GEOMORPHOLOGY LABORATORY MANUAL

GEOG 2351 / ENST 2351

Dr. Kamil Zaniewski

Jason T. Freeburn

FALL 2016

DEPARTMENT OF GEOGRAPHY & THE ENVIRONMENT

LAKEHEAD UNIVERSITY

Course Outline
Fall 2016

Course Instructor:
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Lectures: Mondays, Wednesdays 5:30 – 6:30 in AT-1006

Labs: (F1) Fridays 2:30 – 4:30 in RC-2003
(F2) Thursdays 10:30 – 12:30 in RC-2003

Course Description:

This course is an introduction to geomorphology, the study of landforms and the processes that produce and alter them. Emphasis is placed on the mechanics of geomorphic processes. The relationships between landscapes and the forces responsible for their shape (endogenic processes, gravity, wind, ice, water and waves) will be discussed in lectures. Students will be expected to understand the fundamental principles of geomorphology and be able to demonstrate clear understanding of the global landscape forming processes and landforms. Students will also be expected to attend field trips and participate in any discussion initiated during lectures or labs. Laboratory work will include analysis of landforms from maps and air photos.

Course Objectives:

On completion of this course you will be thoroughly familiar with the basic concepts and laws of geomorphology. You will be able to identify landforms and explain the processes by which they were formed. You will also learn basic practical skills (through lab work) associated with this field of science.

Textbook:

Trenhaile, A.S. 2013. Geomorphology: A Canadian Perspective. Fifth Edition. Don Mills, Ontario: Oxford University Press.

Lab Manual:
Geomorphology Laboratory Manual. Fall 2016.

Course Grading:

Lab Assignments	30%
Fieldtrip Attendance	5%
1st Test*	15% (Oct. 19)
2nd Test*	20% (Nov. 16)
Final Exam*	30%

*To pass the course, students are required to have at least 33 of the 65 marks allocated to the tests.

Course Policies

The following course policies are consistent with those of the Geography Department and Lakehead University.

1. Regular attendance is expected in lectures.

2. Any absence due to illness, disability, or domestic affliction should be reported to the instructor. Absence due to extracurricular activities (e.g. athletics) should be discussed with the instructor **PRIOR** to the absence. If you miss a class, it is your responsibility to obtain the notes from a classmate. I can provide you with any handouts, but will not provide you a repeat of the lecture or my lecture notes.

3. Students with special needs should talk to me at the beginning of the course and register with the Student Success Centre.

4. Tardiness is frowned upon. Be late at your own risk.

5. Assigned readings, when provided, are to be read prior to the next lecture. This will allow you to get the most out of the lectures and ask informed questions.

6. Questions may be asked **anytime** during lectures. I won’t be offended.

7. No make-up exams will be given without a medical excuse backed by a medical certificate. No one will be allowed to write the tests or the final exam **prior** to the scheduled date.

8. Lab assignments are to be handed in before the specified due date. Material submitted after the deadline will be accepted but may be penalized 10% per day.

9. Lab assignments will be graded for **content, legibility, structure, spelling** and **grammar**.

10. Lab and fieldwork safety instructions will be strictly enforced. Failing to comply with the directions given by the instructor or the lab instructor may result in dismissal from the session concerned.

LAB TOPICS SCHEDULE

Date	Number	Title
Sept 8, 9	1	Basic Analytical Techniques
Sept 15, 16	2	Magnitude – Frequency Concept
Sept 29, 30	3	Cordilleran Glaciation
Oct 6, 7	4	Glacial Spillways
Oct 13, 14		FALL READING WEEK
Oct 20, 21		Field Trip Week – No labs
Oct 27, 28	5	Stream Discharge/Field trip follow-up
Nov 3, 4	6	Stream Networks
Nov 10, 11	7	Stream Sinuosity
Nov 17, 18	8	Mass Movements
Nov 24, 25	9	Coastal Processes

FIELD TRIP

Date	Title
Oct 23	Thunder Bay's Past and Modern Geomorphic Processes (*handout to be provided at time of trip.*)

Basic Geographical Techniques Useful in Geomorphology

Objective: To review and practice a subset of analysis techniques commonly used for study in the field of geomorphology, including unit conversions, plotting graphs, and drawing isolines.

TASK 1: Unit Conversions

Table 1. Matrix of unit conversions for length.

	Metre	Centimetre	Millimetre	Kilometre	Inch	Foot	Mile
Metre	1	100	1,000	0.001	39.37	3.2808	0.000621
Centimetre	0.01	1	10	0.00001	0.3937	0.0328	6.21E-06
Millimetre	0.001	0.1	1	0.000001	0.03937	0.00328	6.21E-07
Kilometre	1,000	100,000	1,000,000	1	39,370	3,280.8	0.62137
Inch	0.0254	2.54	25.4	2.54E-05	1	0.0833	1.58E-05
Foot	0.3048	30.48	304.8	0.000304	12	1	0.000189
Mile	1,609.34	160,934	1,609,344	1.60934	63,360	5,280	1

Table 2. Matrix of unit conversions for weight.

	Metric Ton	Kilogram	Gram	Pound	Ounce
Metric Ton	1	1,000	1,000,000	2,204.62	35,273.96
Kilogram	0.001	1	1,000	2.20462	35.273
Gram	0.000001	0.001	1	0.0022	0.03527
Pound	0.00045	0.45359	453.59	1	16
Ounce	0.00002834	0.028349	28.349	0.0625	1

Table 3. Matrix of unit conversions for area.

	m^2	km^2	hectares	acres
m^2	1	0.000001	0.0001	0.000247
km^2	1,000,000	1	100	247.1
hectares	10,000	0.01	1	2.471
acres	4,046.9	0.004047	0.4047	1

Some other common measures and their units include:

- Speed or Velocity: $m\ s^{-1}$, $km\ h^{-1}$
- Volume: ml, L, m^3
- Density: $g\ cm^{-3}$, $kg\ m^{-3}$
- Acceleration: $km\ h^{-1}s^{-1}$, $m\ s^{-2}$

Lab #1 Questions

Name:__________________

1. Answer the following questions. Show your calculations.

   a) # of feet in 4.3 kilometres

   b) # of centimetres in 4 miles 665 metres

   c) # of grams in 24 pounds 9 ounces

   d) # of hectares in 150 acres plus 46 NFL football fields (Note: 1 football field = 360 feet X 160 feet)

2. A rectangular bucket has dimensions of 24"x30"x12". The bucket is completely full of sediment, and the sediment weighs 42.3 pounds. What is the density of the sediment in kg m^{-3}?

3. Due to significant rain and intense, spring freeze-thaw period, a large section of rock rests precariously at a height of 8500 feet. A rockfall occurs, sending the rock tumbling down the

mountain slope. 4.2 seconds downslope, the velocity of the rockfall is 39.8 miles $hour^{-1}$. What is the average acceleration of the rockfall, in m s^{-2}, over this distance?

4. A mountain has 5500 vertical feet of elevation. A skier gets on a chairlift going up the mountain at a speed of 2.7m $second^{-1}$. One minute and 42 seconds later, an avalanche starts 50m below the mountain summit, descending at a speed of 64 miles $hour^{-1}$. How far from the summit, in metres, is the skier when she gets intercepted by the avalanche.

<u>Task 2</u>: Plotting Graphs

Graphs provide a means of presenting (usually quantitative) data in an alternative form for the purpose of providing additional context for the viewer. In many sciences including geomorphology, graphs are often used to examine and evaluate the relationship between two or more variables. When the case is that of simply wishing to know whether a relationship exists, the choice of X vs. Y-axis variables is irrelevant. When graphing one variable as a function of another, the standard convention is to place the 'dependent' variable on the Y-axis and the 'independent' variable on the X-axis.

1. Using the standard graph paper provided and the data listed below, plot runoff as a function of rainfall [i.e., Runoff = *f*(rainfall)]. Make axes increments such that all data can be plotted and as much of the graph is used as possible. Be sure to label both axes. Add a straight line through your plotted points.

Rainfall (cm)	Runoff (cm^3)	Rainfall (cm)	Runoff (cm^3)
5	10	3.5	6
1	0	4.5	7
1.5	0	4	8
7	13.5	2	1
3	6	8	15

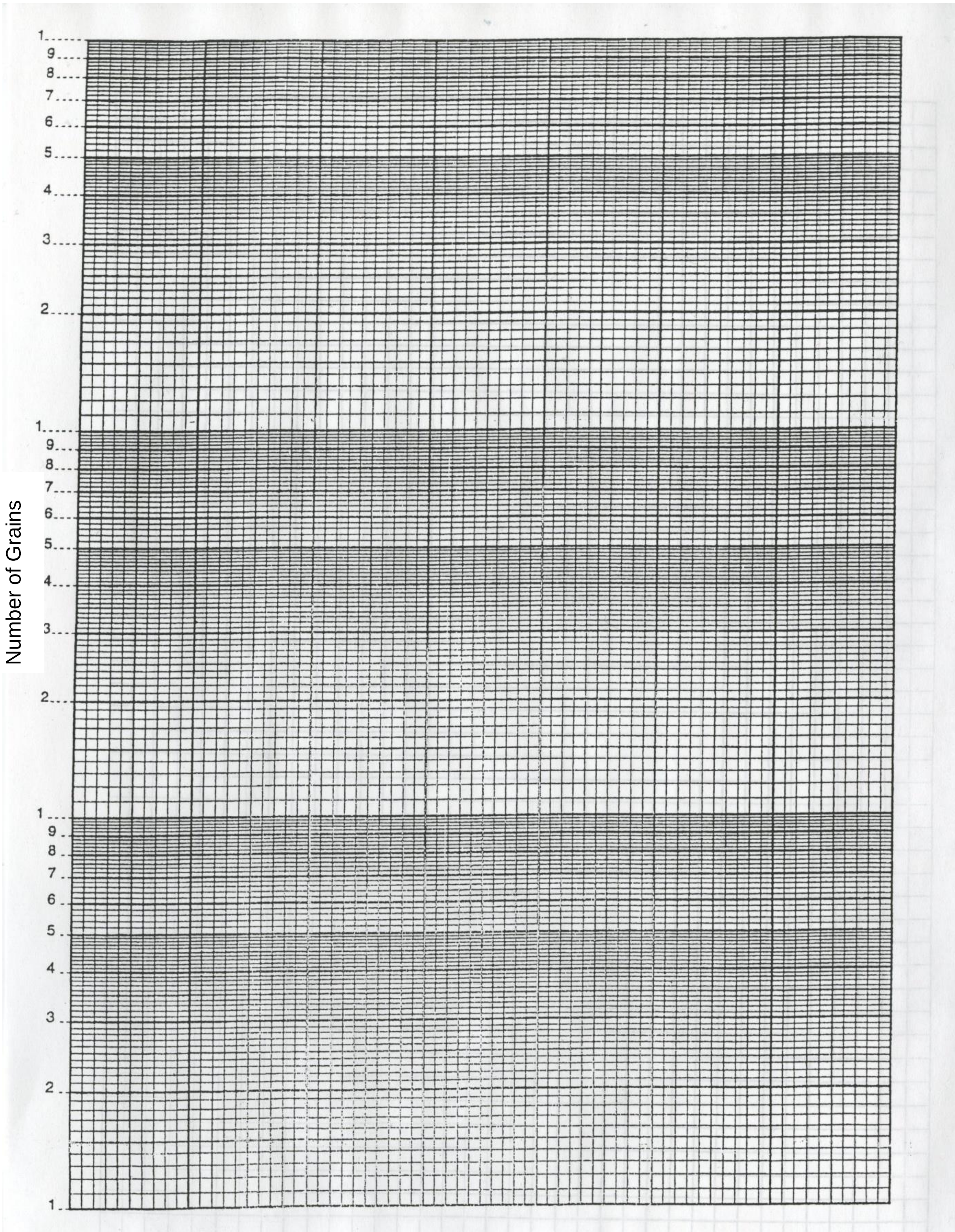
In the example above, a simple linear relationship can be illustrated on standard graph paper. However, sometimes two variables share a power relationship where values in the variable series increase by multiples rather than additive increments. These relationships may be referred to as exponential or logarithmic, and they are often problematic to plot on standard graph paper. A variable series of 2, 3, 4, 85, 1000, and 3500, when plotted on standard graph paper, would eliminate any visual difference between the lower numbers. Evaluation of the relationship between the variables could also be jeopardized, and graphically appears as a curve rather than a straight line. In such instances, a useful alternative is often to plot on logarithmic paper. Semi-log graph paper is used when one variable increases arithmetically and the other geometrically. Log/log paper is used when both variables increase geometrically.

2. Using the semi-log graph paper provided and the data listed below, plot the number of sediment grains in transport as a function of the grain size [i.e., # of grains = *f*(grain size)]. Add a straight line through your plotted points.

# of Grains	Grain Size (Φ)	# of Grains	Grain Size (Φ)
1	0	55	5
2	1	125	6
5	2	270	7
12	3	595	8
25	4		

Runoff as a Function of Rainfall

Number of Grains as a Function of Grain Size



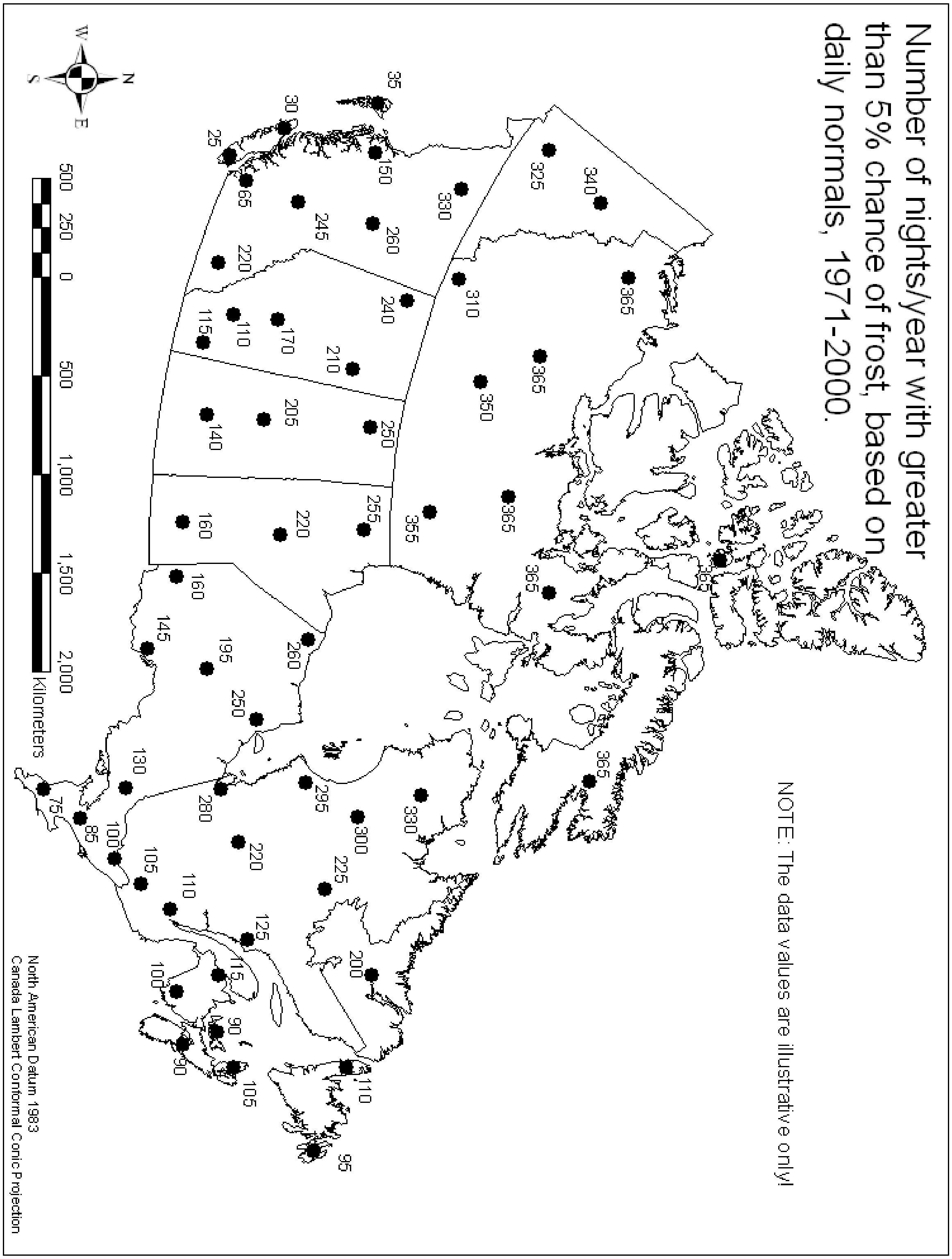
Grain Size (Φ)

<u>Task 3</u>: Drawing Isolines

Isolines connect points of equal value. Geographers are often confronted with point spatial data variables collected at a number of points throughout an area. A good example could be meteorological station data from across Canada. To better visualize the variability of the data and study that variability at multiple spatial scales, isolines can be created. Perhaps the most commonly used isolines in geography appear on topographical maps as contours; lines connecting points of equal elevation. Some other examples of isolines include:

- Isobars – equal air pressure
- Isotherms – equal air temperature
- Isobath – equal depth under water
- Isochrone – equal time-distance from a point

1. On the sketch map below, the point values represent the number of days/year with frost (i.e., how long the uppermost layer of ground is frozen each year). Draw isolines representing equal number of nights with potential frost at an interval of 50 days, starting at 50 and ending at 350. Label each line at the edge of the mapped area.


