YUKON LAND USE PLANNING COUNCIL

NORTH YUKON DISTURBANCE TRACKING

A DISCUSSION PAPER

Abstract

This document briefly describes four options for a disturbance tracking process, before describing a recommended option in greater detail. The Plan's definitions of "disturbance" and "recovery" that underpin disturbance tracking some end-uses of the tracked disturbance data are also described.

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Contents

Executive Summary

The North Yukon Planning Commission recommended that two cumulative effects indicators, surface disturbance and linear disturbance, be tracked and ideally kept below levels specified for each geographic sub-division of the region, or "Land Management Unit" (LMU). To do this effectively, disturbances need to be tracked over time. This document describes four options for a disturbance tracking process: 1) *status quo* – relying on the Commission's estimates; 2) periodic reinterpretation of imagery; and 3 & 4) tracking new disturbances and modelling recovery using available data. It then details a recommended option that whereby option 2 is used until a tracking and modelling process is deemed superior. Option 2 is a new idea that is much simpler than the modelling-based ones because recovery is addressed by observations rather than data-backed models. However, the costs of this option could be higher.

This discussion paper also discusses some end-uses of the tracked disturbance data. It also discusses some of this issues, and potential solutions, with the Plan's definitions of "disturbance" and "recovery" that underpin disturbance tracking.

Purpose

The purpose of this discussion paper is to inform decisions on how anthropogenic disturbances in the North Yukon Planning Region may be tracked. In the near term, this document should help design a pilot project that determines the baseline of anthropogenic surface disturbances in Land Management Unit (LMU) 9 "Eagle Plains". This discussion paper is meant to be circulated among most of the people that have been involved in disturbance tracking in North Yukon so that they can provide feedback to me prior to the May meeting of the Parties. Therefore, this paper is subject to substantial changes once interested parties (including the Council & staff) have provided comment.

Context

The North Yukon Regional Land Use Plan (Vuntut Gwitchin & Yukon Governments, 2009) is the only regional plan to be completed and approved as per Chapter 11 of the Umbrella Final Agreement. As such, it set a precedent for the process of regional planning in the Yukon, the content and approach of Yukon regional plans, and, now the implementation of plans in the Yukon. This document explores options for the implementation of one aspect of the Plan: tracking anthropogenic disturbances.

The Plan, originally written by the independent North Yukon Planning Commission (North Yukon Planning Commission, 2009) and later approved with very few modifications by the Yukon and Vuntut Gwitchin Governments ("the Parties"), provided recommendations on research directions, on strategies applicable to all land uses, on a few policies specific to individual land uses, and on others. The Commission made many of these recommendations in order to address a key issue of oil and gas development in a significant portion of the winter range of the Porcupine Caribou herd. Most relevant to this document, the Commission recommended that the cumulative effects of human activities should be kept below levels it determined were sufficient for oil and gas development, yet were not likely to overly impact caribou over the long term. More specifically, the Commission recommended that two cumulative effects indicators, surface disturbance and linear disturbance, be tracked and ideally kept

below levels[1] specified for each geographic sub-division of the region, or "Land Management Unit" (LMU). While these levels are not considered hard caps on development, they do represent thresholds in decision-making. For this reason, and to better differentiate these levels from levels of existing disturbance, they will be referred to here as "thresholds".

In their approval and implementation planning, the Parties agreed that they should track disturbance levels, that the Commission be dissolved, and that the Yukon Land Use Planning Council ("the Council") check the conformity of project proposals to the plan. Relevant project proposals would be referred to Council staff by the YESAB. To check conformity, the Council would (among other things) compare the combined proposed and existing disturbances to the thresholds specified for the LMU.

Since the Plan's approval, the Parties and the Council have struggled to determine how to best track disturbances and how they are to be used to determine conformity. Though perhaps not conceptually difficult, in practice these tasks are complicated by the Plan's inconsistent definitions of disturbance and recovery, the number of agencies involved, inaccurate and/or incomplete existing disturbance data, and poor understanding of the current state and likely recovery trajectories of existing disturbances. Further, the methods must be practical, defensible, accurate at a regional scale[2], scalable to all or most of the Yukon as more regional plans are made, and must be able to be efficiently communicated to all agencies and stakeholders.

Until recently, there have been few projects proposed in the Region, none of which were to result in significant new disturbances. As such, only recently did the Council need disturbance levels and a linked conformity check process approved by both Parties. The first case where these were needed was with Northern Cross (Yukon) Ltd's *Eagle Plains 3D Seismic Survey* (YESAB project #2013-0067). In the absence of approved disturbance levels, the Council resorted to using the best available disturbance estimates of the Commission (North Yukon Planning Commission, 2008) (Appendix 2.5). These estimates were made by combining all available spatial disturbance data, then manually removing features so as to minimize double counting of features. The Commission noted that though many of these features have recovered, a number were never captured by spatial data. Considering this, the Commission estimated that, on balance, current disturbances should be considered to be 20% less than their overall estimates. The Parties never approved of these estimates: their removal was one of the few changes the Parties made to the recommended plan (North Yukon Planning Commission, 2008) during approval (Vuntut Gwitchin & Yukon Governments, 2009).

End-Use Cases/Needs

Before spending much time and effort determining a baseline of surface disturbance, it is important to understand potential end-uses. Potential uses include:

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[1] The Commission specified cautionary and critical levels. The first is an "early warning signal" that triggers "proactive management steps", while the second are the maximum acceptable levels.

[2] Though disturbance levels need to be accurate as possible, the Parties need to accept that some accuracy will be traded off with practicability and scalability. This is in keeping with *regional* planning, which, in the Yukon, generally views the landscape at a 1:250,000 scale.

- Conformity checks
- Disturbance and recovery forecasting
- Proposal self-assessment
- Compliance, monitoring and inspections

Use cases not directly pertaining to the Council, such the conformity checks, are somewhat speculative and have not been consulted on.

Conformity Checks

Council staff, in lieu of an active commission, are charged with determining the conformity to the approved North Yukon Regional Land Use Plan of project proposals moving through YESAB's process. At a minimum, these staff need current estimates of linear density (km/km^2) and surface disturbance (%, or km^2/km^2) for each Land Management Unit (LMU) in a tabular form. These estimates would be based upon agreed-upon definitions of disturbance for this plan. The staff would then assess the proposed general location and amount of activity to estimate the project's disturbance, taking into account: the proportion of the project area that is forested, the season and types of activity, and disturbance exemption zones. This assessment could use spatial tools to estimate some of these considerations. The staff could then add the proposed disturbance levels to the current estimate levels to arrive at the forecasted post-project total. If this total exceeds the cautionary or critical level, then the project may not conform and the Parties to the plan would be notified. More details of this process are discussed under "Conformity Checks" towards the end of this paper.

