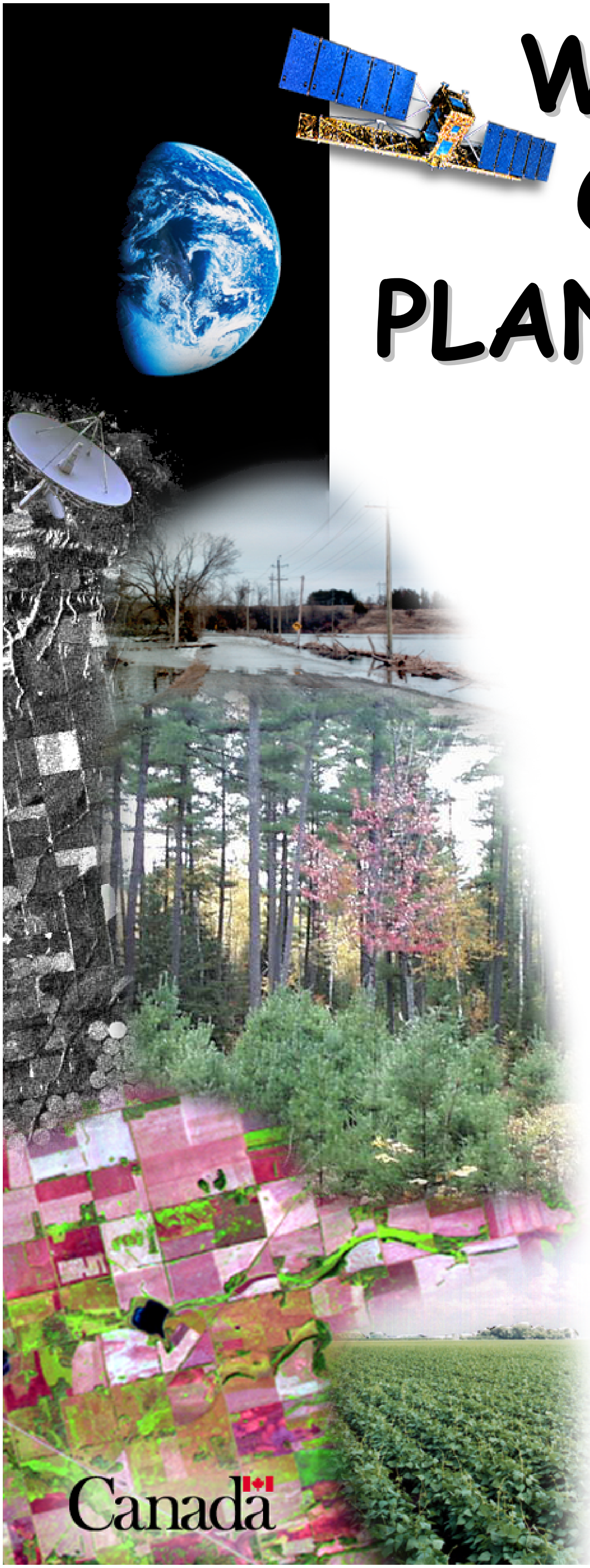

WATCHING OVER OUR PLANET FROM SPACE

Hands-on activities for young people on monitoring the Earth's environment using remote sensing

from the

Canada Centre for Remote Sensing

version 1.1.0

Natural Resources Canada
Ressources naturelles Canada

Watching Over Our Planet From Space

is

a series of hands-on activities for young people
(but quite suitable for not-so-young people)
on the topic of monitoring the Earth's environment from
space using satellite images

from the

Canada Centre for Remote Sensing
Natural Resources Canada

Version 1.1.0
February 2000

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A free digital version is available for download in the
Education chapter of the CCRS website at:
www.ccrs.nrcan.gc.ca

WATCHING OVER OUR PLANET FROM SPACE

An Earth Observation education kit for elementary schools from the **Canada Centre for Remote Sensing, Natural Resources Canada** Version: 1.1.0

This education kit introduces the subject of **Remote Sensing,** also known as **Earth Observation,** to children aged 11-15. It is based on a series of short activities dealing with the interpretation of satellite images for application to environmental monitoring and the management of natural resources in Canada.

Table of Contents

1.1 About this Tutorial

Educational Objectives

After completing several of the activities in this tutorial, the student:

- will be familiar with the basic concepts of "remote sensing" technology;
- will be able to recognize/interpret some features in satellite images;
- will be able to describe how remote sensing contributes to monitoring the environment.

Content

The material in this tutorial makes use of Canadian examples of environmental monitoring.

Presentation of the Material to Students

Sections 2.1, 2.2 and 2.3 should be carefully examined by the students. Sections 4.1, 4.2, 4.3 are intended as additional reading; Appendices A, B, and C, may be useful resources while working on the activities. The answers are found in Appendix D. The activities in Section 3 are presented in a recommended order.

Level of Difficulty

These activities and exercises are intended for children aged 11 and up. Some of the activities will be more suitable for older children. Length of time required for each activity varies between 5 and 30 minutes.

Format

It is anticipated that this tutorial will be used in a classroom setting. The activities can be completed by students working either individually or in small groups. While the current version of this tutorial is intended for use as a printed copy, an electronic / interactive version is in development. Watch the CCRS Web site (www.ccrs.nrcan.gc.ca) for news about such a module, as well as additional tutorials.

Considerations Regarding Printing

The tutorial pages should be printed on a colour printer. Please use the best quality colour printer and paper that is available and check the results to ensure that features referred to in the exercises are indeed visible in the printed version.

Prerequisite Knowledge

The student should be familiar with:

- Cartesian co-ordinates (x, y) for referencing locations of features in the imagery;
- the cardinal points of the compass;
- map reading.
- See Appendices for descriptions of Cartesian co-ordinates, points of a compass and the dot grid technique for measuring area.

Acknowledgements

We would like to thank the following people and organizations for their contributions to this education kit:

- MAS staff: Tom Alföldi, Berthe Boucher, Julie Chartrand, Heather Dickinson, Fran Pearl, Rhonda Sabino, Joanne Straby, Andrew Trebble, Marguerite Trindade
- Lingua / Services Momentum for French translation
- Other CCRS contributors: Joanne Ellis, Caroline Forest, Robert Landry, Josée Levesque, Mike Manore, Heather McNairn, Christian Prévost

Details of Activities

Description of Activity	Skills Development	Time Required	Level of Difficulty	Extra Materials Used
3.1 **Which is Which?** … Becoming familiar with the appearance of features (colour, shape, size, texture, etc.) in satellite imagery	Matching images with a description of features	10 - 15 min	Introductory	None
3.2 **Find it!** …Becoming familiar with the use of cartesian coordinates and the appearance of features in satellite imagery	Finding and determining the location of features on an image	15 – 20 min	Introductory	None
3.3 (a & b) **Measure This** … Recognizing features and measuring distances	Measuring distances, feature recognition, determining direction	25 - 30 min	Introductory	String
3.4 **Clearcutting in the Forest** …Monitoring a logging operation	Aligning an image and a map; measuring area	25 – 30 min	Challenging	Acetate and markers
3.5 **Oil Spill Danger** … Measuring and monitoring the motion of an oil slick	Measuring area, distance, speed and direction of movement (predicting change over time)	25 – 30 min	Challenging	Acetate and markers
3.6 **Crop Types** …Identifying crop types, other rural features and assessing flood damage.	Using an interpretation key to match features; position analysis	15 - 20 min	Moderate	None
3.7 **Forest Fire** …Becoming familiar with the strategies of fighting forest fires	Measuring distances; identifying routes; feature recognition	10 – 15 min	Moderate	Acetate, markers and string
3.8 **Navigating a Ship Through Ice** …Using a satellite image to navigate a ship through ice	Determine the best route and measure its distance	10 – 15 min	Moderate	String
3.9 **You Figure it Out** … Interpreting an image with coastal features	Multiple choice questions using image reading skills and contextual logic	20 – 25 min	Challenging	None
3.10 **Urban Land Use** … Identifying urban land use and colouring a land use map	Recognizing urban features in a satellite image from written descriptions	15 - 20 min	Moderate	Markers, or coloured pencils, or crayons
3.11 **At a Mine Site** …Observing the activity at a mine site using remote sensing imagery	Finding similar features on an image	20 - 30 min	Moderate	None
3.12 **A Different Perspective** … Matching oblique aerial photographs to corresponding satellite images	Comparing low-altitude oblique views to high-altitude vertical views	10 –15 min	Challenging	None

2.1 What is Remote Sensing?

“Remote” means far away. Remote sensing means sensing things from a distance. Of **our** five senses **we** use three as remote sensors when we:

a. watch a football game from the stands (sense of sight)

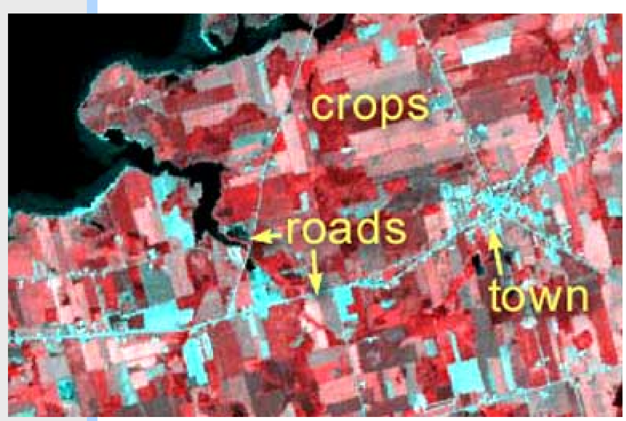
b. smell freshly baked bread in the oven (sense of smell)

c. hear a telephone ring (sense of hearing)

What are our other two senses and why aren’t they used “remotely”?

In the world of science, “remote sensing” means observing the Earth with sensors from high above its surface. They are like cameras except that they use not only visible light but also other bands of the electromagnetic spectrum such as infrared, radar and ultraviolet. Because they are so high up, these sensors can make images of a very large area, sometimes a whole province.

Today, remote sensing, also known as Earth Observation, is often done from space using satellites. Many countries including Canada have them. Hundreds of images are sent every day from the satellites to receiving stations on Earth. The Earth’s entire surface is imaged every week or so. Can you imagine how these images could be used?



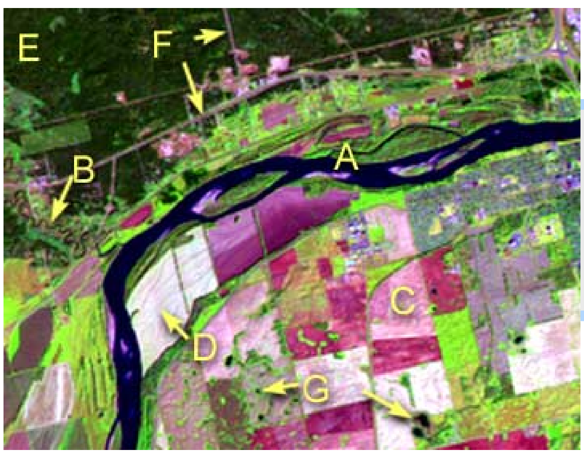
Remote Sensing Satellites

2.2 What Can You See on a Satellite Image?

You see the things that would be seen by eye or a camera if they were looking down from space. Because we can't see in parts of the spectrum like the infrared, ultraviolet or microwave, we have to use colours that we can see, to represent this kind of information. That's why many remote sensing images have strange colours.

In this view of downtown Vancouver, British Columbia, you can see:

A. Tall buildings and their shadows
B. Bridges **C**. Residential street patterns
D. A large stadium **E**. Marinas for small boats **F**. A ship and its wake

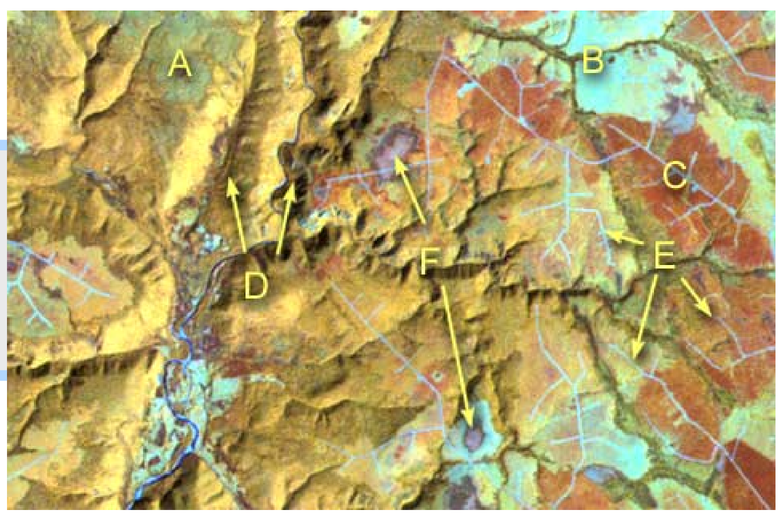


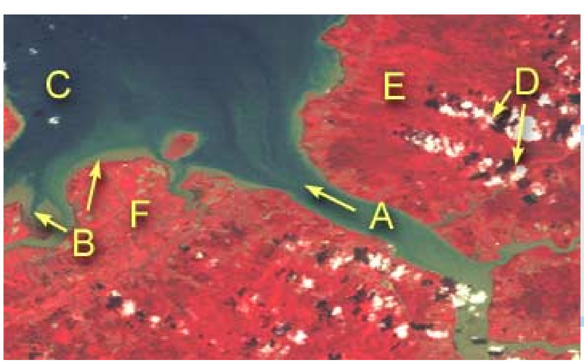
Near Prince Albert, Saskatchewan, you can see:

A. A large river **B**. A small, meandering river **C**. Farm fields with crops **D**. Farms fields showing bare ground **E**. Forest **F**. Roads **G**. Small ponds

In the Cape Breton Highlands of Nova Scotia, you can see:

A. Standing forest **B**. Recent forest clearcut **C**. Older forest clearcut **D**. Deep river valley **E**. Logging roads **F**. Swamp





In the Minas Basin of Nova Scotia, you can see:

A. A river carrying sediment into the Basin **B**. Shallow water areas **C**. Deep water areas **D**. Clouds and their shadows **E**. Forests

2.3 Who Uses Remote Sensing and Why?

. . . the geographer, who looks for changes on the Earth's surface that need to be mapped;

. . . the forester, who needs information about what type of trees are growing and if they have been affected by disease, fire or pollution;

. . . the environmentalist, who wants to detect, identify and follow the movement of pollutants such as oil slicks on the ocean;

. . . the geologist, who is interested in finding valuable minerals;

. . . the farmer, who wants to keep an eye on how his crops are growing and if they've been affected by drought, floods, disease or pests;

. . . the ship captain, who needs to find the best route through the northern ice packs;

. . . the firefighter, who sends out his crews based on information about the size and movement of a forest fire.

--- And there are many more ways to use remote sensing. ---

3.1 Which is Which?

Instructions: On the next pages you will find twelve satellite image segments. Can you find which image contains the feature(s) described below? Enter the correct image number in the box beside each "Feature Description". Be careful! Some images are used more than once!

Feature Description

☐ a) **Two race tracks,** a smaller one inside a larger one. Some roads and two golf courses are also visible in the image.

☐ b) **An airport** at the edge of a city. You can also see a smaller river joining a larger river in the image.

☐ c) The effect of **a cyclone** on the surface of ocean waters.

☐ d) A smooth coastline showing a coastal **town and its breakwater** which creates a safe harbour for boats.

☐ e) **5 bridges** across a river. Three of the bridges also pass over islands in the river.

☐ f) There are many **clouds** (and their shadows) over land and water in this image.

☐ g) A coastal area showing **ice flows** in the largest of the inlets. The land area is studded with lakes and there are many islands offshore.