Number of nights/year with greater than 5% chance of frost, based on daily normals, 1971-2000.
NOTE: The data values are illustrative only!
W N S E
500 250 0 500 1,000 1,500 2,000
Kilometers
North American Datum 1983
Canada Lambert Conformal Conic Projection

Magnitude/Frequency Concept, Stream Flow and Flood Analysis

<u>Objective</u>: To analyze the magnitude/frequency concept with regard to stream flow and flooding. Flood recurrence intervals, long-term flood levels, and stream hydrographs will be studied using the Red River as an example.

<u>TASK 1</u>: Developing a Magnitude/Frequency Graph

The magnitude/frequency concept can be applied to geomorphic events, considering the more catastrophic the event (i.e., higher magnitude), the less likely it will occur (i.e., lower frequency). The concept can be applied to earthquakes for example, where higher magnitude quakes occur far less frequently than lower magnitude quakes. The concept can also be applied, as we will do in this exercise, to stream flow and flood events. The impact of flood events can be measured in terms of the "work" done on the landscape, and one way of measuring such work is to consider the amount of sediment removed from the stream's basin and transported.

Figure 1 (below) illustrates how the "stress" applied to the landscape varies as a function of the rate of movement, or magnitude, of an event, the frequency of events, and thus the total "work" done. This graph is intended to represent the theoretically ideal situation for the magnitude/frequency concept. For Task 1, the validity of the magnitude/frequency concept will be evaluated using data from Table 1, representing the 1983 stream flow record for the Red River, Manitoba.

Figure 1: Theoretical Relationship between Rate of Movement, Frequency of Occurrences, and Work Done on the Landscape.

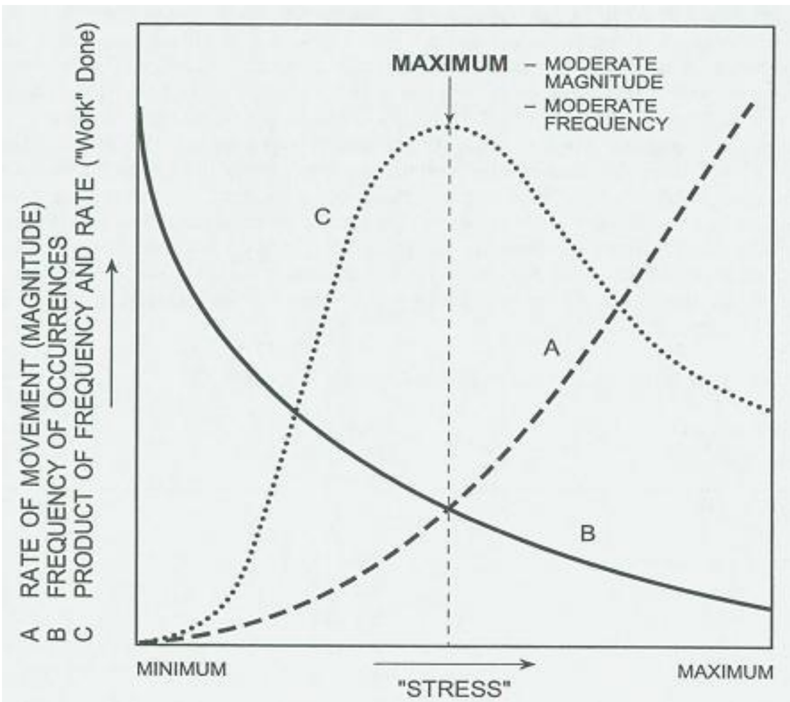


Table 1: Flow Data for the Red River, Manitoba (1983).

1 Discharge Class (m^3s^{-1})	**2 # of Discharges (*Frequency*)**	**3 Total Sediment Load in tonnes (*Work*)**	**4 Average Sediment Load (*Magnitude*)**
0-99	225	110,730	492.1
100-199	72	236,064	3278.7
200-299	28	175,440	6265.7
300-399	30	122,680	4089.3
400-499	3	19,950	6650.0
500-599	2	14,160	7080.0
600-699	4	63,400	15850.0
>700	1	19,400	19400.0
Total	365	761,824	

TASK 1 Exercise:

1. Using Figure 2 and the values from Table 1, plot the Magnitude (column 4) on the vertical axis as a function of the midpoint of the discharge class (column 1) on the horizontal axis (e.g., for the 0-99 discharge class, plot the value at 50).

2. Plot the Frequency (column 2) as a function of the midpoint of the discharge class (column 1).

3. Plot the Work done (column 3) as a function of the midpoint of the discharge class (column 1).

4. Answer Summary Question 1.

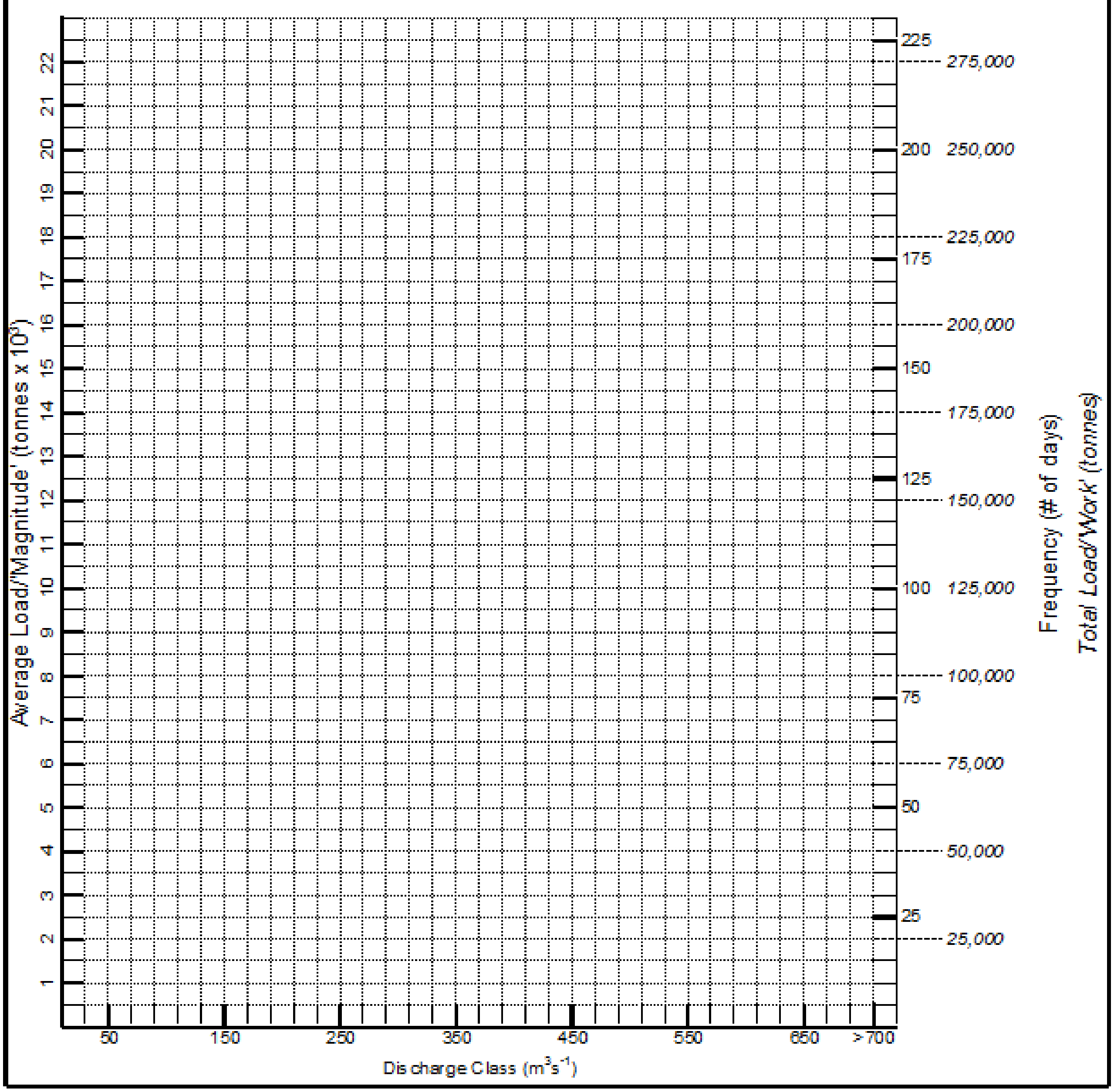
<u>TASK 2</u>: Analysis of Flood Recurrence Interval

Of primary concern to urban planners, engineers and others, with regard to stream flow, is how often a flood of a given magnitude will recur. As demonstrated in Task 1, larger flood events will occur less frequently than smaller events, but that does not answer the probability of a flood of a given magnitude occurring. The method to make such assessments requires calculation of a recurrence interval and associated probability, which can be defined as follows:

$T = (n + 1) / m$ where:
- T = recurrence interval (years)
- n = total number of years of hydrological record
- m = magnitude, or rank of the flood (e.g., $m=1$ for largest flood on record)

$\%Probability = (1 / T) * 100$

Figure 2: Stream Flow Analysis, Based on Discharge Class, for the Red River, Manitoba (1983)



These calculations allow for each discharge to be plotted against its recurrence interval, with a line of best fit through such points representing a frequency curve. The frequency curve can then be used to predict the frequency (or probability) of a flood of a given magnitude to occur.

TASK 2 Exercise:

1. In Table 2 (provided), 60 years of hydrological data for the Neebing River, Thunder Bay, Ontario have been ranked. The recurrence interval and probability have been calculated for 50 of the 60 years. Using the formulas above, calculate the recurrence interval and probability for the final 10 years.

2. On Figure 3 (provided), the recurrence interval has been plotted as a function of the discharge for the first 50 years of hydrological data. Using your calculations for the last 10 years of hydrological data, add those points to Figure 3.

3. Add a curvilinear line through the series of points on Figure 3.

4. Answer Summary Questions 2 and 3.

TASK 3: Constructing a Stream (Flood) Hydrograph

A stream hydrograph illustrates the changes in discharge as a function of time during a flood event. A flood is not an instantaneous event; rather the discharge increases to a peak flow then decreases back to a normal flow. Figure 4 (below) represents an idealized hydrograph, which in this case also includes precipitation and temperature information. For much of Canada, spring flooding is most common as a result of discharge increases from the snow pack melting combined with precipitation. Flooding in other seasons is often caused solely by precipitation/runoff.

Figure 4: Theoretical Hydrograph for a Flood Event

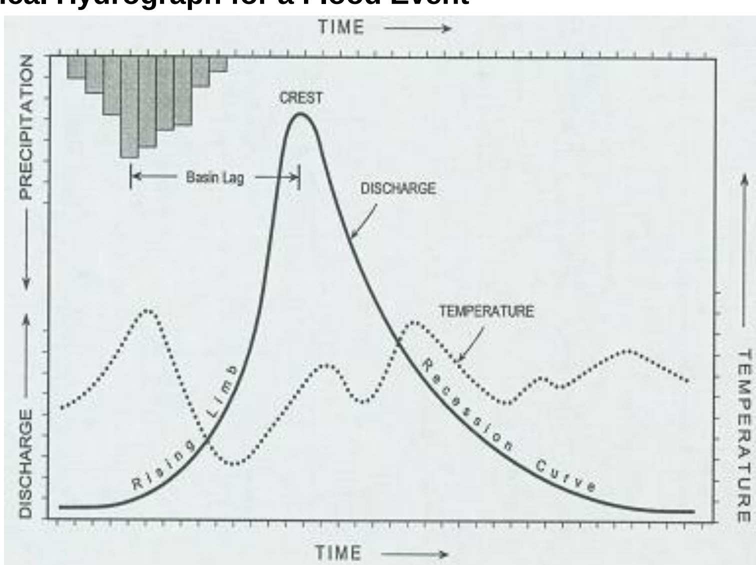


Table 2: Maximum discharge in each year for the Neebing River, Thunder Bay, Ontario

YEAR	Qmax: m^3s^{-1}	RANK	Recurrence Interval (T)	%Probability
1954	38.2	12	5.1	19.7
1955	18.8	39	1.6	63.9
1956	19.1	38	1.6	62.3
1957	34.3	14	4.4	23.0
1958	6.8	58	1.1	95.1
1959	8.44	57	1.1	93.4
1960	21	32	1.9	52.5
1961	9.66	55	1.1	90.2
1962	10.5	51	1.2	83.6
1963	22.8	29	2.1	47.5
1964	29.2	19	3.2	31.1
1965	24.4	26	2.3	42.6
1966	23.7	27	2.3	44.3
1967	16.5	43	1.4	70.5
1968	49.3	5	12.2	8.2
1969	33.4	15	4.1	24.6
1970	25.7	25	2.4	41.0
1971	64.6	2	30.5	3.3
1972	27.9	20	3.1	32.8
1973	33.1	16	3.8	26.2
1974	27.5	21	2.9	34.4
1975	17.5	42	1.5	68.9
1976	45.3	7	8.7	11.5
1977	60	3	20.3	4.9
1978	16.5	43	1.4	70.5
1979	41.6	10	6.1	16.4
1980	16.5	43	1.4	70.5
1981	21	32	1.9	52.5
1982	26.5	24	2.5	39.3
1983	16.5	43	1.4	70.5
1984	10.4	52	1.2	85.2
1985	14.2	48	1.3	78.7
1986	21.1	31	2.0	50.8
1987	2.75	60	1.0	98.4
1988	12.3	50	1.2	82.0
1989	10.3	53	1.2	86.9
1990	12.4	49	1.2	80.3

YEAR	Qmax: m^3s^{-1}	RANK	Recurrence Interval (T)	%Probability
1993	26.8	22	2.8	36.1
1994	9.78	54	1.1	88.5
1995	9.21	56	1.1	91.8
1996	26.6	23	2.7	37.7
1997	20	36	1.7	59.0
1998	17.9	40	1.5	65.6
1999	22.9	28	2.2	45.9
2000	19.7	37	1.6	60.7
2001	21	32	1.9	52.5
2002	33	17	3.6	27.9
2003	56.4	4	15.3	6.6
2004	44	8		
2005	37.6	13		
2006	17.6	41		
2007	30.4	18		
2008	46.3	6		
2009	22.2	30		
2010	5.4	59		
2011	21	32		
2012	91.5	1		
2013	40.4	11		

One notable recent flood event in Thunder Bay was the 2012 Neebing River flood. Table 3 includes discharge data for the Neebing River during that period.