Forecasted post-project disturbance levels
=
Estimated current disturbance level*
+
(Proposed amount of winter work X proportion of the project area or actual disturbances that is forested)
+
Proposed amount of other work that disturbs soil/hydrology
-
Amount of proposed work above within exemption zones

*How this is determined is the subject of much of this paper. Recovery is considered in every case.

Though simple to apply, this tabular approach is inappropriate for cases where work is proposed over existing disturbances, as it would "double count" the disturbance. A more thorough approach would be for the staff to overlay (more specifically union) spatial data of the disturbance (based upon agreed-upon definitions of disturbance for this plan) with spatial data for the proposed project. This spatial approach would also take into account the proportion of the project area that is forested, the season of activity, and disturbance exemption zones, but would do more accurately than the tabular approach.

Likely both approaches would be necessary. The majority of project proposals arrive without spatial data and are small enough that an tabular (aspatial) approach reasonably accurate. However, the spatial approach could be used for some larger projects that provide detailed spatial data.

Data Requirements

Disturbance data needs to be generated by a well-documented process that is approved by all parties to a regional plan (YG & VG in the case of the North Yukon Region). This is more important than even the accuracy and precision of these data, since it is unreasonable and unnecessary for exact disturbance metrics at a regional scale.

Tabular Approach

Simple spreadsheets updated quarterly or annually (depending on the scale of recent projects) would show the amounts of each disturbance indicator estimated to be in each LMU.

Spatial Approach

Spatial data (e.g., shapefile, etc.) updated quarterly or annually (depending on the scale of recent projects) showing linear and surface disturbance in the region. These data do not necessarily need attributes, but would almost certainly be derived from a more general and fully attributed disturbance dataset (**Error! Reference source not found.**). Surface disturbance should include that contributed by the linear features (e.g. by buffering linear features).

Disturbance and Recovery Forecasting

The Parties, proponents and future commissions charged with plan review may all be interested in modeling or forecasting disturbance levels based on expected development and recovery trajectories. Much as the Commission's ALCES© models (Francis & Hamm, 2009), these models could test plausible outcomes of current, adjusted and new management recommendations (*e.g.,* disturbance thresholds) in order to inform plan revisions or amendments or project planning.

Data Requirements

For future disturbance to be modelled, modellers need to know many aspects of the existing disturbances. Therefore, spatial data with all relevant attributes (or "fields", see **Error! Reference source not found.**) would be necessary.

Proposal self-assessment

Project proponents designing a project to best conform to the plan or those seeking more certainty as to whether or not an already designed project may conform to the plan will need access similar information required by the YLUPC (above), though preferably in a simple web-accessible format. The tabular approach would easiest to implement by providing the tables on-line. These tables would also include relevant information for each LMU such as actual cautionary and critical levels (i.e., km and km^2 rather than relative levels like km/km^2 or %), key values and special management considerations. This tabular data should also be available in an on-line GIS.

A more elaborate on-line spatial self-assessment tool (with-in an on-line GIS) is also possible. The proponent could either upload spatial data for their project, or sketch out their project using the tool. The tool would then integrate the project's data with data for the current existing disturbance, forest

cover, exemption zones, etc., and would report whether or not the project is likely to be in conformity to the plan.

Data Requirements

These on-line tools would use essentially the same data as the YLUPC for their conformity checks. The up-front development of the on-line tools and meta-data could be significant; however periodic updates using the data for the YLUPC would be trivial.

Compliance, Monitoring and Inspections

Inspectors could focus their inspections by using disturbance data to explore if a project may not have adhered to permitted amounts and types of activities. It is possible that disturbance data of sufficient quality (e.g. based on high resolution imagery) could be used by the inspectors as evidence or to focus their inspections.

Data Requirements

For disturbance data to be most useful for this role, they should be recaptured from imagery frequently so that inspections may occur with appropriate timeliness. They should also be based on reasonably high resolution imagery and they should have a number of descriptive attributes. These requirements may make this use impractical over the broad areas typically of interest to regional plans. However, imagery supporting inspections may support disturbance tracking.

Definitions

The amount of disturbance in a Land Management Unit depends firstly on how "disturbance" is defined for each disturbance indicator. The Plan refers to "surface disturbance", "linear density", "functional disturbance", and "disturbance" and provides for each slightly different definitions. Further, it's definition of when human-caused disturbances are "recovered" is not consistent with most of the definitions for disturbance.

Changes to definitions could be considered plan amendments and would be part of plan reviews (compare (Vuntut Gwitchin & Yukon Governments, 2009, pp. 7-2,3) with (North Yukon Planning Commission, 2007, pp. 7-2,3)); therefore, before finallizing significant defintion changes, an appropriate level of public and stakeholder engagement may be required. In the absence of a Commission, it is unclear which organization would undertake such engagement, though some collaboration between the parties to the Plan and the Council may be appropriate.

Disturbance

The Plan's definition for "Functional Disturbance", defined in Table 3.1, is perhaps the most clearly defined and operational definition, and should be the basis for any clarification. It is applicable to both disturbance indicators. It reads:

> ***Functional Disturbance:*** *Physical land use disturbance that results in disruption of soil or hydrology, or that requires the cutting of trees. Activities considered exempt from functional disturbance creation are: 1) new linear features less than 1.5 m in width; 2) land use activities that occur on frozen water-bodies; 3) winter work with no required clearing of trees; 4) winter work that utilizes existing disturbances and linear features.*

Issues with this definition:

1. This definition includes the cutting of trees, while the Plan's definition of "Direct Surface Disturbance" is defined very similarly except that it includes the clearing of trees *and woody vegetation*. The Plan's definition of "recovered" (p. 3-6) also refers to woody vegetation:

   > *…In forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 metres in height….*

There are three resolutions to this inconsistency, starting with the recommended one. **Options:**

a. Keep the definition referring to "cutting of *trees*". Shrubby areas, when cut, quickly recover to a shrubby seral stage. It isn't worth tracking cut shrubs since that disturbance is so ephemeral.
b. Change the definition to refer to the "cutting of woody vegetation (trees and shrubs)". This would make the definition more consistent, and would be (at least for awhile) relevant to increased predator access which underlies these definitions. See Figure 1.
c. Change the definitions so that cutting of "cutting of woody vegetation (trees and shrubs)" applies to surface disturbance ("Direct Surface Disturbance" is defined this way) and "cutting of trees" applies to linear disturbance. While it could be argued that broad areas of cut shrubs would recover much slower than linear cuts, this narrow interpretation would add unnecessary complexity.