☐ h) **A hook-shaped peninsula** ending in a point.

☐ i) A rugged coastline showing many **sharp coves and inlets**.

☐ j) This scene shows **farmland** near the mouths of 2 rivers. You can also see several roads meeting at a village.

☐ k) In this view you see many **lakes** in a rugged and rocky forest area. A large swampy section shows no lakes at all.

☐ l) A forested region showing clear-cut areas as well as the **logging roads** that were built to access this site.

☐ m) A mouth of a river showing **the sediment** that is carried by the river into the sea.

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2

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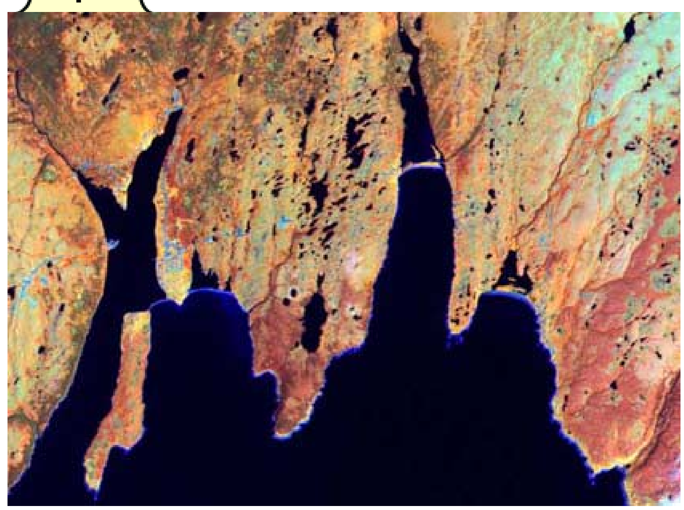

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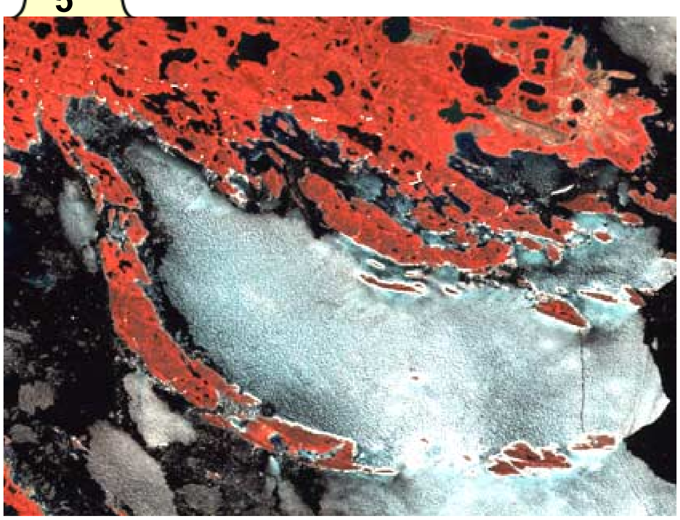

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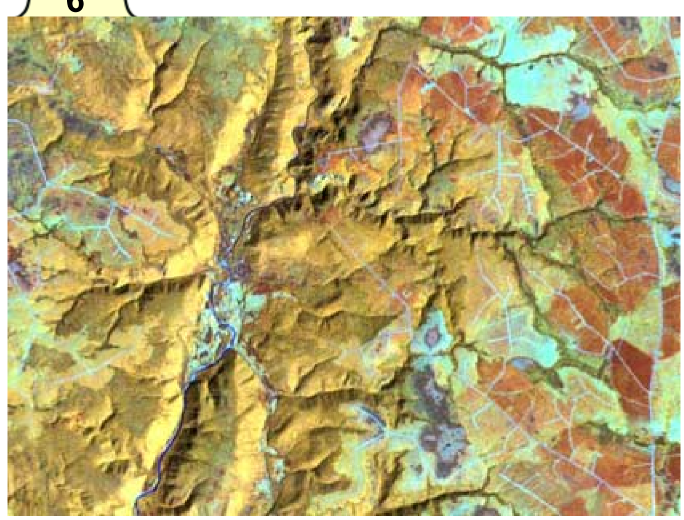

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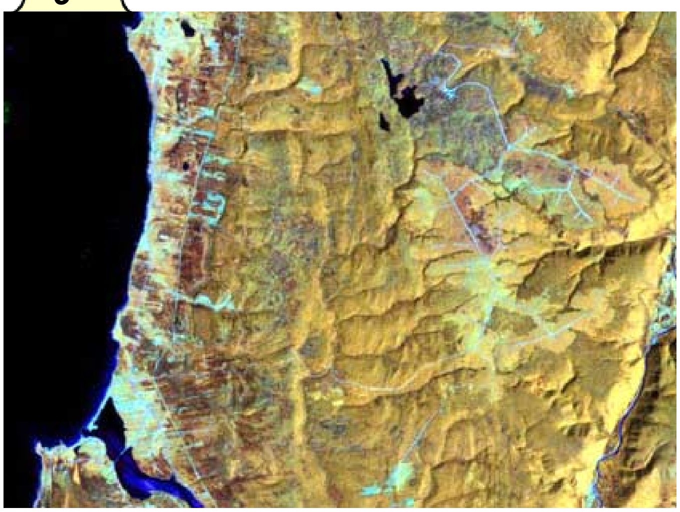

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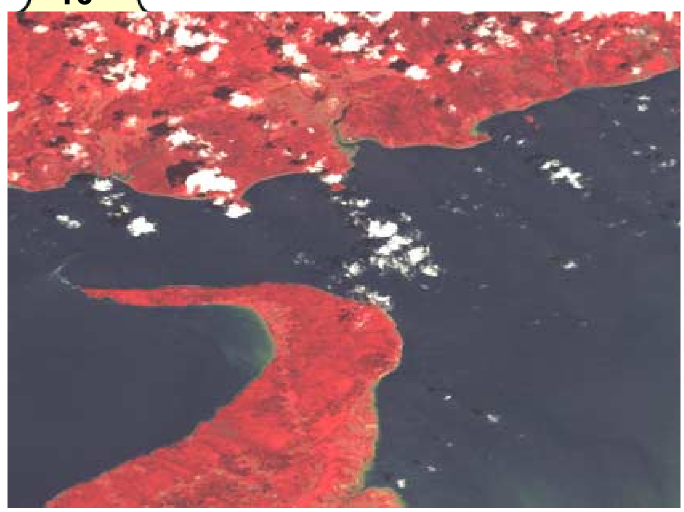

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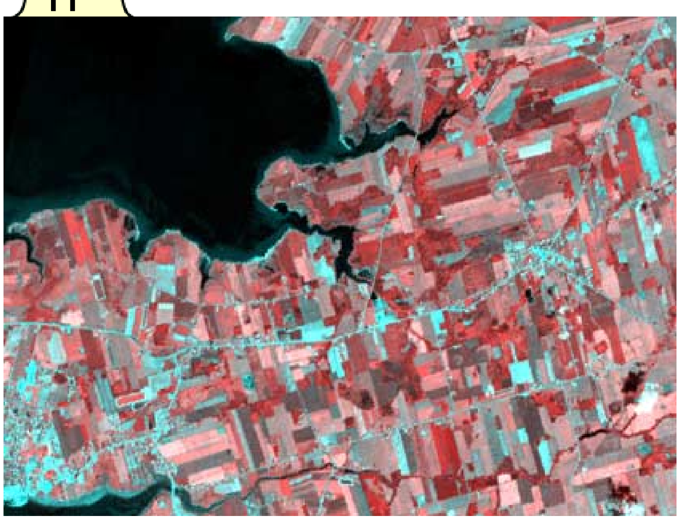

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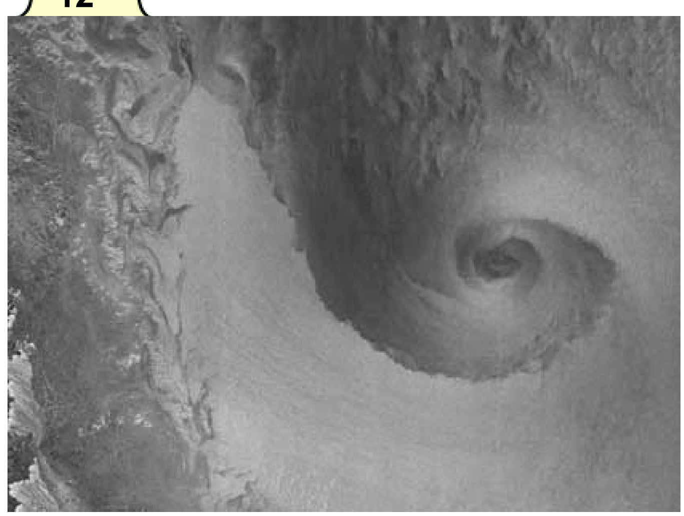


3.2 Find it !

Instructions:

In this Landsat satellite image of northern Saskatchewan, we see farm fields (pink and white and light green rectangles), forests (dark green), the town of Prince Albert (blue/purple), and the North Saskatchewan River (dark blue). The colours are strange because we are using information from parts of the spectrum that we don't normally see (like the infrared) and are showing them as colours that we do see. Lets find some more features in this image! Use the number coordinates on the edge of the image.

Find it ! - question 1:

The town of Prince Albert is located at:

A: (5.5, 8.0) C: (7.7, 6.1)

B: (5.6, 3.2) D: (9.8, 11.4)

Find it ! - question 2:

The field located at: (3.2, 2.6) is the same colour (and therefore is of the same material) as the field at:

A: (5.2, 2.6) C: (5.3, 1.1)

B: (4.7, 3.7)

Find it ! - question 3:

There is a long, meandering river which flows into the image at location: 0.0, 1.2. It is too narrow to see the water, but you can see the vegetation on the riverbanks. It joins (flows into) the North Saskatchewan River at:

A: (6.9, 6.1) C: (8.2, 5.3)

B: (4.8, 6.7)

Find it ! - question 4:

There is a lake in the middle of the forest at:

A: (8.2, 4.2) C: (2.2, 2.5)

B: (9.3, 9.8)

Find it ! - question 5:

The field at (5.4, 3.2) has several green dots in it. These are "sloughs" or small ponds surrounded by grasses and weeds. The water is too small to see in most cases but the vegetation shows as green. Another location of sloughs is at:

A: (1.9, 5.3) C: (1.7, 8.5)

B: (5.0, 7.0) D: (5.7, 8.0)

Find it! - question 6:

In the North Saskatchewan River are many islands. Some are without vegetation (pink/white) and some have grasses and shrubs (light green). One of these vegetated islands is at:

A: (4.4, 8.6) C: (7.5, 7.5)

B: (5.5, 6.4) D: (0.8, 7.7)

Find it ! - question 7:

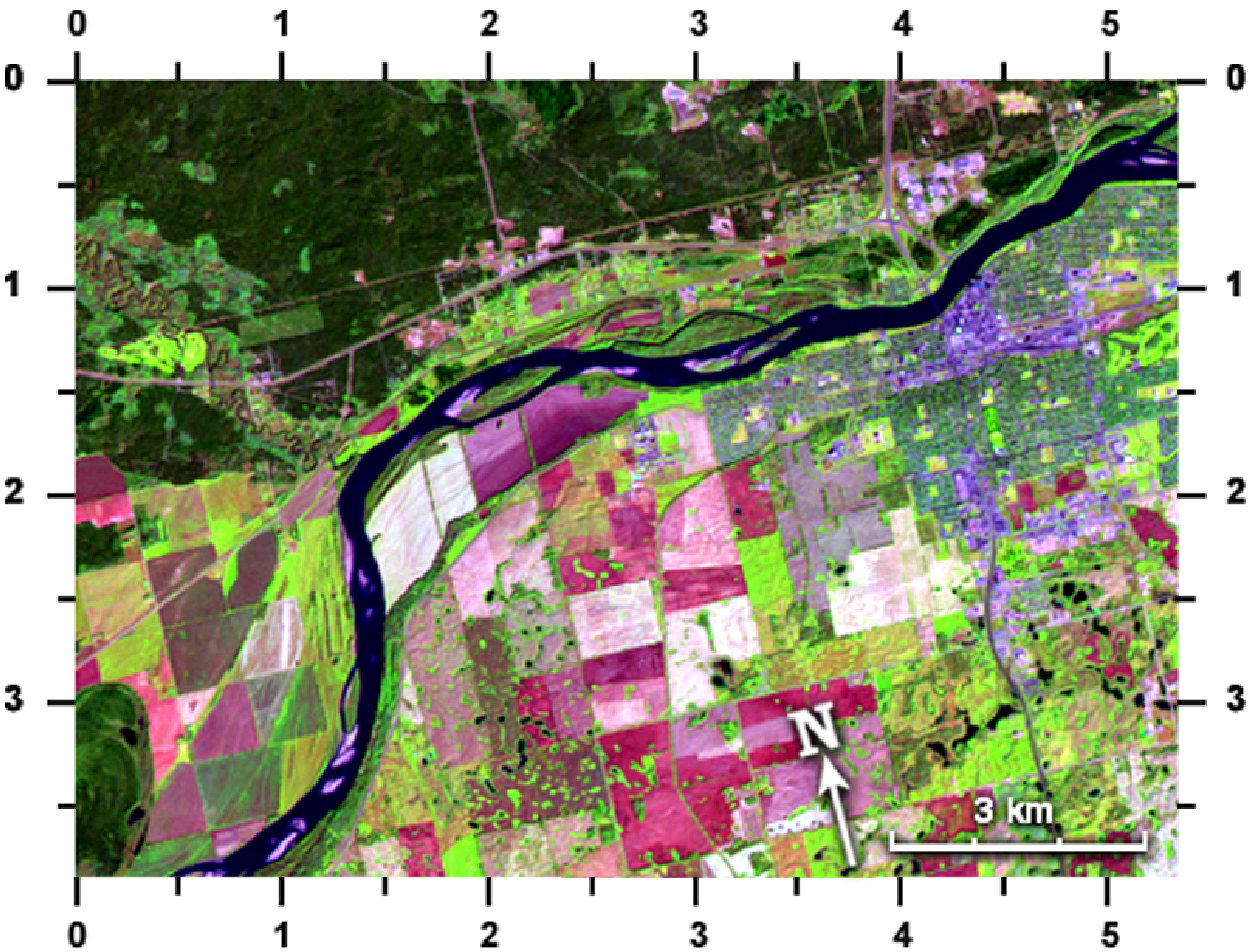
Which road runs north-south? It is the one at:

A: (1.6, 6.4) C: (2.0, 2.4)

B: (4.0, 7.3) D: (5.3, 5.0)

3.3a Measure This (Northern Saskatchewan)

Instructions: Inserted in the Landsat satellite image of northern Saskatchewan, is a scale bar (3km) and a North arrow (bottom right of the image). These will help you to answer some of the following questions.



Saskatchewan - question 1:

Which road is oriented north-south? The one at:

A: (1.6, 1.2)
D: (2.0, 0.5)
B: (3.1, 0.6)
E: (1.1, 0.6)
C: (1.4, 3.0)

Saskatchewan - question 2:

Directly west of (1.6, 3.2) is a small island in the river which is:

A: light pink in colour (no vegetation)
B: green in colour (covered with vegetation)
C: has equal amounts of pink and green

Saskatchewan - question 3:

Find the town of Prince Albert (blue/purple) on the south shore of the big river (North Saskatchewan River). Look carfully for the bridge that crosses the river near the town. This bridge is:

A: almost 3 km long

B: more than 1 km long

C: much less than 1 km long

D: I can’t tell how long without taking a trip there.