Table 3: Stream Discharge Data for the Neebing River at Thunder Bay, Ontario during the 2012 spring flood

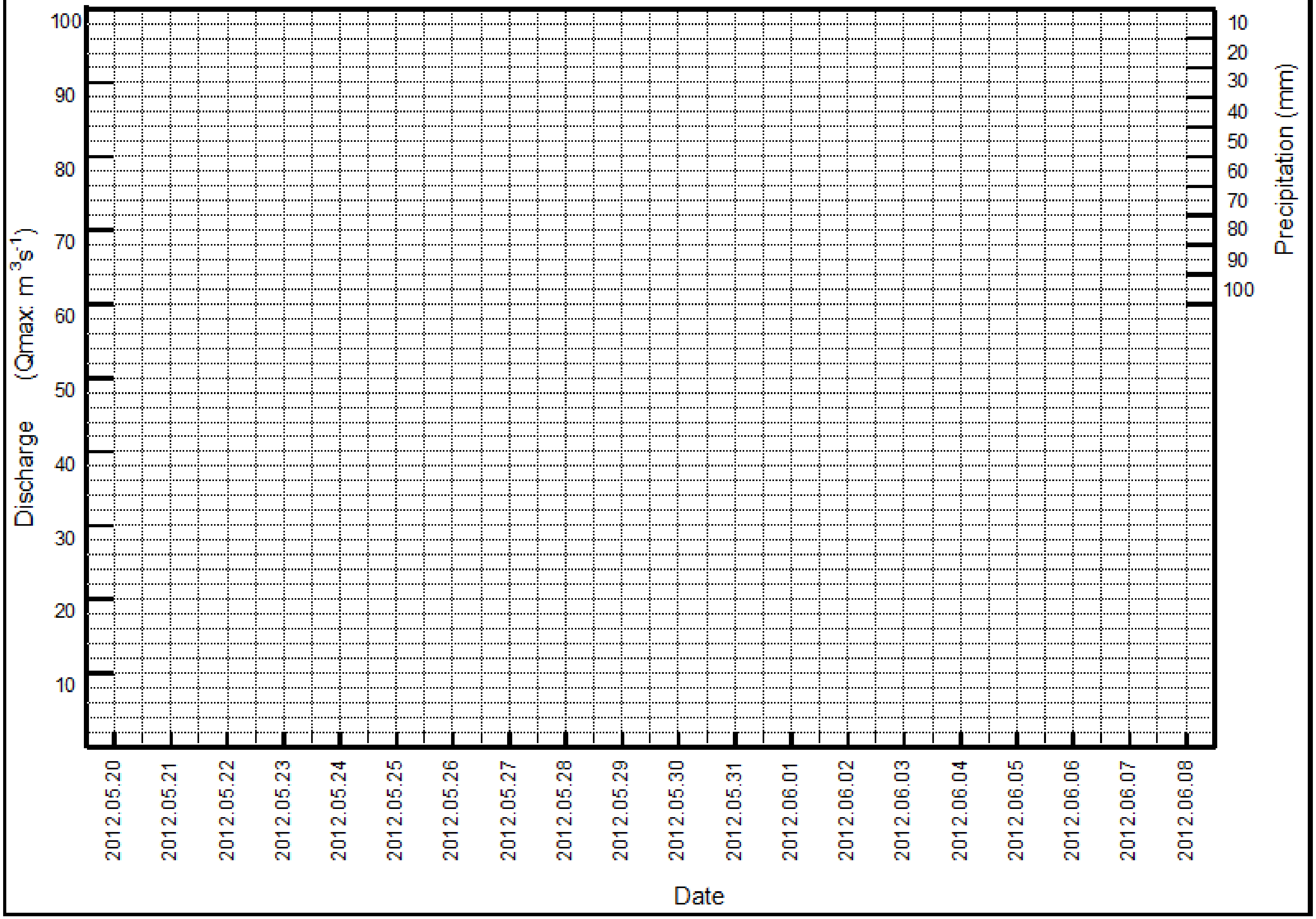
DATE	Discharge (Qmax: m^3s^{-1})	Precipitation (mm)
2012.05.20	1.0	15.0
2012.05.21	1.3	0
2012.05.22	1.2	1.2
2012.05.23	1.3	12.6
2012.05.24	3.5	48.1
2012.05.25	18.1	0
2012.05.26	17.3	0.7
2012.05.27	13	91.3
2012.05.28	91.5	3.0
2012.05.29	56.2	2.1
2012.05.30	21.4	0
2012.05.31	12.3	0.3
2012.06.01	8.4	0
2012.06.02	6.2	0
2012.06.03	4.6	0
2012.06.04	3.9	0
2012.06.05	3.4	0
2012.06.06	2.9	0.3
2012.06.07	2.2	7.3
2012.06.08	1.8	0

TASK 3 Exercise:

1. Using Figure 5 (provided) and the values from Table 3, construct a hydrograph for the 2012 Neebing River flood. Connect your points with a spline curve (i.e., not straight lines).

2. Answer Summary Questions 4 and 5.

Figure 5: Hydrograph for the Neebing River, Thunder Bay, Flood of 2012



Lab #2 Summary Questions

Name: ____________________

1. Given there is nothing extraordinary about the Red River, do you think your results on Figure 2 support the magnitude/frequency concept? Explain why or why not.

2. Based on your results from Figure 3, what discharge must be accommodated to protect against a:
   a) 10-year flood (T = 10) __________________________
   b) 5-year flood (T = 5) ____________________________
   c) 50-year flood (T = 50) ___________________________

3. Based on data in Table 2, the Mean Annual Flood (MAF) (i.e., average of the discharges) is 26.13 m^3s^{-1}. From Figure 3, estimate the recurrence interval (T) for the MAF.

   T = _______________________

4. The events of 2012 did not result in an extensive regional flooding and the damage was limited to few, low-lying, areas. However, it could have been worse. Let's envision a scenario where a 75 m^3s^{-1} discharge rate of the Neebing River produced a breach of the banks and flooding – forcing an evacuation of the affected areas. Using Figure 5, how many days would the evacuees be left out of their homes (assuming they wouldn't be allowed to return until the discharge rate fell to below 60 m^3s^{-1})?

   # of days = _________________

5. What is the basin lag (the time delay between the peak precipitation and the river crest expressed in days) for the Neebing River?

Cordilleran Deglaciation:
Analysis and Interpretation of Landforms of Valley Glaciation

Given: NTS 1:250,000 map sheet, St. Elias [115B and 115C (E half)] – based on 1951 and 1956 aerial photography;
Air Photo pairs (various) from the late 1960's (*undated, but received in 1968*)

The history of the Cordilleran Ice Sheet was largely unrelated to that of the main Laurentide Ice Sheet, and more closely resembles the traditional Scandinavian hypothesis of coastal mountain chain glaciation. Though at the Wisconsin maximum, a linear ice sheet covered most of the Cordillera, there is evidence that due to the 'rainshadow effect', the eastern foothills ice margin seldom, if ever, joined with the Laurentide sheet, and a large part of Yukon is known to have remained unglaciated, since it was too dry for much precipitation.

Deglaciation commenced in those areas in which an ameliorating trend would be felt first (i.e., where low elevation, south easterly aspect and drier conditions prevailed). To generalize, deglaciation proceeded from the south and east, the ice cap degenerating into marginal valley glaciers and ultimately into fluvial systems, this wave of geomorphological and climatic change breaking up the Cordilleran sheet into a number of independent patches, each of which retreated upslope until today the only vestiges lie at high elevation where snow accumulation still manages to exceed ablation.

The St. Elias mapsheet shows well the transition from ice field to late stage valley glaciation to ice free conditions, along a west to east axis. Since a similar sequence of events has taken place or will take place at every point along that axis, the map can be said to provide a diachronous (Greek- dia=throughout, chronos=time) picture of Cordilleran deglaciation, the western portion of the map one day becoming ice free as in the eastern portion. Meantime, strong east to west and north to south variations due to elevation and aspect are sustained.

The strongest differences between valley sides will be seen when valleys are of an east-west orientation, as many are on this map sheet. Very strong contrasts in **insolation** on north and south facing slopes result in a valley asymmetry which is a feature of the Mt. St. Elias area.

NOTE: The US portion of the area is represented by a section of a USGS map which illustrates a different cartographic approach from the Canadian part. The contour interval is different and much more detail of the glacier surface is portrayed. The Canadian map makes the glaciers appear even and smooth which is far from the real condition.

Lab #3 Summary Questions

Answer the questions below briefly but concisely using the map, air photos, and any other sources (duly referenced) that you find useful. Careful map observation and some thinking will be required.

1. The central area of the map is labelled an “Icefield”. Look closely at Mt. Queen Mary’s actual elevation (i.e., read the elevation value very carefully). Why does it support the use of the term “Icefield”? What other characteristics of that area support the term “Icefield”? (2 marks)

2. The Canadian side of the map has a lack of symbols and a different contour interval, conveying a false impression of the smoothness of the glacier surfaces. Look at the pattern of crevasses on the US portion of the Seward Glacier, particularly between Dome Pass and Mt. Glorious (532000E 6672000N), and the adjacent topography. State the type of crevasses present on the Seward glacier. What does their presence indicate about ice flow and the underlying topography in that location? (3 marks)

3. There are small supra-glacial meltwater lakes shown in several areas of the map, on both sides of the border. What do you notice about their preferred location with respect to the glaciers they’re associated (look at the Logan and Walsh glaciers)? How can this preference be explained? (3 marks)

4. On the Malaspina glacier, as on many others, there is a large quantity of supra-glacial debris shown. Look closely at the relationship between this debris and the pattern of contours crossing it at 520000E, 6660000N. What are the many similar features present? Describe the nature of the topography of the glacier surface in this area. [It might help to examine a similar feature on the Kaskawulsh Glacier at 617000E, 6732000N, and on aerial photography A15517-50&-51.] (3 marks)

5. On both the Logan and Kaskawulsh glaciers there is a marked asymmetry (i.e., north-side vs. south-side) in both the orientation of tributary glaciers reaching the main ice stream and the concentration of debris along one side. Identify the significant process which accounts for this asymmetry. Describe the relationship between the position of the tributary glaciers and the presence of debris. (4 marks)

6. Along the north side of the Kaskawulsh glacier there are numerous small meltwater streams (e.g., 619500, 6739500) descending from the snouts of remnant tributary glaciers. Why do these not become supra-glacial streams on the glacier? To where does the water flow? [It might help to look at the feature shown at 626000E, 6743500N] (2 marks)

7. Focus on the lower extent of the Kaskawulsh glacier (near Observation Mountain) and the streams noted in question 6. This area is depicted in aerial photos A15517-21&-22. You will note that a change in the position of these streams has occurred between the time on which the map is based and the time of the more recent aerial photography. Construct a pair of sketches showing the main changes noted between the map and the photos. Sketches should be schematic (i.e. not to scale), but be clearly labelled with a title and major elements (i.e. ice position, lateral moraine, streams, etc.). Also provide a caption with each sketch describing the scenario, stressing the changes that occurred. (6 marks)

8. Explain why the ice of the Kaskawulsh glacier reaches below 3000 feet elevation at its terminus, yet the tributary glaciers to the southeast (e.g., the Disappointment Glacier or Maxwell Glacier) transition to small melt streams at much higher elevations. (3 marks)

Glacial Spillways

Objectives:

1. to investigate the geomorphological properties of glacial spillways (**Task 1**)
2. to estimate the volume of water that occupied these spillways when they were active (**Task 2**)

As discussed in class, a vast glacial lake (Glacial Lake Agassiz - GLA) formed a number of times during the waning of the Laurentide Ice Sheet (LIS) in the last glacial cycle in North America, covering much of northwestern Ontario, Manitoba and neighbouring provinces. The lake drained via a network of **glacial spillways** (also known as meltwater channels) that connected GLA at various times to the Mississippi basin and the Great Lakes basin. Whether or not a particular spillway was active was governed by the level of the lake and by the position of the receding LIS.

Of particular interest in northwestern Ontario are the glacial spillways that form the “eastern outlets”, which connected GLA to modern-day Lake Nipigon. The eastern outlets of GLA have been well-studied by Teller and his research associates (e.g., Teller and Thorliefson, 1983), however the outlets connecting Lake Nipigon to Lake Minong (pre-cursor to modern Lake Superior) have been less-studied. Our focus for this lab will be on this latter set of spillways (see **Figure 1**).

Task 1: Measurement of Channel Cross-Sections

We are going to estimate the geometric properties of the glacial spillway that occupies modern day Moraine Lake and Wolf Lake (see **Figure 1**). For each location specified (on **Figures 2** and **3**), measure these properties and record the results in **Table 1**. You will be shown in class how to measure these. The results will be compared to those of other known measurements of GLA spillways (**Table 2**).

- construct a **cross-sectional profile** on metric graph paper (provided) between the points indicated (on each figure) to estimate width, depth, wetted perimeter (*given*), hydraulic radius and cross-sectional area; put appropriate titles and labels on the cross-section, as well as the vertical exaggeration. **This lab will be completed in pairs.**
- determine the **channel longitudinal slope (or ‘energy slope’)**, using the current surface elevations of Moraine Lake and Wolf Lake, which are 350 m.asl. and 270 m.asl., respectively; the distance between the two cross-sections is approximately 20,170 m (or 20.17 km).

