Thanks to the Engineers.

You are the ones that build what Society asks you to build.

You are not the problem; you can be part of the solution.

Definitions:

Incremental – what we fail to see when we are not careful observers.

Cumulative – What we finally see; and hopefully before the damage is beyond repair.

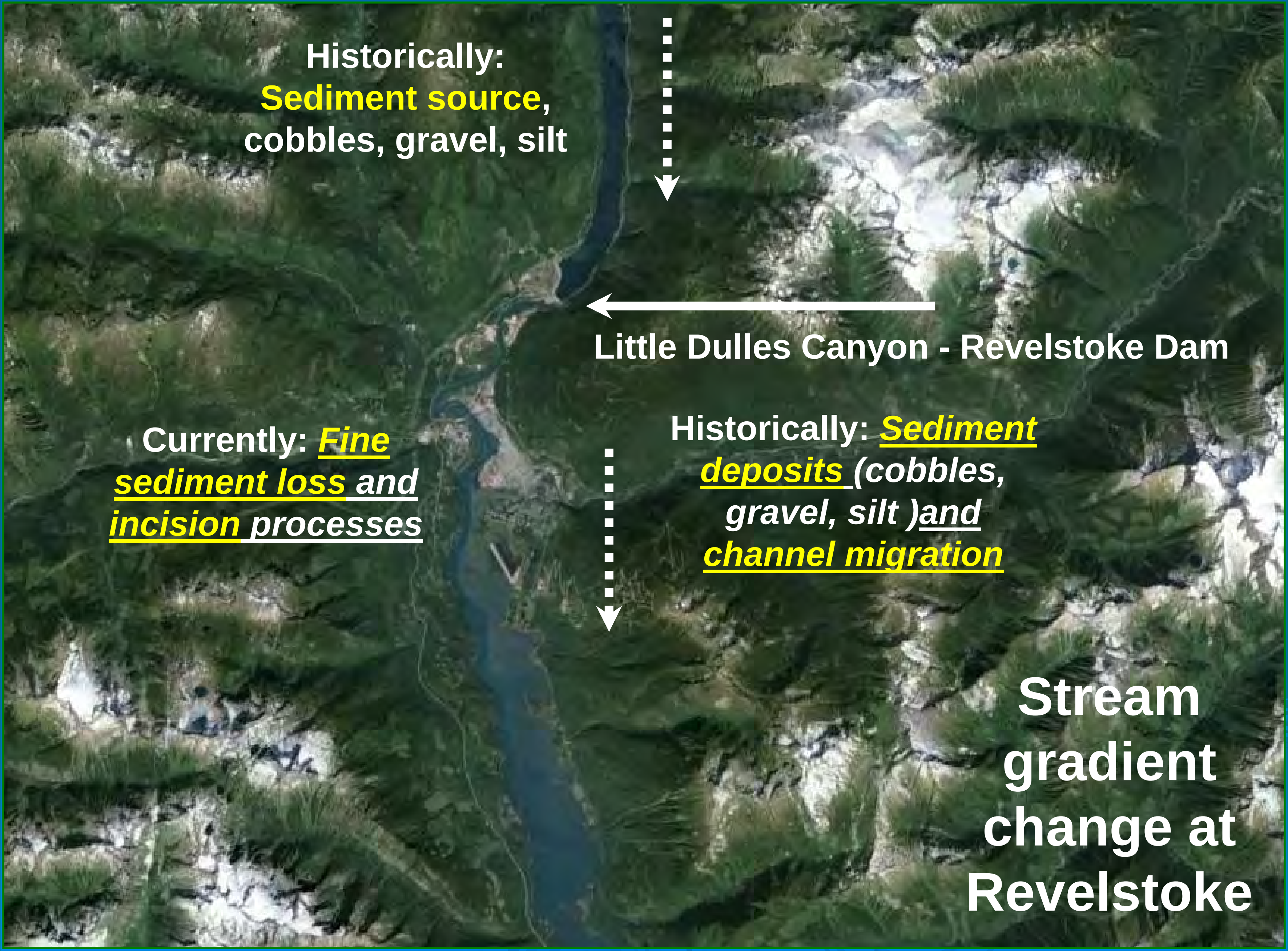
These stream channels, these river and side channels, they are the ribbons of life for fish, birds and animals.

These marshes, the vital steeping stones in migratory journeys 10,000 years old and of 3000 to 10,000 miles in distance.

Physical Processes of Water and the Ecological Effects of Peaking Plant and Reservoir Operations At Revelstoke, B.C.

January 22, 2014

Francis L. Maltby


Historically:
Sediment source, cobbles, gravel, silt
Little Dulles Canyon - Revelstoke Dam
Currently: Fine sediment loss and incision processes
Historically: Sediment deposits (cobbles, gravel, silt)and channel migration
Stream gradient change at Revelstoke

What's missing now?

Sediment from upstream:

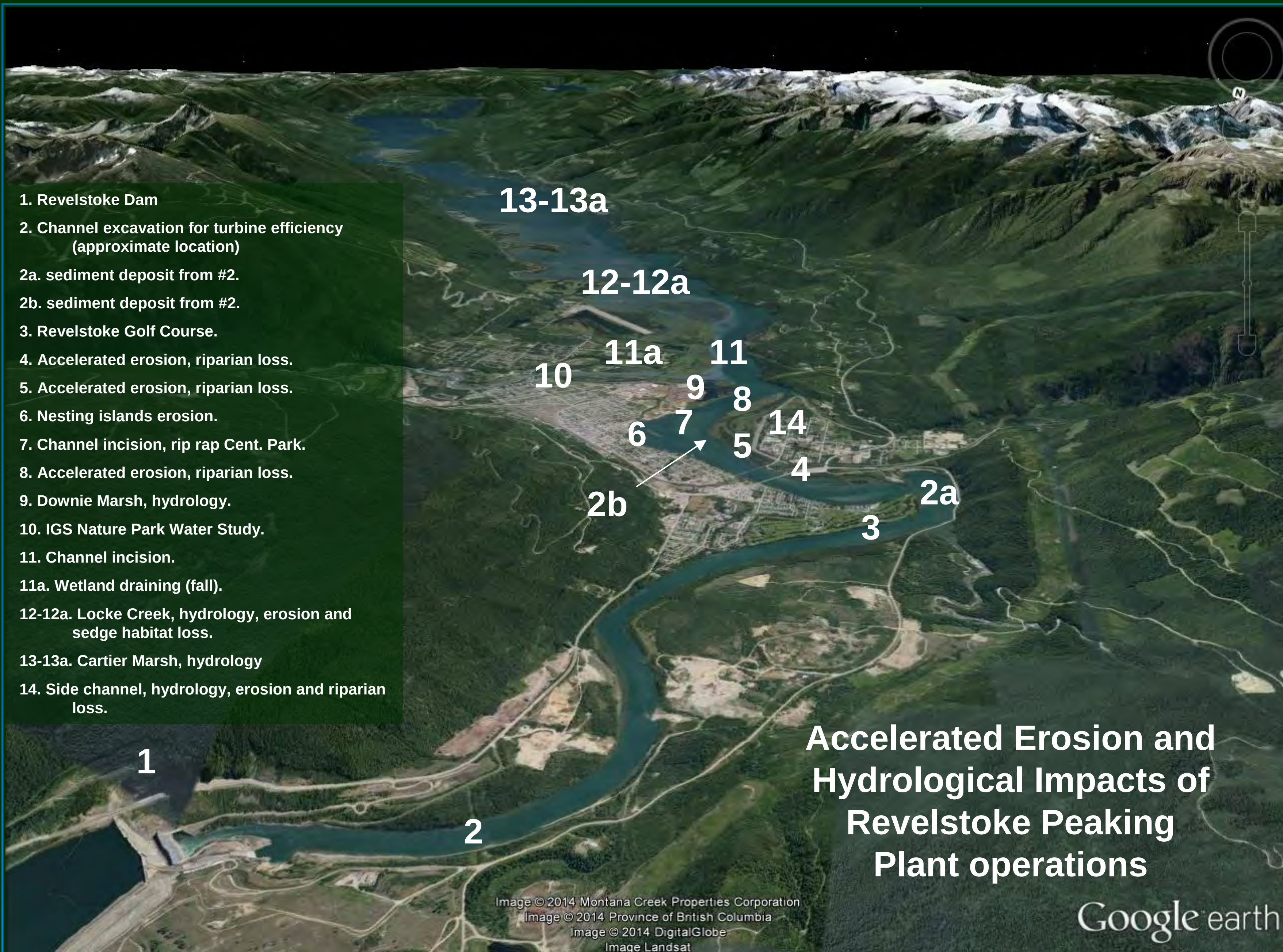
- ***Suspended*** – from May 1 to August 31, 1966, estimates 2,000,000 cubic yards of fine sediment were delivered at Steamboat Rapids (Revelstoke Dam), 30% as silt / clay, remainder as fine sand. Supports ecological productivity. Material was deposited between Revelstoke and Arrow Lake.
- ***Bed Load*** – estimates ranged from 20,000 – 100,000 cubic yards per year. Promotes channel infilling and migration. It would be expected that much of this heavier material would be deposited starting where channel gradient declined, below little Dulles Canyon at Revelstoke.