2. The plan does not specify whether or not the cutting of dead trees counts as disturbance. Often forest fires leave behind "forests" of dead trees that, to some extent, influence predator access and sightlines. **Options:**
   a. Cutting dead trees is not a "disturbance". Disturbance features in the database should be marked as "burned" should a forest fire occur after image interpretation or in cases where disturbance is only visible because of lack of standing dead trees. Burned features without soil or hydrological disruptions would not be counted for conformity checks. This definition is in line with the Commission's model of oil & gas development and resulting recovery (Francis & Hamm, 2009).
   b. Cutting dead trees is a "disturbance". This would simplify maintenance of the disturbance database.

Figure 2: Several years after a forest fire in the Eagle Plains area.

3. "Functional Disturbance" in the plan is directly linked only to the general description IMA Zone I, leaving more ambiguity to the definitions of IMA Zones II-IV. However, the glossary does link "Surface Disturbance" to "Functional Disturbance". **Recommendation:** The definitions of "Surface Disturbance" *and* "Linear Disturbance" should be explicitly linked to "Functional Disturbance", and the descriptions of IMA Zones I-IV should consistently reference functional disturbance.
4. The Plan only mentions the visibility of disturbances in the definition of "Direct Surface Disturbance":

> *Visible, human-caused disturbances that result in the physical disruption of soil or hydrology, or the clearing of trees and woody vegetation.*

This definition doesn't say from where or how far away a disturbance must be visible. However, all but the *status quo* tracking options imply that disturbances must be remotely sensible, that is, visible from a satellite or plane. **Recommendation:** If any of the other tracking options are selected, then a more precise definition of visibility should be included into the definition of the two disturbance indicators.

Recovered

The Plan's definition for "Recovered", defined in a footnote on page 3-6, reads:

> *As human-caused surface disturbances, including linear features, recover through natural re-vegetation or active reclamation, they are subtracted from the total amount of disturbed area. As a guide, human-caused surface disturbance is considered recovered when it no longer facilitates travel or access by wildlife and people. In forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 metres in height.*

Not withstanding the woody vegetation question discussed earlier, the definition of recovery doesn't address cases of functional disturbance soil or hydrology are disrupted. Further, it should address visibility and/or be closely linking to "functional disturbance". A definition that addresses these concerns is described in the next section. An alternative definition is the one suggested by the Peel Watershed Planning Commission (Peel Watershed Planning Commission, 2011), and later approved by the Yukon Government (Yukon Government, 2014):

1. *When the feature no longer enables travel or access by wildlife and people.*
    - *in forested or shrubby areas, a feature is covered by woody vegetation (trees and shrubs) at least 1.5 metres in height.*
    - *In areas mostly covered with low-growing vegetation (less than 1.5 metres), a feature can be considered recovered when (a) it is covered with native species roughly the same height and composition as the surrounding dominant vegetation.*
2. *When increased run-off and sediment loading returns to background levels.*
3. *When its contours roughly match the original contours.*
    - *it may be necessary to re-contour certain disturbances, such as bridge abutments or elevated road beds, before the site can be considered fully restored to natural conditions.*
4. *When all debris and human-brought materials have been removed from the site.*

Solutions

Considering the above issues with the definitions in the Plan, and the options for resolving them, perhaps the Plan should be amended to include these revised definitions:

Term: Functional Disturbance
Revised Definition: Physical land use disturbance that results in disruption of soil or hydrology, or that requires the cutting of **living** trees. Activities considered exempt from functional disturbance creation are: 1) new linear features less than 1.5 m in width; 2) land use activities that occur on frozen water-

bodies; 3) winter work with no required clearing of trees; 4) winter work that utilizes existing disturbances and linear features. **For practicality, functional disturbances are anthropogenic disturbances visible in imagery with at least 1.5m resolution that are not interpreted to fall under the exceptions listed above.**
Current Definition: Physical land use disturbance that results in disruption of soil or hydrology, or that requires the cutting of trees. Activities considered exempt from functional disturbance creation are: 1) new linear features less than 1.5 m in width; 2) land use activities that occur on frozen water-bodies; 3) winter work with no required clearing of trees; 4) winter work that utilizes existing disturbances and linear features.
Plan Reference: Glossary of Terms p. A5-3 & Table 3.1 p. 3-2

Term: Direct Surface Disturbance (1 of 2 cumulative effects indicators)
Revised Definition: The amount of area **functionally** disturbed by human activities. Such things as structures, roads, gravel quarries, seismic lines, access trails and similar features all create physical *footprints* on the land, resulting in direct habitat impacts.
Current Definition A: the amount of area physically disturbed by human activities. Such things as structures, roads, gravel quarries, seismic lines, access trails and similar features all create physical *footprints* on the land, resulting in direct habitat impacts.
Plan Reference A: p. 3-5, when defining the cumulative effects indicators
Current Definition B: Visible, human-caused disturbances that result in the physical disruption of soil or hydrology, or the clearing of trees and woody vegetation.
Plan Reference B: Glossary of Terms, p. A5-2

Term: Linear Density (1 of 2 cumulative effects indicators)
Revised Definition: The total length of all human-created linear features **of functional disturbance** (roads, seismic lines, access trails, etc.) in a given area.
Current Definition: the total length of all human-created linear features (roads, seismic lines, access trails, etc.) in a given area.
Plan Reference: p. 3-5

Term: Recovered
Revised Definition: As human-caused **functional** disturbances, including linear features, recover through natural re-vegetation or active reclamation, they are subtracted from the total amount of disturbed area. As a guide, human-caused surface disturbance is considered recovered when it no longer facilitates travel or access by wildlife and people. In forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 metres in height, **or when the surrounding forest has been burnt in a wildfire and the soil and hydrology have not been disrupted. Similarly, in non-forested areas, a feature can be considered recovered when soil and hydrological disruptions are no longer apparent.**

Current Definition: As human-caused surface disturbances, including linear features, recover through natural re-vegetation or active reclamation, they are subtracted from the total amount of disturbed area. As a guide, human-caused surface disturbance is considered recovered when it no longer facilitates

travel or access by wildlife and people. In forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 metres in height.
Plan Reference: p.3-6

Term: Zone I
Revised Definition: Very high ecological and heritage/cultural values within a sensitive biophysical setting. Maintaining ecological integrity and protecting heritage and cultural resources is the priority. All-season industrial infrastructure is discouraged. [Note: the zones are further defined in Table 3.2 with their assignment of specific cumulative effects thresholds.]
Current Definition: Very high ecological and heritage/cultural values within a sensitive biophysical setting. Maintaining ecological integrity and protecting heritage and cultural resources is the priority. Land uses are acceptable provided they do not result in creation of significant functional disturbance. All-season industrial infrastructure is discouraged.
Plan Reference: Table 3.1 on p.3-2. See also Table 3.2 on p. 3-7.