Saskatchewan - question 4:

If I wanted to take a boat trip along the North Saskatchewan River from where it enters the satellite image to where it exits the image, my trip length would be (a piece of string or a shoelace would help you in this task):

A: 17 km

B: 28 km

C: 14 km

D: 11.4467 km

Saskatchewan - question 5:

The very light pink/white field at: (2.6, 2.6) has an area of about:

A: between 2 and 3 square kilometres

B: a bit less than 1 square km

C: more than 4 square kilometres

Saskatchewan - question 6:

The yellow-green feature at (0.4, 1.3) is a golf course. If you lived in the town of Prince Albert, at (4.4, 1.1) and wanted to drive to this golf course, the distance would be about:

A: 12 km

B: 22 km

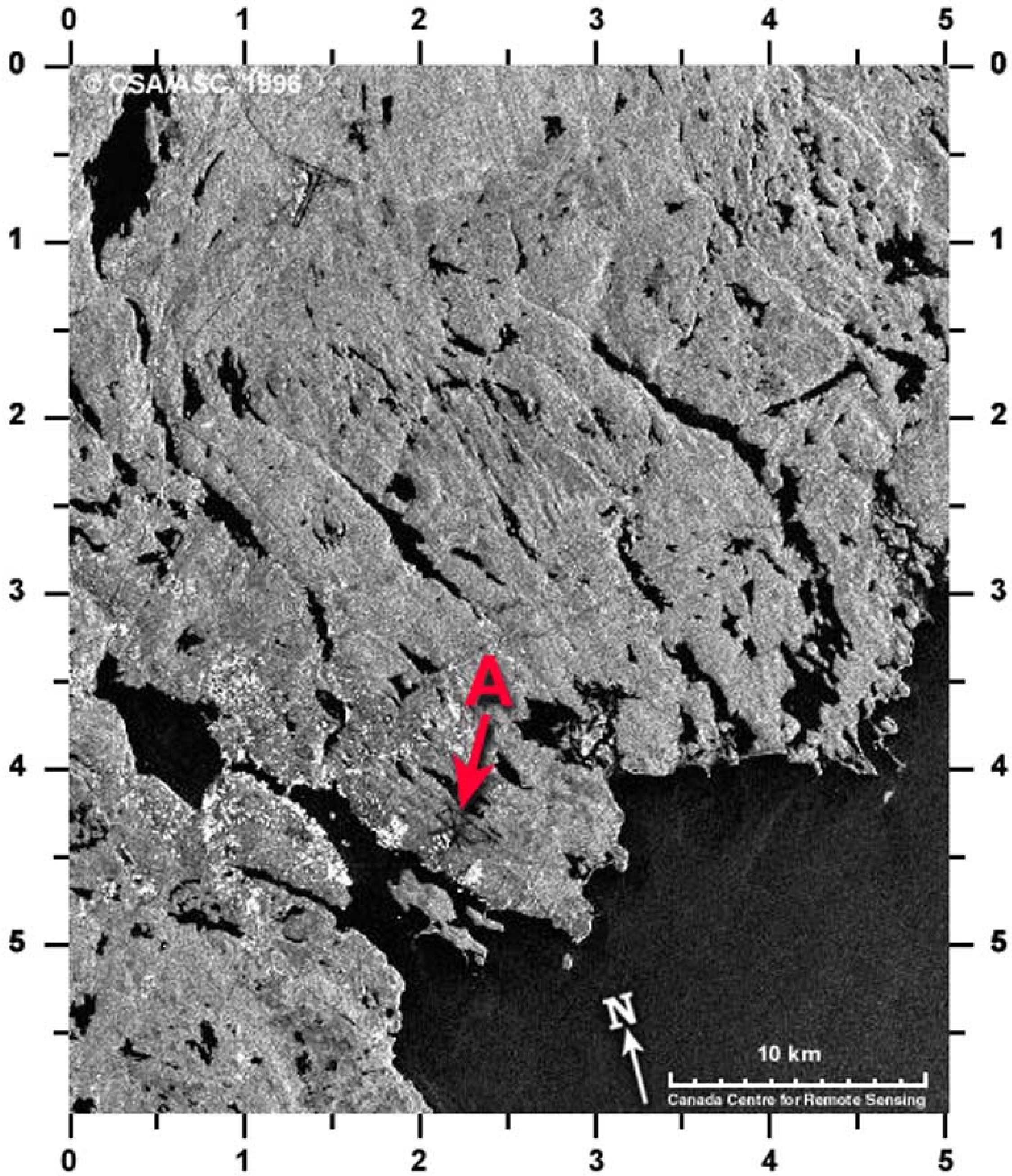
C: 8 km

D: 10 km

3.3b Measure This (Halifax area)

Instructions:

In the RADARSAT image of the Halifax area, the letter A is pointing to Shearwater airport. You can see the dark criss-crossing lines which are the airport runways. They are dark because on the ground they are smooth, just like the water bodies nearby (ocean at the bottom right and the many inland lakes). The many buildings in Halifax and nearby reflect the radar beams well, giving lots of bright spots on this image.



Halifax - question 1:

Find another airport in this image. The runways will be similar in appearance but not exactly in the same pattern. The other airport is at:

A: (1.6, 5.4) C: (3.9, 0.9)

B: (4.0, 2.6) D: (1.4, 0.7)

Halifax - question 2:

If you were flying from this other airport towards the ocean, you would be travelling:

A: south C: north-west

B: south-west D: west

Halifax - question 3:

Can you see any roads in this image? One road is located at:

A: (1.7, 2.7) C: (1.0, 1.2)

B: (1.2, 5.8) D: (4.0, 3.6)

Halifax - question 4:

The inner part of Halifax harbour is at 0.7, 3.9; the straight line distance from here to Devil's Island at 2.8, 5.1 is about:

A: 6 km B: 16 km C: 7 km

3.4 Clearcutting in the Forest

In the satellite image on the next page, we use those bands of the electromagnetic spectrum which best show the forest types in this area, as well as the clearcutting that has taken place and the forest re-growth that is occurring. "Clearcutting" means that all of the trees in an area are cut, not just selected trees. The standing forest of coniferous trees is shown as dark green, the bare ground (areas that have been recently cut) shows as pink, and the newly growing trees (and grasses and bushes) are yellow in colour. Notice also, that the logging roads (used by the logging trucks) are pink; where they cross the clearcut areas, they are a darker pink. A number of river valleys criss-cross this area, and of course, extend into some of the clearcuts.

Step A:

Find in the satellite image: standing forest, clearcut areas, logging roads, forest re-growth areas, river valleys.

On another page, you will find a map. The red lines show some of the roads that you can also see on the satellite image. The black outlines on the map indicate where the logging company was allowed to cut the trees last year.

Step B:

Trace the lines on the map onto a sheet of acetate. Use a different colour for roads and for the "allowable cut" area outlines.

Step C:

Place the acetate (with the lines you've traced) onto the satellite image. Fit the two together by matching the road lines from the acetate, to the roads as seen on the satellite image. Remember that while the satellite image shows all of the existing roads, only some of them are on the map. Only match the roads; don't try to match the clearcut areas.

Step D:

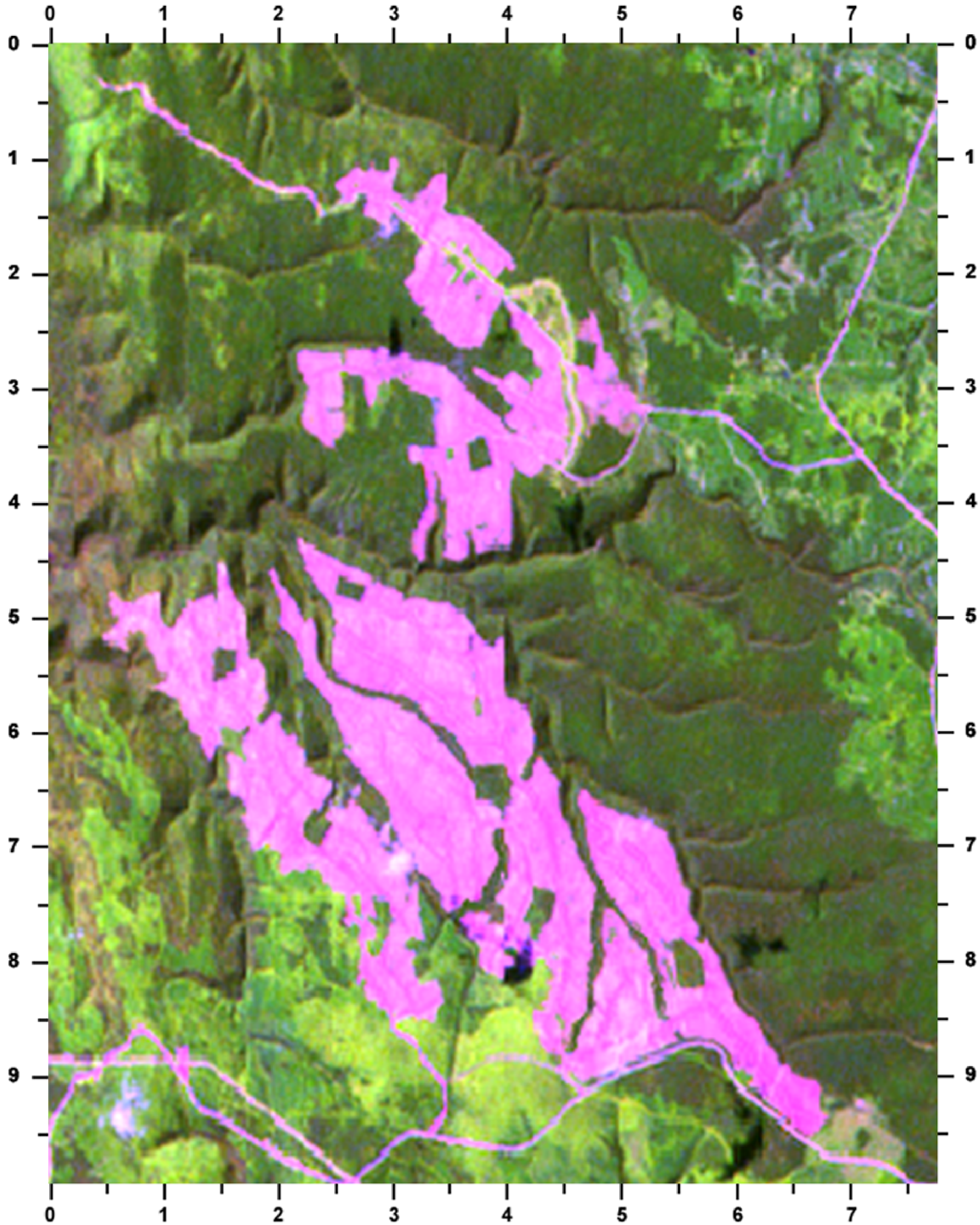
Once the roads are matched between the acetate and the satellite image, check how the "allowable cut" areas on the acetate match the actual clearcuts on the satellite image. Can you find some areas where the company was allowed to cut but didn't? Can you find some areas where the company wasn't allowed to cut but did? Identify them (non-permitted cuts only) by giving the coordinates of the middle of each such area, using the number grid on the edges of the image.

Answer: (___, ___) (___, ___) (___, ___)

Step E:

How many square kilometres were cut outside the "allowable cut" areas? Use the dot grid technique in Appendix A to measure those areas. Each five dots that you count, will represent 1 square kilometre.

Answer: ____________ **sq. km.**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Map of "Allowable Cuts"

Black Lines: outlines of areas that may be cut

Red Lines: roads

3.5 Oil Spill Danger

Image - June 10:

What do we see on the satellite image of June 10? About 20 km offshore, we see a ship travelling parallel to the coastline, and it looks like it has released some oily material. The lighter blue tone located behind the ship is an oil slick floating on the water surface. If the water current pushes that slick towards the coast, then the shoreline will be polluted with oil! If we act quickly, we can send people and equipment to try to protect the shore with floating barriers. But where do we send them? Should we send the team to Dewel, Canto, or Ormond? These towns show up as pink areas on the coast, because the image is processed to show vegetation as green and yellow, and non-vegetated areas like pavement and bare earth as pink. These are not the real colours that we would normally see by eye.

Question A: If you know that the water current is coming from the north-west, you should be able to estimate which part of the coast the oil slick will reach. The nearest town is where we should send our clean-up team. Considering only what we knew on June 10th, which town should it be?

Answer:______________________

Image - June 12:

We managed to get another satellite image of this area, two days later. The image of June 12 shows the slick (the ship itself is long gone) as it spread and moved towards the coast. But it didn't move exactly in the direction that we expected. Wind, waves, currents and tide combined in a complicated way can make it difficult to predict the slick motion. But with this second image, we can tell how the slick actually moved.

Question B: Trace the outline of the slick on the June 12 image onto a sheet of acetate. Also trace the coastline onto the same acetate. Position this acetate carefully on top of the June 10 image by matching the coastline on the acetate with the coastline on the image. Draw a straight line on the acetate joining the approximate middles of the two oilslick positions. Extend this straight line until it hits the coastline. If the oilslick keeps moving the way it has in the last two days, then it should hit the coastline near the town of:

Answer: ___________________________

Question C:
How long will it be before the slick reaches the coast? No more hints or instructions for this! You figure it out! The slick will arrive on:

June________

Question D: We also need to know how many floating barriers to send to this location. It will depend on how much oil there is in the slick. Measure the area of the slick on the July 12 image using the dot grid technique in Appendix A. Each five dots that you count, represents 1 square kilometre. We will need to send 4 barriers for each square kilometre of slick that we measure. How many do we send?

Answer: ___________________________

June 10
Ormond
Canto
Dewel
N
10 km
Canada Centre for Remote Sensing

June 12
Ormond
Canto
Dewel
N
10 km
Canada Centre for Remote Sensing

3.6 Crop Types

Introduction

This satellite image shows a farming area with many fields and several types of crops growing in mid-summer. The different colours indicate different crops, or perhaps what condition the crop is in. Small white dots in some fields are the clearings where the farmhouses and barns are located. Sometimes the image captures a crop being harvested. Look for instance at the field at (3.7, 6.7). The different coloured “outline” of the field indicates that the farmer has just started to harvest the corn, starting, of course, on the outside of the field. The very dark green, irregular shaped areas are small patches of woods (trees) – see, for example: (2.8, 3.8).

Task #1:

There is a larger town and a smaller village in this satellite image. The approximate middle of each are at the coordinates:

town: (____, ____) village: (____, ____)

A river cuts through the image. It is so narrow that you can’t see the water itself, just the vegetation on the river bank. It doesn’t follow the road grid and is not a perfectly straight line. It exits the picture on the right at (6.0, ____).

A railroad also cuts through the image. It’s a much straighter line and comes from the town and exits the image on the left at (0.0, ____).

