Alberta Energy Regulator, pers. comm., January 8, 2020).

A detailed analysis of well casing failure rates has not been conducted. Preliminary analysis of casing failure rates since 2010 indicates, that on average, 416 casing failures are detected annually. As of January 2020, approximately 9400 casing failure incidents have been reported to the AER, of which, approximately 96% have been resolved as per our requirements. The AER monitors any outstanding incidents.

Per Interim Directive 2003-01, licensees are required to report a casing leak or failure to the AER within 30 days from the date of initial detection. Licensees are also required to begin planning and perform

remedial action within 90 days from the reporting date. Licensees are required to request for approval if they are unable to meet the repair guidelines or deadlines. The AER tracks the status of outstanding casing failures and helps ensure adequate risk mitigation is in place if licensees deviate from the requirements.

The likelihood is most unlikely and the severity is insignificant.

33. Air emissions/flaring

Peace Airshed Zone Association is the organization responsible for monitoring air quality in the Wapiti Watershed. Their stations, the parameters the monitor and their reports are available at https://www.paza.ca/air-quality/.

The likelihood is most unlikely and the severity is insignificant.

34. Suspended wells and pipelines

In the Wapiti Watershed, the Orphan Well Association has identified 4 orphan pipeline segments and 4 orphaned wells to be abandoned ((Orphan Well Association, 2019). The term orphan refers to infrastructure that has no legally or financially responsible party that can be held accountable. Abandoning infrastructure, refers to the proper decommissioning of infrastructure as per regulations. The Alberta Energy Regulator identifies approximately 1001 Abandoned wells within the Wapiti Watershed in their repository ((Alberta Energy Regulator, 2020). The wells listed here have a range of statuses including Abandoned (407), Issued (1), RecCertified (501), RecExempt (81), Re-Entered (7) and Suspension (2). The features are on the landscape however, current standards and regulations reduce the potential risk.

The likelihood is most unlikely and the severity is insignificant.

35. Linear disturbance incl seismic lines and pipelines (pathway)

In the Wapiti Watershed there are 7225.35 hectares of pipelines and 7306.43 hectares of seismic lines (Table 3 Watersheds Human Footprint Inventory Overview). Approximately, 1.5% of the land base is covered by these linear disturbances that affect hydrology, runoff and riparian zones.

The likelihood is possible and the severity is insignificant.

36. Pads

Older pads will have a higher risk associated with them as improving regulations reduce potential contamination. Refer to the discussion about Wood storage yards as the risks and pathways are similar (22. Wood storage yards).

The likelihood is unlikely and the severity is insignificant.

37. Water access infrastructure

This includes issues with pump, fuel spills or the increased sedimentation from the access point. The key concern here is the proximity to water and the immediacy with which any contaminant may reach the water. Nevertheless, the activity itself and the contaminants present do not present a major concern in terms of source water.

The likelihood is unlikely and the severity is minor.

38. Herbicide Spraying

The use of herbicide, primarily Glyphosate, to reduce deciduous competition is a common practice in the Wapiti Watershed. A study based in Alberta suggested that the transport mechanism for glyphosate, a pesticide often considered not to migrate, is dust and that indeed glyphosate does migrate (Humprhies, Byrtus, & Anderson, 2005). The concern for source water is not only for the individual chemicals that may migrate into source waters but also the interactions between glyphosate and other chemicals that occur in the water. The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014).

There is a concern for long term chronic effects, however, the short-term, acute affects are anticipated to be low, particularly as application practices improve.

The likelihood is possible and the severity is minor.

39. Camps

Dunn et al. note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of septic/private systems contaminant contribution.

The likelihood is unlikely and the severity is minor.

40. Sumps (new)

Improving regulations and compliance again have reduced the risk of this hazard.

The likelihood is most unlikely and the severity is insignificant.

41. Sumps (old)

It is recognized that historical sumps were not well regulated or necessarily in compliance with existing regulations. These sumps present a hazard similar to 7. Active Landfills (includes operations, fires and leachate).

The likelihood is possible and the severity is minor.

Recreational

42. Erosion caused by OHVs

The Government of Alberta has undertaken education on this issue and have recommendations for appropriate use ((Government of Alberta, 2020). The impacts of Off-Highway Vehicle use on the terrain have been well documented and include soil erosion and compaction as well as loss of vegetation (Farr, Braid, & Slater, 2018).

The likelihood is almost certain and the severity is insignificant.

43. Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)

Operation of OHVs in water bodies is illegal 9 (Government of Alberta, 2020), however this continues to happen and the Government of Alberta has targeted this behaviour with various campaigns including “Keep Wheels Out of Water” and “ATVs and Water Don’t Mix” ((Government of Alberta, 2020).

Operation of vehicles in and near water bodies compounds the effect on source water as the impact is more direct (Farr, Braid, & Slater, 2018).

The likelihood is almost certain and the severity is minor.

44. Unauthorized boat launches

There is not a lot of information on this hazard, however, should it occur the impacts are direct and unmitigated.

The likelihood is possible and the severity is minor.

45. Boat operation leading to incidental discharge and emissions

Normal operation of recreational motorized boats produced emissions and introduces residue of petroleum into the water ways (Whitfield & Becker, 2014)

The likelihood is almost certain and the severity is insignificant.

46. Sediment due to wake or boat disturbing channel

Motorized boats produce a wake that eventually reaches the shore as wave action increasing erosion (Bilkovic, et al., 2019). Moreover, boats can directly impact the river channel by direct contact when the water is shallow.

The likelihood is probable and the severity is insignificant.

47. Recreational development (new & existing)

Please refer to the section on 4. Development to see the discussion about this hazard.

The likelihood is probable and the severity is minor.

48. Parks outhouses

There is a sewage lagoon at Saskatoon Island, but the nearby lakes don't have any surface outflow. The outhouses at Saskatoon Island and O'Brien parks have tanks that are pumped out. The Kleskun Hills and Demmit campgrounds are also away from flowing water and have outhouses on tanks. Big Mountain Recreation Area, O'Brien Park, Shuttler Flats and Two Lakes Recreation also have outhouses with pump out tanks (email correspondence from Albert Environment and Parks and MD of Greenview staff).

The likelihood is unlikely and the severity is minor.

Rural residential properties (not agricultural and not in subdivisions)

49. Sediment from Rural properties

Farias, Medeiros, Navarro-Hevia, & de Araujo (Farias, Medeiros, Navarro-Hevia, & de Araujo, 2019)measured sediment production from bare roads and surfaces that were at least one order of magnitude greater than undisturbed catchment areas.

Sedimentation from these properties will occur at a level elevated from background but is anticipated to predominately have an insignificant impact on source water.

The likelihood has been ranked as almost certain and the severity is identified as insignificant.

50. Runoff in stormwater management systems

The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014). The hazards for the gamut of substances and their impacts on source water including their potential synergistic interactions, challenging to quantify (Harper, 1998). However, road runoff is big constituent in stormwater and is well known to carry a broad range of contaminants including heavy metals and other particles under 100µm which are difficult to remove (Drapper, Tomlinson, & Williams, 2000). Rural stormwater has different contaminants than urban stormwater (Mallin, Johnson, & Ensign, 2009), however the same cumulative effect. At this point both the County of Grande Prairie and the Municipal District of Greenview have stormwater systems that discharge untreated water into water courses.