What has changed?

Annual Hydrological Cycle and Sediment Budget:

- River level fluctuation that would previously occur over an entire year now can occur one or more times per day.
- Each day the river can fluctuate between what was an historic summer flood to a low winter flow.

  (~ 7000 to 60 - 90,000* cfs - Rev @ 6 units*).
- The effects of "daily peaking" fluctuations all year + winter freeze/thaw erosion produce substantially accelerated erosion rates throughout entire system.
- All fine sediment loss, vegetation loss and loss of ecological productivity is permanent.


1. Revelstoke Dam
2. Channel excavation for turbine efficiency (approximate location)
2a. sediment deposit from #2.
2b. sediment deposit from #2.
3. Revelstoke Golf Course.
4. Accelerated erosion, riparian loss.
5. Accelerated erosion, riparian loss.
6. Nesting islands erosion.
7. Channel incision, rip rap Cent. Park.
8. Accelerated erosion, riparian loss.
9. Downie Marsh, hydrology.
10. IGS Nature Park Water Study.
11. Channel incision.
11a. Wetland draining (fall).
12-12a. Locke Creek, hydrology, erosion and sedge habitat loss.
13-13a. Cartier Marsh, hydrology
14. Side channel, hydrology, erosion and riparian loss.
13-13a
12-12a
11a
11
10
9
8
7
6
14
5
4
2b
2a
3
1
2
Accelerated Erosion and Hydrological Impacts of Revelstoke Peaking Plant operations
Image © 2014 Montana Creek Properties Corporation
Image © 2014 Province of British Columbia
Image © 2014 DigitalGlobe
Image Landsat
Google earth


5
14
4
*
4. Accelerated bank erosion, riparian loss.
5. Accelerated erosion, riparian loss.
14. Side channel hydrology, erosion and riparian loss
Image © 2014 Montana Creek Properties Corporation
Google earth

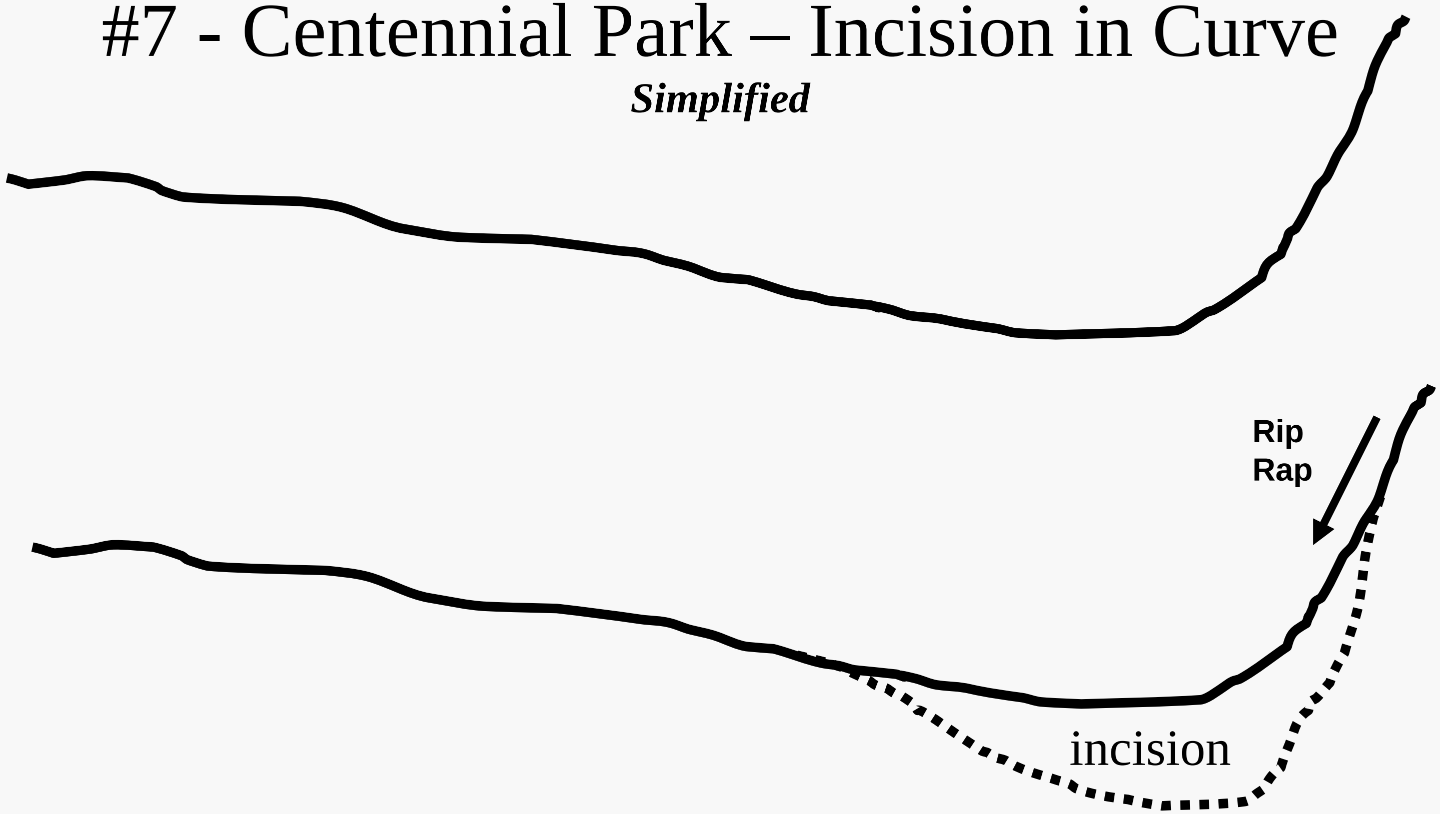
10
9
8
14
7
2a
6
6
5
14
Connaught Ave
Centennial Park Rd
Douglas St
Front St
Pigeon Rd
Lundell Rd
Haines Rd
Law Rd
2a. Deposition due to upstream channel excavation for turbine efficiency
5. & 8. erosion and riparian loss.
6. Nesting island erosion.
7. Channel incision
9. Downie Marsh, hydrology.
10. IGS Nature Park, water study.
14. Side channel, hydrology, erosion, riparian loss
© 2013 Google
Image © 2014 Montana Creek Properties Corporation
Google earth