Task #2

What type of crop is growing at:

a) (1.5, 4.6) ____________________

b) (2.9, 3.3) ____________________

c) (5.1, 1.7) ____________________

d) (4.4, 1.2) ____________________

e) (1.4, 3.1) ____________________

f) (3.8, 2.2) ____________________

g) (4.7, 3.0) ____________________

Task #3:

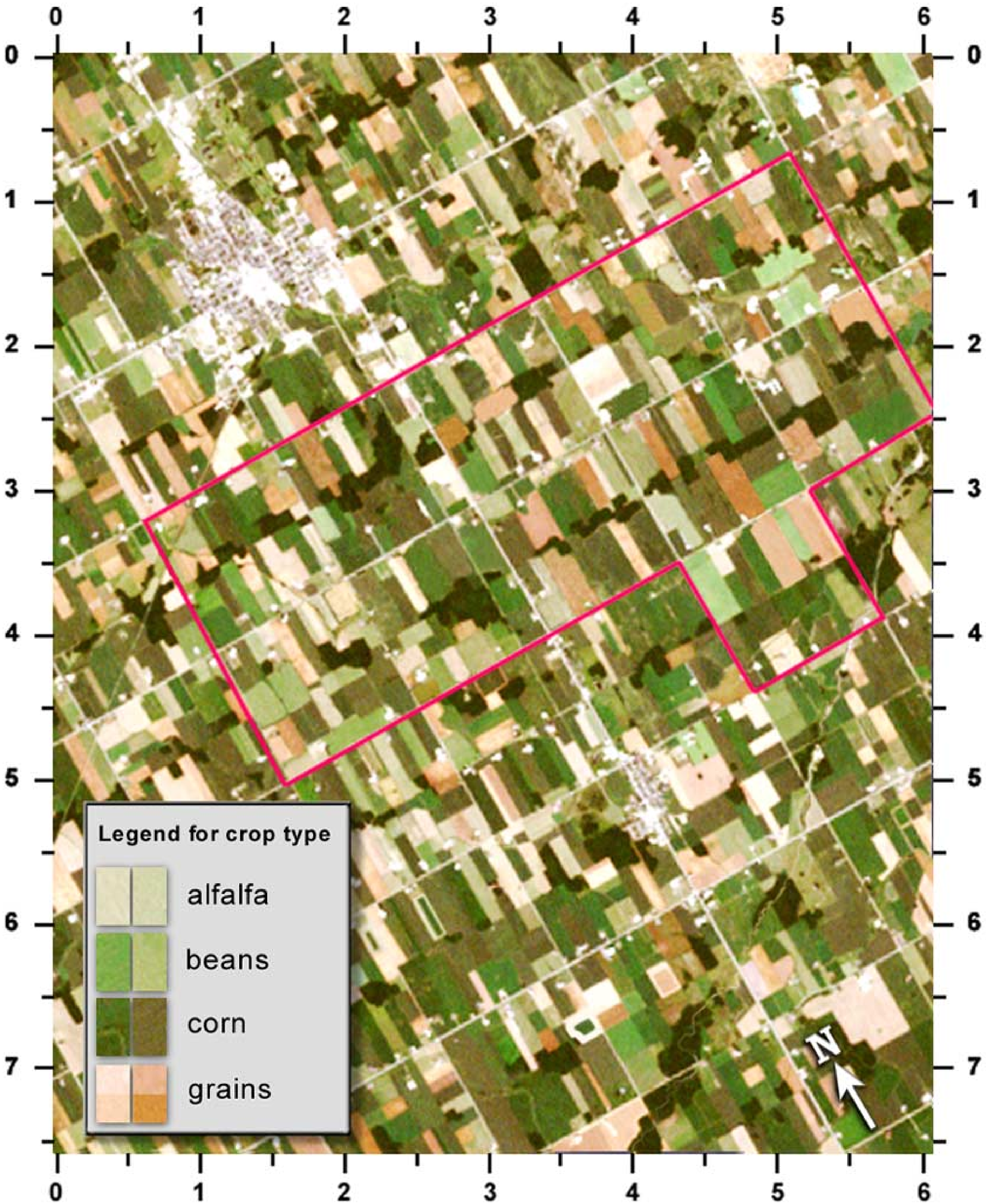
The second satellite image is the same area, but it was imaged during a time when too much rain has caused a small river to flood. The water rose about ½ metre above normal, which was enough to flood many farms.

a) What are those patches of green inside the flood zone?

____

b) An insurance company has insured the grain crops for those farms inside the red outline. For how many fields will they have to pay compensation?

____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Legend for crop type
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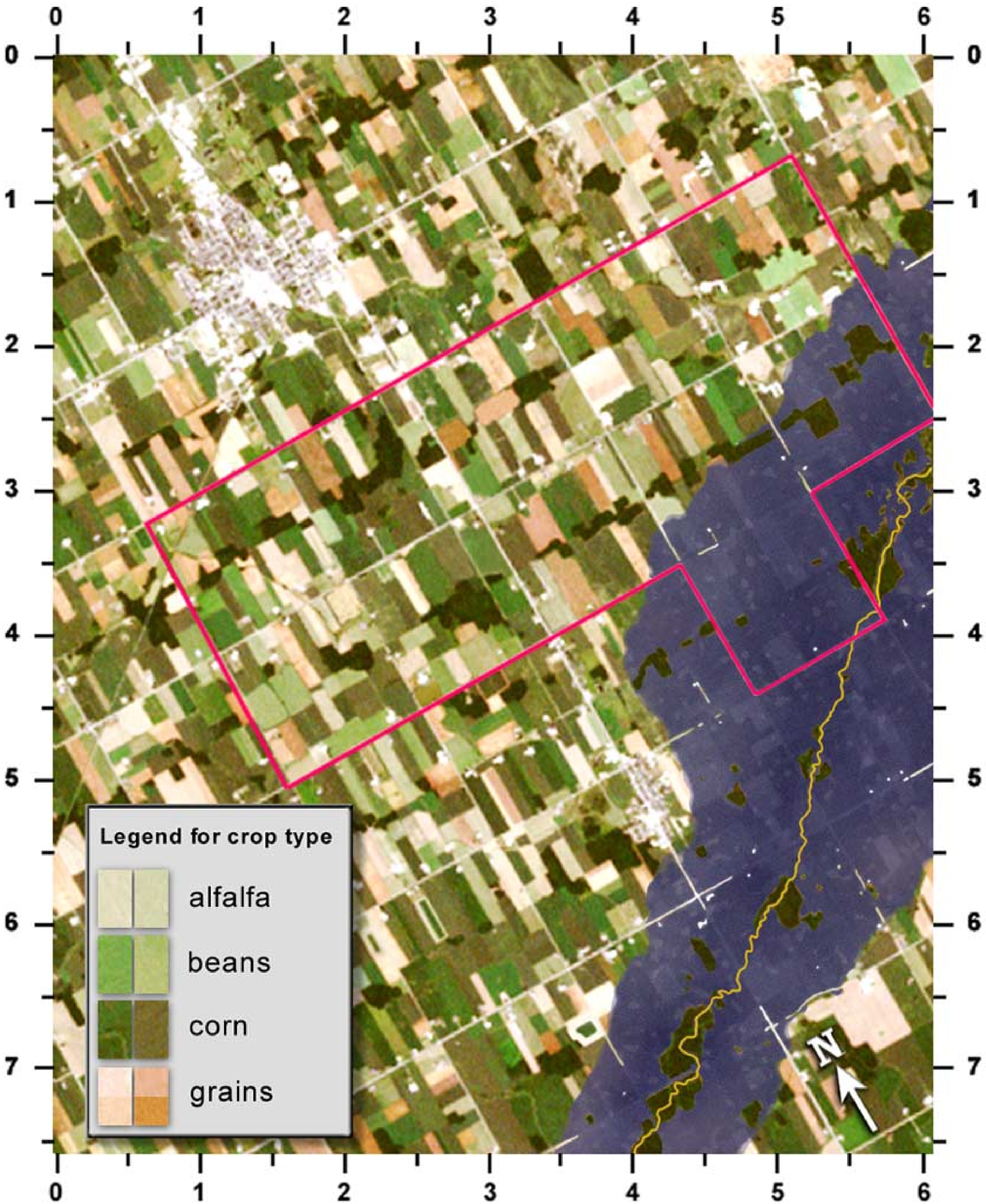

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beans
corn
grains
N

3.7 Forest Fire

Introduction:

There are many forest fires in Canada every year. The ones in the northern parts of Canada are difficult and expensive to fight, because it's complicated to get people and supplies quickly to those isolated areas, and there are probably no airports or roads. Satellite images can be used to map the types of vegetation, sources of water and areas that are difficult to travel over, like swamps.

In this satellite image, the yellow and green colours show unburned forest and other vegetation types. The red/orange colour is a recently burnt area. The black shapes are lakes and rivers. The small pink areas around the burn are unvegetated areas where rock shows through the soil. Notice that the fire was stopped mostly by reaching the edge of a river or lake. At other points, it probably stopped because of swamps or bare ground or because the wind reversed direction.

The main camp for firefighting in this area is at location "A". A smaller advance camp has been set up at "B", because there is a good chance that the fire will flare up again and the wind will push it to the north. We need to send people, equipment and supplies by boat to the advance camp from the main camp.

Task #1:

Find the shortest route by water from "A" to "B". Measure this distance, using string (or a shoelace).

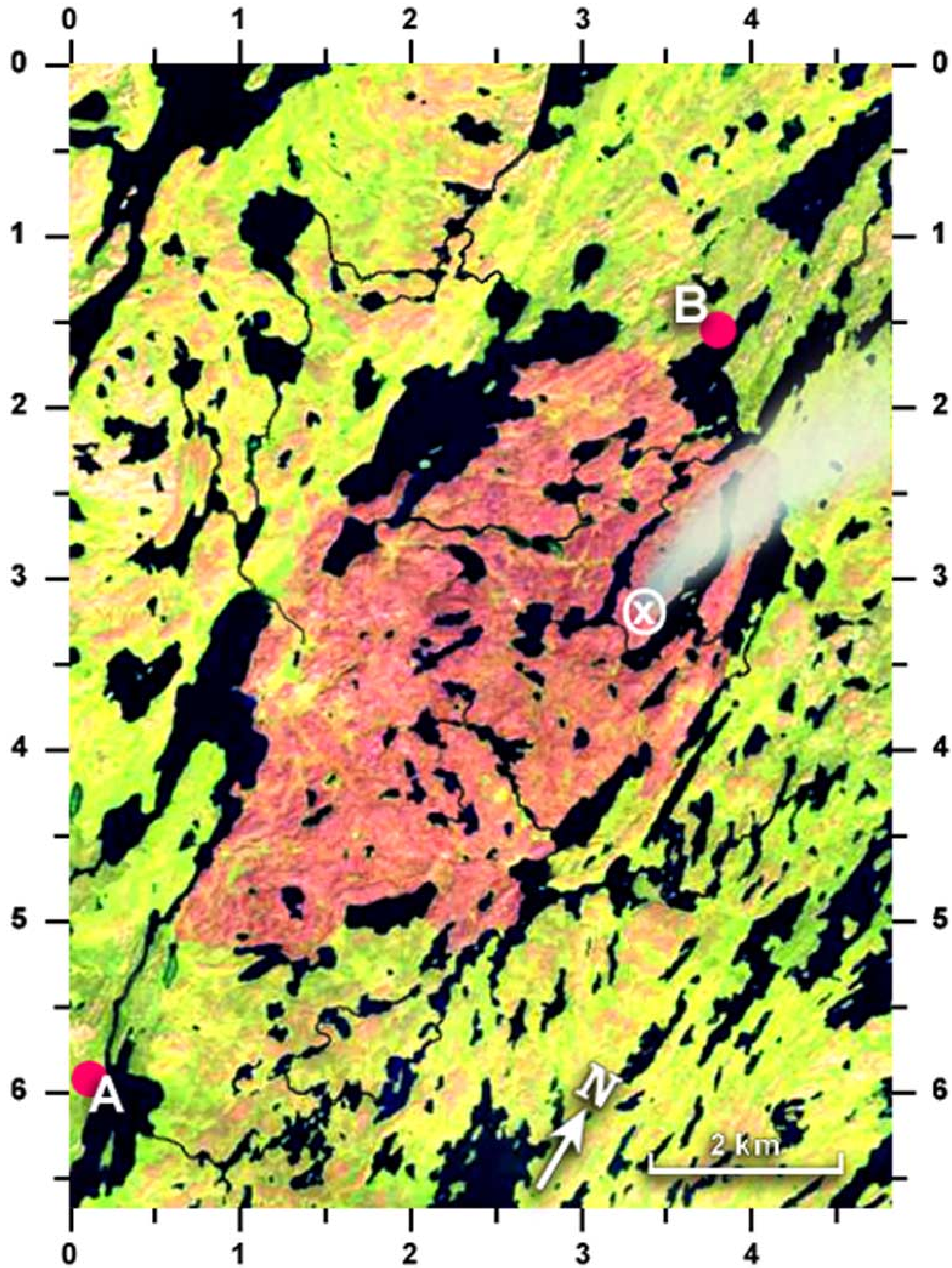
That distance is: ______________ km.

Task #2

A fire has flared up at "X". We can use firebombers (airplanes that drop water) to try to douse it. The planes need 2km of straight-line distance over water to safely collect a full tank of water. To which lake would you send them?

The middle of the lake that is closest for such a purpose is at: (____, ____).

The middle of the next closest lake would be at: (____, ____).



0
1
2
3
4
5
6
B
A
N
2 km

3.8 Navigating a Ship Through Ice

Introduction

In Canada's ice-infested waters, ship captains have to pay careful attention to where, how much and what type of ice is in front of them. Going the wrong way can waste fuel, slow the ship down and be dangerous if the ship gets damaged or gets stuck in the ice. Satellite images can give a large view of the area in front of a ship and will allow an experienced interpreter to estimate the age, type and concentration of the ice. With radar sensors, images can be acquired through clouds and even at night! The images are sent to the ship by communications satellites, so the captain can see the most recent ice conditions in front of his ship.

The image in this activity shows a radar image of ocean ice, from Canada's RADARSAT satellite. An example of a first year ice floe is shown at "A". Broken ice fragments, called "brash ice", such as at "B", fill much of the space between the floes. A crack in the ice, exposing the open water surface is called a "lead" and one example is shown at "C".

A ship captain would want to navigate through leads as much as possible, since there is no ice resistance to his ship's travel. He would also want to avoid ice floes, since the brash ice is easier for the ship to push through.

Task

Starting at (3.0, 0.0) and ending up at (0.5, 9.5), find the best passage for a ship. Use leads, wherever possible, and avoid ice floes. Measure the distance over the route that you've chosen.

That distance is:

_______km.

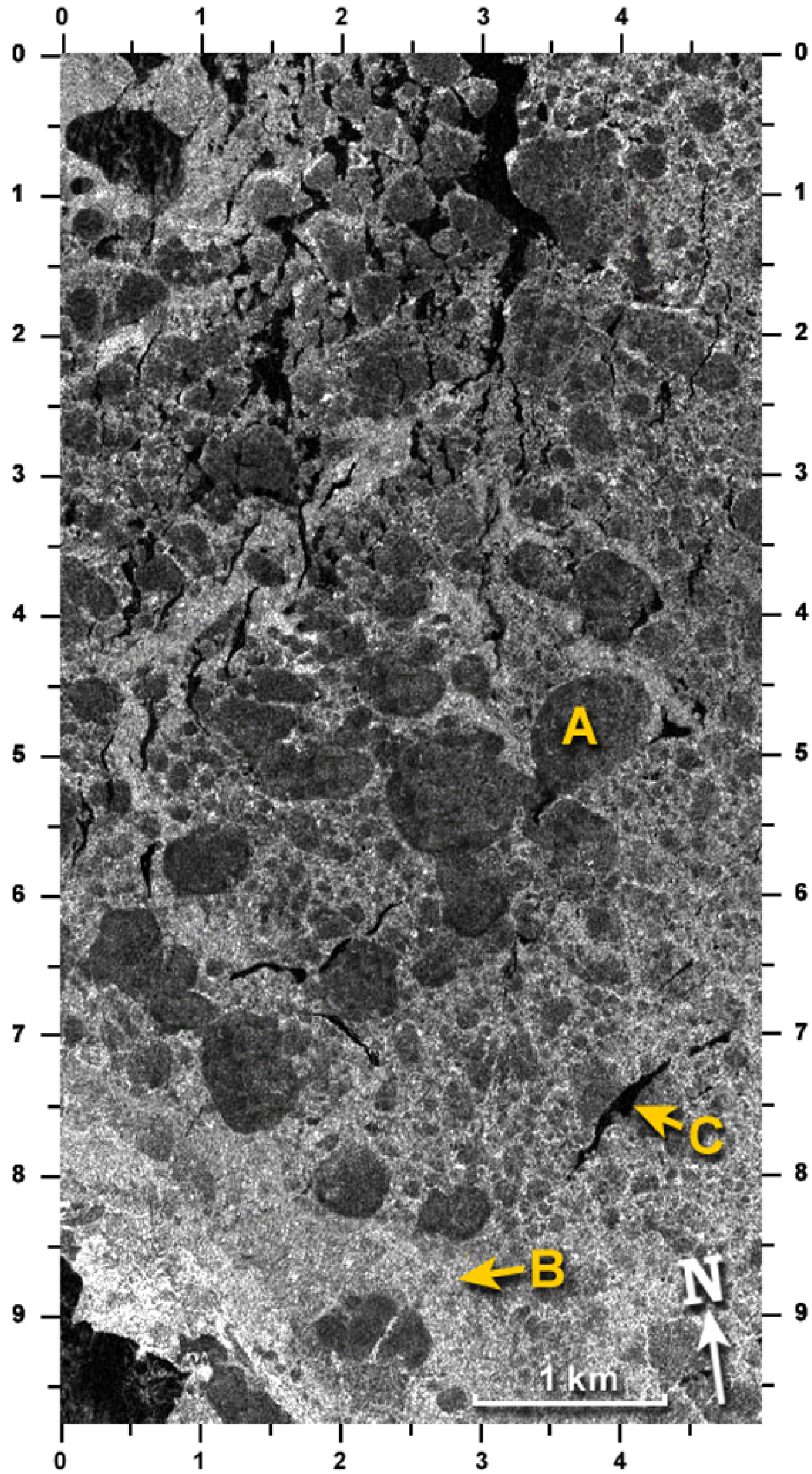
Hint: It should be less than 10 km.