The rationale for the low severity of impact is that most commonly the most hazardous constituents are not present in large quantities (Mallin, Johnson, & Ensign, 2009). This does not include intentional illegal dumping.

Likelihood has been assessed as almost certain and the impact is insignificant.

51. Spill of hazardous materials (lawnmower, recreational vehicles, chainsaws, etc.

The pathway for this hazard is most likely through surface runoff that enters ditches or stormwater. Refer to 69. Stormwater (pathway) for a discussion of the hazard and risk assessment.

The likelihood is most unlikely and the severity is insignificant.

52. Garbage burning (both barrel and otherwise)

Although this is known to happen, there is no direct pathway for contaminants to reach source in any substantial volume.

The likelihood is most unlikely and the severity is insignificant.

53. Improper hazardous waste disposal

This hazard has similar risks and pathways as that of 7. Active Landfills (includes operations, fires and leachate) because it addresses substances that should be delivered to a waste management facility but are not.

Likelihood is probable and the severity is minor.

54. Water wells

Contamination of groundwater can occur from contaminated surface water that reaches groundwater using water wells as a conduit ((Gailey, 2017). Local hydrogeology will determine the transport of any contaminants that reach groundwater. However, management of the wells will determine the probability of groundwater and surface water via groundwater contamination.

The likelihood is unlikely and the severity is moderate.

55. Septic systems/private systems

Dunn et al. (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of

septic/private systems contaminant contribution. The location of the septic system, its proximity to water and the contours of land will greatly influence the risk ranking.

The likelihood is unlikely and the severity is minor.

Transportation

56. Highway 40 Bridge Spill

In summary, for the years 2012 to 2016, on Highway 40, Control Section 24 from kilometre post 28.691 to kilometre post 30.691 (one kilometre on either side of Wapiti Bridge), there were a total of 55 collisions (one fatal collision, 14 injury collisions, and 40 property damage only collisions). In these collisions, one person was killed and 23 were injured. Of the 55 total collisions, four involved a load spill. (Transportation Policy Branch, Alberta Transportation, Government of Alberta).

The likelihood is unlikely and the severity is severe.

57. Road salt/de-icer application

The application of road salt and de-icers poses a chronic, long-term risk to source water in the Wapiti Watershed. This impacts of this study have been demonstrated in the North Saskatchewan River watershed (Laceby, et al., 2019) and (Scott, Goulden, Letman, Hayward, & Jamieson, 2019) found that when a watershed is more than 25% developed land springtime chloride concentration tended to exceed the Canadian freshwater quality guidelines. A map developed by World Wildlife Fund details chloride concentrations in Ontario waters that are driven by road salt application (Chattha, 2019).

The likelihood is almost certain and the severity is insignificant.

58. Road salt storage

Here improving management practices and containment are reducing the risk to source water and the concerns around this around the same as 57. Road salt/de-icer application.

The likelihood is unlikely and the severity is minor.

59. Crossings/culverts/ditches (this more of a pathway)

At every intersection between a road and a water body there is a portal for the introduction of sediment and other substances into the water. See the sections on 4. Development, 17. Ditching/draining, and 35. Linear disturbance incl seismic lines and pipelines (pathway),

The likelihood is almost certain and the severity is minor.

60. Trucking (primarily Transportation of Dangerous Goods)

This is a chronic and ongoing hazard that it is multi-facetted because of the range of substances that are transported. In addition, the standard emissions of vehicular traffic constitute part of this hazard (Markiewicz, et al., 2017).

The likelihood is unlikely and the severity is severe.

61. Construction

Construction involves clearing land, installing culverts and recontouring the landscape, thus the main concern is the surface runoff from the site. In this regard, this hazard is similar to 49. Sediment from Rural properties and 59. Crossings/culverts/ditches (this more of a pathway).

The likelihood is almost certain and the severity is insignificant.

62. Petroleum from vehicles day to day operation

A study by (Markiewicz, et al., 2017) determined that 990-3900 µg of polycyclic aromatic hydrocarbons were emitted per vehicle driven. Although a portion of this is from exhaust and tire wear and portion is also from leaked motor oil. Furthermore, they determined that 2-6% of the emissions made it into the aquatic environment.

The likelihood is almost certain and the severity is insignificant.

63. Calcium application for dust control

There is not a lot of research on the impacts of applying calcium chloride to roads for dust control, however as this is also a common de-icing refer to 57. Road salt/de-icer application for a discussion of this hazard.

The likelihood is almost certain and the severity is insignificant.

64. Railway spills

Transportation Safety Board of Canada (data retrieved November 12, 2019 from http://www.bst-tsb.gc.ca/eng/rapports-reports/rail/index.html) does not have any records of railway accidents in the Wapiti Watershed after 1990. The Library and Archives Canada do have record of railway accidents as recently as 1970 and 1973, causing death and injury respectively, but no records of spills (retrieved November 12, 2019 from http://www.bac-lac.gc.ca/eng/collectionsearch/Pages/collectionsearch.aspx?q=railway+accident+and+alberta&start=10&num=10&DateBucket=1970-1979). The local railway company is not able to release cargo information so it is not possible to determine what the actual contaminants may be.

The project team did not complete a risk ranking for this hazard due to a lack of information.

65. Railway oil/grease/fuel leakage

Refer to 62. Petroleum from vehicles day to day operation for a discussion of this hazard.

The likelihood is almost certain and the severity is insignificant.

66. Creosote Ties

Across North America 97% of wooden rail ties are sent for co-generation (Canadian National Railway, 2016). However, it was not possible to determine the number of creosote rail ties present in the Wapiti Watershed nor their location.

The project team did not complete a risk ranking for this hazard due to a lack of information.

67. De-icing at GP airport

The Grande Prairie Airport has a small stormwater system that empties into surface water bodies south west of the airport. There is no treatment of the runoff so the risk assessment for Stormwater in general applies here as well (see Stormwater (pathway)).

The likelihood is almost certain and the severity is insignificant.

68. Tarmac run-off

The Grande Prairie Airport has a small stormwater system that empties into surface water bodies south west of the airport. There is no treatment of the runoff so the risk assessment for Stormwater in general applies here as well (see Stormwater (pathway). Refer to 62. Petroleum from vehicles day to day operation and 70. Stormwater (pathway) for a discussion of the potential contaminants and their pathways.

The likelihood is possible and the severity is insignificant.

Urban

"Indeed, the importance of indirect effects in the analysis suggests that we are often missing key mechanistic evidence by which urbanisation pressures influence key biological receptors." (Van der Brink, et al., 2019)

69. Institutional/commercial/industrial

Runoff from urban sites that have institutional, commercial or industrial land use is complex and varied. There are range of contaminants that vary with the particular land use or activity and the management practices in place. Common constituents found in runoff from the sites have been identified, however, modelling their movement remains challenging. The reader is referred to (Shi, et al., 2019) and (Van der Brink, et al., 2019).

The likelihood is possible and the severity is insignificant.

70. Stormwater (pathway)

The MD releases their stormwater back into water courses with minimal treatment (Personal Communication, Gary Couch, Manager of Environmental Services, MD of Greenview, October 25, 2019). The new (2018) Grovedale Area Structure Plan references BMPs and Low Impact Development, however at this point there is no Master Stormwater Management Plan.

The County of Grande Prairie has Stormwater Management Plans associated with some of its Area Structure Plans and in particular the newer ones, however there is no master Stormwater plan for the County. Additionally, the County of Grande Prairie is working on installing stormwater management infrastructure such as bioswales and stormwater ponds in certain areas.