Recovery Modelling

The Plan recognizes that the long-term tracking of surface disturbance must consider the recovery of disturbances. In it's implementation section, it suggests that recovery modelling is needed to gradually remove disturbance features from the disturbance database, and identified recovery as a research priority. Indeed, such research has been done almost continuously since before the Plan was approved. The mechanics of such a model are described in the section "Extract conformity-relevant disturbances" towards the bottom and in the Scenario Report (Francis & Hamm, 2009, p. 22). An example of the kind of data to support such a recovery model.

Current cumulative disturbance
=
Historic disturbance
+
New disturbance
–
Recovered disturbances

Feature Type	Lifespan (years)
Major Road (Dempster Highway)	100
Access Road	50
Winter Road (Old Crow Winter Road)	100
Community Use Trail	30
Trail (unclassified historical linear feature – winter access route)	60
Airstrip	100
Gravel Pit	75
Well Site	60
Seismic Line	Width-modified (see *Figure 6*)
Pipeline	60
Hard Rock Mine	40
Settlement	100
Traditional Camp	100
Tourism / Visitor Facility	100
Work Camp	100

Figure 3: The Commission's estimated base case footprint lifespan for the North Yukon. (From Francis & Hamm, 2009, p. 22, Table 6)

However, the Commission acknowledged the difficulty in modelling recovery (North Yukon Planning Commission, 2007, pp. 4-141):

> *The length of time required for natural re-vegetation processes to reclaim historical disturbances is variable, and may be affected by a number of factors including the method used to create the feature (intensity of the disturbance), the size of the feature, the subsequent level of use (access legacy), landscape type, and fire history. Accounting for all of these factors at a regional level may not be possible.*

Modelling of disturbance recovery is one way to account for recovery in surface-disturbance tracking. With the rapid improvements and declining prices of remote sensing, *observed* recovery is becoming

more feasible. However, this option does not directly build the ecological understanding necessary for forecasting disturbance and recovery.

Disturbance Tracking Options

There are several options for tracking disturbances which may be generalized as:

- *Status quo* using older data and estimations
- Periodic reinterpretation of imagery
- Tracking new disturbances + modelling of recovery

No one option is ideal. However, considering the use cases above, one or more may be sufficient. Further, combinations of these option, such the recommended option, are worth exploring. Regardless of the method, disturbance tracking should address:

- Historical (legacy) disturbances
- New disturbances
- The recovery of disturbances

Option 1: *Status Quo:* Simple reduction of disturbance

In Brief:

Disturbance level predicted upon project completion	=	• 80% of historical disturbance (up to 2008) • + All reported disturbances reported by developers of subsequent project • + Amount of proposed new disturbance • - portion of eligible disturbances that overlap with non-forested ecological land classifications • - portion of above disturbances that are exempted from disturbance tracking

Discussion:

In the absence of complete and current regional disturbance data, the Commission estimated that, on balance, current (as of 2008) disturbances should be considered to be 20% less than their overall estimates. These estimates, in Appendix 2.5 of their Recommended Plan (North Yukon Planning Commission, 2008), were used in the conformity checks of Northern Cross (Yukon) Ltd's *Eagle Plains 3D Seismic Survey* (YESAB project #2013-0067) and *Eagle Plains Multi-Well Exploration Program* (YESAB project #2014-0112), in the absence of more rigorous and formally approved disturbance levels. Data for disturbance subsequent to the Commission's estimates (e.g., those resulting from YESAB project #2013-0067) were provided by the developer to the Council by way of the regulatory agency. These were added to the Commission's estimates for the conformity check of YESAB project #2014-0112. For both of these projects, the portion of disturbances that overlap with non-forested ecological land classifications were not counted.

The processes for determining the conformity of projects #2013-0067 & #2014-0112 were developed *ad-hoc* by one staff-member of the Council as new information was made available. Not only were they based on unsupported data, they were not agreed-to by the Parties, were inadequately documented for the public, and were not peer-reviewed or otherwise checked. Some comments on YESAB's on-line registry for #2014-0112 critically review the methods and their results and indicate possible short-comings. Nonetheless, the conclusions of the #2013-0067 & #2014-0112 conformity checks are thought to be sound.

Analysis:

Pros:

- Simple – already being done
- Based on best available data

Cons:

- Based on data which had gaps and did not account for recovery. The Commission accounted for these shortcomings with a somewhat arbitrary 20% reduction of disturbance.
- Based data that has not been approved by the Parties.
- Based data that has not been updated since 2008.

- Does not account for recovery
- Is 100% reliant on accurate project-end reporting by the developers to track new disturbances.

It is possible that this arrangement could continue, though its rigorousness could be legally questioned.

Option 2: Periodic Reinterpretation of Imagery

In Brief:

- Medium or high-resolution satellite images are acquired every 5 years or sooner if triggered by a determined level of development.
- Disturbance is digitized or interpreted from these images, with consideration of historical data.
- Year-end reporting of projects adds disturbance to the database in years between imagery recapturing.
- Recovery of disturbances is not explicitly considered: it is assumed recovery will be reflected in changes in the imagery.

Analysis:

Pros:

- No modelling of recovery is required, so fewer assumptions are need.
- No attributes are needed (beyond width of linear features).
- No need for table of recovery rates for types of disturbances and surrounding ecosystems (and therefor no need for agreement on such a table from the Parties, and less need for supporting fieldwork).

Cons:

- Image capture and interpretation is expensive, especially when expanding this approach to other LMUs or regions.
- May not responsive enough for busy LMUs or those close to cautionary/critical
- Interpretation may need ground-truthing
- Definition of disturbance may need to be changed to refer to the remote sensibility of disturbances at a determined scale.

Option 3: "Pro-rated" reduction of disturbance

In Brief:

- Medium or high-resolution satellite images are acquired at the beginning, and infrequently thereafter (e.g., to support plan reviews)
- Disturbance is digitized or interpreted from these images, with consideration of historical data.
- Annually, the amount of disturbance is reduced based on year of disturbance and type of disturbance

- The % that an LMU is forested further reduces the amount of disturbance. Other ecological classification could also be considered.
- Year-end reporting of projects adds disturbance to the database in subsequent years following the initial imagery capturing.