Radar Image Legend

A. Ice Floe (solid ice)

B. Brash Ice (ice fragments)

C. Lead (open water)



3.9 You Figure it Out !

Read this first:

Here are two small sections of a satellite image of the Queen Charlotte Islands, off the coast of British Columbia. We used some visible light and some infrared light information in these images, to better show vegetation. Healthy and dense vegetation is red. As the vegetation gets less dense, it is shown as pink (less red). When there is no vegetation at all, like bare earth, rock or pavement, it shows up as light blue. The deep water is very dark, almost black.

The top image shows a very small town called “Sandspit”, at the edge of a forest and on the shore of the Pacific Ocean. The bottom image is of another town called “Queen Charlotte City”, also on the shoreline and at the edge of the forest.

Now choose the correct answer to these questions:

Sandspit: at A

There are some small openings in the forest which are caused by:

1. Insects destroying the forest
2. Beavers cutting down the trees
3. People cutting some of the forest to make room for houses and gardens
4. Aliens landing their flying saucers.

Sandspit: at B

There is a light blue, straight line which is:

1. A scratch on the picture
2. A long, skinny garden
3. A short road
4. An airplane landing strip

Sandspit: at C

The colouring here is pink and white which means that:

1. The vegetation is very sparse (thin).
2. There is dense forest here.
3. There are lots of pink and white buildings.
4. Aliens are still landing their flying saucers.

Sandspit: at D

This patch of dark, slightly red coloured area is off the shoreline, in the ocean. If red colour means vegetation, then this area must be:

1. Trees that have been cut and are now floating in the ocean.
2. Seaweed growing in shallow water.
3. A flooded lawn
4. Aliens growing an underwater garden.

Sandspit: at E

This light blue feature in the ocean can't be vegetation but it's a strange shape. It must be:

____

1. Made of sand
2. Naturally, not artificially created
3. A shallow-water sandbar formed by tides and current
4. All of the above

Sandspit: at F

There is a light blue semicircle on the shoreline. The colour and shape mean that it is:

____

1. A sand pit
2. A hill made of sand
3. Deep water
4. Sand outflow at the mouth of a river.

Queen Charlotte City: at A,B

Two different shades of red in a forested area mean that:

____

1. The imaging sensor on board the satellite is confused.
2. There are two major types of forest here.
3. One shade of red is forest, the other is sand.
4. The darker shade of red is a cloud shadow.

Queen Charlotte City: at D

There is a light blue fringe around each island in this image because:

____

1. There is no forest there (red colour).
2. The water is not deep (black colour).
3. All the shorelines are made of sand and rock in shallow water.
4. All of the above.

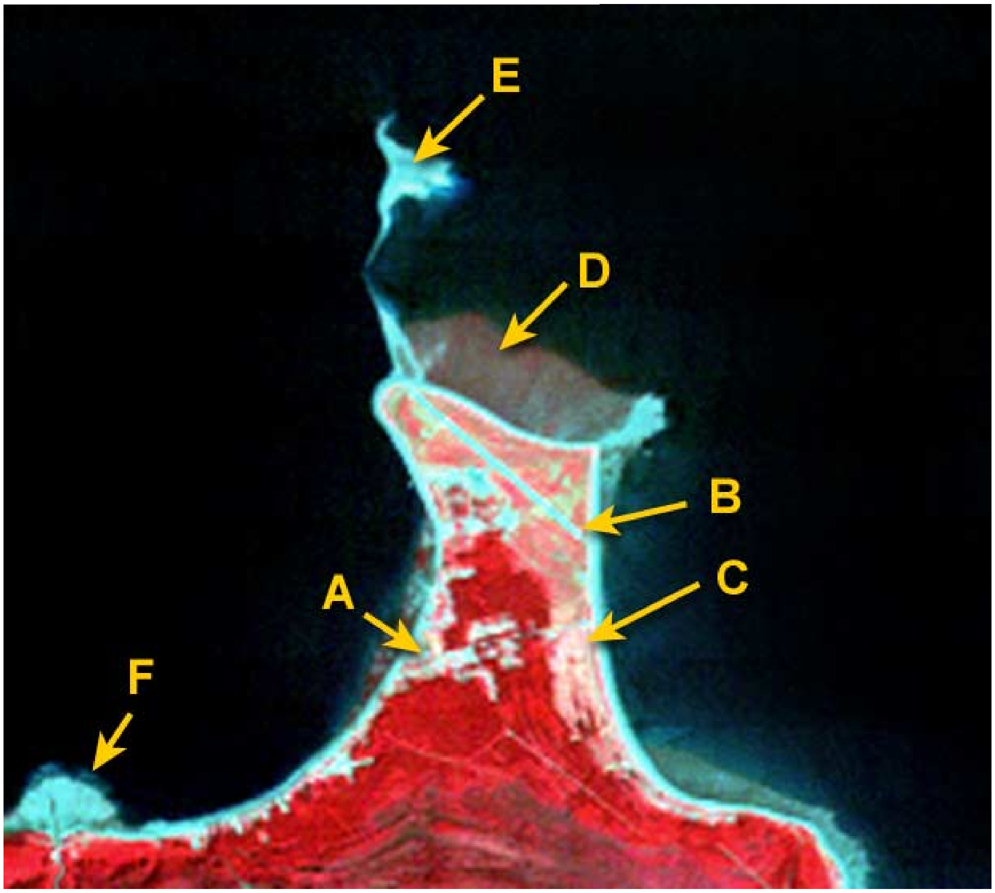
Queen Charlotte City: at C

This area of light blue covers Queen Charlotte City. It extends along the shore and has patches inland. You can see roads through the forest and a pier for docking ships. But you cannot see streets or buildings on this image because:

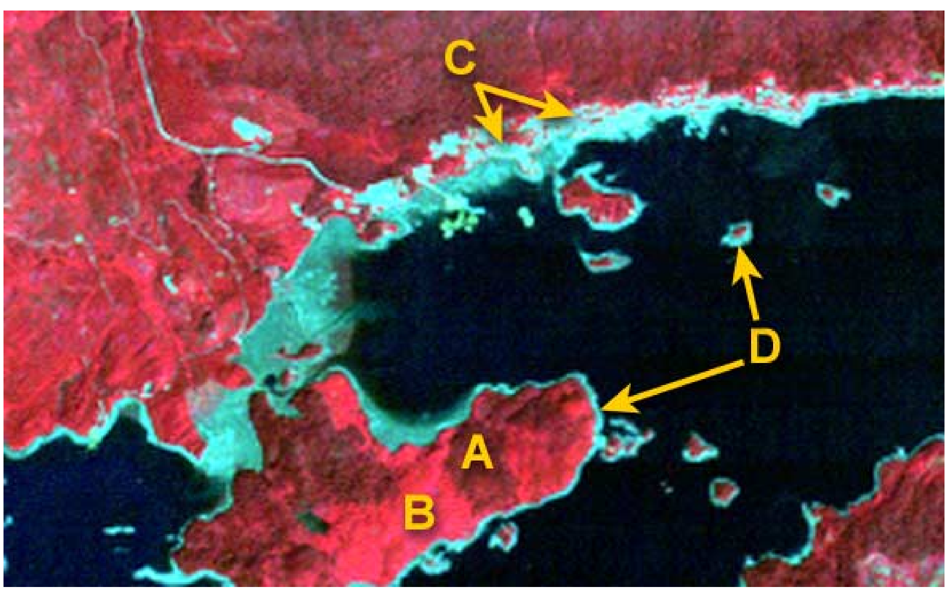
____

1. The buildings are hidden in the woods.
2. There are no buildings here, just tents.
3. There are very few buildings and they are too small to see with this imaging sensor.
4. The buildings look the same as trees.

Sandspit



Queen Charlotte city



3.10 Land Use Mapping

City planners need to know which areas of a city are used for which purpose. Therefore, they produce a map of "land use", that identifies parts of a city and the major activities (land use) that happen there. Remote sensing imagery is very useful for this purpose, since you certainly don't want to spend many weeks or months walking or driving around a city to map its land use. But to use remote sensing imagery effectively, you have to be able to interpret it accurately.

The satellite image in this activity shows a part of downtown Montreal. It will be a bit harder to interpret this black and white image, because you don't have colour clues to rely on. But you can see quite a bit of spatial detail – even individual streets and large buildings.

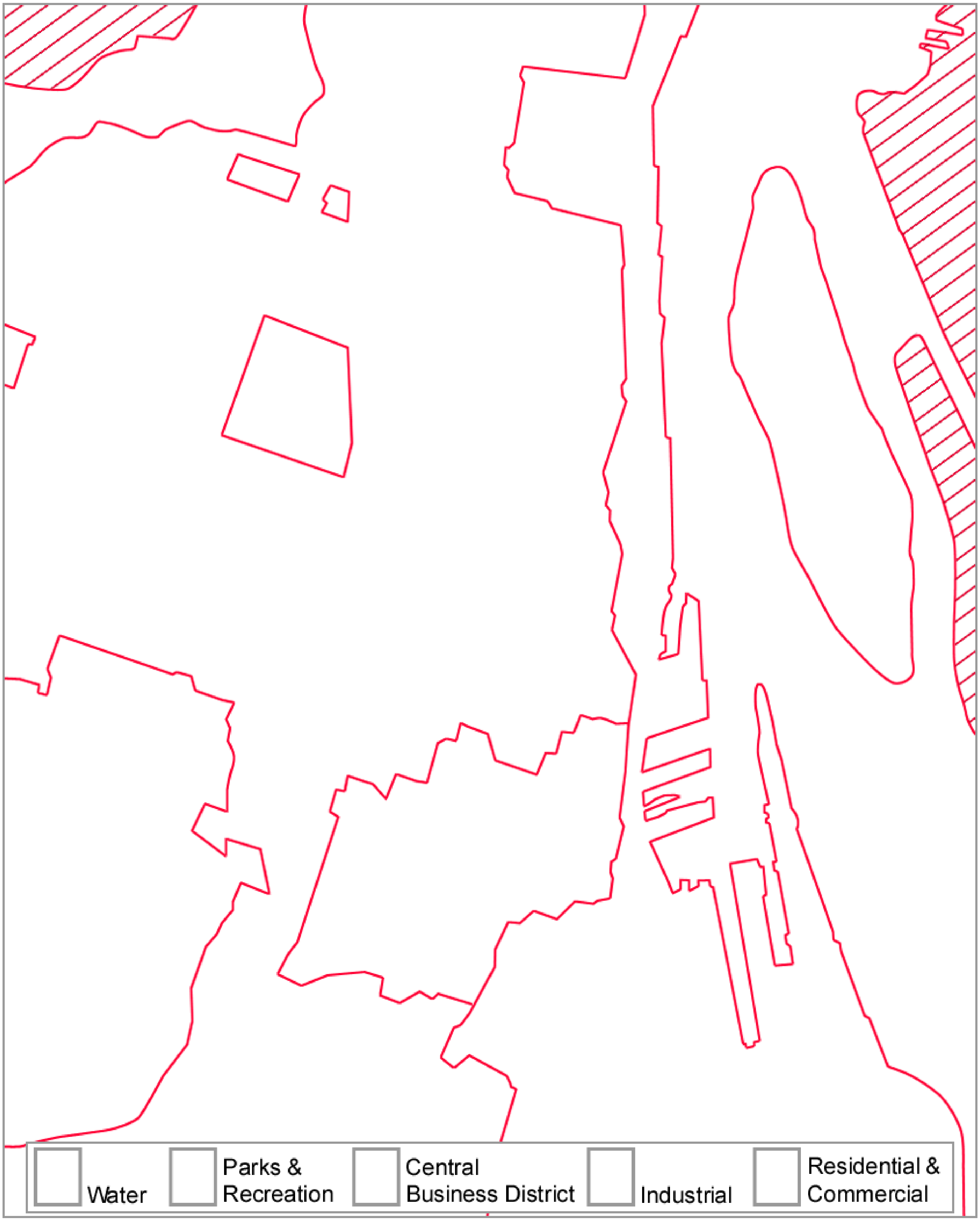
Task

There are five categories to map: water, industrial, central business district, parks & recreation, and residential & commercial. Choose a different colour for each of these categories and colour in the boxes in the index of the blank map. Then for each area outlined on the map, interpret the corresponding area on the image. Use the interpretation key below for clues. Once you figure out the land use for a particular area, colour in the map to match it.

Land Use Category	What does it mean?	Look for this in the image
water	rivers, lakes	smooth, dark areas with docks and bridges
industrial	large factories, railway yards, docks, storage yards	rail yards; large (wide) buildings; empty lots; bare ground; lack of rectangular street pattern
central business district	tall office buildings, hotels	closely packed, tall buildings casting large shadows
parks and recreation	parks, golf courses, race tracks, amusement parks, sports arenas	large grassed areas; winding paths; ponds; oval tracks; large, irregular buildings
residential and commercial	houses, apartment buildings, stores, shopping centres	rectangular street pattern, closely spaced houses and some larger buildings

Satellite Image – Downtown Montreal

Land Use Map – Downtown Montreal



3.11 At a Mine Site

There seems to be a lot of activity going on in this remote sensing image of a copper mine. We are using a sensor on an airplane here, so we have very fine detail of features. Also, the spectral band combinations are chosen to show healthy, dense vegetation as bright red. Less healthy and thinner vegetation will show less red and more brown colouring. Artificial materials like pavement and buildings will appear in different shades of pale blue.

Of course you can't see what is going on underground, but let's take a tour of what happens above ground:

"Ore" is taken from the ground and processed at a mill (A). This involves grinding it up and adding water. The parts of the mixture that are useful are called "concentrates" and passed to the smelter "B" for further processing, while the unwanted parts are called "tailings" and need to be disposed of.

At the smelter, the concentrates go through several processes, including melting at very high temperatures, to isolate the metals that are the desired end products. The remaining materials are called "slag" and also need to be disposed of.