The synergistic and complex effects of multiple chemicals at low levels is not fully understood and poses a risk even when individual constituents are below recommended levels (Villanueva, et al., 2014). The hazards for the gamut of substances and their impacts on source water including their potential synergistic interactions, challenging to quantify (Harper, 1998). However, road runoff is big constituent in stormwater and is well known to carry a broad range of contaminants including heavy metals and

other particles under 100µm which are difficult to remove (Drapper, Tomlinson, & Williams, 2000). Rural stormwater has different contaminants than urban stormwater (Mallin, Johnson, & Ensign, 2009), however the same cumulative effect.

The likelihood is probable and the severity is minor.

71. Yard care

Lawns and gardens in urban areas continue to expand and can contribute ecological goods and services but also pollutants depending upon the management approach (Bolund & Hunhammar, 1999). Cosmetic application of chemicals to urban yards and gardens may be more intense because there is generally not the training, the corporate responsibility or the auditing associated with industrial (agriculture or forestry) or government applications. See 9. Application of chemicals for weeds for a discussion of this hazard.

The likelihood is possible and the severity is minor.

Water/Wastewater Infrastructure

72. (jet) boat hitting water intake

Staff at Aquatera are aware of one time when a boat struck the intake, so there is a historical precedent. This hazard is specific only to the source water use associated with water treatment plants; however, this is how the bulk of the population receives their water.

The likelihood is most unlikely and the severity is insignificant.

73. Lagoons (breach or failure)

This is not a common phenomenon but one that could occur particularly in light of a changing climate and events such as hazards. Dunn et al. note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of septic/private systems contaminant contribution.

The likelihood is unlikely and the severity is minor.

74. Stormwater (pathway)

The MD releases their stormwater back into water courses with minimal treatment (Personal Communication, Gary Couch, Manager of Environmental Services, MD of Greenview, October 25, 2019). The new (2018) Grovedale Area Structure Plan references BMPs and Low Impact Development, however at this point there is no Master Stormwater Management Plan.

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in stormwater and is well known to carry a broad range of contaminants including heavy metals and other particles under 100µm which are difficult to remove (Drapper, Tomlinson, & Williams, 2000). Rural stormwater has different contaminants than urban stormwater (Mallin, Johnson, & Ensign, 2009), however the same cumulative effect.

The likelihood is almost certain and the severity is minor.

75. Camp wastewater

Newer camps follow stricter regulations, better management practices and use better equipment. Industrial camps are common in the Wapiti watershed so the changing practices around wastewater are reducing the risk. Dunn et al. (Dunn, Harris, Cook, & Prystajecky, 2014) note that there is a lack of watershed risk assessment for microbial hazards and the lack of this monitoring heightens the potential risk of septic/private systems contaminant contribution.

The likelihood is unlikely and the severity is insignificant.

76. Drought

Reviewing Agriculture Canada's Drought Analysis tools it is apparent that drought does occur in the Wapiti Watershed (see for example http://www.agr.gc.ca/eng/programs-and-services/drought-watch/canadian-drought-monitor/drought-analysis/historic-drought-animation/?id=1518636801170) and that we can expect it in the future.

The likelihood is unlikely and the severity is insignificant.

77. Flooding

Severity of the impact will be proportional to the severity of the flood event and its location in the watershed. (Ascott, Lapworth, D, Sage, & Karapanos, 2016) reported that flooding effects on source water are acute including greater than 1 log increase in micro-organic contaminants, microbial detects and turbidity but found recovery to occur within several weeks. Sediment is the primary concern, however, increase microbial contamination as well as other contaminants picked up by surface runoff are a hazard.

The likelihood is almost certain and the severity is minor.

78. Bank slumping

A range of soil types, vegetation and topography are present in the Wapiti Watershed which provide a corresponding range in erodibility. However, in general the banks in the Wapiti Watershed are susceptible to erosion and this is source of sediment and other pollutants to source water (see (Twardy & Corns, 1980)

The likelihood is probable and the severity is minor.

79. Discharges (treated wastewater intentional releases)

Treated wastewater is discharged from lagoons and Waste Water Treatment Plants to neighbouring water courses at planned times as part of water treatment process and regulatory requirements. Although the wastewater has been treated there are still constituents in the water that can function as contaminants and the variety, the species and the volume of this constituents is dependent about the treatment processes used. Wastewater releases impact water quality by increasing sediment, metals

and microbes as well as altering ecological function such as nitrogen cycling in the receiving rivers (Martínez-Santos, et al., 2018).

The likelihood is almost certain and the severity is insignificant.

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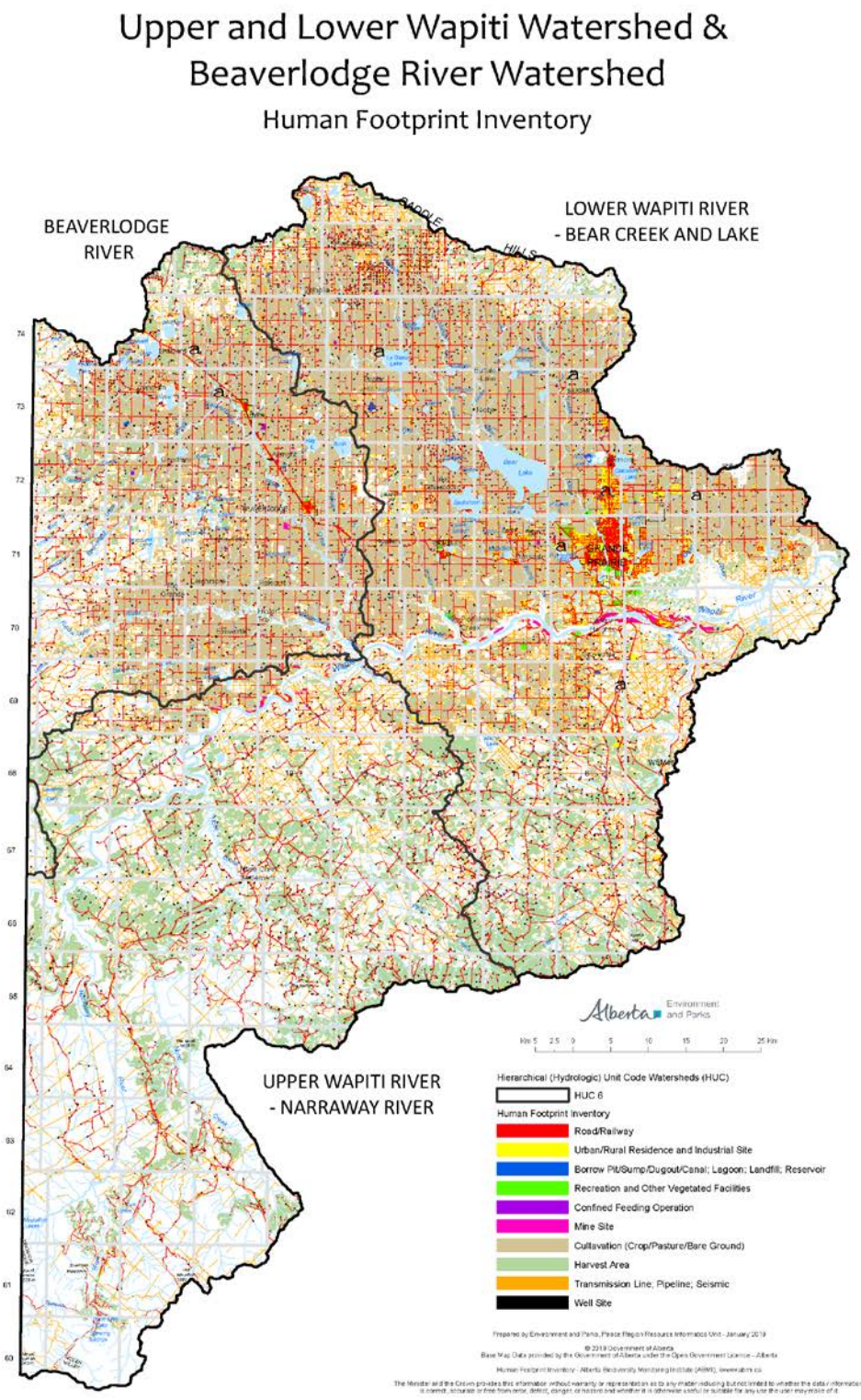
Appendix A