7. Channel incision, Centennial Park rip-rap

#7 : Incision Centennial Park as channel has deepened the rip-rap bank armouring has settled into the river channel.

#7 - Centennial Park – Incision in Curve

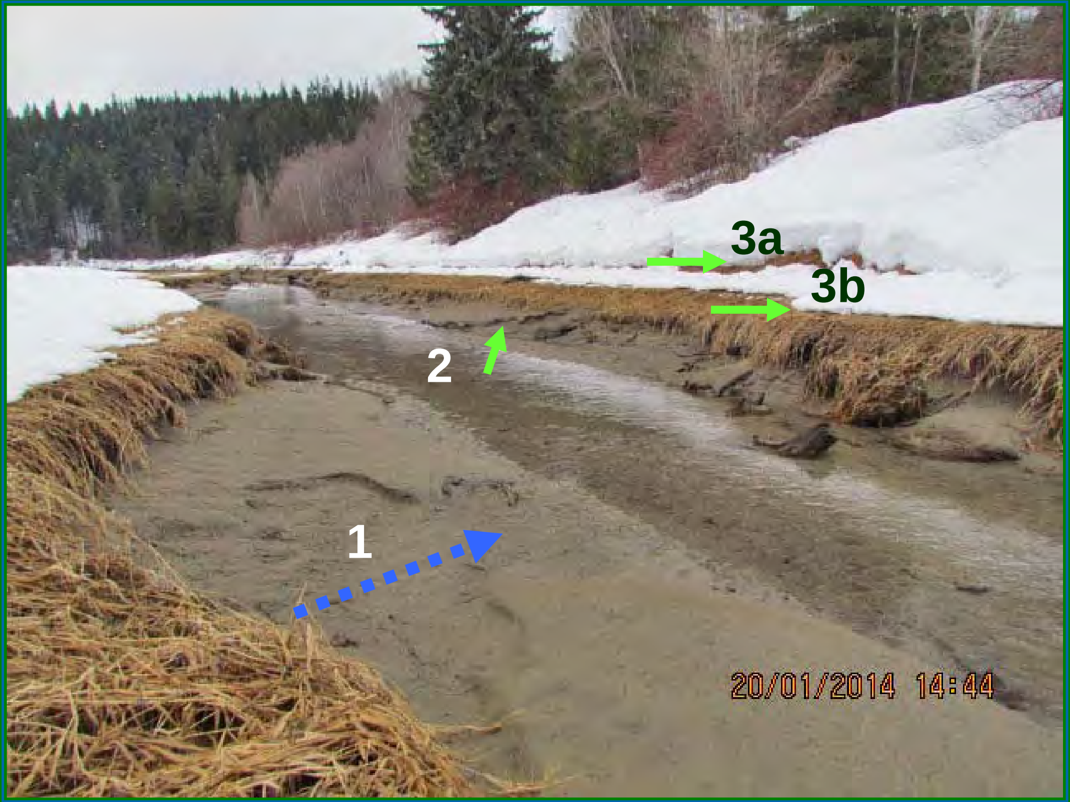
Simplified



River channel is deepening in curve and rip-rap is sliding into deepened channel.
Incision at this location is definitely occurring.


9
9. Downie Marsh, hydrology
Image © 2014 Montana Creek Properties Corporation
Google earth

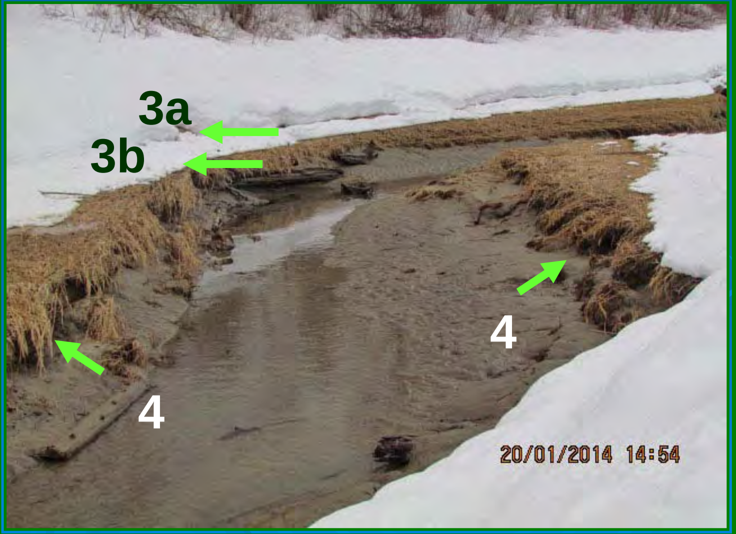

14
14. Side channel, hydrology, erosion, riparian loss.
Image © 2014 Montana Creek Properties Corporation
Google earth



2. A sluff scarp, a rapid bank failure resulting in a portion of sloped sand bank sliding into stream channel. The processes is accelerated by "Tidal" like hydrological regime. The sand material is rapidly carried downstream and out of channel. **This is a permanent fine sediment loss.**

3a & 3b are two "peak level or snow line" markings representing two different peak dam discharge events. 3a is an earlier event, snow pack above is deeper. 3b a more recent event, snow pack above "wetted line" (top of snow free area) is shallower.

4. undercut and "clumpy" collapse of bank vegetation is an indicator rapid rise & fall of water levels as saturated bank materials flow and fail into the channel as water level drops.