The copper that is produced here, becomes the water pipes and electrical wires in our houses, as well as many other useful products. The unwanted parts of the processes, are allowed to settle and mix with air and water in settling ponds. It takes special effort to overcome the environmental effect that the slag and tailings have on the soil, air, water and vegetation.

Question #1:

We can see in the satellite image, several stages of the environmental recovery that the mine has implemented.

At "C", a pipe is dumping the raw tailings (yellow colour) into a settling pond. What is another location where tailings are entering a settling pond (2.3, 2.6) or (4.7, 1.8) or (4.5, 2.7)?

Question #2:

The settling pond in the satellite image at "D" is almost completely filled in with tailings. Where can you find another almost-filled pond (0.5, 5.2) or (0.5, 3.0) or (2.0, 6.0)?

Settling pond being filled with tailings

Question #3:

Lime is added to the tailings to reduce its acidity. You can see in the satellite image, a big pile of lime stored at "F". Where is another lime pile (2.2, 7.5) or (6.5, 6.7) or (5.6, 1.0)?

Lime pile at the mine site

Question #4:

At "G" in the satellite image, seeds have been planted and grass has started to grow on the tailings. A few young trees are also growing here. Where is another area like this (4.6, 3.2) or (0.4, 7.2) or (0.7, 3.4)?

Grass and young trees growing on the tailings

Mature trees growing on land reclaimed from a tailings pile

Question #5:

Fully mature trees, growing on old tailings can be seen on the satellite image at “H”. Where is another similar area (6.5, 1.0) or (2.2, 0.9) or (3.7, 3.7)?

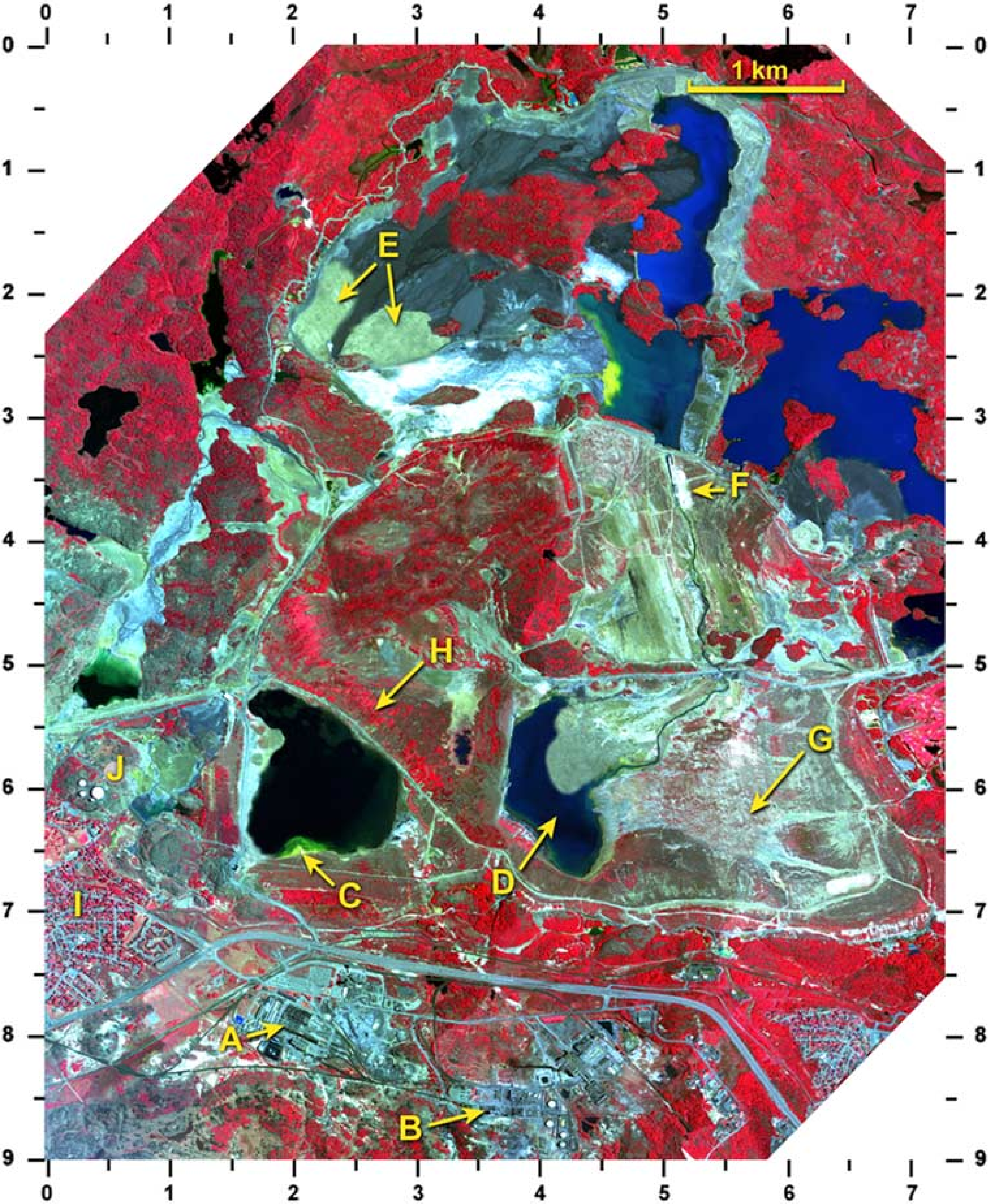
Question #6:

On the satellite image there is a housing development for mine workers, at “I”. Where is another such neighbourhood (0.2, 4.6) or (2.0, 2.0) or (6.5, 8.1)?

Question #7:

A cluster of large storage tanks can be seen on the satellite image at “J”. Where is a second group of storage tanks located (6.9, 7.1) or (3.7, 7.6) or (4.1, 8.8)?

Remote Sensing Image of a Mine



3.12 A Different Perspective

Looking at things from directly above is very different from the normal way that we see things. But when we use satellite imagery, we have to get used to how things look from space. Try the following activity to see this difference.

There are two sets of pictures of places in the city of Ottawa and vicinity. One set was taken from an airplane, looking at things from an angle (obliquely, that is) – which is a more familiar way to see things. The other set was taken from satellite, looking at things from directly above – which we are not used to.

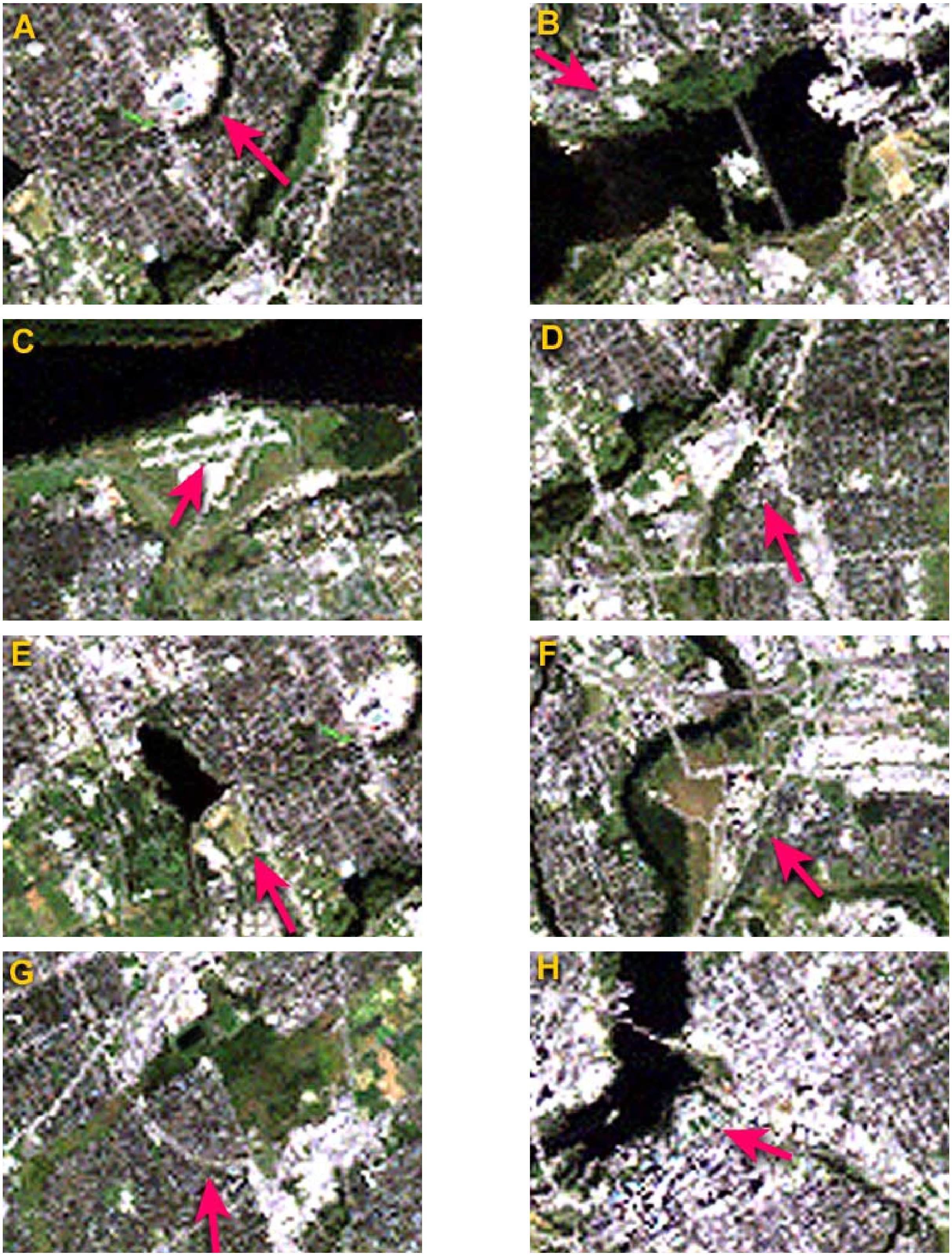
Task

Can you match each aerial photograph to its corresponding satellite image? To help you, we've shown on each satellite image, from where and in which direction the matching air photo was taken.

Aerial Photograph	Satellite Image
1	
2	
3	
4	
5	
6	
7	
8	

Aerial Photographs taken over Ottawa

Satellite Images of Ottawa



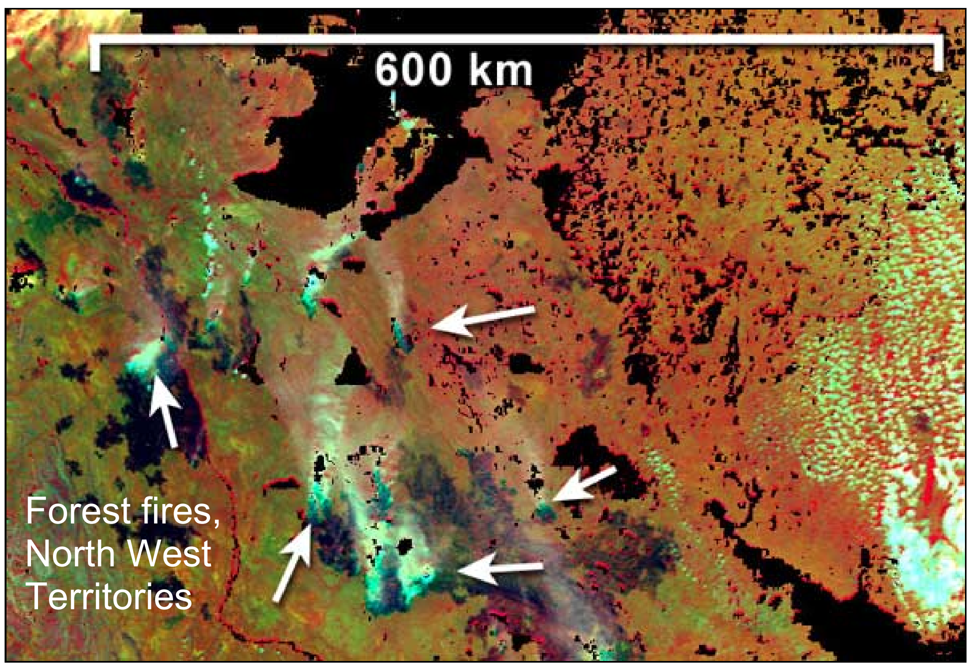
4.1 Why does Remote Sensing work so well?

Without Remote Sensing

Covering a large area on foot, by car, by boat or even by airplane is very expensive and can take a long time. By the time a large area is covered using these methods, things at the beginning of the survey could have changed.

With Remote Sensing

A satellite scans a very large area within seconds.

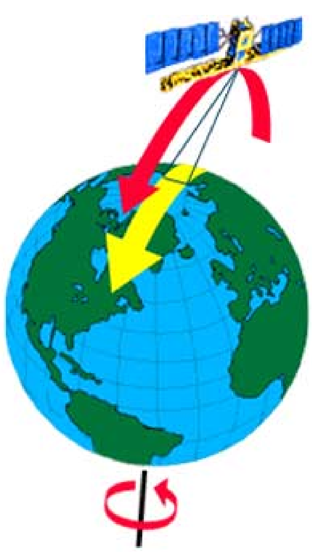


Without Remote Sensing

A survey of a large area of forest, agricultural land, cities or oceans could require paying a team of people and perhaps renting boats or airplanes, potentially making it very expensive for just one project.

With Remote Sensing

The cost of building, launching, and operating a satellite is shared by the many thousands of people who buy images for their own projects.



Without Remote Sensing

It is sometimes hard to see small changes and it is very difficult to count and record many small changes, especially if they occur over a large area. In order to make good decisions about how to help our environment, we need to know accurately, what is happening where and when.

With Remote Sensing

A satellite can acquire repeated views of the same area and computers can accurately show what has changed between acquisitions. When dealing with fast-changing disasters (forest fires, floods) or when looking at the slow change of crops, forests or city growth, remote sensing images can't be beaten.

Without Remote Sensing

There is always a lot of guesswork. Resource managers go to a site to take samples or make a count in only a small portion of the area to be studied. Using this information, predictions are made for the entire area. The same survey done twice could produce very different results.

With Remote Sensing

Remote sensing tells us exactly what is there, how many and where. It doesn't rely on a person's memory or experience. It gives us reliable and repeatable information with measurable accuracy.

Without Remote Sensing

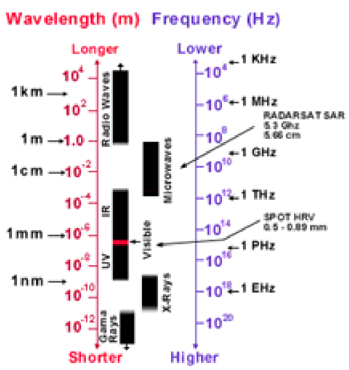
If information is described in writing or even in a drawing, it can be used only in a limited way. It is very difficult to make comparisons to other similar descriptions and it is even more difficult to analyze. It may not be possible to make good decisions based on this type of information.

With Remote Sensing

Remote sensing information is mostly digital and therefore can be analyzed by computer, compared, and statistics can be collected from it. Decisions can be made more accurately from this type of data.


The "radome" covers the microwave antenna

4.2 Frequently Asked Questions



a) Is remote sensing always done using satellites?

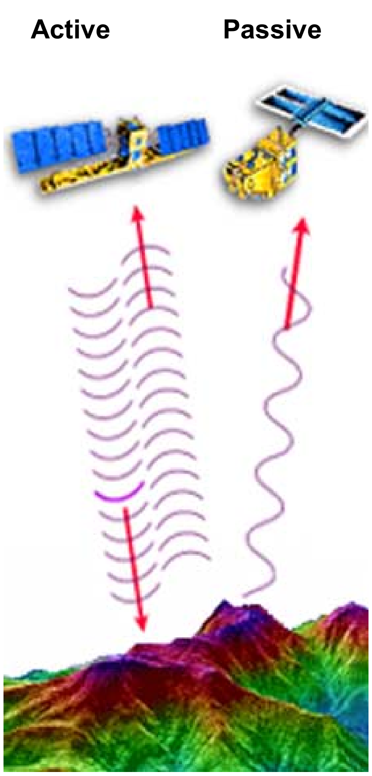
No.