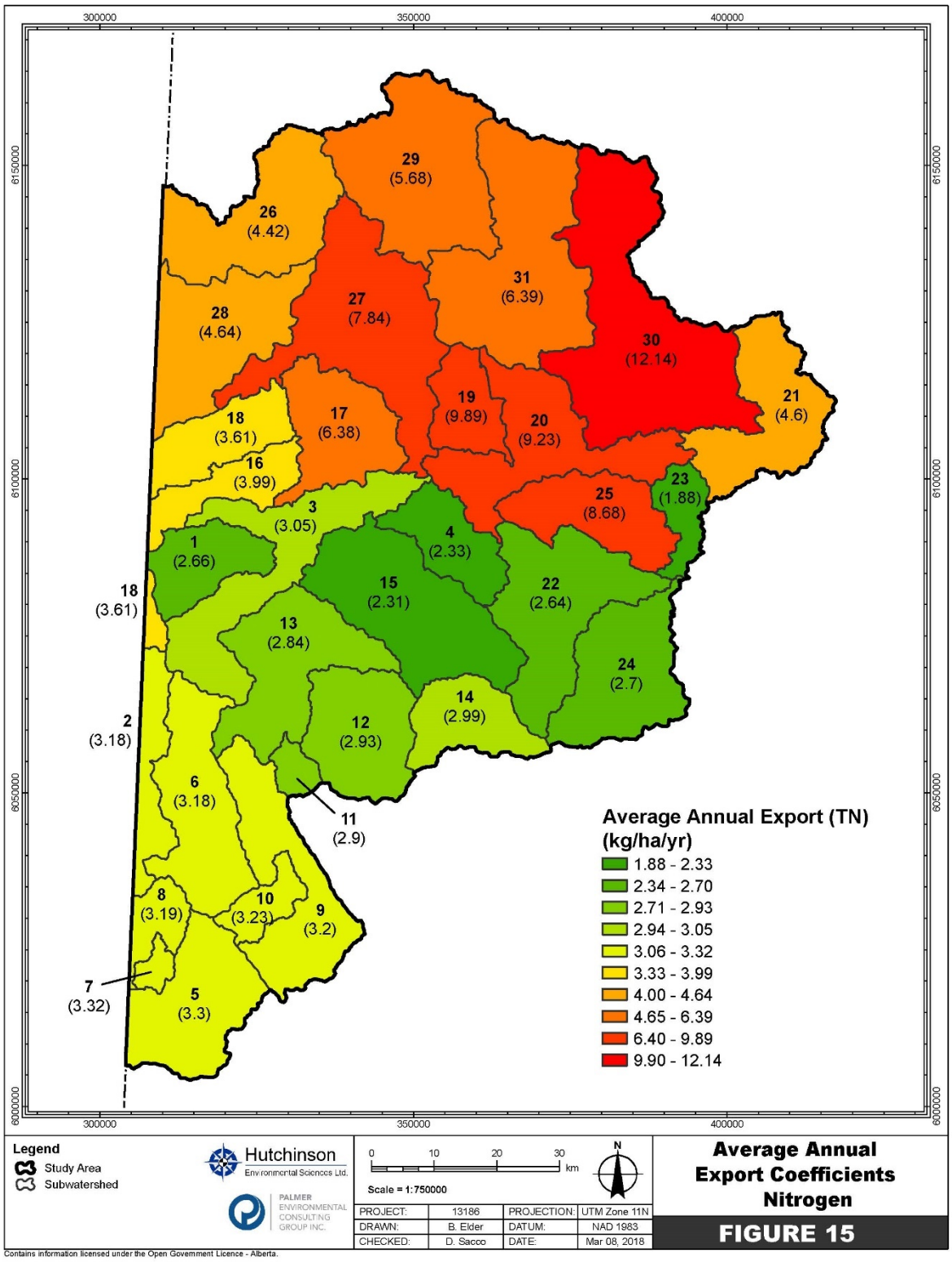
Figure 1 Human Footprint Inventory of the Wapiti Watershed