Analysis:

Pros:

- Reduces need for acquiring and interpreting satellite imagery.
- Representation of different ecological land classifications in each LMU could be considered when modelling recovery.
- Facilitates modelling of disturbance into the future, thus informing plan amendments of reviews.

Cons:

- Ecological characteristics of individual features ignored, making detailed spatial analysis of project proposals less realistic (e.g. it would not be possible to see the modelled recovery status an individual existing disturbance feature when deciding whether or no to re-use it).
- Informed by extensive fieldwork or agreed-upon guestimates
- Requires complete attributes (e.g., type of disturbance, year of disturbance, width of disturbance…)

Option 4: Spatially explicit modelled recovery

In Brief:

- This option uses a similar approach to Option 3, including:
    - Medium or high-resolution satellite images are acquired at the beginning, and infrequently thereafter (e.g., to support plan reviews)
    - Disturbance is digitized or interpreted from these images, with consideration of historical data.
- However, disturbance features are spatially broken up by their underlying/surrounding ecology. This allows for a better spatial understanding of the recovery of disturbance features. There are two ways of adding ecological attributes to the disturbance spatial data:
    - Intersecting the disturbance data with the Ecological Land Classification (ELC) data: This desktop GIS exercise could be quick and inexpensive, though intersecting vector data (disturbance) with raster (ELC) sometimes is not straight forward. Of greater concern is for larger older surface disturbances that show up on the ELC. Intersections in this case would not indicate what the ecology was before the disturbance.
    - During the interpretation of imagery: Imagery interpreters may be asked to breakup their delineated disturbance features by their recovery status (e.g. raw soil, recovered with forbs, recovered with shrubs, recovered with trees). Similarly, they could further breakup up disturbance features wherever the surrounding ecology shifts. This approach would be more expensive, but likely more robust.
- Annually, the spatial disturbance database is reanalysed to:
    - Incorporate that year's disturbances.

- Model recovery of disturbances based on underlying/surrounding ecology, year of disturbance and type of disturbance. Remaining disturbances would then be exported as spatial data and as a table for use in conformity checks.

Analysis:

Pros:

- Reduces need for acquiring and interpreting satellite imagery.
- Recovery is modelled spatially. This allows for detailed spatial analysis of project proposals with current disturbance.
- Facilitates modelling of disturbance into the future, thus informing plan amendments of reviews.

Cons:

- Informed by extensive fieldwork or agreed-upon guestimates
- Requires complete attributes (e.g., type of disturbance, year of disturbance, width of disturbance, underlying/surrounding ecology, observed recovery state…)

Recommended Option:

Given that most options start with acquiring high-res satellite images from which disturbance is digitized or interpreted, I recommend piloting Option 2. This will help better understand the feasibility of using this approach for other LMUs or other regions of the Yukon, and will refine the data model and data processes. Another benefit of this options is that it can be completed within six months.

Over time, as resources become available, existing vegetation field data may be analyzed and used in recovery modelling (likely Option 4). This approach could then be tested while having an approved disturbance baseline and tracking process in place. If successful, it could be phased in at a later date. However, later testing of Option 4 would require more in-depth (and therefor more expensive) image interpretation up-front.

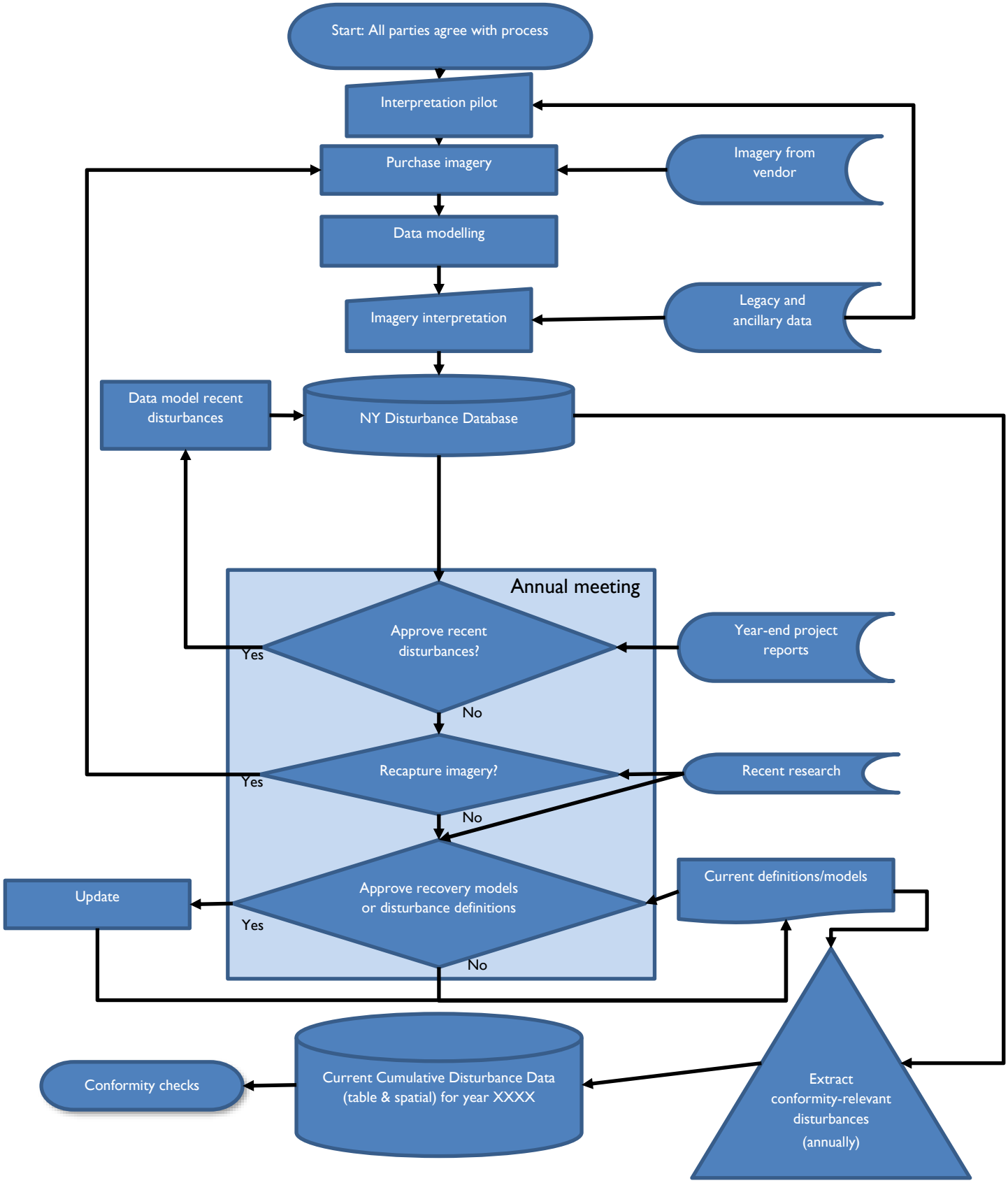

Figure 4: Overall process for the recommended option

The overall process for the recommended option is diagrammed in Figure 4 above. Additional details and recommendations are provided for each step in the in the next sections.