Remote sensing is simply sensing things from a distance. You do "remote sensing" whenever you look, hear or smell. Remote sensing can be done for business and scientific research using helicopters, airplanes, rockets, or balloons. Even kites have been tried, but satellites are definitely the most popular platform for carrying remote sensing equipment.

b) Is there a difference between a Landsat satellite and a RADARSAT satellite?

Yes.

Landsat carries a "Thematic Mapper" scanner that uses the visible and infrared parts of the electromagnetic spectrum to make images. As humans, we can only see the visible light part of the spectrum (the colours of red, orange, yellow, green, blue and violet), but we can't see the infrared parts as Landsat can. RADARSAT, however, carries a radar instrument that uses the radar or microwave part of the spectrum to make images. We can't see that part of the spectrum either. These are the same microwaves that are used in many other ways such as in microwave ovens.



c) What is the difference between an ACTIVE and a PASSIVE sensor?

A camera provides an excellent example of both passive and active sensors. It is the film of the camera that is the sensor. It records the light that is reflected from the object that is being photographed.

If the illumination for the scene is coming not from the camera but from another source (say, the sun) then the camera is a **PASSIVE** sensor. On a cloudy day or inside a room or at night, there may not be enough light. When the camera also has to provide the illumination for the scene (using a flash) it becomes an **ACTIVE** sensor.

d) How does radar work?

A short pulse of energy is sent out by the radar antenna at an angle, towards the ground. The pulse bounces off targets on the ground (houses, trees, grass, telephone poles, etc.) and some of the energy is reflected back to the antenna. This is called "backscatter". The more energy a target backscatters, the brighter it will be shown on the radar image.

e) Is there one remote sensing satellite that is the best?

There is no "best". The best choice of satellite data depends upon the application.

Some satellites (and the sensors they carry) are designed for looking at fine detail so that small targets can be imaged. Other satellites specialize in covering very large areas all at once, or perhaps in revisiting the same area often. Radar-carrying satellites are chosen for use at night, for penetrating clouds or for mapping special targets like ice. Other satellites carry sensors that are particularly good at imaging in colour, to help in the "spectral" identification of targets.

f) How high up are these satellites?

The earth observation satellites such as Landsat and RADARSAT are about 900 km above the Earth. This is much higher than the international space station (about 200 km) but not as high as the communication satellites (in geostationary orbit) that are used for TV and telephone (about 32,000 km).

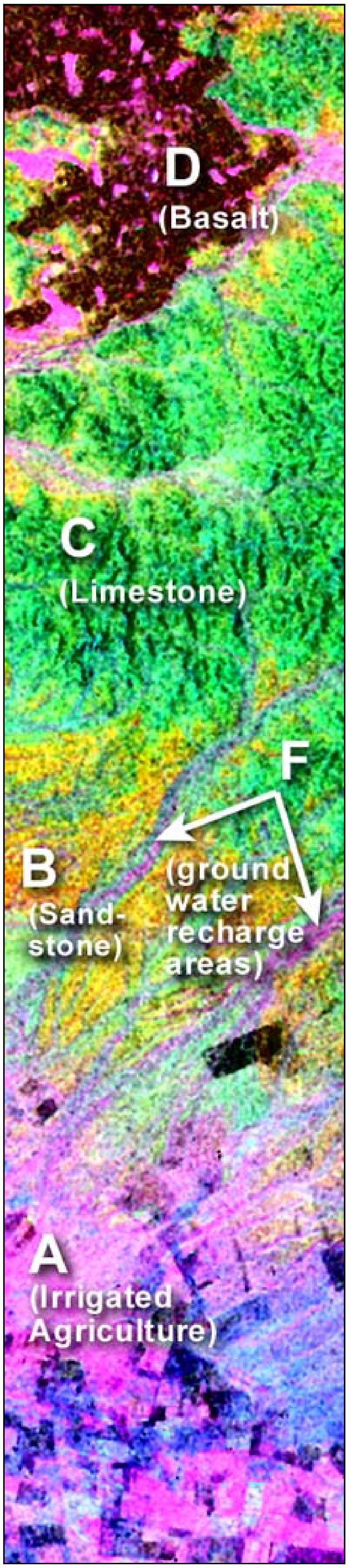
g) How many remote sensing satellites are there?

Lots.

RADARSAT is Canadian. Other satellites belong to different countries such as U.S., Europe, Japan, France and India. Private companies are now launching remote sensing satellites too, because they have realized that this technology is very useful and profitable.

h) How do the remote sensing satellites "cover" the Earth?

The Earth Observation satellites move in a "near polar" orbit. As the Earth spins west to east beneath them, they orbit from the North Pole down to the South Pole, back up to the North Pole, etc., each time passing close to, but not exactly over the poles. These two motions



(the satellite orbit and the rotation of the Earth) make it possible for them to see almost the entire surface of the Earth.

i) How long does it take for a satellite to "cover" the Earth?

One Landsat satellite, which looks straight down, takes 16 days to cover the whole of the Earth's surface. The NOAA satellite, which also looks straight down but covers a much wider area takes much less time. The RADARSAT and SPOT sensors, on the other hand, can be steered to point at a sideways angle at a target area from several neighbouring orbits. In this way, in a limited fashion, it is possible to get daily views of an area for several days.

j) How is the satellite data sent from way up there, down to us?

There are two receiving stations in Canada. One is in Gatineau, Quebec, the other in Prince Albert, Saskatchewan. Together these two receiving stations can pick up all the data transmitted by satellites passing over any part of Canada. Other ground stations have been set up around the world to similarly capture data from a variety of satellites when they are overhead.

Most of the time the satellites re-transmit the data that they receive directly to the ground station below them, using radio waves. At other times when the satellite is not within line-of-sight of a receiving station, it will store the data on board temporarily, and then transmit to the ground station when it passes overhead.

k) How long does it take the data to reach Earth?

The data is transmitted instantaneously (well . . . . to be accurate, it's transmitted at the speed of light).

l) Why are some satellite images in black and white and others in colour?

Some sensors record images from just one part of the electromagnetic spectrum, showing the image in shades (usually 256) of grey making what's called a "black and white" image. This is how RADARSAT works.

When an image is recorded simultaneously in several parts of the spectrum, then three of those spectral "bands" are shown as shades

of red and green and blue. Landsat and SPOT images are often displayed this way. From those three primary additive colours, one can make any of the other colours such as orange, brown, turquoise, etc. That is also how your TV and your computer monitor work – when the three images in red, green and blue are superimposed on the screen, a full range of colour results.

m) Why do we get such strange colours in many of these satellite images?

Remote sensing uses parts of the spectrum that people can't see by eye: infrared, ultraviolet, radar, etc. If we want to display (on a photo or a computer monitor) one or more of these bands, we must use one or more of the three primary colours that people can see: red, green and blue. Therefore, you could get some strange combinations, like: infrared information shown as blue, red information shown as green and green information shown as blue !! The resulting colours will be nothing like what we experience using just our eyes.

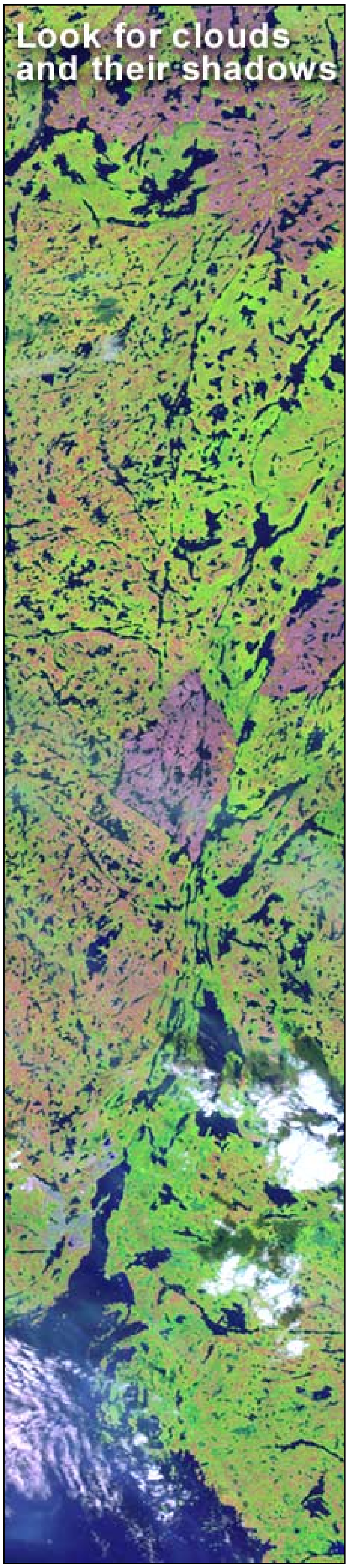
n) Can sensors "see" underground or underwater?

Under very special circumstances (using long wave radar over an area that is extremely dry) it is possible to see a few metres into the ground. In Canada, where usually the ground has lots of moisture, we are limited to seeing what's on the surface only.

Some of the visible wavelengths, like blue for instance, penetrate water quite well and if the water is clear, we can see down several metres.

o) What is a "spectral fingerprint"?

It's a way to try to identify objects in a satellite image. By using many parts of the spectrum, including the visible colours and perhaps parts of the infrared band, we try to find how an object reflects light. The way that an object reflects different parts of the spectrum is its "spectral fingerprint". There are different spectral fingerprints for different kinds of trees, crops, soil, etc.



4.3 Glossary of Remote Sensing Terms

AIRBORNE SENSING: Remote sensing from an airplane. *(Related words: airphoto, aerial)*

ANALOGUE: This is the opposite of DIGITAL. It refers to things that aren't made up of numbers. A photo taken with a film camera would be an analogue picture. A photo taken by a digital camera would be defined in terms of zeros and ones and would be considered digital. *(Related word: digital)*

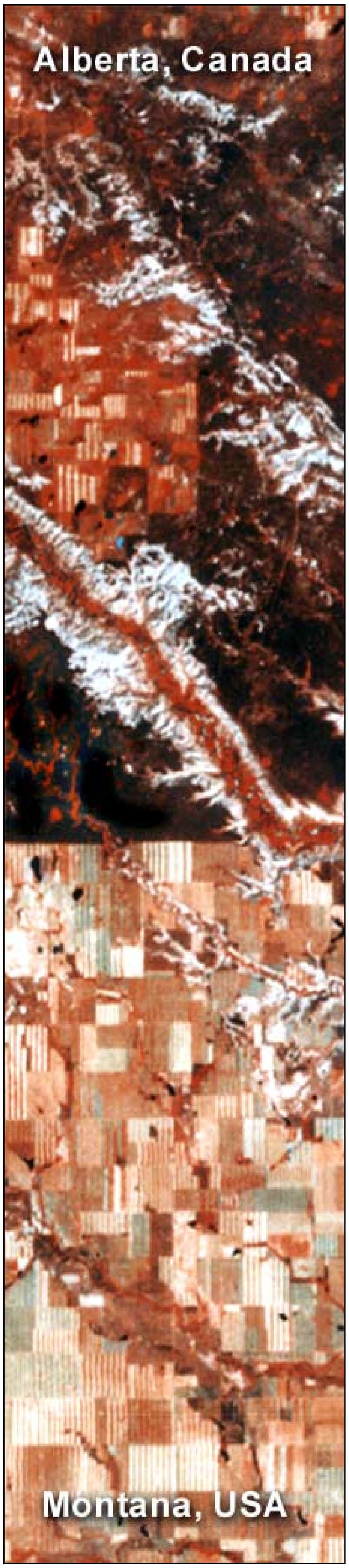
APPLICATION: The end purpose for which remote sensing is used. Most often remote sensing is used to measure, map or monitor features of our environment. (See "Student's Introduction to Remote Sensing" for examples of applications) *(Related word: apply)*

BACKSCATTERING: Energy, when hitting a target, can be scattered in many directions. The part of the energy that is scattered back in the exact direction where it came from, is "backscattered". *(Related word: reflection)*

CLOUD: If there are clouds in the area and an optical satellite like SPOT, IRS or Landsat passes overhead, the satellite image will show the cloud but the features below the cloud won't be seen. A cloud shadow, the same shape as the cloud, will be seen nearby. *(Related words: penetration, reflection, opaque)*

CLASSIFICATION: When image pixels are the same colour, or nearly the same colour, an image "classification" computer program can recognize this and group such pixels together. Such a grouping is called a "class" and the process of doing the grouping is called "classification". The remote sensing researcher then has the challenge of identifying just what each "class" represents in the real environment (pine trees? pavement? shallow water? dry grass?). *(Related word: classes)*

COMPOSITE IMAGE: We can make a "composite" image by selecting the most appropriate parts of other images. For instance, we could take only the cloud-free parts of



many images to make a “composite” image of all of Canada showing no clouds at all. It would not be a realistic scene, since we always have some clouds, but it would show all of Canada without allowing cloud cover to mask parts of it. *(Related words: combining, mosaic)*

DETECTION: If you are detecting something, you are trying to determine if it is there. This could be done using your senses or by using instruments. Once it is found, it has been detected. *(Related words: sensing, discovery, detect)*

DIGITAL DATA: Information that is made up of numbers is digital data. Telephone numbers are digital data, so are the percentage scores on your last test. So are digital images from satellites. The opposite of digital is ANALOGUE. *(Related words: digitized, analogue)*

DIGITAL ANALYSIS: If you have a digital satellite image, then it’s useful to analyze it digitally. Special computer programs are available for this. Such programs can stretch and distort a digital image to make it fit a map, they can enhance it to make it show some features more clearly, they can classify the image into categories which contain similar features, and much more. *(Related words: image analysis, classification, enhancement)*

EARTH OBSERVATION: Looking down at the Earth from aircraft and satellites using various sensors which make images that are afterwards used to study what is happening on or near the Earth’s surface. *(Related word: remote sensing)*

ELECTROMAGNETIC SPECTRUM: The range of energy which contains parts or “bands” such as the visible, infrared, ultraviolet, microwave (radar), gamma ray, x-ray, radio, and which travels at the speed of light. Different parts of the electromagnetic spectrum have different wavelengths and frequencies. *(Related words: spectrum, radiation, spectral band)*

EMIT: This word means the same as “sent out” or “given off”. The sun emits radiation, some of which we can feel as heat and some of which we can see as light. The radar sensor in RADARSAT emits a radar beam. *(Related words: transmit, radiation)*

ENHANCEMENT: Anything that you do to an image to

make it simpler, faster or more accurate to analyze and interpret by eye is a form of “enhancement”. Special enhancement techniques can improve colour, brightness, contrast, sharpness, etc. *(Related words: visual interpretation)*

GROUND STATION: See RECEIVING STATION

GROUND TRUTHING: Remote sensing analysts must be sure that their image analysis is accurate. This is done by field where they go out to the actual places shown in the images and confirm that what they think they see on the image is actually true. *(Related words: verification, calibration)*