WATERSHEDS HUMAN FOOTPRINT INVENTORY OVERVIEW

			BEAVERLODGE RIVER 215,780.55 ha		LOWER WAPITI RIVER - BEAR CREEK AND LAKE 416,326.01 ha		UPPER WAPITI RIVER - NARRAWAY 381,237.93 ha	
			ha		ha		ha	
Industrial and Rural Areas Footprint	Reservoirs	Reservoir	46.66	0.0%	75.41	0.0%	0.00	0.0%
	Municipal (Water and Sewage)	Lagoon	59.28	0.0%	89.08	0.0%	0.03	0.0%
	Borrow Pits, Sumps, Dugouts	Borrow Pit	135.14	0.1%	214.66	0.1%	255.03	0.1%
		Borrow Pit - Dry	4.67	0.0%	30.76	0.0%	64.81	0.0%
		Borrow Pit - Wet	20.76	0.0%	84.21	0.0%	88.51	0.0%
		Sump	18.64	0.0%	179.27	0.0%	46.37	0.0%
		Dugout	216.17	0.1%	265.16	0.1%	24.70	0.0%
	Canals	Canal	35.93	0.0%	51.00	0.0%	1.06	0.0%
	Mine Sites	Gravel/Sand Pit	58.63	0.0%	599.38	0.1%	186.29	0.0%
		Open Pit Mine	0.00	0.0%	52.37	0.0%	22.34	0.0%
	Industrial Site Rural	Industrial Camp	0.00	0.0%	5.78	0.0%	10.19	0.0%
		Unknown Clearning	66.38	0.0%	302.98	0.1%	219.45	0.1%
		Unknown Facility	37.37	0.0%	573.19	0.1%	8.53	0.0%
		Miscellaneous Oil/Gas Facility	67.03	0.0%	387.42	0.1%	82.95	0.0%
		Facility - Other	8.67	0.0%	162.11	0.0%	0.02	0.0%
		Urban - Industrial	187.66	0.1%	2,571.00	0.6%	0.00	0.0%
		Oil-Gas-Plant	13.95	0.0%	65.47	0.0%	25.05	0.0%
		Mill	0.00	0.0%	172.69	0.0%	0.00	0.0%
		Wellpad Clearing Unconfirmed	18.17	0.0%	46.94	0.0%	30.67	0.0%
	Landfill	Transfer Station	1.13	0.0%	11.15	0.0%	0.00	0.0%
		Landfill	0.00	0.0%	186.26	0.0%	0.00	0.0%
	Well Sites	Gas Well	1,514.14	0.7%	1,827.15	0.4%	1,820.32	0.5%
		Oil Well	204.90	0.1%	1,469.29	0.4%	151.73	0.0%
		Other Well	130.50	0.1%	521.68	0.1%	155.17	0.0%
		Well Sites - Abandoned	650.38	0.3%	1,244.78	0.3%	350.41	0.1%
	Other Vegetated Facilities and Recreation	Campground	1.97	0.0%	23.73	0.0%	4.59	0.0%
		Golf Course	0.00	0.0%	65.52	0.0%	0.00	0.0%
		Green Space	4.51	0.0%	104.99	0.0%	0.00	0.0%
		Recreation	105.43	0.0%	1,225.89	0.3%	5.37	0.0%
		Surrounding Vegetation	24.33	0.0%	0.00	0.0%	0.00	0.0%
		Runway	0.00	0.0%	0.00	0.0%	21.29	0.0%
	Confined feeding operations (CFO)	CFO	127.24	0.1%	100.21	0.0%	0.00	0.0%
	Urban and Rural Residential	Country Residence	223.49	0.1%	2,894.74	0.7%	9.64	0.0%
		Rural Residence	2,085.01	1.0%	4,624.46	1.1%	141.43	0.0%
		Urban Residence	112.78	0.1%	1,736.67	0.4%	0.00	0.0%
		Residence Clearing	0.20	0.0%	710.69	0.2%	0.00	0.0%
		Sub Total	**6,181.13**	**2.9%**	**22,676.07**	**5.4%**	**3,725.98**	**1.0%**
Linear Footprint	Road – Hard Surface	Paved Road Divided	14.43	0.01%	276.26	0.1%	0.00	0.0%
		Paved Road - 1 Lane	0.00	0.00%	12.34	0.0%	1.16	0.0%
		Paved Road - 2 Lane	62.69	0.03%	635.96	0.2%	0.00	0.0%
		Paved Road - 3 Lane	0.00	0.00%	3.14	0.0%	0.00	0.0%
		Paved Road - 4 Lane	0.00	0.00%	15.88	0.0%	0.00	0.0%
		Undivided Paved Road - 1 Lane	4.14	0.00%	110.95	0.0%	0.00	0.0%
		Undivided Paved Road - 2 Lane	353.21	0.16%	789.56	0.2%	28.84	0.0%
		Undivided Paved Road - 4 Lane	0.00	0.00%	3.63	0.0%	1.07	0.0%
		Interchange Ramp	0.48	0.00%	22.89	0.0%	0.00	0.0%
		Gravel Road - 1 Lane	961.45	0.45%	1,588.48	0.4%	777.16	0.2%
		Gravel Road - 2 Lane	621.60	0.29%	1,093.24	0.3%	594.24	0.2%
		Unclassified Road	215.34	0.10%	544.80	0.1%	19.66	0.0%
		Unimproved Road	504.88	0.23%	1,206.15	0.3%	562.96	0.1%
		Truck Trail	71.04	0.03%	98.13	0.0%	77.08	0.0%
		Winter Road	0.34	0.00%	125.76	0.0%	489.82	0.1%
		Airport Runway	2.93	0.00%	34.63	0.0%	0.00	0.0%
		ATV Trail	0.00	0.00%	0.00	0.0%	0.60	0.0%
	Railway - Hard Surface	Railway	46.69	0.02%	101.36	0.0%	0.00	0.0%
	Vegetated Surfaces of Roads, Trails and Railways	Vegetation alongside road edge	2,735.08	1.27%	6,300.64	1.5%	2,374.93	0.6%
		Vegetation alongside railway edge	103.41	0.05%	318.42	0.1%	0.00	0.0%
	Transmission Lines	Transmission Line	271.77	0.13%	894.76	0.2%	3.66	0.0%
	Pipelines	Pipeline	1,402.89	0.65%	3,018.07	0.7%	2,804.39	0.7%
	Seismic Lines and Trails	Low Impact Seismic	0.00	0.00%	0.21	0.0%	1.65	0.0%
		Pre Low Impact Seismic	1,927.30	0.89%	3,261.95	0.8%	2,117.18	0.6%
		Trail/ATV	386.32	0.18%	642.07	0.2%	414.58	0.1%
		Sub Total	**9,685.99**	**4.49%**	**21,099.31**	**5.1%**	**10,268.98**	**2.7%**
Agriculture Footprint	Cultivation (Crop/Pasture/ Bare Ground)	Crop	71,420.20	33.10%	138,820.82	33.3%	3,769.62	1.0%
		Tame Pasture	24,561.14	11.38%	23,035.56	5.5%	733.71	0.2%
		Rough Pasture	5,580.51	2.59%	3,351.64	0.8%	861.46	0.2%
		Abandoned Cultivation	5.06	0.00%	154.79	0.0%	44.83	0.0%
		Sub Total	**101,566.90**	**47.07%**	**165,362.82**	**39.7%**	**5,409.61**	**1.4%**
Forestry Footprint	Cut Blocks	Harvest Area	9,981.82	4.63%	35,317.15	8.5%	66,636.71	17.5%
		Grand Total	**127,415.85**	**59.05%**	**244,455.34**	**58.7%**	**86,041.28**	**22.6%**