Peaking Plant Operations are "Tidal" like

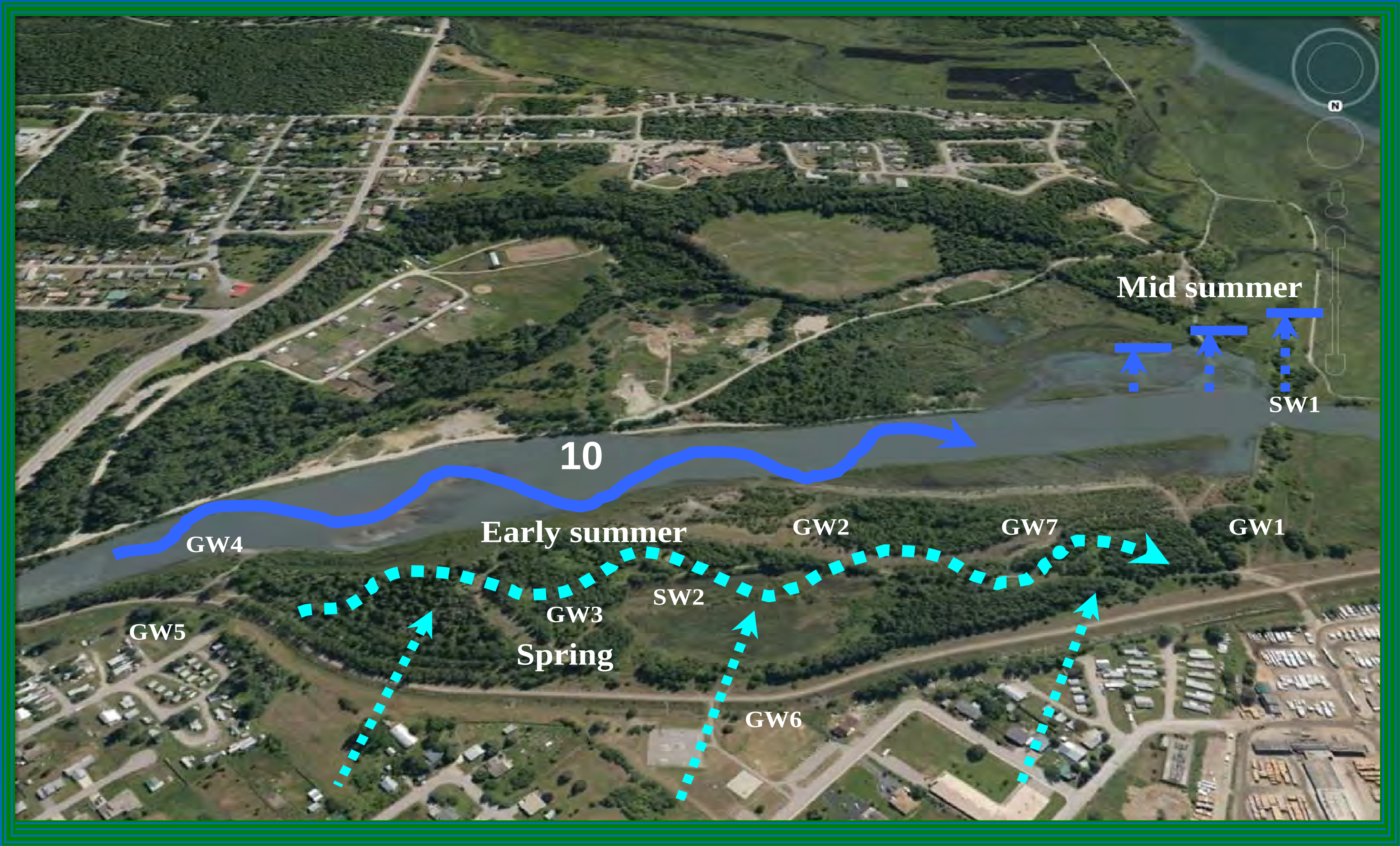
One or more times daily water surges up this channel then rushes out as dam discharge increase then decline with peaking.

1. An erosion flow channel created by water draining from bank materials. As water level goes up in the channel bank materials are "surcharged". As water level goes down the water drains from the bank and carries fine sediment into the channel then into the river. **Fine sediment loss here is permanent.**

In the absence of peaking plant operations the area outside of the wetted stream channel would be snow covered during the entire winter season and not subject to "tidal" and or freeze/thaw erosion processes

An interesting diversion

- Local ground water systems
- Coarse materials underground are very permeable, leaky.
- Draining and flooding risks high.
- Illecillewaet Water Study 1996-98

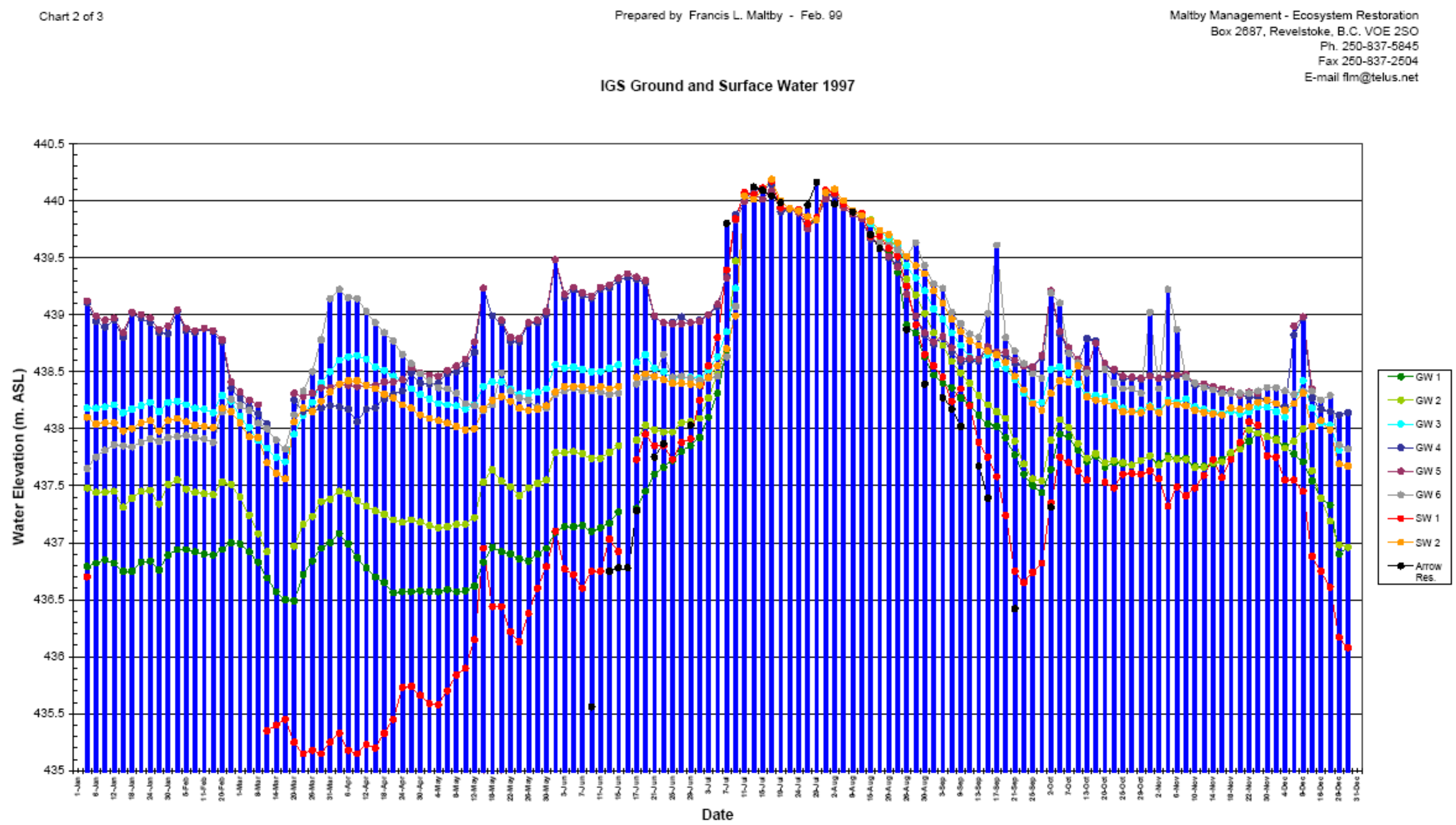


Illecillewaet Greenbelt Nature Park – Water Study 1996 - 1998

Spring – upslope drainage

Early summer – river fluctuations, NOTE: effects inland / permeability

Mid summer – Arrow reservoir levels



Illecillewaet Greenbelt Nature Park – Water Study

Annual Surface and Ground water hydrograph for 1997


11a
11
Image © 2014 Montana Creek Properties Corporation
Google earth
Physical Works Project:
1. Side-channel filled with rock to prevent channel erosion and wetland draining.
2. Main-channel incision may be dominant process and risk