All parties agree with process

This discussion paper is meant to be circulated among most of the people that have been involved in disturbance tracking in North Yukon so that they can provide feedback to me prior to the May meeting of the Parties. At that meeting, I can present the ideas, feedback and necessary decisions, and will facilitate those decision-making, if needed. An MOU that refers to an updated version of this document could be signed as well. While this process may be complicated, I don't anticipate disagreements that can't be resolved within a small portion of the May's meeting.

To be most effective, feedback should include as many of the following as possible:

- Alternative options or methods
- Comments on whether or not there is sufficient information to make a decision, and if not, what information is required
- Comments on roles and responsibilities
- Etc

Interpretation Pilot

A pilot project on a small area of LMU 9 using existing imagery and ancillary data would help develop the data model and collection guidelines as well as confirm the best imagery and costs. Results of this pilot would help inform the next three steps of the process: imagery purchase, imagery interpretation, and data modelling.

Recommended Roles and Responsibilities:

- Set-up of a work-station with all available data: Manon Desforges
- Interpretation workshop: Manon Desforges, Sam Skinner, Kirstie Simpson, Ryan Gould
- Reporting: Sam Skinner

Decisions:

1. Is a pilot necessary considering that the iterative improvements to the collection guidelines and data model could be made with the contracted interpreter?

Purchase Imagery

Manon Desforges, GIS Database Administrator, Energy Mines and Resources – Corporate Services, recently discussed[3] imagery purchasing options and factors that should be considered. That report described two options:

[3] In the document "Recommendation from Pilot Project review in LMU9", file: "DisturbanceMapping_Recommendation_20150314.doc" circulated 2016-03-15.

I. "Purchase of SPOT 6 2014 imagery (at 1.5 meter resolution) for the entire LMU9 area, minus the image we currently have around the Northern Cross area, at an approximate cost of $38,000." It is known that this imagery exists and is readily available, therefore there is less risk. Further, this type of imagery would make wide-spread disturbance tracking more feasible.

II. "Request to purchase the reminder of LMU9 at 50cm resolution. We currently have a significant part of the area that has already been captured with various sensors and years (Pleiades 2014 – Northern Cross area, GeoEye, 2010 & Quickbird 2007 along the highway). There is approximately 1,100 km2 that is not covered. Cost of this area would be approximately $14,300 ($13 x 1,100 km2), if it can be captured next year. One must however keep in mind the possibility that new data capture isn't always guaranteed, depending on weather, cloud coverage during the next season." Further, reliance of such high-resolution imagery would make wide-spread disturbance tracking less feasible and more expensive. However, the existing high-resolution imagery could help with QA for a pilot project using SPOT 6 imagery.

Manon went on to recommend the first option. Similar work by Environment Yukon also used SPOT 6. However, a third alternative was recently presented by John Cosco of Timberline Forest Inventory Consultants. He described his recent contracts doing aerial regeneration surveys in Yukon (south-central Yukon, and Haines Junction area) for the Forestry Branch. Capturing ortho & stereo images in those areas ran about $0.20/ha. For LMU 9, this would work out to about $130,000, but would likely be more considering the smaller scale and remoteness of the North Yukon project. These images would be higher resolution (~0.4m) and would be in four light bands allowing superior interpretation of vegetation.

The Yukon Land Use Council was approached to buy the initial round of imagery, with the understanding that the Parties would fund such purchases in subsequent years (if needed). However, given the positive relationships between Geomatics Yukon and imagery vendors, and Geomatics Yukon's infrastructure and expertise for holding and disseminating imagery, it may make sense for the Council to provide the funding, but for Geomatics Yukon to do the actual transaction. The Council won't be able to approve paying for imagery until their next meeting, likely in late May. They will need to know the answer to the decisions listed below.

Recommended Roles and Responsibilities:

- Initial purchase funds: the Council with a purchasing agreement.
- Purchasing: Geomatics Yukon
- Custodian & Governance of the imagery: Geomatics Yukon (with the understanding that the Council will have access to it).

Decisions:

1. What type (and extent) of imagery should be purchased? Options:
    a. SPOT 6 at 1.5m resolution
    b. Top-up of 0.5m imagery with Pleiades imagery
    c. Ortho and stereo photography
2. Who will be the custodian of the data? Options:
    a. The Council

    b. Geomatics Yukon
3. How the Council will they have access to the data? Options:
    a. Their own local server
    b. Via YNET
4. If necessary, how can funds be moved from the Council to Geomatics Yukon?

Data Modelling

Yukon Environment published standards and guidelines for surface disturbance mapping (Version 1.0, Yukon Environment, 2014), and thus have developed a data model and dictionary for their work. In previous technical meetings discussing the data model necessary for this North Yukon project, it was recognized that Yukon Environment's model should be extended with new attributes to support the filtering (or extraction) of mapped disturbances using the Plan's definitions and to possibly support modelling of recovery.

The number of new attributes required by options that model recovery will be higher than the simple option that relies on periodic reinterpretation (Option 2). Some additional attributes that may be required are described in Table 1.

Table 1: Possible Additional Attributes

Attribute	Option 2	Option 3	Option 4	Other Uses	Example
Disturbance Year	*	●	●	●	2013
Disturbance Year Accuracy		●	●	●	1, 5, 10 (+/- # years)
Age	*	●	●	●	5 (recalculated annually)
Data contributor	*	●	●	●	Northern Cross 2013
Season of disturbance	*		●	●	Winter
Surrounding veg class	*		●	●	Dense Conifer
Surrounding fire year	?		?	?	2018
Current veg class			●	●	Shrub <1.5m
Approximate Radius (points only)	●	●	●	●	6

*These attributes wouldn't be needed for the initial image interpretation, but would be necessary when tracking and filtering subsequent contributed data.