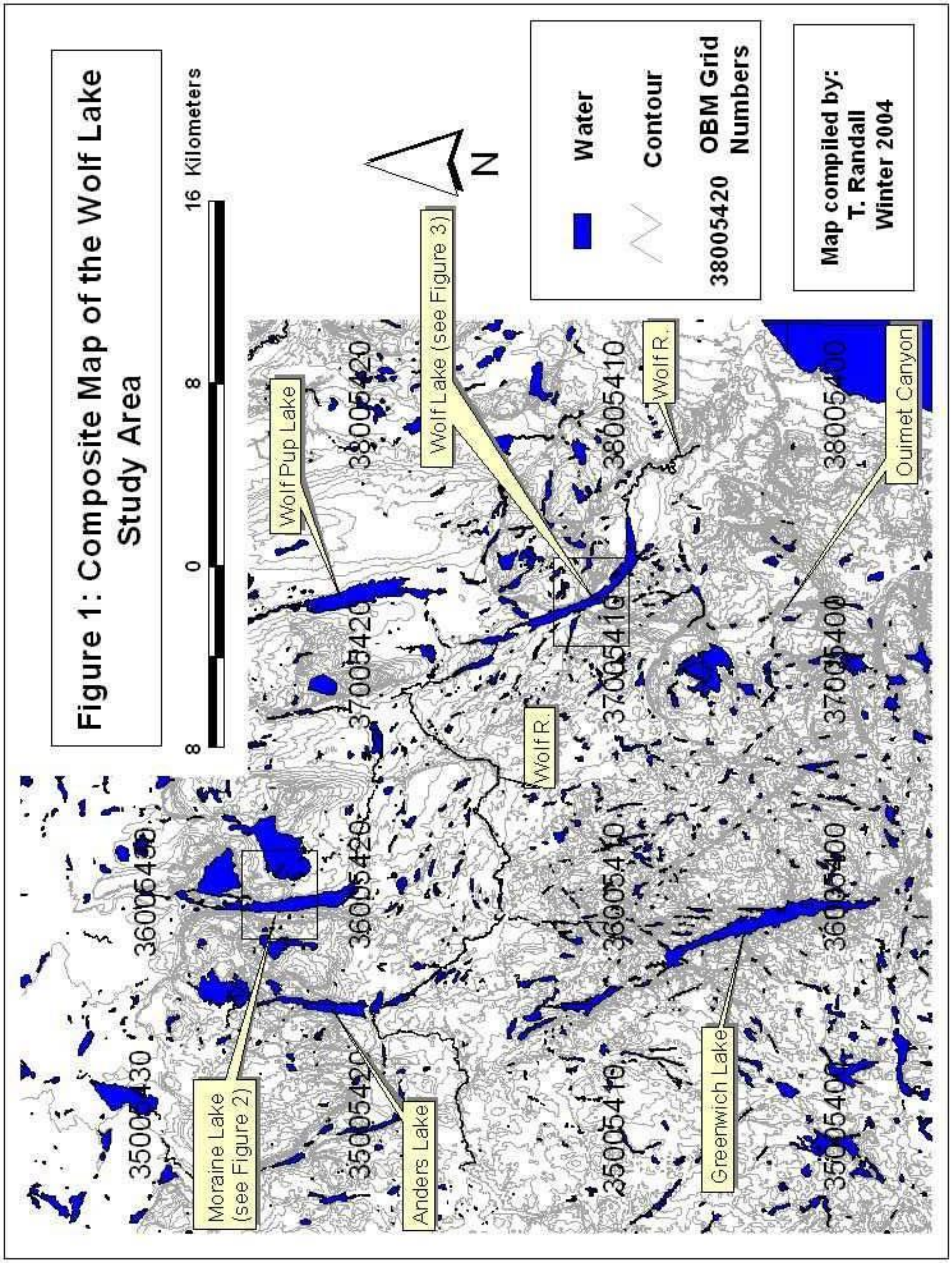


Figure 1: Composite Map of the Wolf Lake Study Area

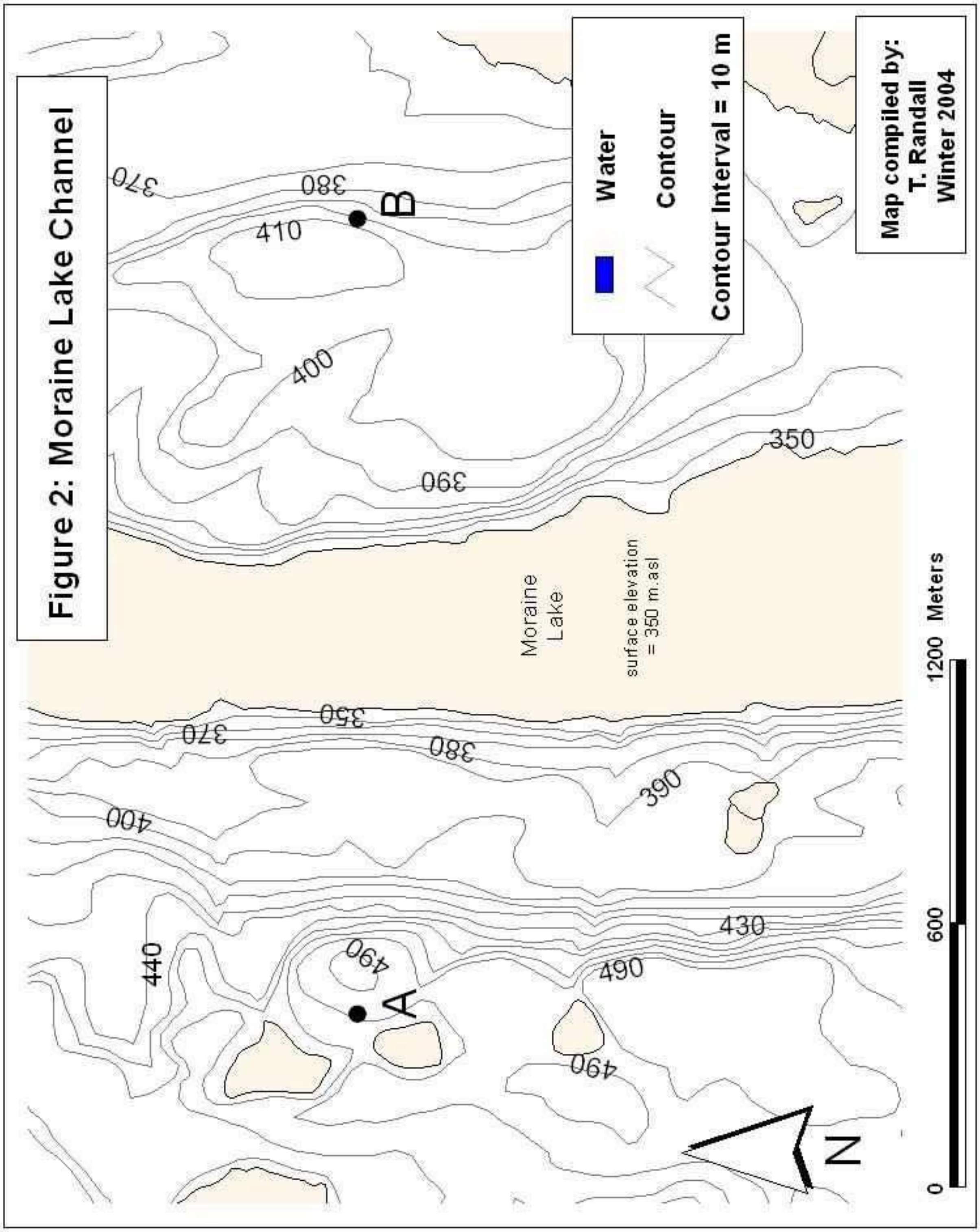


Figure 2: Moraine Lake Channel
Water
Contour
Contour Interval = 10 m
Map compiled by:
T. Randall
Winter 2004
Moraine
Lake
surface elevation
= 350 m.asl
A
B
N
0
600
1200 Meters
350
370
380
390
400
410
430
440
490

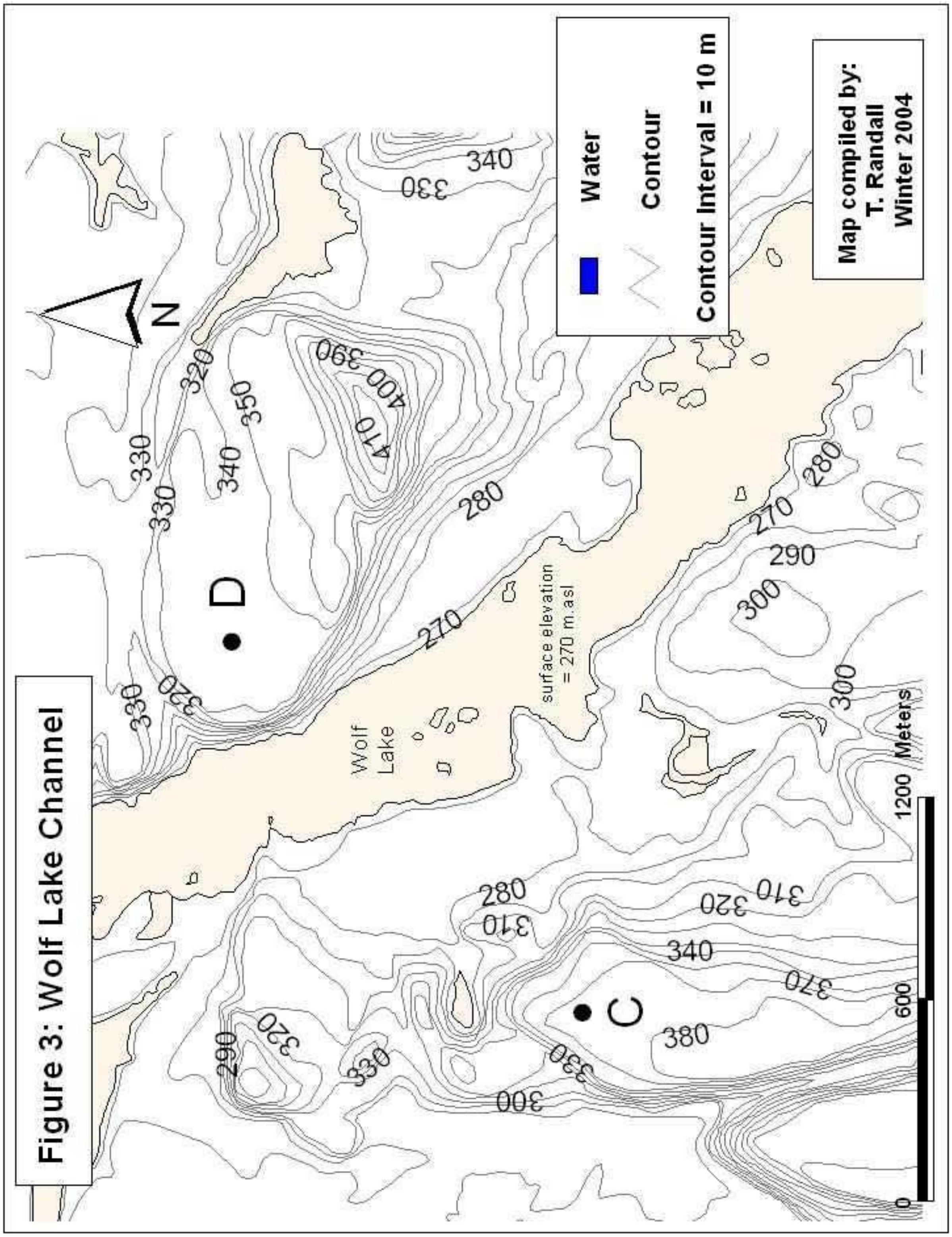


Figure 3: Wolf Lake Channel

Table 1: Spillway Cross-Section Measurements

variable	units	Moraine Lake Cross-Section		Wolf Lake Cross-Section	
		bank-full	½ bank-full	bank-full	½ bank-full
channel width, W (bottom)	m				
channel width, W (top)	m				
channel depth, D	m				
wetted perimeter, P	m	1400	572	1160	897
hydraulic radius, R	m				
cross-sectional area, A	m^2				
energy slope, S	-				
discharge, Q	m^3/s				

Notes:

1) R = A / P
2) *** For simplification in this lab, assume that the channels were completely full (when occupied); in reality, it is quite likely that they were not always full and one would do a number of calculations at different stages.

Table 2: Geomorphic characteristics of select Glacial Lake Agassiz spillways

	Eastern Outlets (Teller and Thorleifson, 1983)	Northwestern Outlet (Smith and Fisher, 1993)
Dimensions:		
Width:	< 1 km to several km's	1500 m
Depth:	variable; some over 100 m	110 m
Deposits:	>1 m diameter boulders	<1.5 m diameter boulders
Morphology Features:	-Bouldery gravel terraces -Bifurcating channels -Delta or subaqueous fan where channels emptied into receiving basin	-Bifurcating channel -Delta where channel emptied into receiving basin

Task 2: Estimation of Channel Discharges

The magnitude of flows occupying and eroding these glacial spillways is potentially quite significant, given the size of the ice sheets that were being melted!!! Previous researchers have attempted to quantify discharges from these spillways using the Manning Equation (see below), and there are some sizeable *re-constructed* flows (see **Table 3**) in comparison to modern river discharges.

Using the parameters summarized in **Table 1**, estimate the volume of water that occupied your spillway when it was active using the Manning Equation.

$$Q = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

where: Q = discharge (in m^3/s)
A = cross-sectional area (in m^2)
R = the hydraulic radius (m) (R=A/P)
S = energy slope
n = Manning's roughness coefficient (use n = 0.04)

Table 3: Estimated discharges of other glacial spillways / meltwater channels (various sources noted).

Location	Water Source	Mannings "n" Value	Maximum Q (m^3/s)	Reference
Channeled Scablands, Washington State (USA)	Glacial Lake Missoula	0.032-0.04	5,334,000 to 229,209,600	Baker (1973)
Clearwater / Athabasca Outlet, AB/SK, (Can.)	Glacial Lake Agassiz	0.03	2,400,000	Smith and Fisher (1993)
Souris Spillway, SK (Can.) / N. Dakota (USA)	Glacial Lake Agassiz	0.02	87,000 to 270,000	Kehew (1982)
Eastern Outlets, ON (Can.)	Glacial Lake Agassiz	0.03-0.05	100,000 and up	Teller and Thorleifson (1983)

Note:

1) Modern-day discharges of some of the world's major rivers:
(Amazon = 175,000 m^3/s; Mississippi = 17,704 m^3/s; St. Lawrence = 13,030 m^3/s)

References

Baker, V.R., 1973. Paleohydrology and sedimentology of Lake Missoula flooding in eastern Washington, *Geological Society of America Special Paper* 144, 79 pp.

Kehew, A.E., 1982. Catastrophic flood hypothesis for the origin of the Souris spillway, Saskatchewan and North Dakota, *Geological Society of America Bulletin* 93: 1051-1058.

Smith, D.G. and Fisher, T.G. 1993. Glacial Lake Agassiz: the northwestern outlet and paleoflood, *Geology*, 21: 9-12.

Teller, J.T. and Thorleifson, L.H., 1983. The Lake Agassiz-Lake Superior connection, IN: Teller, J.T. and Clayton, L. (eds.), *Glacial Lake Agassiz*, Geological Association of Canada Special Paper 26. 261-290.

Lab #4 Summary Questions

Table 1: Spillway Cross-Section Measurements

variable	units	Moraine Lake Cross-Section		Wolf Lake Cross-Section	
		bank-full	**½ bank-full**	**bank-full**	**½ bank-full**
channel width, W (bottom)	m				
channel width, W (top)	m				
channel depth, D	m				
wetted perimeter, P	m	1400	572	1160	897
hydraulic radius, R	m				
cross-sectional area, A	m^2				
energy slope, S	-				
discharge, Q	m^3/s				

Notes:

1) R = A / P
2) *** For simplification in this lab, assume that the channels were completely full (when occupied); in reality, it is quite likely that they were not always full and one would do a number of calculations at different stages.

1. Show your calculation of the channel longitudinal slope (i.e. energy slope) between Moraine Lake and Wolf Lake.

2. How do the width and depth measurements obtained compare with those of other Glacial Lake Agassiz spillways? Refer to **Table 2**.

3. Provide <u>one</u> example of your discharge calculations.

4. How do your estimated discharges compare with those values obtained by other researchers? Refer to **Table 3**. The discharges from the draining of Glacial Lake Missoula seem daunting.

Cross-sectional profile of Moraine Lake

Cross-sectional profile of Wolf Lake

Measuring Stream Flow Dynamics

Objective: To gain practical experience measuring and calculating several properties which define river flow. Cross-sectional area, flow velocity, discharge, Reynolds number and Froude number will be calculated using the Whitefish River as an example.

Lab #5 will be completed in two parts. The first portion will be completed in the field to gather the required measurements to determine the river's cross-sectional area and flow characteristics. The second part will be completed during the following lab period to finish off the necessary computations.

You will be working in groups (to be determined on the field day) to gather the necessary data from the river. Aside from collection of that data, the remainder of the lab can be completed during the lab period.

Before you get started, each group should decide on an appropriate division of tasks. At least one person, but probably two, should be in the river collecting depth or velocity measurements. Other tasks include timing and recording the data. Groups are encouraged to rotate duties so everyone has an opportunity to use the equipment. Each group will work on one section of the river, collecting the necessary data to complete Task 1 and Task 2.

TASK 1: Stream Profile and Discharge Calculation

Using the equipment provided, follow the steps below to gather the necessary data to be recorded in Figure 1 (attached).

1. At the location specified by an instructor, string the tape measure across the river perpendicular to the direction of flow. The tape should be taut and be as close to the surface of the river as possible. Take special note of the measure at the river's edge (particularly if it is not zero) as this will be your starting point (i.e., the zero point on the x-axis).

2. From the starting point, the depth of the river should be collected every 0.5m (e.g., 0.5m, 1m, 1.5m, etc.) and be recorded at the appropriate location on Figure 1. Once all depth points are collected, they can be connected with a smooth line to show the river's depth profile.

3. The flow velocity should also be collected at the midpoint of each 0.5m section (e.g., 0.25m, 0.75m, 1.25m, etc.). Stream velocity is known to change with depth (as we will see in Task 2), however research has shown that mean river flow can be approximated by measuring the velocity at 0.63 times the river's depth. This is commonly referred to as **the 0.6 rule**. Therefore note the depth at the appropriate location, calculate 0.6 times that depth and collect the flow velocity accordingly. Use the flow velocity formula at the bottom of Figure 1 to calculate the velocity using an impeller count of 15 seconds. Record the velocity at the appropriate location on Figure 1. Note: the other calculations for Figure 1 can be completed in the lab.

TASK 2: Flow Velocity Analysis

Using the equipment provided, follow the steps below to gather the necessary data to be recorded in Figure 2 (attached).

1. Using the same depth measurements collected for Task 1, the depth of the river should be plotted at the appropriate location on Figure 2. Once all depth points are plotted, they can be connected with a smooth line to show the river's depth profile.

2. The flow velocity should be collected for every point in Figure 2 within the profile (i.e., above the line). Take care to ensure measurements are collected at the appropriate depth (e.g., 0.1m, 0.3m, 0.5m, etc). Neatly record (with small writing) the calculated flow velocity beside the appropriate point on Figure 2. Repeat until each point within the profile has a velocity. Note: the drawing of isovels can be completed in the lab.

3. The final measurement to be recorded in the field is the 'wetted perimeter'. Take down the tape measure then use it to measure the cross-sectional length across the bottom of the river. Ensure that the measurement is taken along the same line as your profiles. Record the wetted perimeter length on Figure 1.

This ends the required field collection component.

Back in the lab . . .

TASK 1: Stream Profile and Discharge Calculation

1. Calculate the cross-sectional area for each 0.5m section of the river using the 'give-and-take' method outlined in lab4. Count the total number of squares in the profile and multiply by the area of a single square (provided at the bottom of Figure 1).

2. Multiply the derived cross-sectional area (in m^2) by the determined flow velocity (in $m\ s^{-1}$) to calculate the discharge (in $m^3\ s^{-1}$) for each 0.5m section.