Northwest Airport Marsh outlet channel (seasonal flow)
April 28, 2008

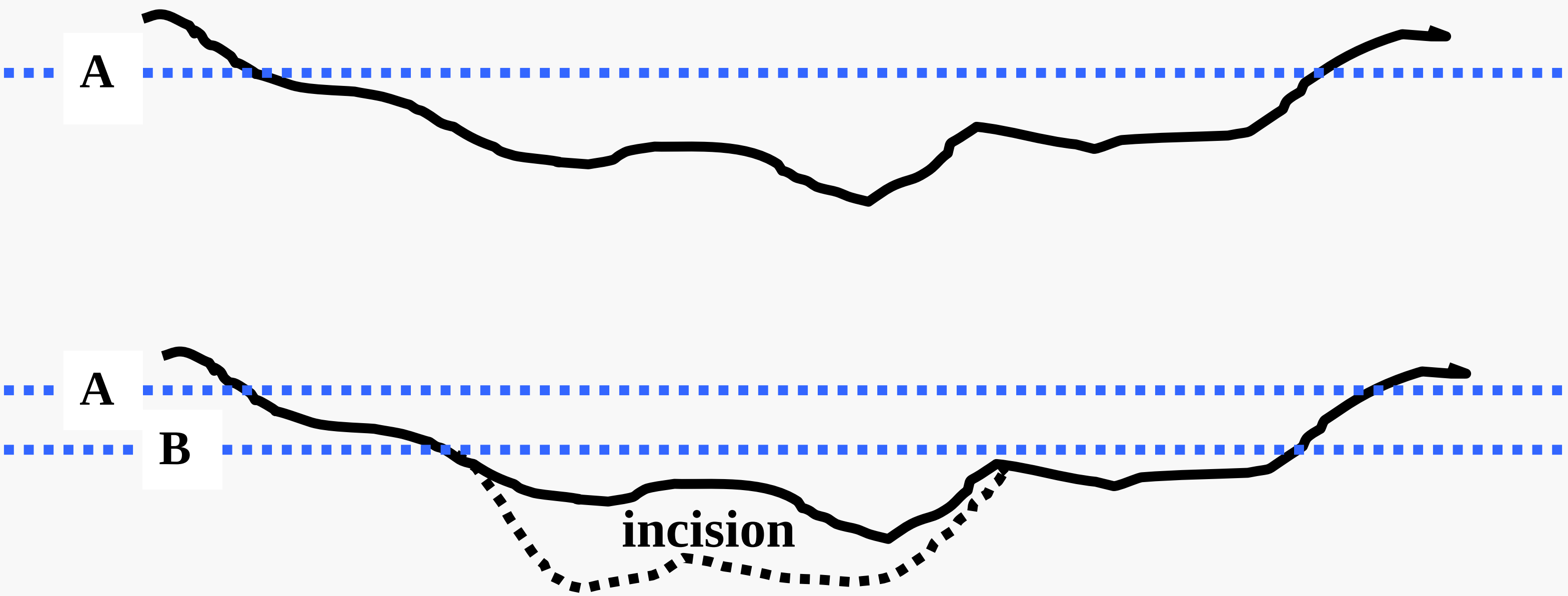
Arrow res. 431.05m @ Nakusp

Rev. avr.day.dis. 16.9 kcfs

(kcfs =1000 cubic ft / sec)

11 - North-West Airport Wetlands
Incision in Straight Channel

Simplified



River & ground water levels drop as incision process takes place.
At this location evidence* suggests incision is occurring.

* Tributary channel incision and tributary mouth's position above river water level, dewatering of northwest airport wetlands.

Lower Locke Creek

- Sedge flats, flood tolerant to a point, annual flood duration limits apparent.
- This species of sedge occurs in a relatively narrow elevational band (~ 1.5 - 2m) within the Arrow Reservoir. I have not found it abundant above or below that band.
- Sedge is a very valuable food resource for migratory and resident waterfowl, including support of rearing young.
- **Sedge losses likely occurring due to: prolonged inundation, unnatural exposure to freezing temperatures, overland and bank erosion processes**
- **All of these unnatural factors are caused by peaking plant operations.**

Note: Veg. free area.

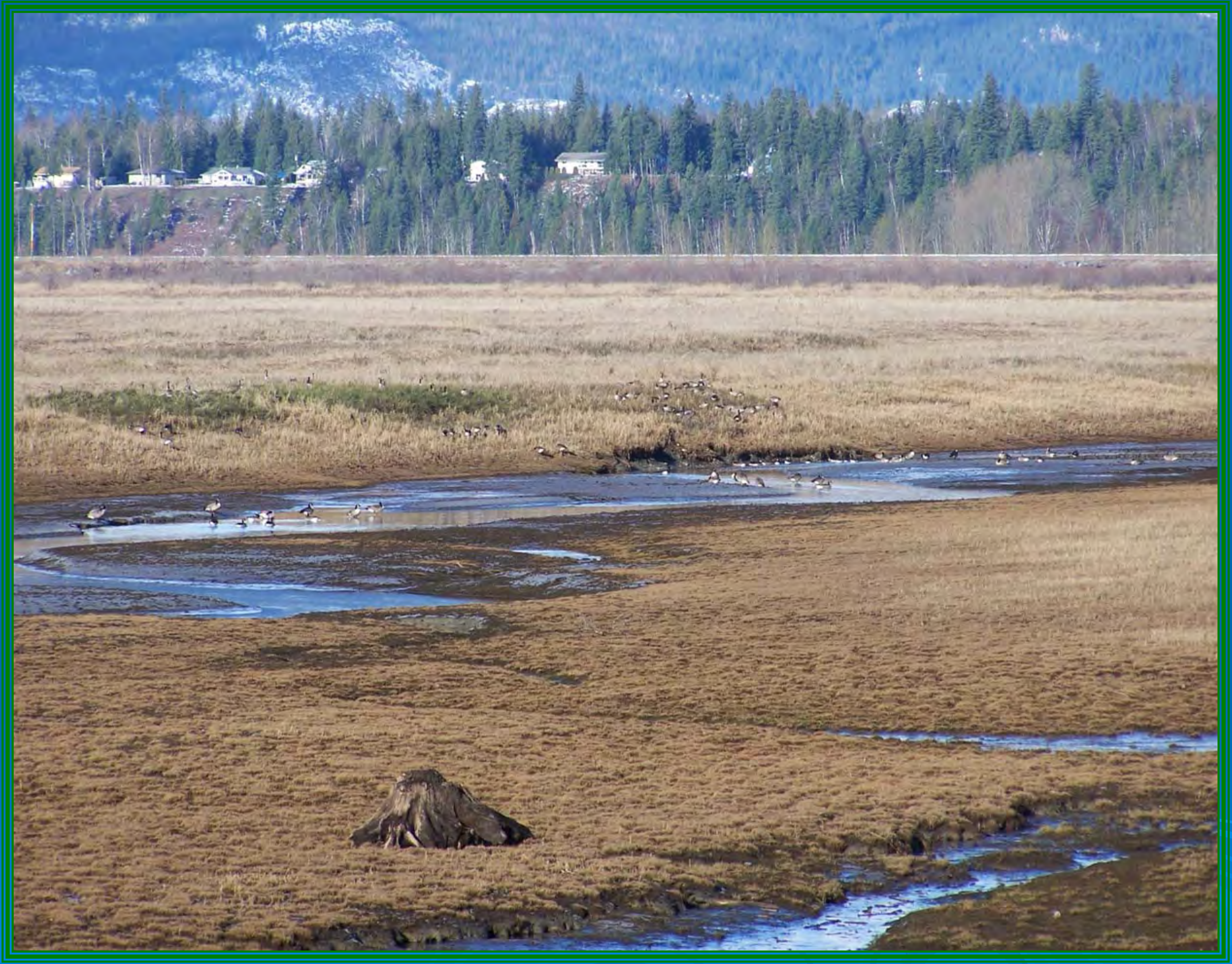
While Sedge is flood tolerant, permanently saturated soil does not support sedge growth.
Extending saturation (or flooding) period may reduce sedge cover.