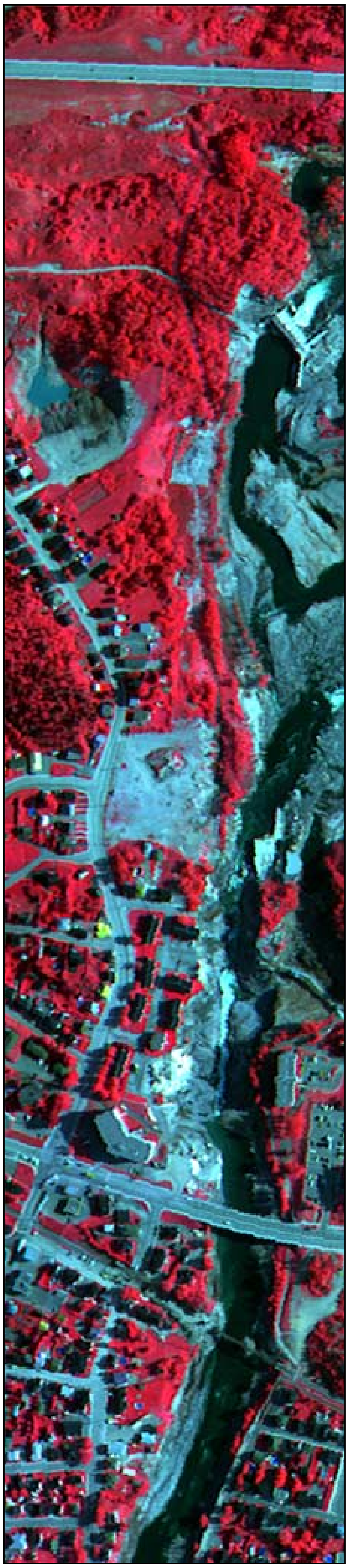
IMAGE: The picture that is a result of the sensing process. A remote sensing image can be displayed on a computer monitor or it can be made into a printed copy. *(Related word: imagery)*

IMAGE ANALYSIS: This is the process of studying an image in order to explain, measure, map, count or monitor what is on the Earth’s surface. *(Related words: interpretation, classification)*

LANDSAT: Owned and launched by the United States, this is a series of remote sensing satellites that use the visible and infrared parts of the spectrum to record images of the Earth’s surface. *(Related words: SPOT, IRS, RADARSAT, NOAA, satellite)*

LINE-OF-SIGHT: When two objects (such as a satellite and a receiving station) have nothing in between them, then they are in “line-of-sight” of each other. When a satellite is on the other side of the Earth from a receiving station, the Earth is in between them, so the satellite and the receiving station are not in “line-of sight” of each other. *(Related words: visibility, data reception)*

MONITORING: Keeping track of how things change over time. For example, with remote sensing, using several images taken over time, you can monitor the result of logging in a forest or how much of an oil slick in the ocean has been cleaned up or how well crops are growing or how much a glacier has melted or how far a plume of sediment travels in a lake, etc. *(Related words: change detection, multi-temporal analysis)*



MOSAIC: A big image made by combining smaller images. For example, to get an image of a whole province in Canada, we must combine many images. This is tricky because the images were probably taken at different times and possibly in different seasons so they could look different in colour or brightness.

ORBIT: The path traced by a satellite as it passes around a planet. *(Related words: path, satellite, near polar, geostationary)*

PIXEL: The smallest unit in a digital image. A satellite image is made up of a matrix of many pixels, each having its own digital value. *(Related words: image, digital analysis)*

PLATFORM: This is what carries a sensor – usually a satellite or an airplane. But a remote sensing platform could also be a hot-air balloon, a tall tower, etc. *(related words: satellite, aircraft, sensor)*

RADAR SHADOW: Just as with a flashlight, a radar sensor "illuminates" a scene, and if an object blocks the beam, a shadow area develops behind it. Such shadows can be seen in a radar image. Radar shadows are pure black – they contain absolutely no information. *(Related word: radar beam)*

RADARSAT: This is the first Canadian remote sensing satellite. It uses radar technology to capture images of the earth's surface. *(Related words: satellite, radar)*

RECEIVING STATION: At a receiving station, antennas collect the signals sent by an orbiting satellite. Electronic devices process the signals and the data are stored. Usually the station also converts the data into usable digital and printed images. *(Related words: satellite, reception, downlink)*

REFLECTION: Reflection occurs when radiation (light, radar signals, etc.) bounces off a target. It is very important in remote sensing how that reflection happens, how much is reflected and how the radiation is changed in the process of reflection, because it tells us much about the target that caused the reflection.

REMOTE SENSING: Remote sensing is the action of collecting images or other forms of data about the surface of the Earth, from measurements made at some distance above the Earth, processing these data and analyzing them. *(Related words: earth observation, environmental monitoring)*

RESOLUTION: Spatial resolution describes how clearly you can see detail in a picture. Consider the focussing done by a camera. If the picture is blurry and you can't see small objects, the resolution is poor (low resolution). If the picture is sharp and you can see small objects, the resolution is good (high resolution). Resolution is also used in describing colour detail (how similar colours are) and even time detail (how close in time things happen). *(Related words: detail, image analysis)*

SATELLITE: A satellite is a natural or man–made object continuously orbiting above the Earth or another planet or star. A remote sensing satellite carries one or more instruments for recording images of the Earth, which are transmitted to a receiving station using radio waves. *(Related words: platform, receiving station, orbit)*

SCANNER: While a camera would take a picture of an area all at once, a scanner is a device that examines an area point by point until the entire area has been imaged. These points become the pixels in a digital remote sensing image.

SENSOR: A sensor is the device that records a remote sensing image, much like a camera. *(Related words: scanner, platform)*

SPECTRUM: See ELECTROMAGNETIC SPECTRUM

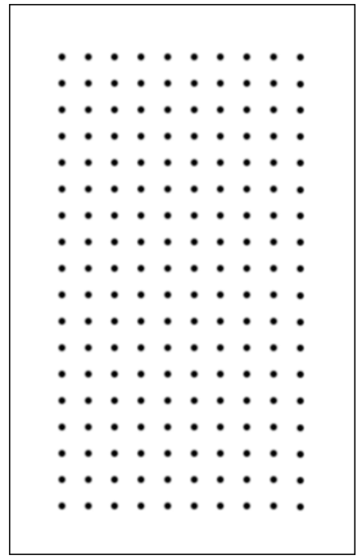
TARGET: Targets are the features being studied in a remote sensing image. *(Related words: backscatter, reflection)*

TRANSMIT: Energy that passes through an object or material is "transmitted". This is in contrast to energy that may be reflected or absorbed. A window (which is not too dirty) allows light to transmit through and thus we are able to see through glass. *(Related words: reflect, absorb, backscatter)*

Appendix A: Using a Dot Grid (to Measure Area)

Using the dot grid technique:

1. Trace the dot grid onto a piece of acetate film.
2. Place the acetate with the dot grid, over the area that you want to measure. It doesn't matter how the acetate fits over the image, as long as all of the area to be measured is covered by the dots.
3. Count the dots that fall within the area to be measured. Once you start counting, don't move the acetate. If a dot is on the edge of the area, count it if it's more than one half inside the area, and don't count it if it's less than one half inside the area.
4. The number of dots that represent 1 square kilometre will be specified in each activity. Divide the total dot count that you made by that number to arrive at the final area in square kilometres.



Appendix B: Using a Compass

A "compass rose" is an illustration such as the one on this page, showing the points of the compass.

The main directions: north, south, east, west are called the "cardinal points" of the compass.

Always look for the compass rose, or perhaps a "north arrow", to see in which direction an image is oriented. North isn't always to the top, although that is a popular convention.

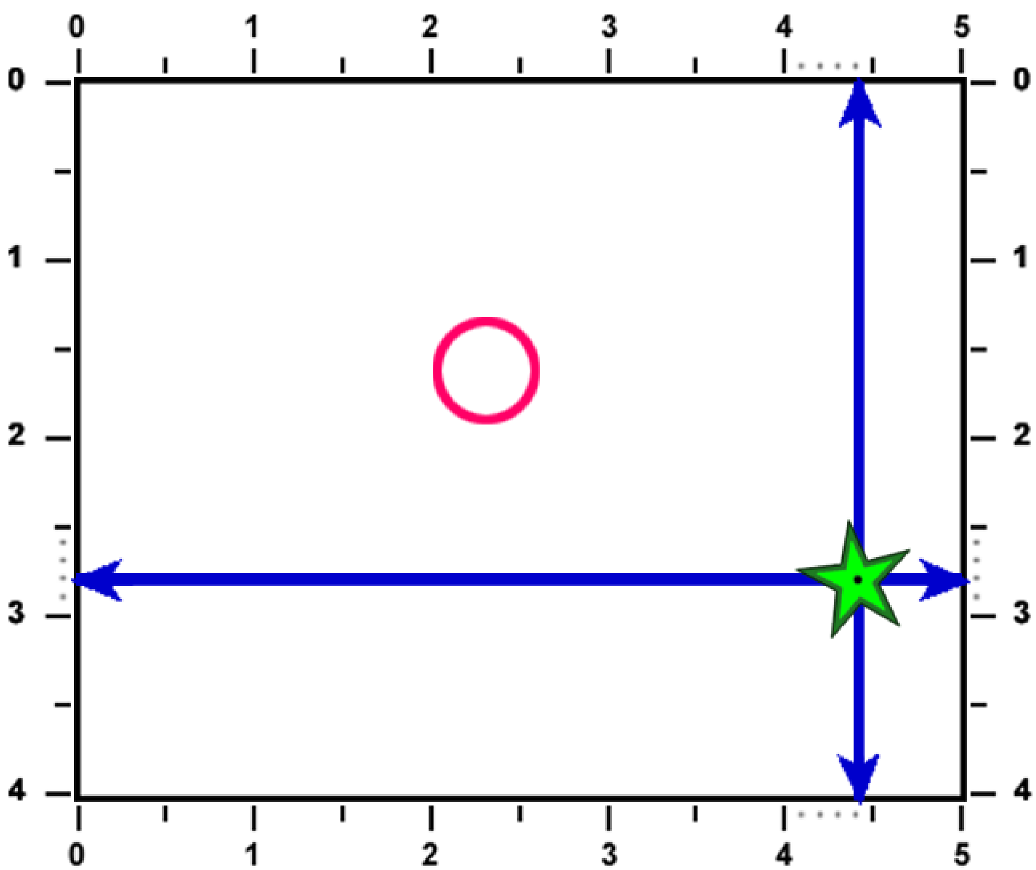
Appendix C: Using Coordinates

One convenient and precise way to point to a certain spot on a picture (or a map) is by the Cartesian Coordinate method. A series of numbers (or sometimes letters) on the edge of the picture lets you identify a spot without having to put some reference mark inside the picture.

If we want to talk about a feature such as a lake, road or field in a satellite image and we don't want to mark up the image itself, then we can use two numbers to identify the spot. The first number is always the horizontal distance and the second number is always the vertical distance.

In the example here, the star has a horizontal coordinate of 4.4 and a vertical coordinate of 2.8, and they are often written as: (4.4, 2.8). Use a straight edge like a ruler or a piece of paper to line up the numbers. Make sure the straight edge is exactly parallel to the edge of the image. This can be done by connecting the same number (4.4 in this example) on both the top and the bottom scale. Do the same for the second number by lining up the same number (2.8 in this example) on both the left and right scales.

To see if you can do this, try to find the coordinates of the centre of the circle in the diagram. They are: (____, _____)



Appendix D: Answers to the Activities

3.1 Which is Which ?

a) 2 b) 7 c) 12 d) 9 e) 8 f) 10 g) 5	h) 10 i) 4 j) 11 k) 3 l) 6 m) 1

3.2 Find It

1) C: (7.7, 6.1) 2) A: (5.2, 2.6) 3) B: (4.8, 6.7) 4) A: (8.2, 4.2)	5) D: (5.7, 8.0) 6) B: (5.5, 6.4) 7) D: (5.3, 5.0)

3.3a Measure This (northern Saskatchewan)

1) D: (2.0, 0.5)
2) A: light pink
3) C: less than 1km long
4) A: 17 km
5) B: less than 1 square km
6) D: 10 km

3.3b Measure This (Halifax area)

1) D: (1.4, 0.7)
2) A: south
3) C: (1.0, 1.2)
4) B: 16 km

3.4 Clearcutting in the Forest

D) (0.7, 5.0) (2.4, 3.0) (6.5, 9.2)
E) approximately 7.4 square km

3.5 Oil Spill Danger

A) Ormond
B) Canto
C) June 18 (in 5 days)
D) Approximately 67 barriers

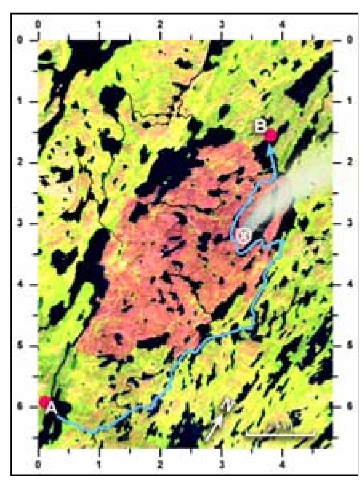
3.6 Crops Types

Task #1 Town: (1.4, 1.6) Village: (4.1, 5.3) River exits at: (6.0, 2.8) Railway exits at: (0.0, 5.5)	
Task #2 a) beans b) beans c) alfalfa d) corn	e) corn f) grains g) grains
Task #3 a) trees and shrubs b) approximately 32 fields	

3.7 Forest Fire

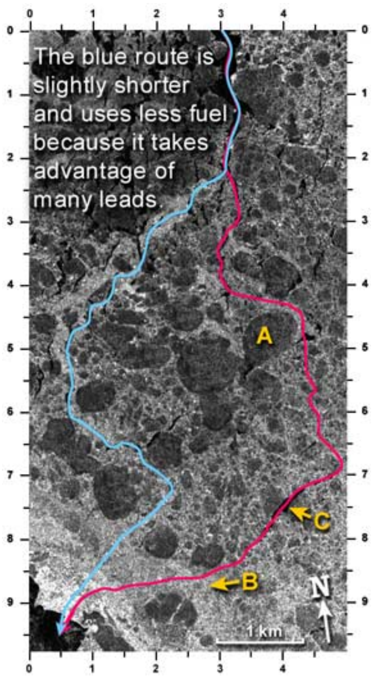
Task #1
Approximately 16 km

Task #2
Closest Lake is at: (2.1, 2.1)
Next closest lake is at: (0.7, 3.7)



3.8 Navigating a Ship Through Ice

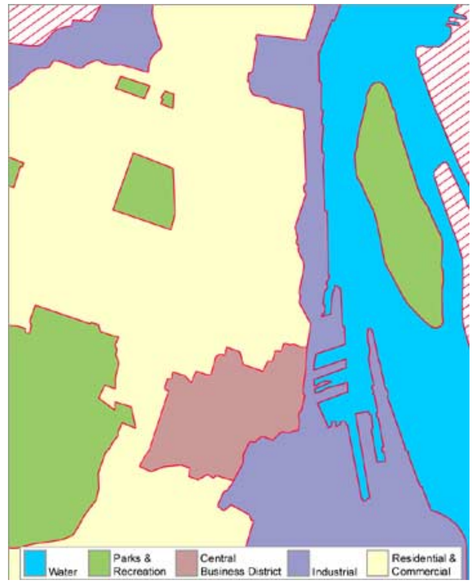
Task Distance: 8.5 km (blue route) The more difficult route is >9 km (red route)



3.9 You Figure it Out !

Sandspit	Queen Charlotte City
A) 3 B) 4 C) 1 D) 2 E) 4 F) 4	A, B) 2 C) 3 D) 4

3.10 Land Use Mapping



3.11 At a Mine Site

1) (4.5, 2.7) 2) (2.0, 6.0) 3) (6.5, 6.7) 4) (4.6, 3.2)	5) (3.7, 3.7) 6) (6.5, 8.1) 7) (4.1, 8.8)

3.12 A Different Perspective

1) H 2) D 3) F 4) A 5) C 6) G 7) B 8) E