3. Sum your discharge measurements to calculate the total river discharge. Record that value where indicated on Figure 1.

TASK 2: Flow Velocity Analysis

1. Using the isovel interval provided by the lab instructor, draw isovels on Figure 2 to show the pattern of flow velocity for the entire river. An isovel should stop at the river's surface or form an enclosed loop (i.e., flow velocity is always zero along the wetted perimeter).

TASK 3: Calculation of Reynolds Number (R_e)

The Reynolds Number is a dimensionless value used to characterize the turbulence in a river. Theoretically, water flowing downstream would exhibit a laminar flow where velocity is greatest at the surface and gradually decreases to zero along the river bed. Natural rivers are never truly laminar but rather have some level of turbulence caused by changing river morphology, variable flow velocity, etc. The Reynolds number therefore can be calculated as the ratio between the forces causing river flow to the forces restricting flow.

The Reynolds Number can be expressed as:

$$R_e = \rho * vR / \mu$$

where ρ is the density of the water, v is the average flow velocity for the river, R is the hydraulic radius, and μ is the molecular viscosity of the water (the friction between water molecules). The kinematic viscosity of water (*v*), which is a measure of water's resistance to flow, can be defined as μ/ρ. Therefore we can rewrite the Reynolds Number formula as:

$$R_e = vR / v$$

To calculate the Reynolds Number using data from Figure 1, follow the directions below.

1. Determine the average river velocity (v) by summing all velocity measurements from Figure 1 and dividing by the number of measurements.

2. Determine the hydraulic radius (R) by summing all cross-sectional area measurements from Figure 1 and dividing by the wetted perimeter.

3. Using the river temperature and Figure 3, determine the kinematic viscosity.

4. Calculate the Reynolds Number and record it on Figure 1.

TASK 4: Calculation of Froude Number (Fr)

The Froude Number is used in fluvial studies to characterize the resistance to flow. A lower Froude Number (<1) suggests a relatively tranquil "subcritical" flow, meaning relatively little force is inhibiting the flow of water downstream, whereas higher values (>1) suggest greater "supercritical" flow which, when considered along with velocity, characterizes a more turbulent environment.

The Froude Number can therefore be expressed as:

$$Fr = v / \sqrt{(g \times d)}$$

Where g is the force of gravity (9.81 m s^{-2}), and d is the average depth of the river.

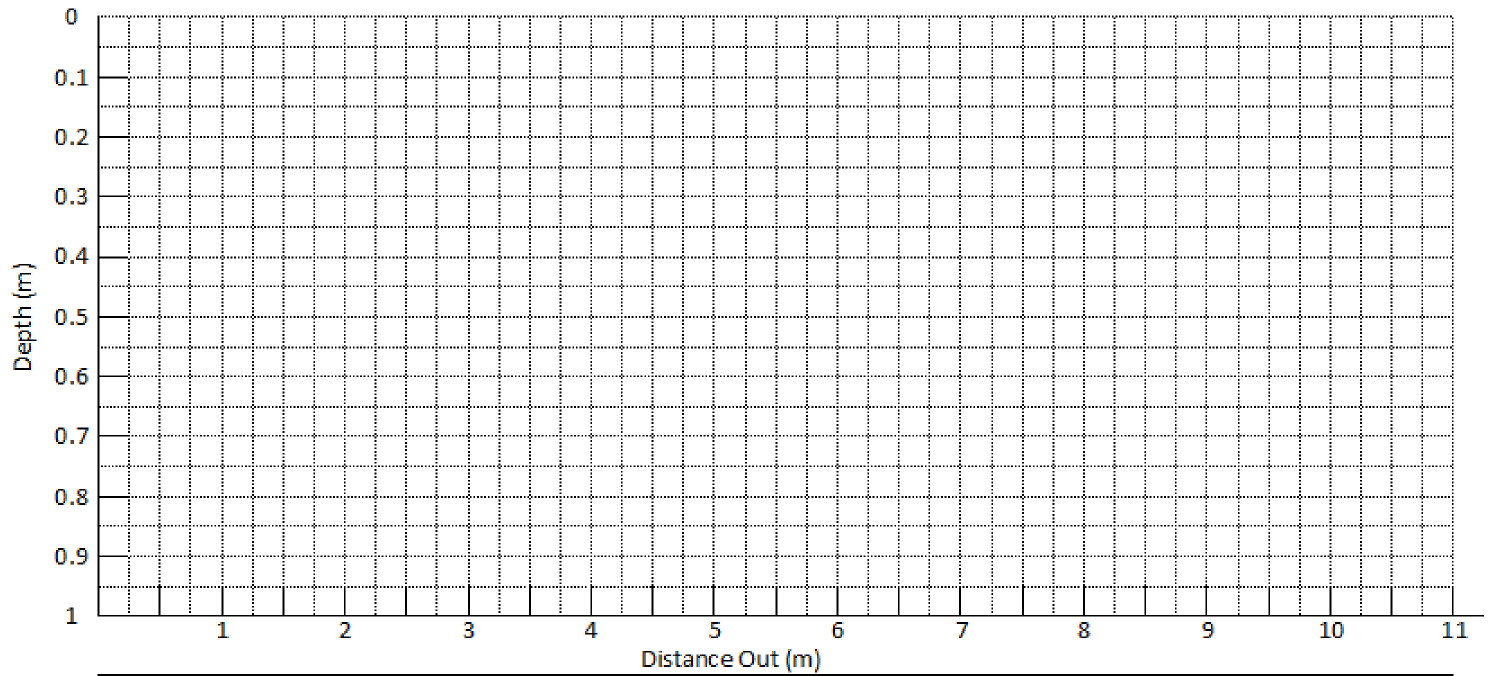
To calculate the Froude Number using data from Figure 1, follow the directions below.

1. Determine the average river velocity (v) by summing all velocity measurements from Figure 1 and dividing by the number of measurements.

2. Determine the average depth by summing all **(non-zero)** depth measurements from Figure 1 and dividing by the number of measurements.

4. Calculate the Froude Number and record it on Figure 1.

Figure 1. Cross-Sectional Profile and Discharge Calculation for the Whitefish River, near Nolalu, Ontario



# of squares:																						
Area (m^2):																						
Flow velocity ($m\ s^{-1}$):																						
Discharge ($m^3\ s^{-1}$):																						

Temperaure = _______°C Wetted Perimeter = _________m Total Discharge (Q) = _________$m^3\ s^{-1}$

Reynolds Number = ____________ Froude Number = _____________

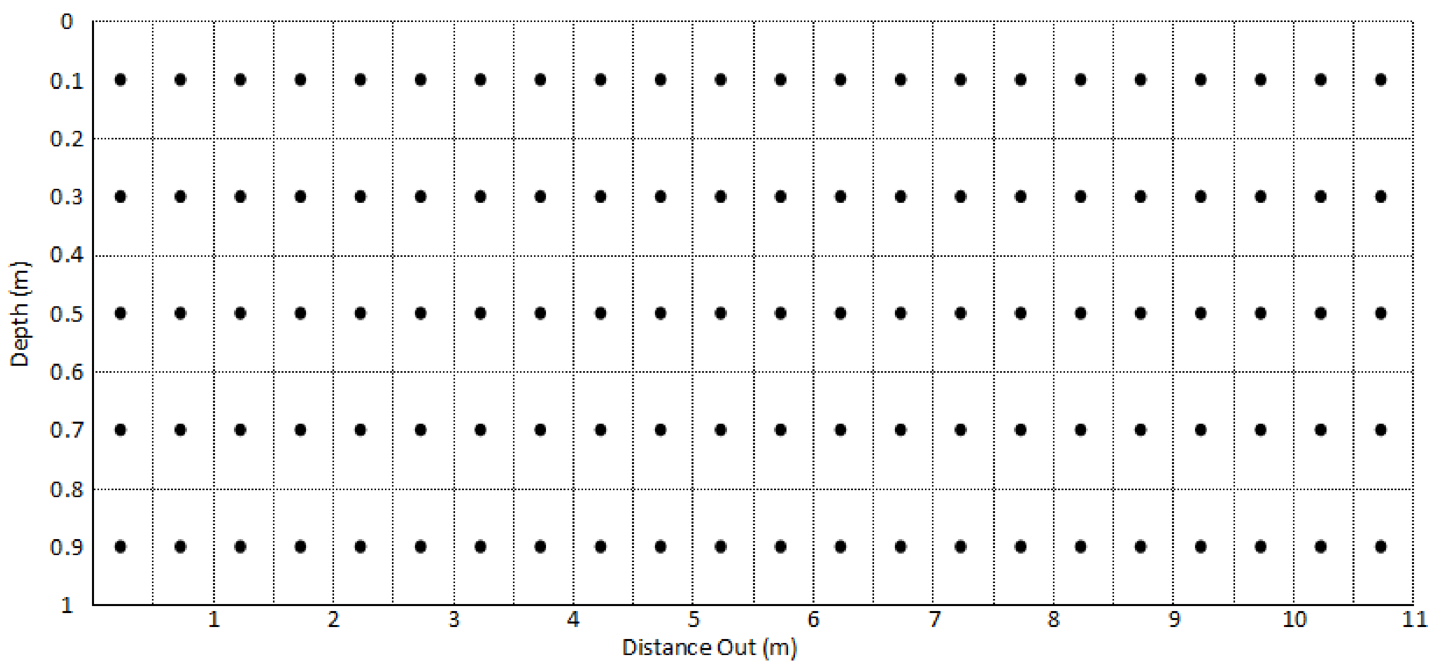
Notes:

Flow velocity (v) = 0.003416(c) + 0.05 where c represents the impeller count for 15 seconds.

Area of one square = 0.25mX0.05m = 0.0125m^2

Total Discharge (Q) = ∑ of all discharge calculations

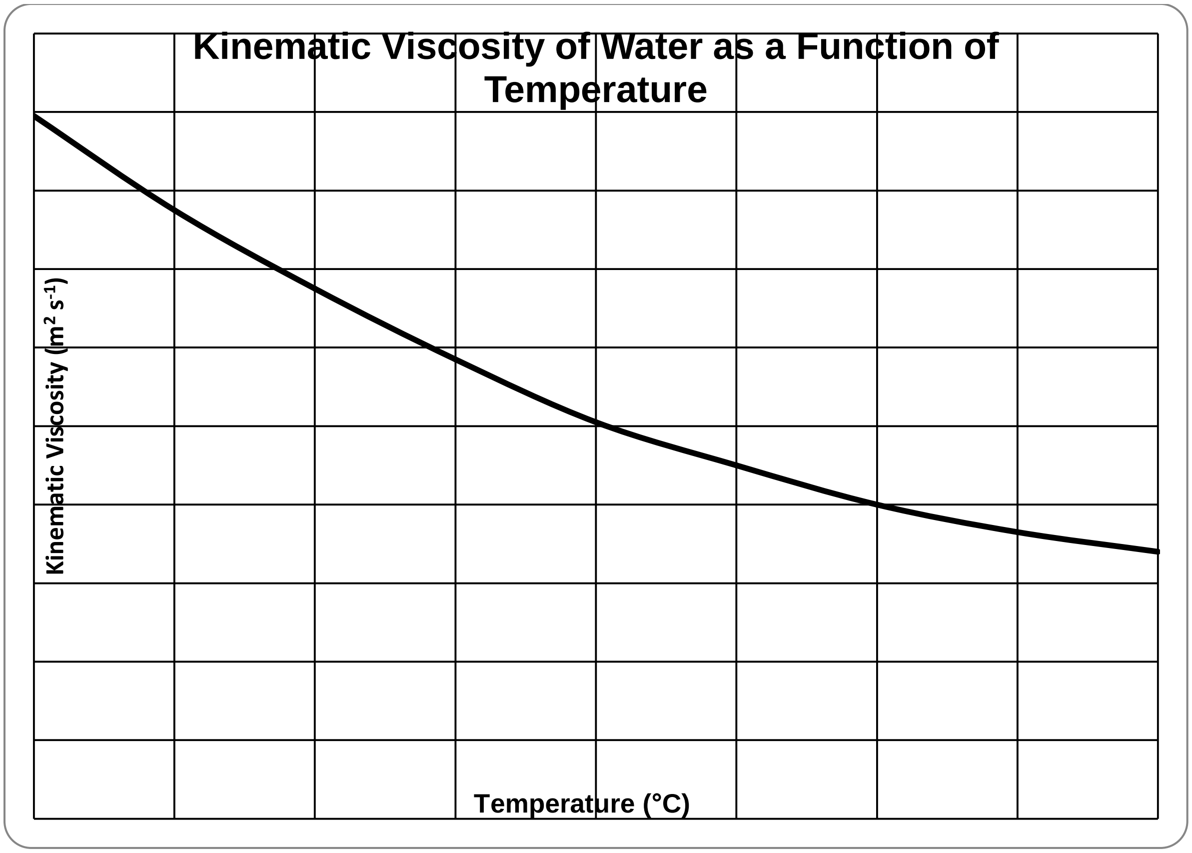
Figure 2. Cross-Sectional Profile and Flow Velocity Analysis for the Whitefish River, near Nolalu, Ontario



Notes:
Calculate flow velocity for every point within the profile.
Flow velocity (v) = 0.003416(c) + 0.05 where c represents the impeller count for 15 seconds.

Isovel Interval = ____________**m s^{-1}** (to be determined in the field)

Figure 3. Kinematic Viscosity of Water



LAB #5 SUMMARY QUESTIONS

Name:________________________

1. What factors limit the validity of your analysis? Explain how and why the results of your study are limited. Assume that your methods and execution are flawless.

2. Given the pattern of isovels drawn on Figure 2, do you feel your results support the 0.6 rule for average stream velocity? Explain why or why not.

Stream Networks:
The Law of Stream Orders and the Random Walk Model

Objective: To compare the organization of a real stream network with that of a randomly generated network.

Given: Map of Lynn Creek drainage basin, North Vancouver, B.C.
Table of stream orders of three selected rivers (**Table 1**)
Semi-log graph paper (Item 1)
Random-network construction sheet (Item 2)
Dice

Task 1: THE LAW OF STREAM ORDERS

Lynn Creek is a long, narrow and steep sloped basin adjacent to the better known Capilano River basin, draining the mountain slopes above North Vancouver. A placid trickle during the summer, the river is a raging torrent in the brief snow melt season.

(i) With careful use of coloured pencils, order the network shown on the map, beginning with 1st order stream segments. (*Use Strahler's method*).

(ii) Sum the number of continuous stream segments of each order, and record this in the table at the side of the map.

(iii) Plot the number of each order against order on the semi-log paper provided (Item 1).

(iv) Draw 'a best fit' line through the set of points plotted, not necessarily passing through any of the points.

(v) To provide some comparison, plot the data for the three rivers in Table 1 on the same sheet as the Lynn Creek plot.

Table 1: Number of stream segments by order

ORDER	ALLEGHENY R. (U.S)	DEE R. (U.K)	BIG BADLANDS R. (U.S.)
1	5966	880	139
2	1529	230	46
3	378	55	11
4	68	15	3
5	13	3	1
6	3	1	-
7	1	-	-

(vi) For each river draw a 'best fit' line through each set of points.

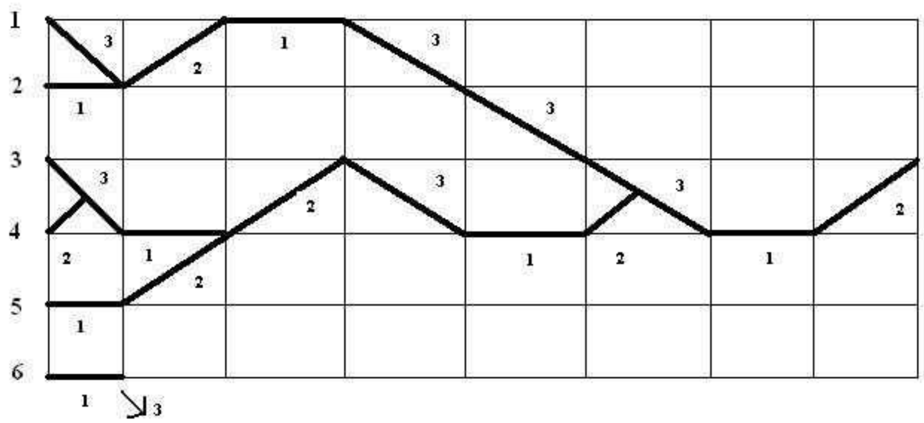
(vii) Fully label your multiple plot, and include a descriptive title at the top of the page.