Aug. 13, 2013

Aug. 13, 2013

Upper Locke Creek

Sedge flats are a very valuable food resource and heavily utilized. Sedge flats here and elsewhere supports both resident nesting and migratory birds.



Locke Creek, fall 2009 – 100 + Canada Geese feeding on scouring rush.

ERDC/CRREL LR-04-16

Cold Regions Research and Engineering Laboratory

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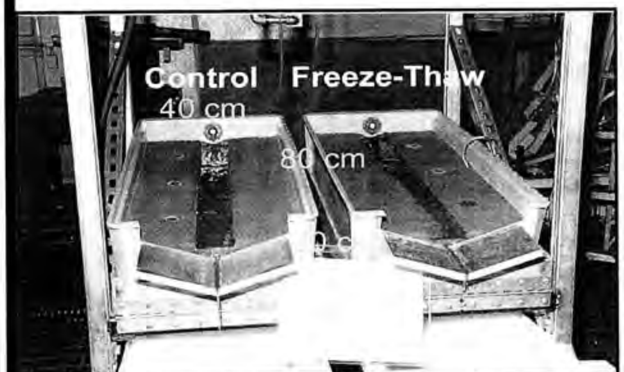
Engineer Research and Development Center

Quantifying the Effect of a Freeze–Thaw Cycle on Soil Erosion

Laboratory Experiments

M.G. Ferrick and L.W. Gatto

July 2004



Relatively well understood physical process.

US Army Corps of Engineers®
Cold Regions Research & Engineering Laboratory

Cold Regions Engineering

U.S. Army Engineer Research and Development Center, Hanover, New Hampshire

Inclusion of Freeze–Thaw-Induced Soil and Bank Erosion in CoE Planning, Engineering, O&M, and Model Development

Soil freeze–thaw (FT) processes directly affect soil erodibility and bank-failure susceptibility (Fig. 1) (Gatto et al. 2001, Simon et al. 2000) and thus have substantial impact on shoreline or bank evolution, system-wide sediment management, reservoir infilling, levee stability, and sediment-bound contaminant transport within watersheds. This technical note outlines how FT cycling affects overland soil erosion and bank failure. In so doing, it alerts Corps planners, designers, O&M personnel, and water-resources modelers to the importance of knowing the magnitude of these effects on sediment detachment, failure, and transport in such cold-climate, navigable systems as the Mississippi, Illinois, Ohio, Missouri, Susquehanna, Delaware, Columbia, and Sacramento Rivers, and the Great Lakes and their connecting channels.

Freeze–thaw processes

During freezing, ice crystals form within a soil, tightly binding soil particles and keeping the soil highly resistant to erosion and failure. However, that ice also pushes soil particles apart, reducing interparticle friction so that thawed soils are less cohesive, dense, and strong (Gatto 2000). One FT cycle can reduce soil shear strength by 50% or more (Formanek et al. 1984, Van Klaveren 1987).

Also, the soil-surface geometry of thawed soil is often changed by frost heaving during freezing, unit weight is often increased by the soil water drawn into the freezing soil, and infiltration is reduced because water content is usually high. The magnitude of these effects is variable and depends on soil type, water content, and freezing intensity.

Figure 1. Banks are highly susceptible to failure upon thaw.

Soil FT cycles are generally inferred from surface air temperature records. According to Hershfield (1974), a FT event

This is a "signature" indicator of peaking plant operations and vegetation impacts, at the waters edge

McCool 1990) and 30 to 90% of bank failures (Thorne 1978, Sterrett 1980, Gardiner 1983, Reid 1985, Lawler 1993, Chase et al. 2001). When rills (Fig. 3) are present on hillslopes they transport 80% of the sediment eroded from that slope (Mutchler and Young 1975). Thus, rill flows are far more important in hillslope erosion than overland sheet flow.

Lesson 3: **Mechanical Weathering by Water/Ice and Erosion**

Learners:

- **<u>This lesson will be taught to 3 grade seven classes</u>**, each having approximately 28 students
- Among students, there are 2 ESL students who will need support in understanding some of the vocabulary associated with the lesson.
- This lesson is a cooperative learning activity. Students will be organized in groups of 4, and desks will be arranged to accommodate group seating

S.L.O(s):

7-4-04 Investigate and describe the processes of weathering and erosion, and recognize that they cause changes in the landscape over time