Appendix B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29 (5.68)
26 (4.42)
31 (6.39)
27 (7.84)
28 (4.64)
30 (12.14)
21 (4.6)
19 (9.89)
20 (9.23)
18 (3.61)
17 (6.38)
16 (3.99)
23 (1.88)
25 (8.68)
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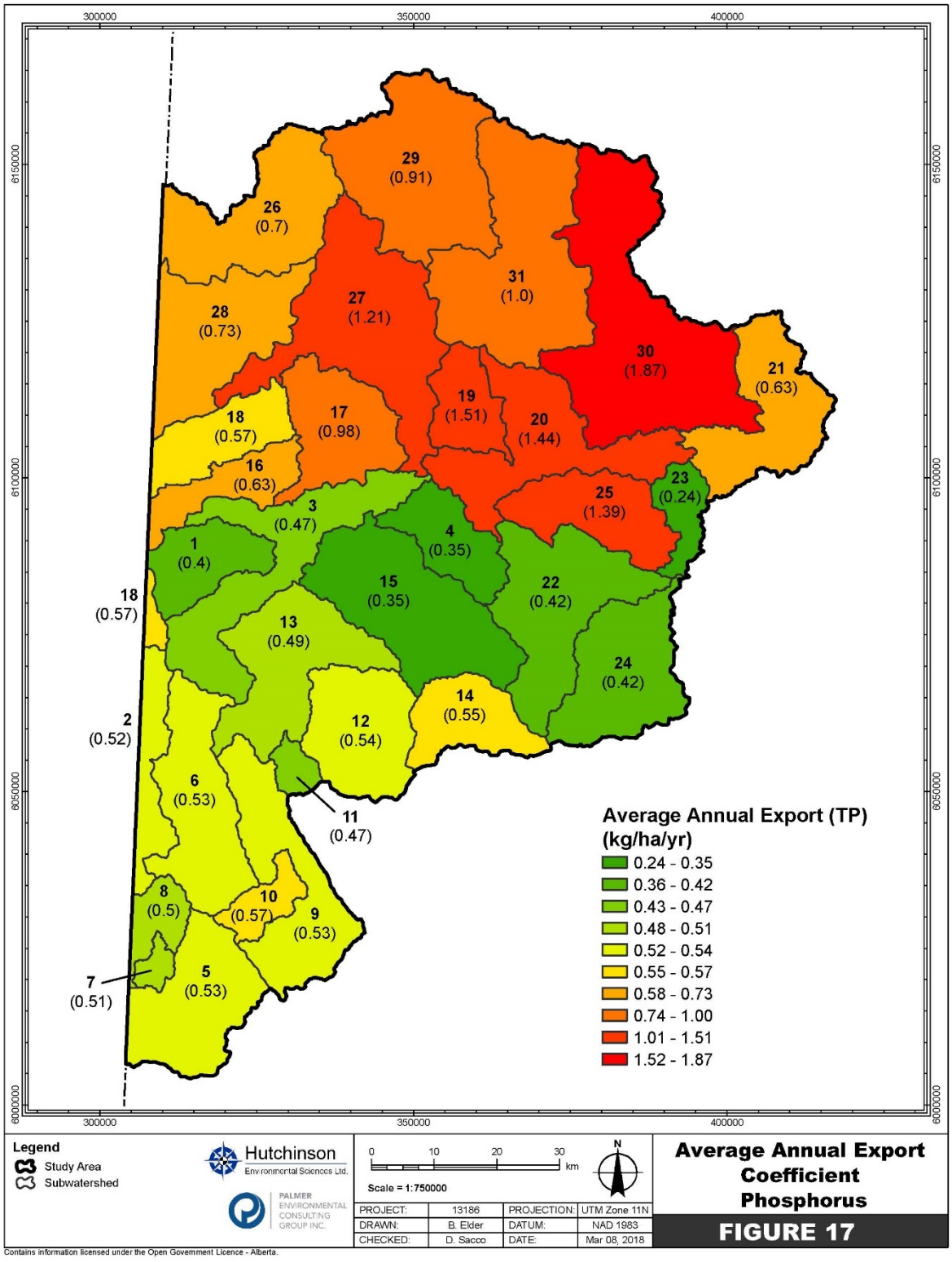
4 (2.33)
1 (2.66)
18 (3.61)
15 (2.31)
22 (2.64)
13 (2.84)
24 (2.7)
14 (2.99)
2 (3.18)
12 (2.93)
6 (3.18)
11 (2.9)
8 (3.19)
10 (3.23)
9 (3.2)
7 (3.32)
5 (3.3)
Average Annual Export (TN) (kg/ha/yr)
1.88 - 2.33
2.34 - 2.70
2.71 - 2.93
2.94 - 3.05
3.06 - 3.32
3.33 - 3.99
4.00 - 4.64
4.65 - 6.39
6.40 - 9.89
9.90 - 12.14
Legend
Study Area
Subwatershed
Hutchinson Environmental Sciences Ltd.
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
0 10 20 30 km
Scale = 1:750000
N
PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
CHECKED: D. Sacco DATE: Mar 08, 2018
Average Annual Export Coefficients Nitrogen
FIGURE 15
Contains information licensed under the Open Government Licence - Alberta.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29 (0.91)
26 (0.7)
31 (1.0)
27 (1.21)
28 (0.73)
30 (1.87)
21 (0.63)
19 (1.51)
20 (1.44)
18 (0.57)
17 (0.98)
16 (0.63)
23 (0.24)
25 (1.39)
3 (0.47)
4 (0.35)
1 (0.4)
18 (0.57)
15 (0.35)
22 (0.42)
13 (0.49)
24 (0.42)
14 (0.55)
2 (0.52)
12 (0.54)
6 (0.53)
11 (0.47)
8 (0.5)
10 (0.57)
9 (0.53)
7 (0.51)
5 (0.53)
Average Annual Export (TP) (kg/ha/yr)
0.24 - 0.35
0.36 - 0.42
0.43 - 0.47
0.48 - 0.51
0.52 - 0.54
0.55 - 0.57
0.58 - 0.73
0.74 - 1.00
1.01 - 1.51