There are now four plots of very different sizes of river, from very different physical and climatic environments. Note for your write up whether the plots are similar or different?

Task 2: CONSTRUCTING A RANDOM NETWORK

The construction sheet (Item 2) represents an uplifted and tilted land surface, with the watershed divide at the left hand margin, the sea (or the direction of base level) on the right margin. On the divide have fallen 15 drops of water. Each of these has 3 possible paths to take: (1) directly downslope (*across* the page), (2) 45° left (*up* the page) and (3) 45° right (*down* the page).

In this model, the 15 drops are situated at half inch intervals and the movement of each is to be plotted by half inch squares at a time. The result will be a pattern like this:



(i) First there is the need to generate the numbers 1 to 3 randomly, representing 'Across', 'Up' and 'Down'. This can be done using a dice, a table of random numbers, or a random generator on a computer or scientific calculator.

(ii) Taking each drop in turn, take the 15 drops on the first half inch of their journey. Note that some junctions may be formed immediately.

(iii) Repeat, in turn 1 to 15, for the next half inch, but NOTE, where a junction has occurred, only one point remains in place of two, and there will be less than 15 to work with.

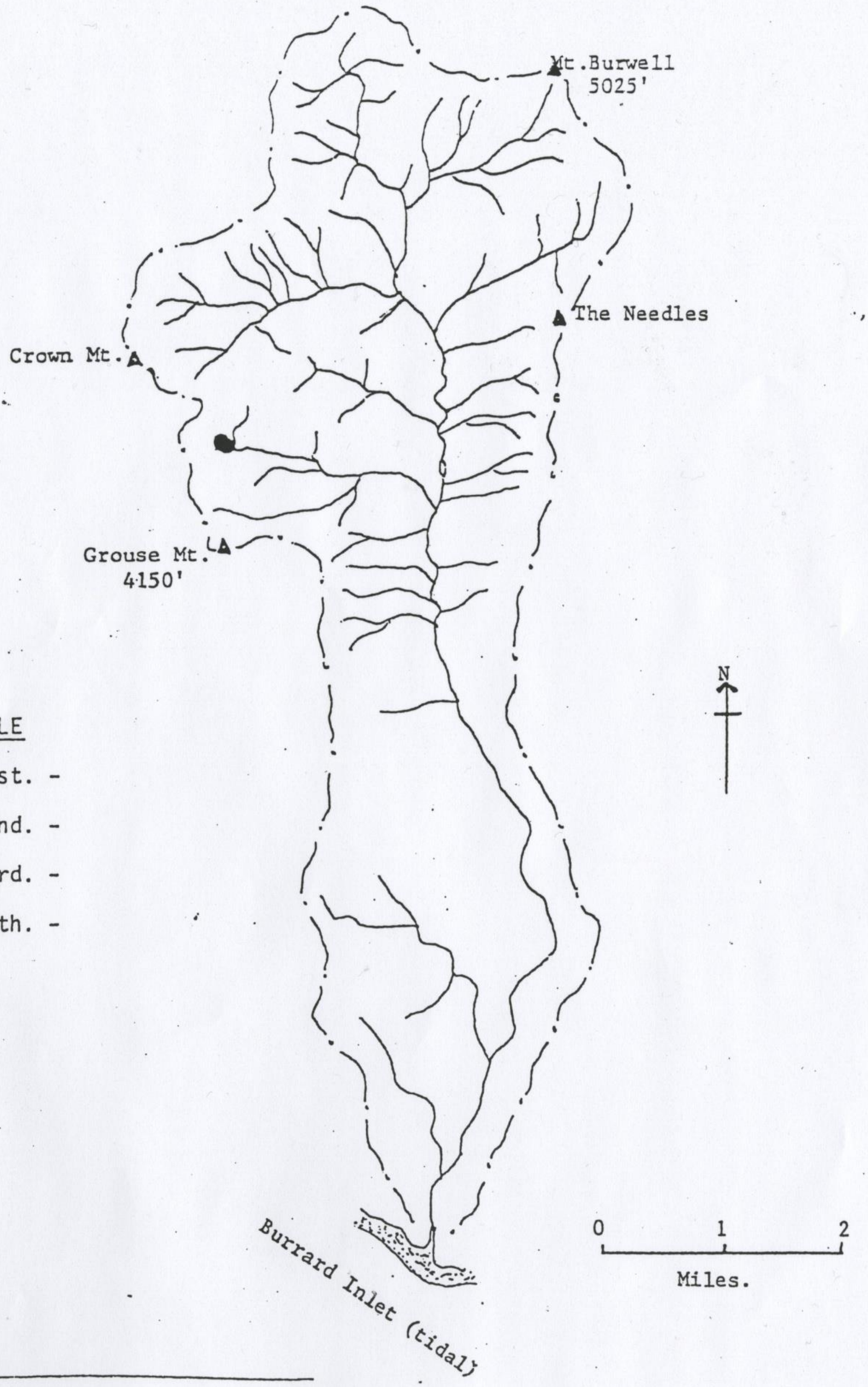
(iv) If a stream goes off the edge of the page, abandon it.

(v) Though this would have to be repeated many times to be valid, you may with luck have generated one or more branched networks, ending with a single stream.

(vi) Using colour pencils, order the largest generated network, beginning with 1st order stream segments. Provide an appropriate title.

(vii) Sum the number of segments of each order, plot on the graph with the other rivers, and label the plot.

LYNN CREEK DRAINAGE BASIN - VANCOUVER, B.C.



TABLE

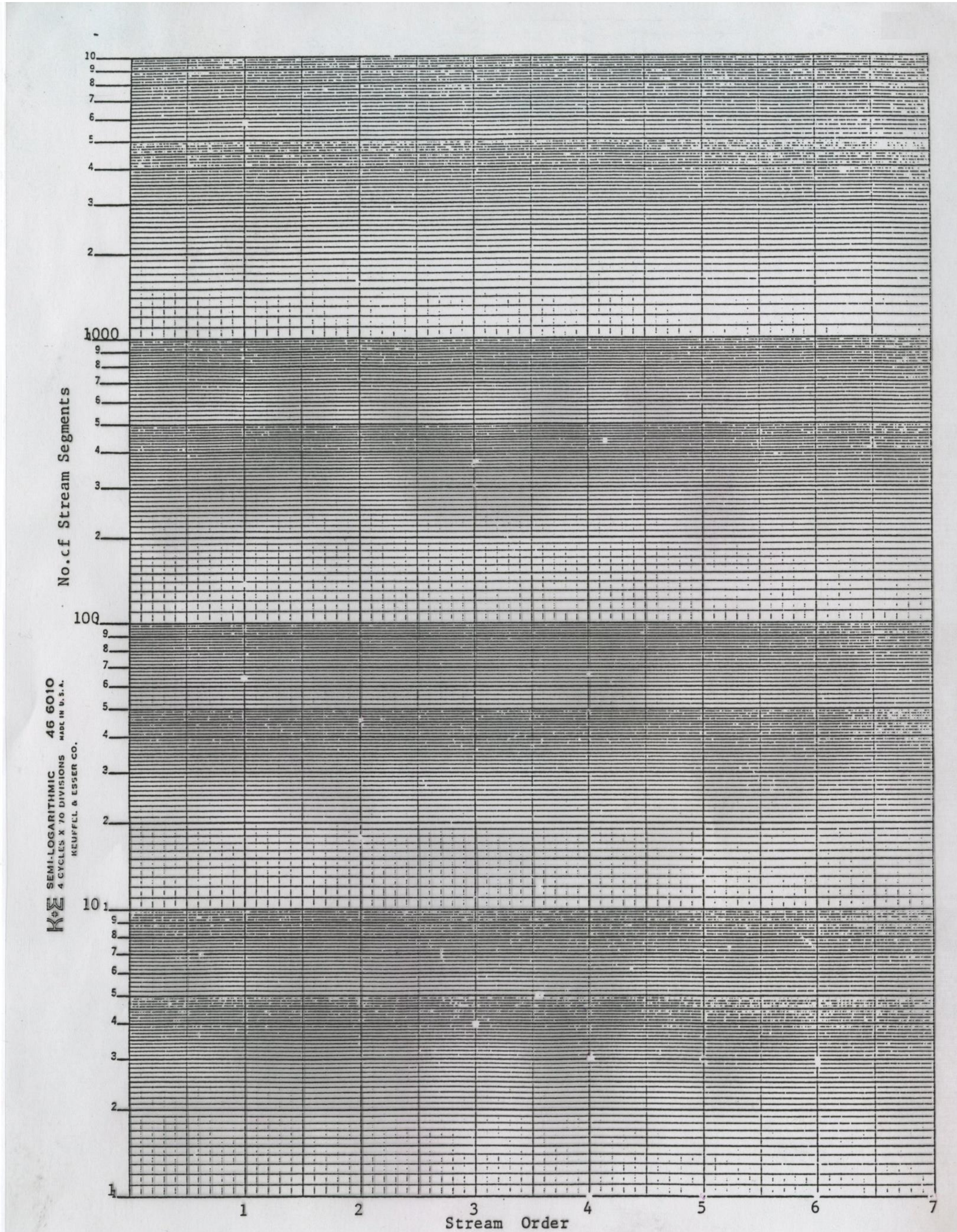
1st. -

2nd. -

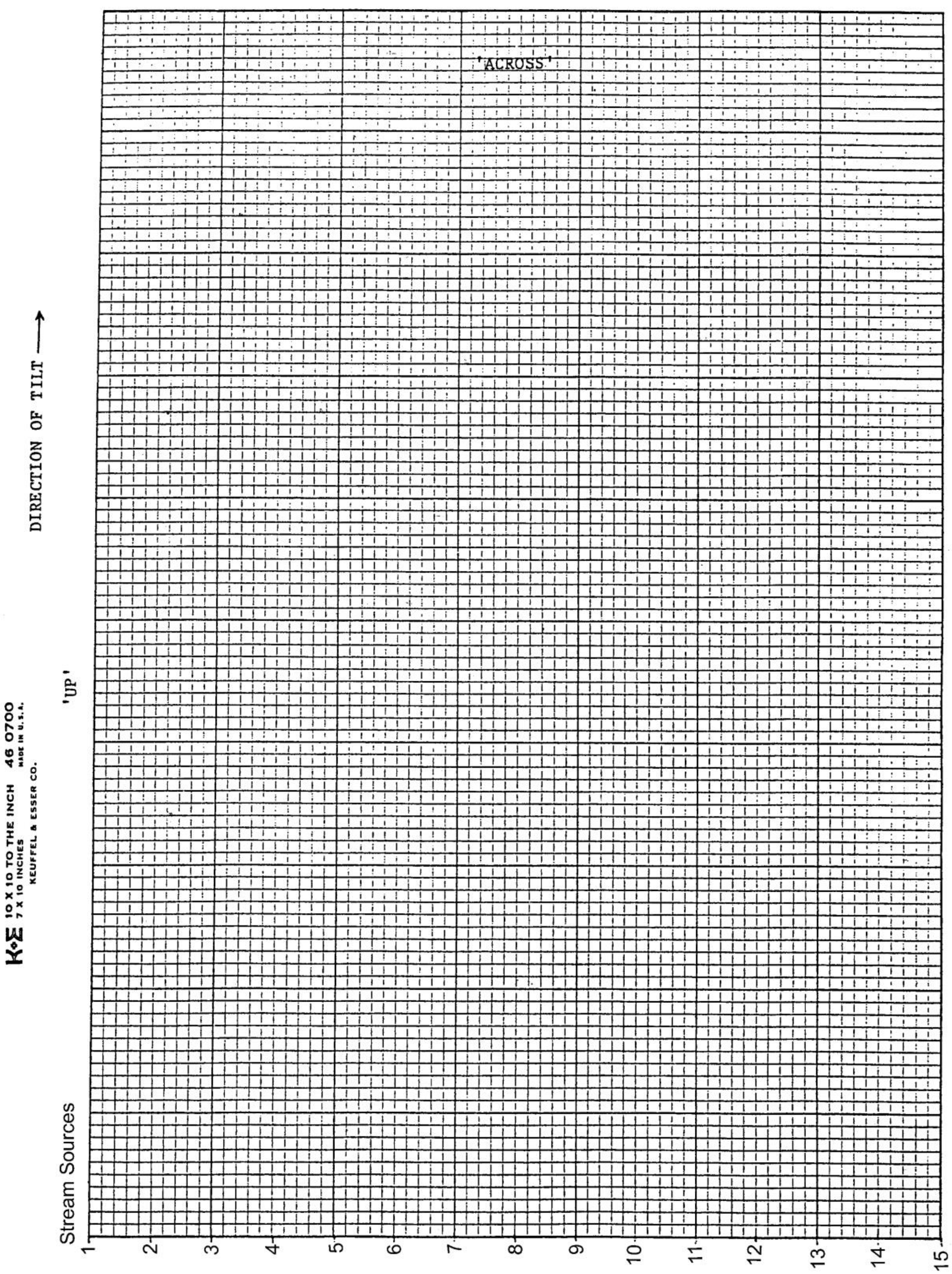
3rd. -

4th. -

NAME ______________________


No.cf Stream Segments
Stream Order
1000
100
10
1
1 2 3 4 5 6 7
SEMI-LOGARITHMIC
4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6010
MADE IN U.S.A.

ITEM 2 - Random Net Construction Sheet



Lab # 6 Summary Questions

1: Describe the nature of the relationship for the function
# of streams per order = *f* (stream order). (1 mark)

2: Viewing the four (real) river plots, and noting that they are of varying sizes and are from very different physical and climatic environments, does the proportional rate of change in # of stream segments per stream order differ (i.e. How do the slopes of the lines on the graph compare)? (1 mark)

3: Comparing the real and generated networks, does the randomly generated river plot differ from those of the real river plots? (1 mark)

4: List two other factors that might influence how stream networks develop? (2 marks)

Analysis of Stream Sinuosity, Radius of Curvature and Mean Channel Width

Objectives: Streams are rarely straight. Channels tend to be sinuous, a very regular sinuosity being termed 'meandering', though this term applies only to certain cases of sinuous pattern. Within a sinuous channel, it will be observed that there is a variation of both the curvature of the bend and the width of the channel.

The hypothesis to be tested by morphometric analysis is that there is a proportional relationship between the radius of curvature (of a sinuous stream) and the mean channel width. We also want to explore the role of sinuosity in characterizing stream behaviour and sediment loads.

Given: Figure 1: A simplified map of part of the Big Muddy River, Illinois.
Figure 2: A selection of stream bends from maps of various scales.
Figure 3: A sheet of Log/Log paper, already labelled and marked with a selection of lines of equal ratio.

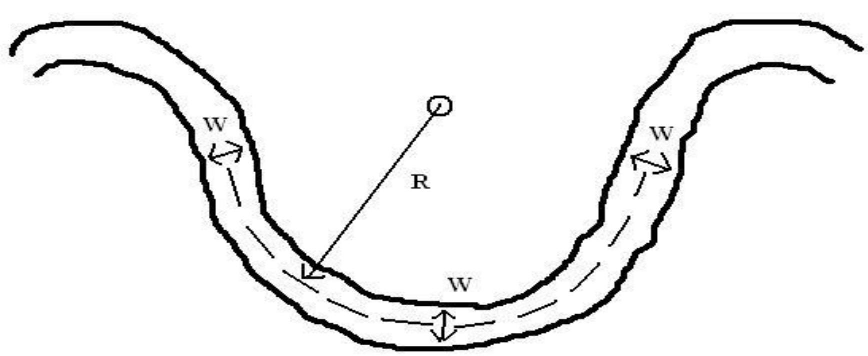
Required: A pencil, compass or dividers, and a finely graduated ruler.

Procedure:

1. Determine the sinuosity (ratio between channel length and valley length) of the Big Muddy River, using appropriate reference points on the Cripps and Horseshoe Bends (**Figure 1**). (*2 marks*)

2. With reference to Figures 1 and 2 and following the diagram below, measure the radius of curvature of each bend listed in **Table 1** by locating by trial and error a point from which an arc most closely follows the centre line of the stream channel. Determine the radius of curvature (R), by reference to the scale given for each bend. Note that each is of a different scale, in feet.

3. Determine channel width (W) by taking the average of several measurements (5 or 6) of width within the bend covered by the arc drawn.