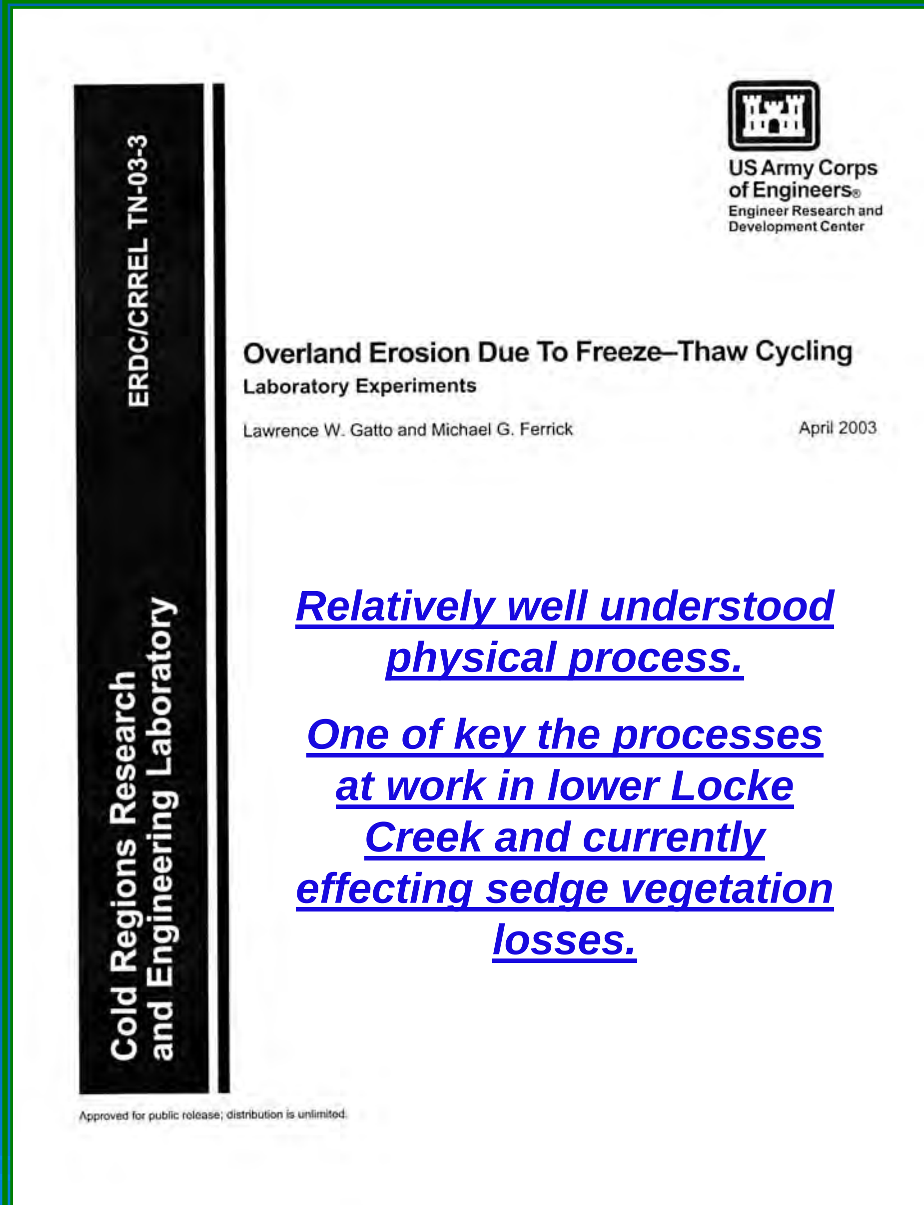
G.L.O(s):

D3- Understand the properties and structures of matter as well as various common manifestations and applications of the actions and interactions of matter

D5-Understand the composition of the Earth's lithosphere as well as the processes involved within and among them

E3- Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved

Instructor: Anise Chanel



ERDC/CRREL TN-03-3

Cold Regions Research and Engineering Laboratory

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Engineer Research and Development Center

Overland Erosion Due To Freeze–Thaw Cycling

Laboratory Experiments

Lawrence W. Gatto and Michael G. Ferrick

April 2003

Approved for public release; distribution is unlimited.

<u>Relatively well understood physical process.</u>

<u>One of key the processes at work in lower Locke Creek and currently effecting sedge vegetation losses.</u>

Nov. 28, 2013

Nov. 28, 2013

Sedge habitat veg. loss:

1. **Freeze/thaw overland erosion.**
2. **Freeze/thaw bank erosion.**
3. **Sedge/plant exposure to freezing weather when natural conditions would have vegetation snow covered through most of the winter season.**

Locke Creek Feb. 11, 2013

Arrow res. @ Nakusp: 428.04

Rev. Discharge: 25.8 kcfs *average daily*

Locke Creek Nov. 28, 2013

Arrow res. @ Nakusp: 431.02m

Rev. Discharge: 22.5 kcfs *avrerage daily*

Data and water levels in these images DO NOT compute??

***Average daily discharge* does not provide sufficient information.**

Instantaneous Rev. discharge data is required to properly "calibrate" on site impacts, site by site.

Note: Veg. free area - 2013.

While Sedge is flood tolerant, permanently saturated soil does not support sedge growth. **Extending flood period may reduce sedge cover.**

Nov. 28, 2013

Feb. 13, 2008 **??**

Locke Creek outlet

Arrow res. @ Nakusp:

13/02/08 – 432.07m 28/11/13 – 431.02m

Revelstoke Plant Discharge:

13/02/08 - 18.3 kcfs 28/11/13 - 22.5 kcfs

Newly deposited sediment, below, is as a result of a peaking plant "surges", that have scoured out of the channel and "blown" sediment upstream approximately 100m.

Above snow line is accumulation between

Nov. 16 – 28, 2013. Area below snow-line is snow free due to peaking plant operations and is exposed to freezing temperatures.

Nov. 28, 2013

Apr. 28, 2008

Locke Creek outlet

Between 2008 and 2013 (5 years) change has occurred here. The important point is that up to 2008 sedge density has persisted and relative channel stability has been maintained for 30 years with 4 units operating at Rev. Dam

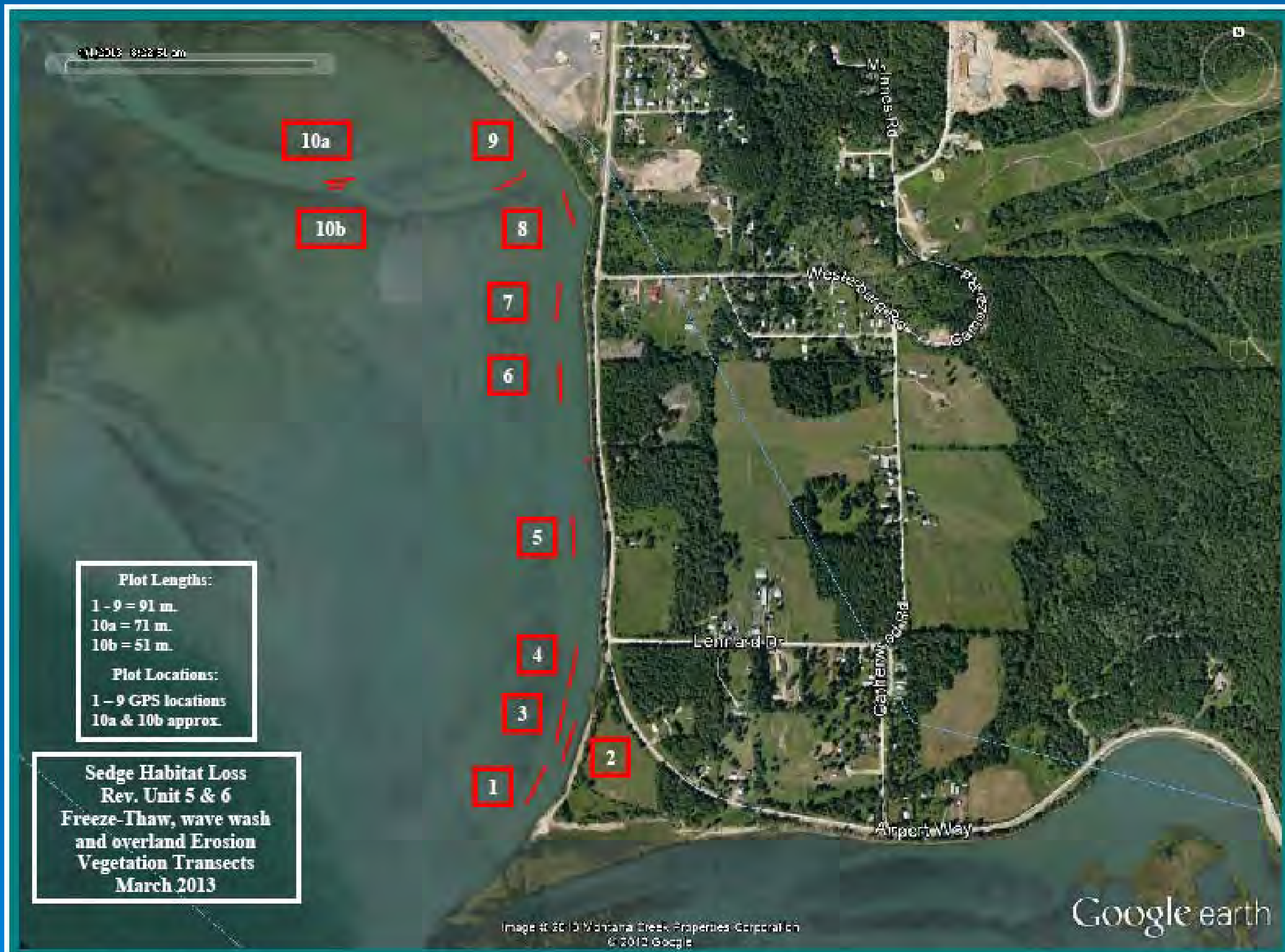
The sedge loss here is the direct result of Rev 5 peaking operations. Rev 6 peaking will increase erosion impacts and likely veg. losses.