Further, additional disturbance types>subtypes will need to be added, including: Oil and Gas>Sump (areal), Oil and Gas>Seismic Line (linear). A pilot of an interpretation of a small area of LMU 9 would likely identify more disturbance types and attributes.

Environment Yukon's data model also dictates that polygons and lines must not overlap. This restriction is an effective way to detect quality problems and is necessary when doing conformity checks. However, overlaps for lines would allow for a better description of when linear features are reused, for example a

new 2m cutline that runs down the center line of an old 8m wide seismic line that has recovered with tall shrubs.

Recommended Roles and Responsibilities:

- Extending Environment Yukon's data model: Manon Desforges

Decisions:

- What topology (overlap) rules should be used?
- What attributes? What values are possible for each

Imagery Interpretation

Like the purchasing of the imagery, the Council has been approached to fund the initial round of imagery interpretation, where a human views the imagery, and using a GIS, draws "attributes[4]" disturbance features. The interpreter draws on experience, field notes, existing disturbance data, ancillary imagery (if any) and other data to make interpretations according to a detailed data model and dictionary. This would be needed each time imagery is purchased (every 5 years or so under option 2).

Recommended Roles and Responsibilities:

- Administration and funding of the interpretation contract: The Council
- Interpretation work: Contractor

Decisions:

1. Is an RFP necessary, considering the Council has a sole-source limit of $30,000?

Data model recent disturbances

New disturbances approved at the annual director's meeting are digitized spatially (if needed) and merged together and checked to ensure the correct data model is used, and that all required information is present. At this point the new disturbance data is merged with the North Yukon Disturbance Database.

Recommended Roles and Responsibilities:

- Submission of collated year-end reports and spatial data to the Council: YG & VGG technical leads
- Spatial digitizing, merging, schema corrections and preliminary quality control: The Council
- Submission to Geomatics Yukon: The Council

[4] Attributes are essentially consistent and organized set of text notes describing each drawn feature. They are like the fields (columns) in a spreadsheet or database. Consistency and organization comes from predefining the attributes and the possible options in the data model and dictionary.

Decisions:

1. Roles and responsibilities

North Yukon Disturbance Database

The North Yukon disturbance database would be the authoritative spatial data of anthropogenic disturbances, including areal, linear and point disturbances. Considering the number of uses for these data, it would need to be have rigorously quality control and security, and would included a wide range of disturbances captured from image interpretation and submitted by developers or inspectors.

End users could interpret these data according to their own needs and definitions. For example, the annual disturbance data for conformity checks would be extracted annually from the main North Yukon disturbance database using the narrower definitions of disturbance set for that plan (e.g., cut-lines <1.5m wide would not be included) and possibly using recovery models.

Recommended Roles and Responsibilities:

- Custodian of database: Geomatics Yukon
- Governance: NY technical working group with representation from YG, VGG, and the Council.

Decisions:

1. Would the database store historical disturbance features that were not visible in subsequent image reinterpretation?
    a. No: simpler
    b. Yes: long-term tracking of disturbances would allow better estimation of recovery rates. Topology (overlap) rules would need to allow this.
2. Would the database be publically available, e.g., on the GeoYukon on-line GIS?
3. Roles & responsibilities.

Annual Meeting of the Parties

The parties to the Plan meet quarterly to discuss plan implementation, and one of these meetings should address the maintenance and use of the North Yukon Disturbance Database. As shown in Figure 4, there generally will be three decisions to be made annually. If the amount regional activity is very high, or if the cautionary level has been exceeded, these discussions could happen more frequently.

Approve recent disturbances:

New disturbances reported to various regulatory bodies by developers as part of their year-end reporting requirements are collated by YG and VGG's technical leads who then present them at the meeting. Provided there are no shortcomings or omissions, these are then approved to be added to the database.

Recapture imagery:

The need for recapturing and interpreting imagery should be re-evaluated initially every five years or in time for Plan reviews. Though recapturing and interpreting imagery is necessary if Option 2 is selected, the length of the intervals between could be adjusted considering:

- Amount of recent or expected activity. low on both accounts→longer interval
- How closely an out-going disturbance database matched the last image recapture/interpretation round. This could be affected by:
    - How closely disturbances reported by developers matched observed/actual disturbances.
    - The extent of observed recovery: little→longer intervals; much→shorter intervals
- New information pertaining to recovery rates, including field-study results and comparisons of the results of recovery modelling with observations.

Approve recovery models or definitions

While implementing the Plan, it may become apparent that definitions and models integral to tracking anthropogenic surface disturbances need to be adjusted. The first examples of such potential amendments were discussed in detail earlier. At the annual meeting, the need for such changes, and the public and stakeholder engagement strategy, if needed, should be discussed.

Recommended Roles and Responsibilities:

- Collation and reporting of year-end reports of developments: YG & VGG technical leads
- Funds of image purchasing and interpretation (subsequent to the initial round): YG & VGG
- Image purchase and interpretation administration: NY technical working group with representation from YG, VGG, and the Council.
- Updating and communicating disturbance definitions and recovery models (if needed): NY technical working group with representation from YG, VGG, and the Council.

Decisions:

1. Roles and responsibilities
2. Redefining disturbance and recovery (as discussed in an earlier section), and the corresponding public and stakeholder engagement strategy, if any.

Extract conformity-relevant disturbances

Though the primary need for the North Yukon Disturbance Database is to inform conformity checks, it may also contain features that do not meet the Plan's definitions of disturbance but could be useful for other purposes. Therefore, the database should be analysed annually to produce that year's current cumulative disturbance data (Figure 5). This reasonably simple spatial analysis could also include recovery modelling if desired.

Recommended Roles and Responsibilities:

- Analysis and extraction of conformity-relevant disturbance: the Council.