1.52 - 1.87
Legend
Study Area
Subwatershed
Hutchinson Environmental Sciences Ltd.
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
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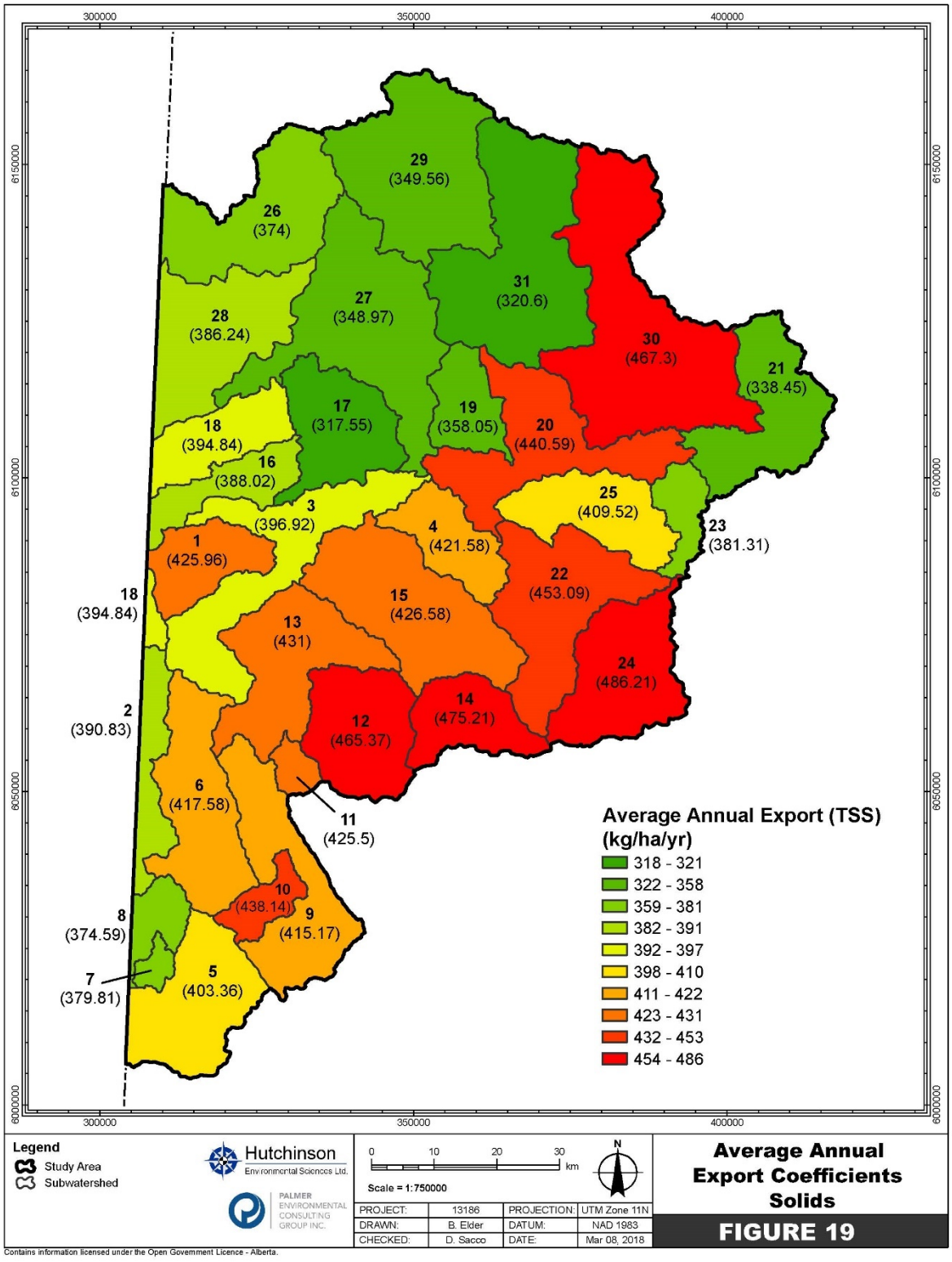
Scale = 1:750000
PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
CHECKED: D. Sacco DATE: Mar 08, 2018
Average Annual Export Coefficient Phosphorus
FIGURE 17
Contains information licensed under the Open Government Licence - Alberta.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28 (386.24)
30 (467.3)
21 (338.45)
17 (317.55)
19 (358.05)
18 (394.84)
20 (440.59)
16 (388.02)
25 (409.52)
3 (396.92)
4 (421.58)
23 (381.31)
1 (425.96)
22 (453.09)
18 (394.84)
15 (426.58)
13 (431)
24 (486.21)
2 (390.83)
14 (475.21)
12 (465.37)
6 (417.58)
11 (425.5)
10 (438.14)
8 (374.59)
9 (415.17)
7 (379.81)
5 (403.36)
Average Annual Export (TSS) (kg/ha/yr)
318 - 321
322 - 358
359 - 381
382 - 391
392 - 397
398 - 410
411 - 422
423 - 431
432 - 453
454 - 486
Legend
Study Area
Subwatershed
Hutchinson Environmental Sciences Ltd.
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
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Scale = 1:750000
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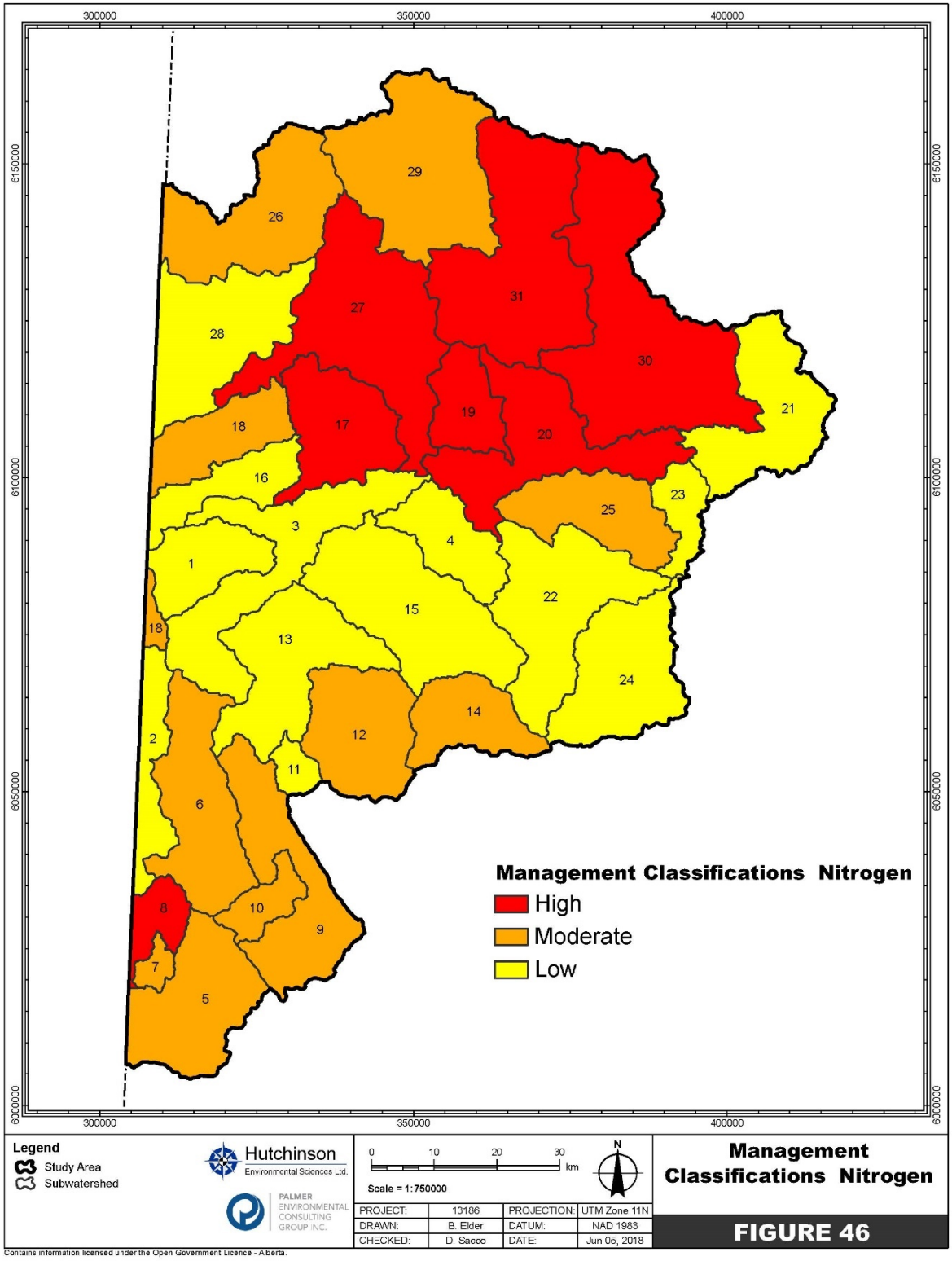
PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
CHECKED: D. Sacco DATE: Mar 08, 2018
Average Annual Export Coefficients Solids
FIGURE 19
Contains information licensed under the Open Government Licence - Alberta.