4. Record your results in **Table 1**.

Table 1: Meander radius (R) and channel width (W) for selected bends. Note details about *measurement precision*. (*14 marks*)

# (for graph)	Name	1 mm represents:	R	W
1	Mill Bend			
2	Dillon Bend			
3	Cripps Bend			
4	Cottonwood (left)			
5	Cottonwood (centre)			
6	Cottonwood (right)			
7	Popo Agie (left)			

# (for graph)	Name	1 mm represents:	R	W
8	Popo Agie (right)			
9	South Loup (left)			
10	South Loup (right)			
11	Red River			
12	Wabash River			
13	Miss R., Providence			
14	Miss, R. Moss Is.			

5. Plot, on the prepared Log/Log graph paper, R against W for each item in Table 1, using caution concerning the logarithmic nature of the scales on both plot axes. Be sure to label each plot point with an appropriate abbreviation. A scatterplot of 14 points will result. (*10 marks*)

The drawn lines of 45º on the Log/Log sheet represent slopes along which the increase in one variable is directly proportional to the increase in the other. Selected ratios are shown, between which interpolation may be made.

If the plotted data are grouped along one of these lines, it can be concluded that a proportional relationship does exist between the two variables. If scattered without association with these lines, then no such conclusion can be drawn.

Lab #7 Summary Questions

1. Show your calculation of the sinuosity of the Big Muddy River.

Table 1: Meander radius (R) and channel width (W) for selected bends. Note details about *measurement precision*. (*14 marks*)

# (for graph)	Name	1 mm represents:	R	W
1	Mill Bend			
2	Dillon Bend			
3	Cripps Bend			
4	Cottonwood (left)			
5	Cottonwood (centre)			
6	Cottonwood (right)			
7	Popo Agie (left)			

# (for graph)	Name	1 mm represents:	R	W
8	Popo Agie (right)			
9	South Loup (left)			
10	South Loup (right)			
11	Red River			
12	Wabash River			
13	Miss R., Providence			
14	Miss, R. Moss Is.			

2. With reference to the eleven plot points excluding the three Big Muddy bends, observe whether the data adhere to a 45º slope. Can it be concluded that a proportional relationship does exist between the two variables and if so, what ratio best describes the data? (*2 marks*)

3. With reference to the three plot points of the Big Muddy bends, observe whether the data adhere to a 45º slope. Can it be concluded that a proportional relationship exists between the two variables and, if so, what ratio best describes the data? (*2 marks*)

4. If the hypothesis appears supported, what does this tell one about streams? (*3 marks*)

5. Concerning the value of sinuosity obtained for the Big Muddy, what (if anything) might this suggest about the river's sediment load? (*3 marks*)

6. There is obviously a departure of the Big Muddy data from the remaining data. With reference to Figure 1, find an explanation in the nature of this particular stream for why the ratio is unlike that for the other selected stream bends, looking closely at the supplementary information given by the map (look up the terms used). Write an explanatory paragraph addressing this matter. (*3 marks*)

FIGURE 1: THE BIG MUDDY RIVER, SOUTHERN ILLINOIS

<u>Note:</u> The interval of the contours is not regular.

The dashed 350' contour shows the channel to be lined by natural levees.

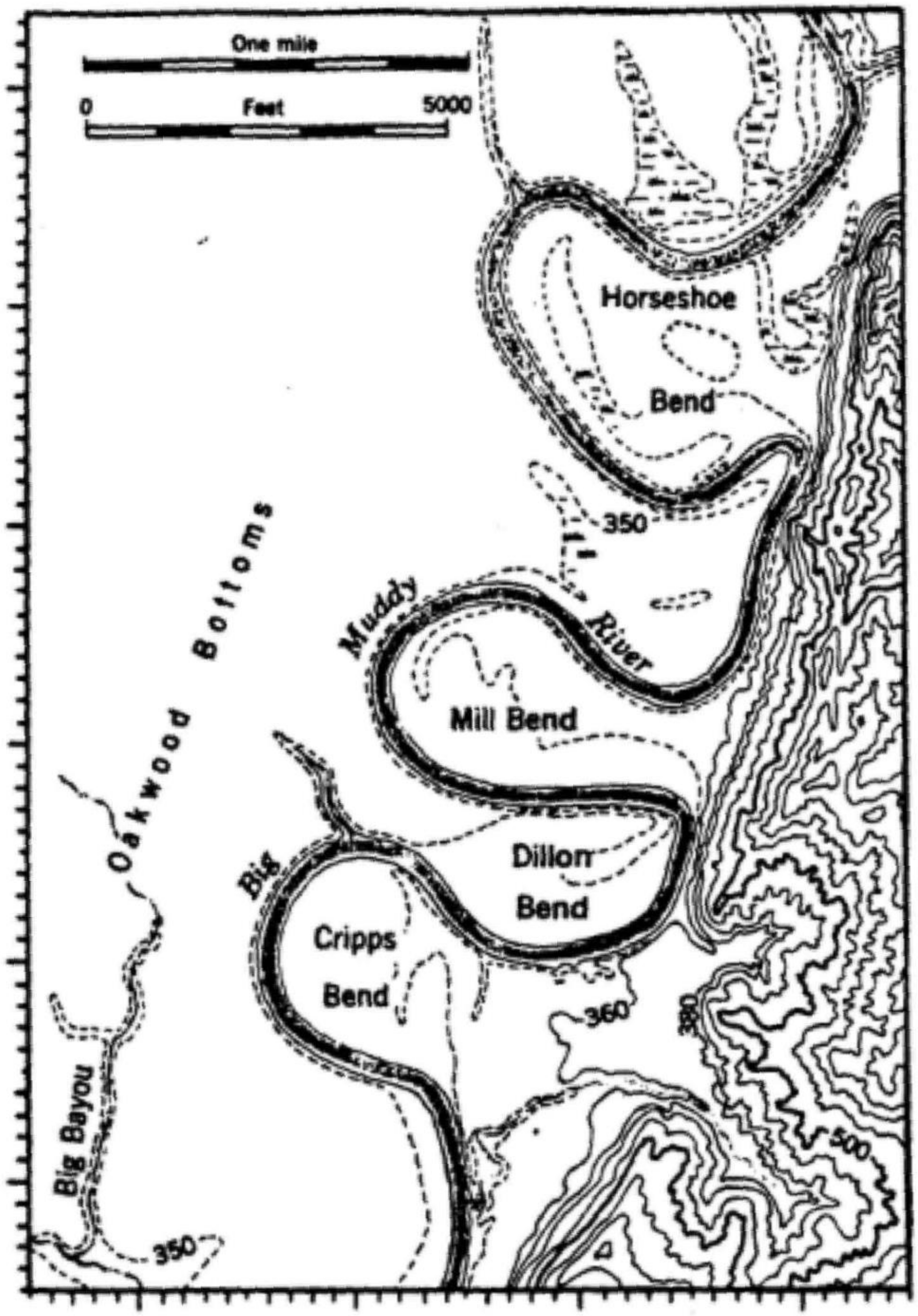
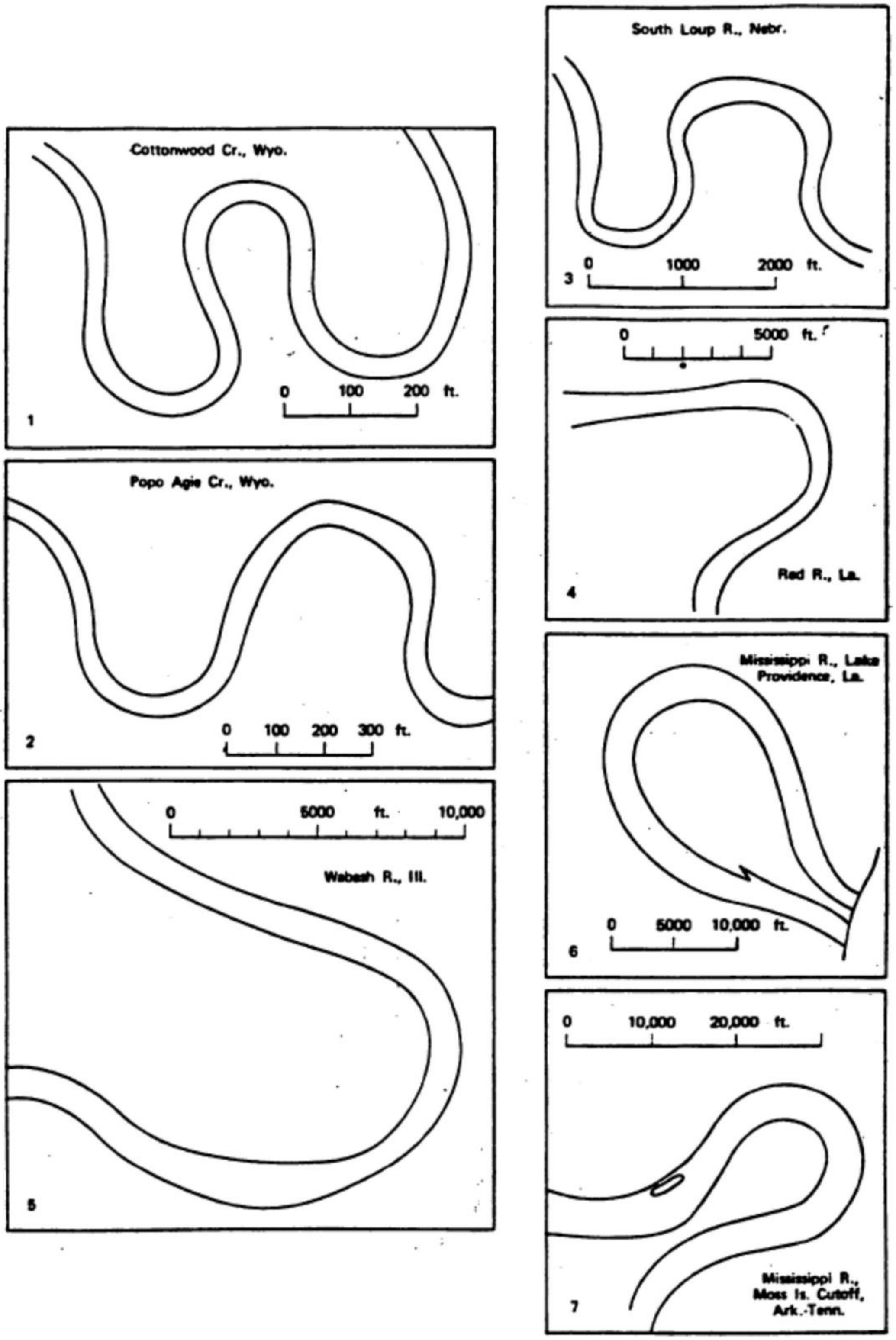
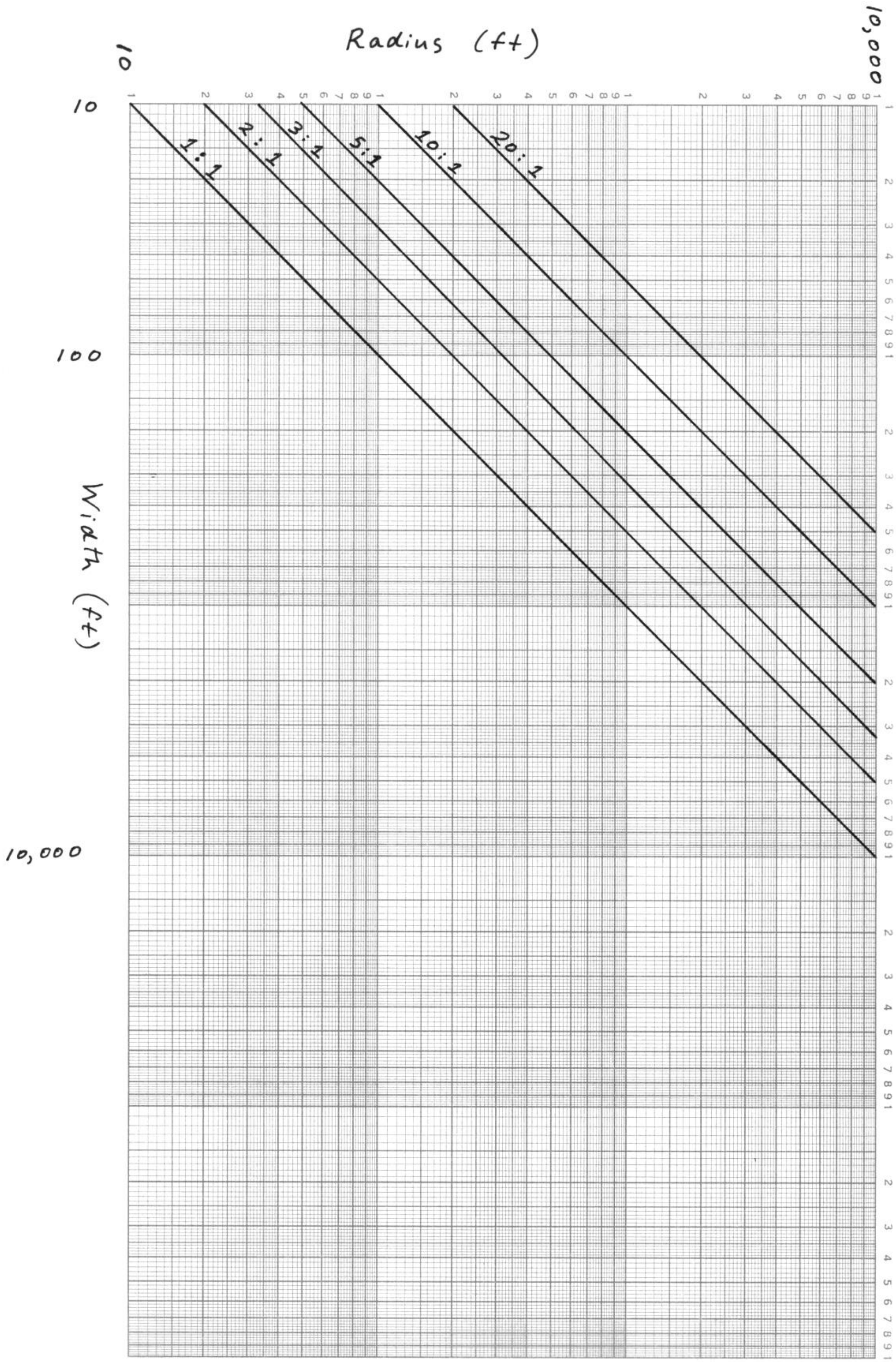


FIGURE 2: SELECTED STREAM BENDS




Radius (ft)
10
10,000
10
100
10,000
Width (ft)
1:1
2:1
3:1
5:1
10:1
20:1

Mass Movements

Task 1: The Frank Slide, Alberta case study (19 marks) (*refer to map*)

On April 29th, 1903 at 4:10 am, following several weeks of rain and a number of minor earth tremors in the region of the Crows Nest Pass, a great mass of limestone – 2100' high, 3000' wide and 500' thick – detached from between the North and South Peaks of Turtle Mountain. The gigantic mass of rock slid 2500' down into the valley of the Crows Nest River, burying part of the town of Frank and a mine, killing 70 people. The momentum of the disintegrated wave of rubble carried it across the valley and part way up the other side. The whole event was over in 100 seconds.

Map 1 shows the limits of the slide and the remaining tension cracks formed on the summit during the slide. Roughly along the 4600' contour occurs a geological boundary between limestone dipping towards the valley floor and vertically disposed bituminous shale. The limestone is well jointed along planes perpendicular to the bedding planes, and the slide took the form of 'bedding plane slip'. The shales were being mined under the base of the mountain at the time of the slide.