Decisions:

1. Roles and responsibilities

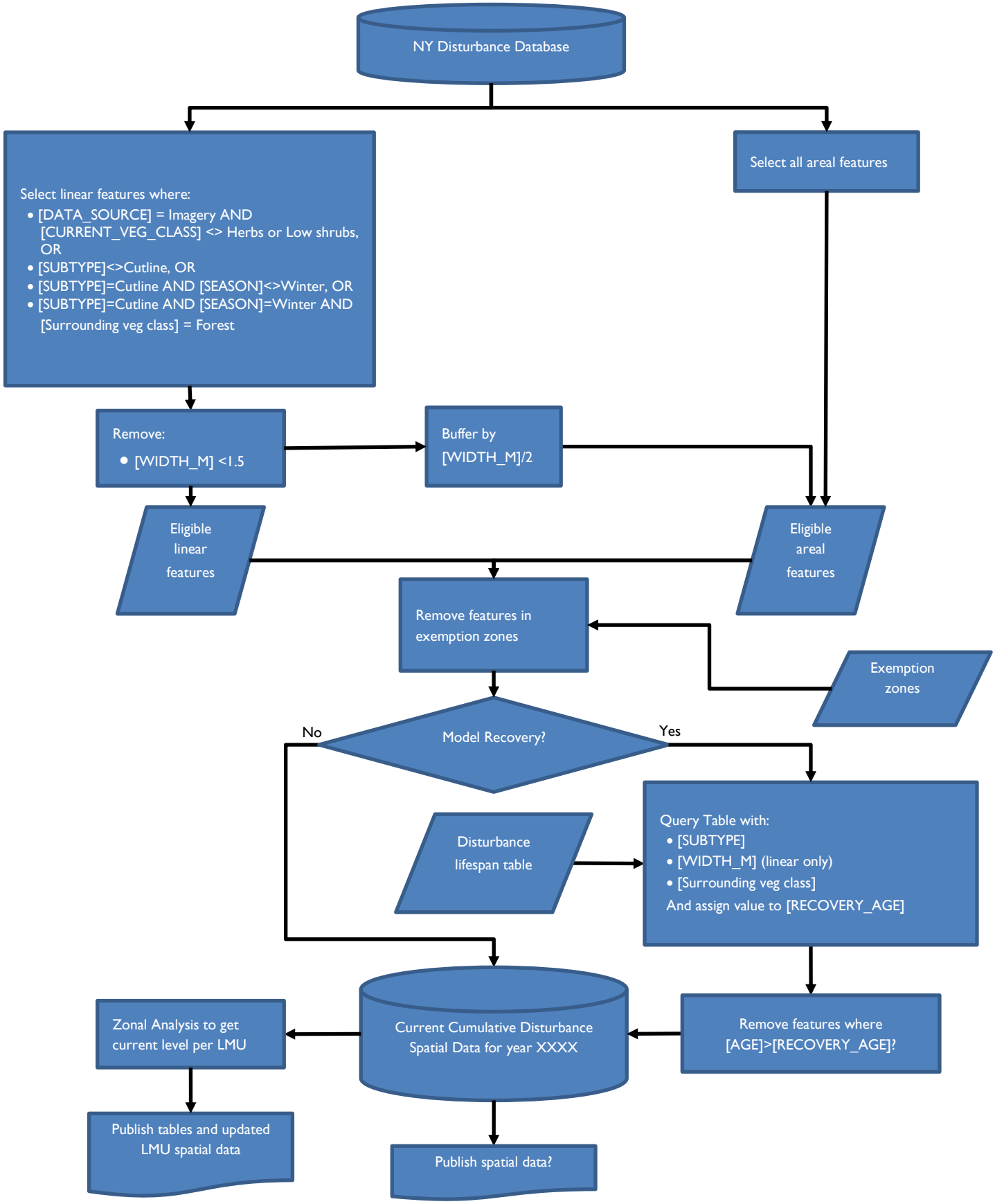

Figure 5: Annual disturbance data processing

Current Cumulative Disturbance Data for conformity checks

For maximum use and benefit, the extracted current cumulative disturbance data should be published in a number of formats. Most importantly, the amount of current surface disturbance and linear density per LMU should be available as a table on-line and should be updated in the LMU layer on GeoYukon. Eventually, the spatial data for the current disturbance could also be place on GeoYukon along with tools that would allow developers to self-assess their proposals.

Recommended Roles and Responsibilities:

- Publication of table on their respective webpages: NY technical working group with representation from YG, VGG, and the Council.
- Updating LMU layer on GeoYukon: Geomatics Yukon

Decisions:

1. Roles and responsibilities

Conformity Checks

Conformity checks using disturbance data so far have been *ad hoc*. Though every project is unique, the process for determining conformity based on disturbance data should follow a set process that is approved by the Parties and is publically available. Though the specifics are the subject of another discussion paper, the workflow would be very similar to the one shown in Figure 5.

Related Tasks to Come

The ideas and suggestions above are meant to spur discussions, suggestions and hopefully agreements on how anthropogenic disturbances should be tracked in the Yukon. Subsequent tasks may include:

- Better defining the conformity check process
- Developing on-line tools that would allow developers to self-assess their proposal

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Appendix 1. Roles and Responsibilities

With several agencies potentially involved and contributing to this project, agreement on roles and responsibilities is needed up-front. Luckily, the roles and responsibilities are somewhat independent of which option is chosen. Suggested roles and responsibilities in the following table were deliberately vague knowing that specific details will be agreed to later. They are discussed in more detail in the main document.

Role/responsibility	Agency/position	Relevant option
Resolution of definitions	NY technical working group	
Set-up of a work-station with all available data for pilot	EMR: GIS/Database support (Manon Desforges)	2, 3, 4
Interpretation workshop/mini pilot	Manon Desforges, Sam Skinner, Kirstie Simpson, Ryan Gould	2, 3, 4
Reporting of results of pilot	Council: Sr. Planner (Sam Skinner)	2, 3, 4
Initial imagery purchase (LMU 9 pilot) - funding	Council	2, 3, 4
Initial imagery purchase (LMU 9 pilot) – transaction	Geomatics Yukon	2, 3, 4
Custodian & Governance of the imagery	Geomatics Yukon	2, 3, 4
Extending Environment Yukon's data model	EMR: GIS/Database support (Manon Desforges)	2, 3, 4
Administration and funding of the interpretation contract (LMU 9 pilot)	Council	2, 3, 4
Initial interpretation (LMU 9 pilot)-work	Qualified local contractor	2, 3, 4
Funds for subsequent imagery purchases and interpretation	YG – EMR Corporate Policy and Planning & VGG	2
Administration for subsequent imagery purchases and interpretation Subsequent interpretation	NY technical working group	2
Annual collation and reporting of year-end reports of developments	YG & VGG technical leads	All
Annual submission of collated year-end reports and spatial data to the Council	YG & VGG technical leads	All
Annual spatial processing of year-end reports	Council	All
Annual submission of new disturbances to Geomatics Yukon	Council	All
Custodian of disturbance database	Geomatics Yukon	All
Governance of disturbance database	NY technical working group	All
Updating and communicating disturbance definitions and recovery models (if needed)	NY technical working group	All

Analysis and extraction of conformity-relevant disturbance	Council	2, 3, 4
Annual publication of table on their respective webpages	NY technical working group	All
Annual updating LMU layer on GeoYukon	Geomatics Yukon	All