Appendix C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Management Classifications Nitrogen
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PALMER ENVIRONMENTAL CONSULTING GROUP INC.
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PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
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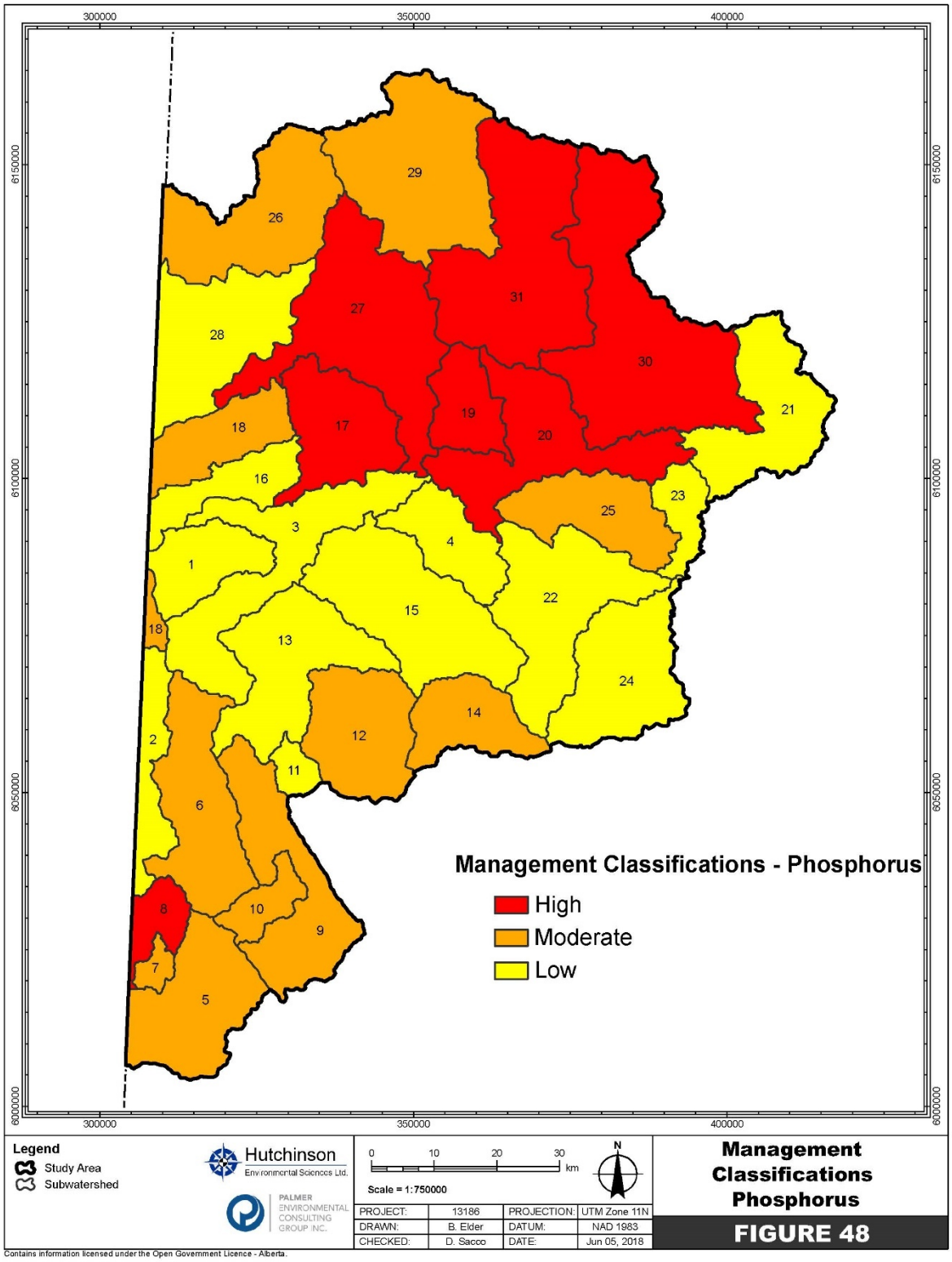
Management Classifications Nitrogen
FIGURE 46
Contains information licensed under the Open Government Licence - Alberta.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Management Classifications - Phosphorus
High
Moderate
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Legend
Study Area
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Hutchinson
Environmental Sciences Ltd.
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GROUP INC.
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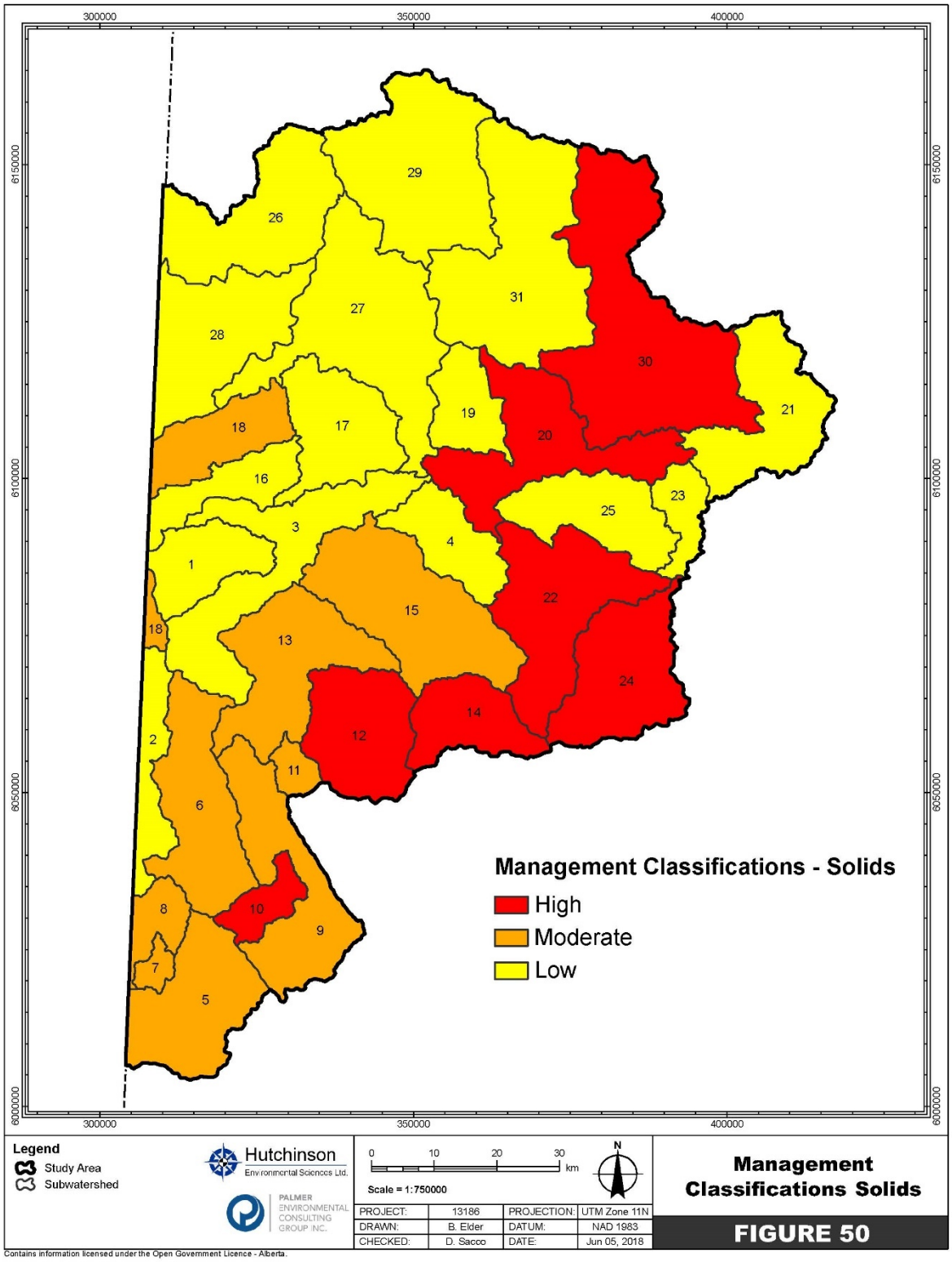
PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
CHECKED: D. Sacco DATE: Jun 05, 2018
Management Classifications Phosphorus
FIGURE 48
Contains information licensed under the Open Government Licence - Alberta.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Management Classifications - Solids
High
Moderate
Low
Legend
Study Area
Subwatershed
Hutchinson Environmental Sciences Ltd.
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
0 10 20 30 km
Scale = 1:750000
N
PROJECT: 13186 PROJECTION: UTM Zone 11N
DRAWN: B. Elder DATUM: NAD 1983
CHECKED: D. Sacco DATE: Jun 05, 2018
Management Classifications Solids
FIGURE 50
Contains information licensed under the Open Government Licence - Alberta.