Nov. 28, 2013

Nov. 28, 2013

Upper Locke Creek

1. **Freeze/thaw overland & bank erosion**
2. **Sedge *"Pedestaling"*: overland erosion removes soils from around plant's base & expose roots to freezing temperatures & desiccation/drying.**


10a
9
10b
8
7
6
5
4
3
2
1
Plot Lengths:
1 - 9 = 91 m.
10a = 71 m.
10b = 51 m.
Plot Locations:
1 – 9 GPS locations
10a & 10b approx.
Sedge Habitat Loss
Rev. Unit 5 & 6
Freeze-Thaw, wave wash
and overland Erosion
Vegetation Transects
March 2013
Westerburg Rd
Lennard Dr
Airport Way
Google earth
© 2012 Google

DRAFT - Vegetation Transects Setup and photo procedures
31/03/13

Procedures:

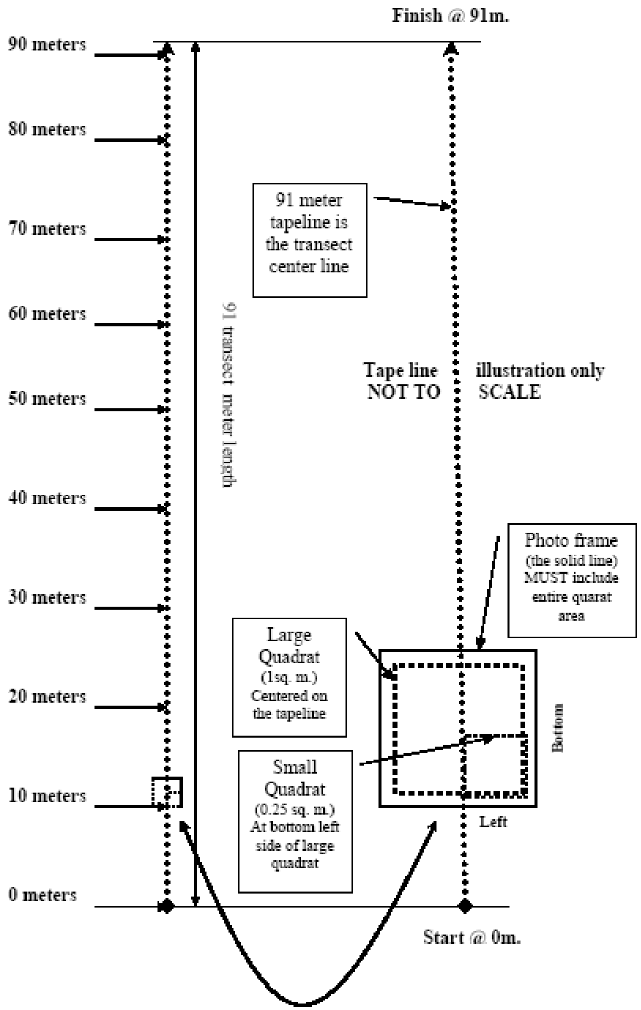
1. The 91 meter tapeline forms the center axis of the transect. The tape must be pulled tight and perfectly straight between the two end posts of the transect. It may be necessary to stake or somehow hold the tape line in place in heavy wind.
2. Photos start at "0" meter, "0"m. photo includes the data sheet. Ensure all info required is on the data sheet.
3. Photos are taken at every ten meter increment i.e. 0-1m, 10-11m, 20-21m, 30-31m, etc. *__Preferably from the "bottom". See Tape line illustration.__*
4. Place 1 sq.m. quadrat centered on the tapeline and starting at the a 10 meter increment i.e. at 0-1m, 10-11m, 20-21m, ... 90-91
5. Place 0.25 quad in the lower left corner of the 1 sq.m. quadrat as close to perpendicular as possible a photo of the large quad __"tight!"__.
6. Take photo as close as possible to directly above the qaudrats.
7. Check and if required re-ribbon/re-paint the end posts so the can be found for next session.
8. Photos of the entire transect line should be taken from both the start and end post positions after the tape line is in place.

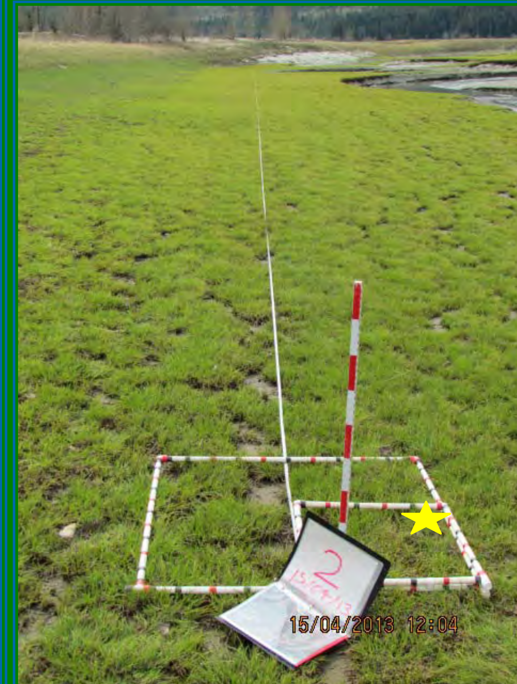
Photo must include all four sides of the quadrats.

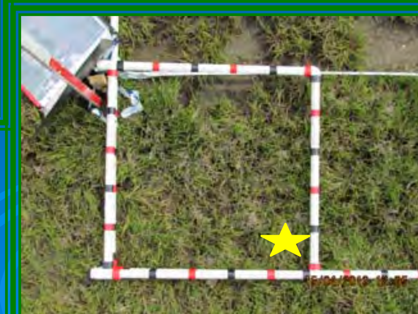
__BE VARY CAREFUL__

__Not to cast shadows on quadrat and photo area!!__

__Do not change sides (of tape line) once photo sequence has started.__







Thank you

Very much!