Lab# 8 Summary Questions

1. Using the bar scale provided, measure the **path length** of the slide, in feet, from S. Peak 030030 to 360150. (*1 mark*)

2. The Crows Nest River lies at an elevation of 4155'. What is the **highest point** to which the slide reached on the opposite valley side? (*1 mark*)

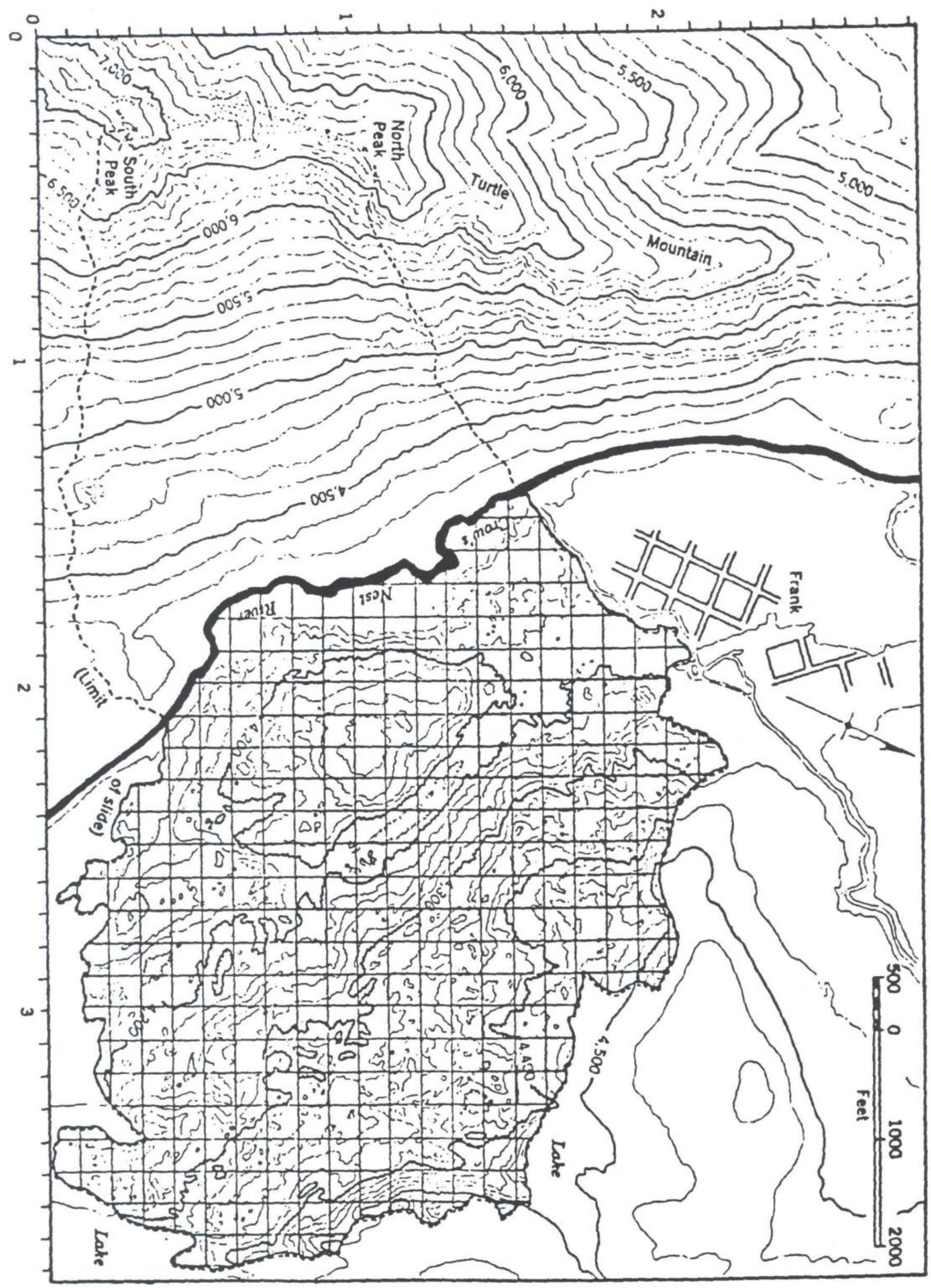
3. Determine the slope between the 6000' and 5000' contours, firstly between 068150 and 096150 representing the approximate condition before the slide, and between 063055 and 110070 representing the slide face after the slide. Calculate **slope** in the units of both 'percent' and 'degrees'. What **reduction of slope** (as a percentage) took place as a result of the slide? (6 *marks*)

4. Determine the **average depth** to which the initial valley floor was infilled with debris to the east of the Crows Nest River. The volume of slide debris was 23 million cubic metres. Estimate the area of the slide debris by the ‘give and take’ method, **using the 100m grid square given**, and the equation V=A x D. (*3 marks*)

5. The slide debris occupies a larger area than it did before the failure occurred. Calculate, as a percentage, how much larger the debris area is in comparison to the original landslide scar area (a so-called “**degree of spread**”). To estimate the area of the debris field, extend the squared grid over the slide area and estimating its area by the ‘give and take’ method. (*4 marks*)

6. In your own words describe the main causes of the Frank Slide. Illustrate as necessary. (*4 marks*)

Map 1. The Frank slide site map.



Coastal Features: Form and Orientation of Beaches and Bars

Given:
The Tracadie map shows part of the eastern shore of New Brunswick which is particularly well known for its constructional coastal landforms. A line of **barrier beaches** and **spits** extend along the coast, almost sealing off **embayments** and forming sheltered **lagoons**.

The Chezzetcook map shows **spits**, **baymouth bars** and **tombolos** on the Atlantic coast of Nova Scotia, just north of Halifax. The features are in most instances formed of coarse sand and pebble materials derived form the erosion of local stony tills of Wisconsin age, particularly from drumlins, which form much of the shoreline topography.

Tracadie Sheet: 1:50,000 scale NTS map, 21P/10 West

Study the Tracadie sheet in conjunction with the two figures and the table provided (Figure 1, Figure 2, Table 1). The Tracadie Lagoon is called Little Tracadie on the figures. Note the pattern of barrier islands and lagoons down the coastline, the tidal ranges given, shoreline bedrock exposure and the drainage basins of the rivers that flow to this coast.

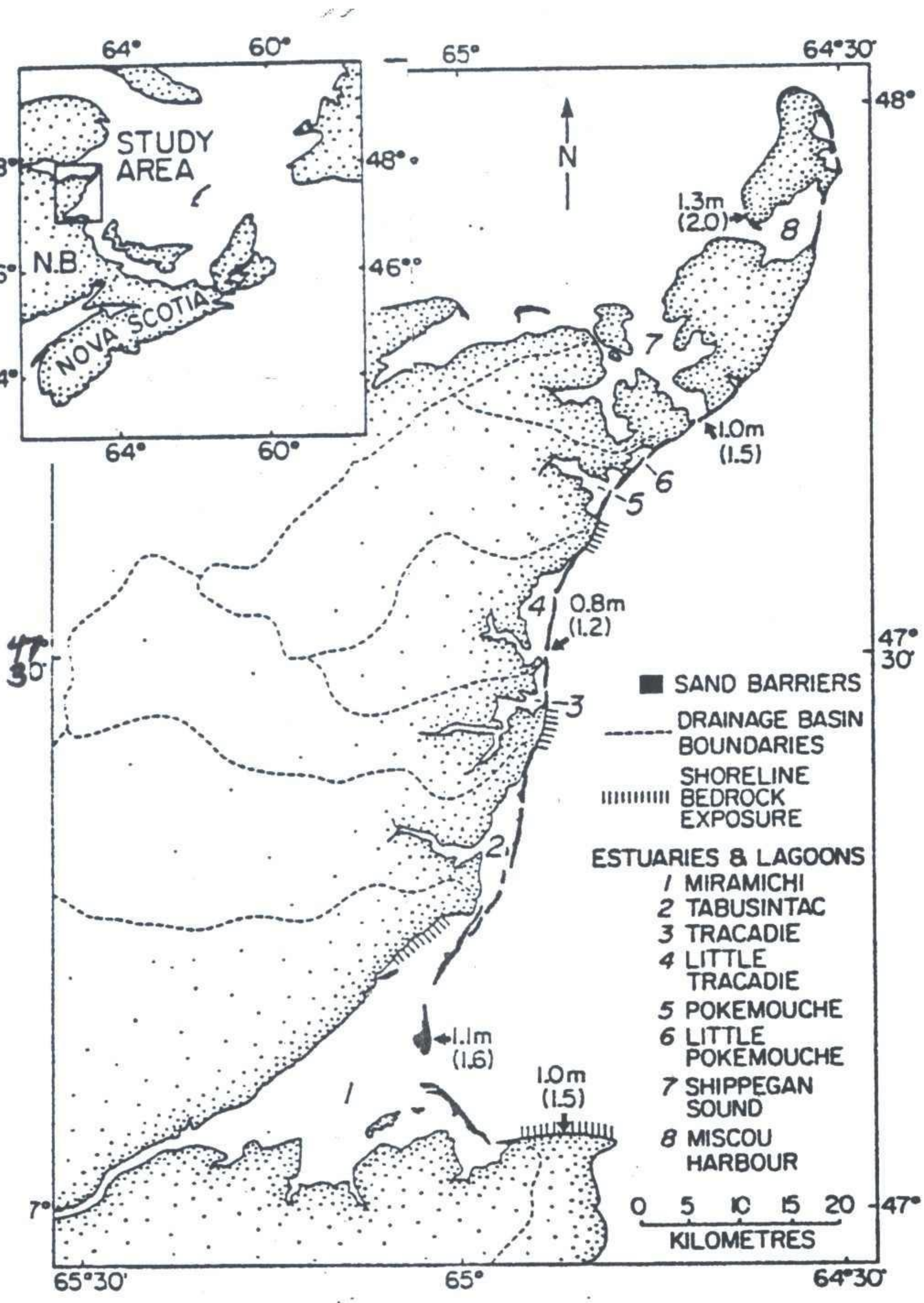
Using Figure 1, Figure 2, and the map, answer Summary Questions 1, 2 and 3.

West Chezzetcook Sheet: 1:50,000 scale NTS map, 11D/11

1. Study the Chezzetcook sheet. On the sketch map provided, carefully mark the coastal segments in which **erosion** (cliffed shoreline, head, point) and **deposition** (beach, bar, spit) prevail. (Most, but not necessarily all the coast will be coloured.) Add to the sketch the **drumlins** in the coastal zone. Add arrows to represent the most likely pattern of **sediment transport** along and around the coastal features. (5 marks)

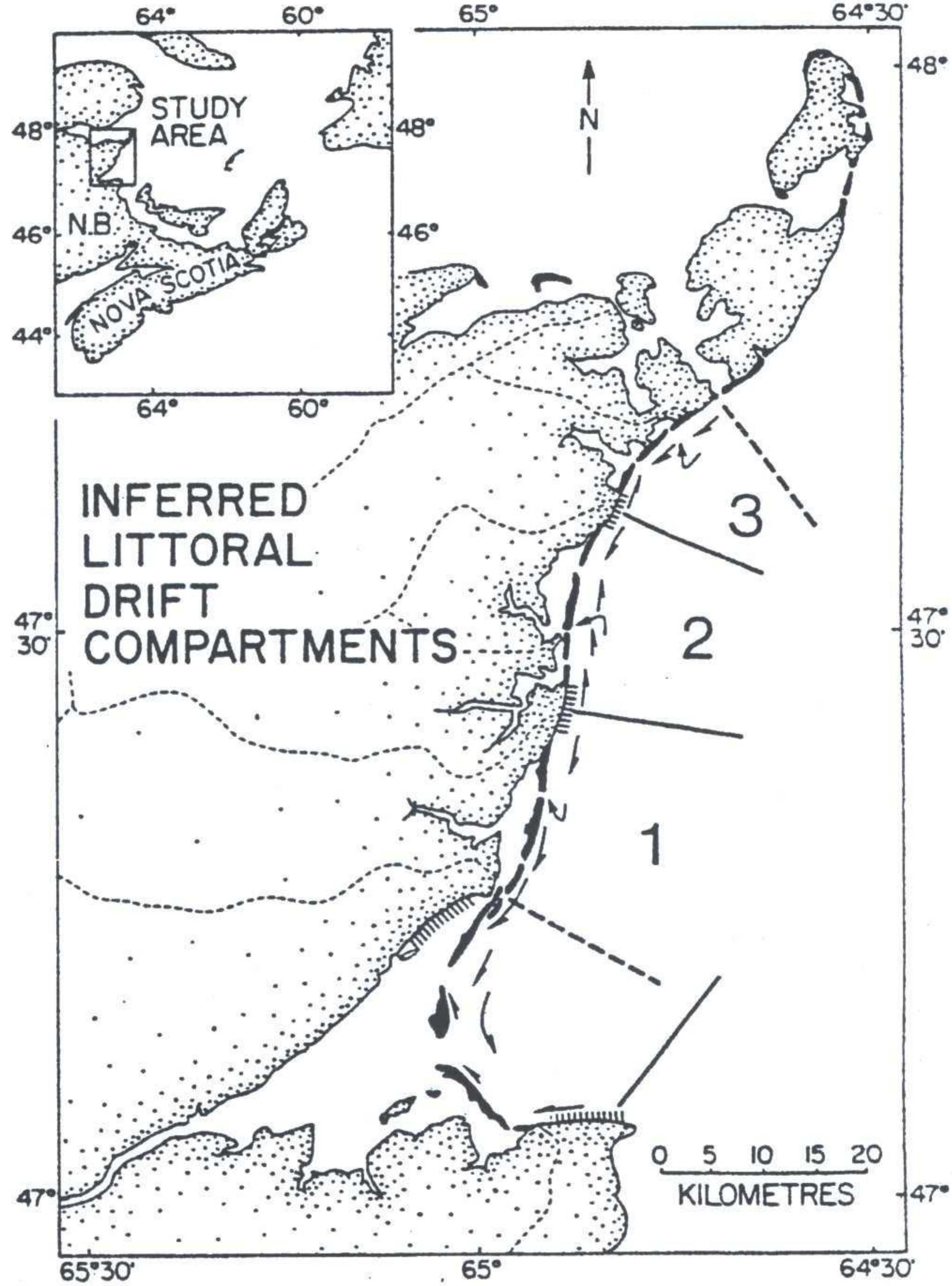
2. The plan shape of a coastal constructional feature has been one element considered in determining the stability or instability of a form. One measure of use is the C/P index, which is the ratio of chord length (C) of the feature to the length of the perpendicular (P) constructed at the mid-point of the chord (see Figure 3). It is stated that a stable beach which has established equilibrium will have a C/P Index close to 15.

Figure 1.



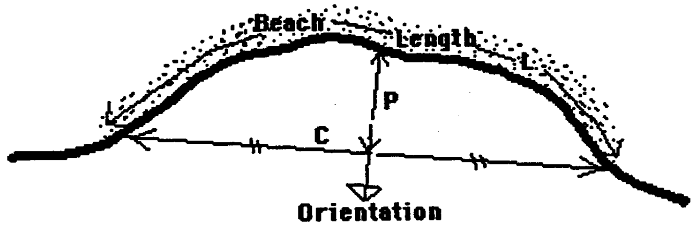
64°
60°
STUDY
AREA
48°
46°
44°
N.B.
NOVA SCOTIA
65°
64°30'
48°
N
1.3m
(2.0)
8
7
1.0m
(1.5)
6
5
4
0.8m
(1.2)
47°
30'
3
2
1.1m
(1.6)
1.0m
(1.5)
1
SAND BARRIERS
DRAINAGE BASIN
BOUNDARIES
SHORELINE
BEDROCK
EXPOSURE
ESTUARIES & LAGOONS
1 MIRAMICHI
2 TABUSINTAC
3 TRACADIE
4 LITTLE
TRACADIE
5 POKEMOUCHE
6 LITTLE
POKEMOUCHE
7 SHIPPEGAN
SOUND
8 MISCOU
HARBOUR
0 5 10 15 20
KILOMETRES
47°
65°30'

Figure 2.



64°
60°
STUDY
AREA
48°
N.B.
46°
NOVA SCOTIA
44°
64°
60°
65°
64°30'
48°
N
INFERRED
LITTORAL
DRIFT
COMPARTMENTS
3
2
1
47°
30'
0 5 10 15 20
KILOMETRES
47°
65°30'
65°
64°30'

Figure 3. Measuring chord length and perpendicular length of constructional features.



3. Make the following measurements from the map sheet for the 13 ***constructional forms*** listed in Table 1, given the constraint of the scale. Record data in Table 1. (10 marks)

    i. Measure the Chord and Perpendicular. Since these are to be used to obtain a ratio, the measurement can be any unit. Compute the C/P Index for each.
    ii. Determine the Orientation of P, using the 16 secondary inter-cardinal directions (ie. N, NNE, NE, ENE, etc)
    iii. Measure the real-world length (L) of the beach features using a thread and the formula Real-world Distance = Map Distance * Map Scale

4. On the circular graph provided, plot the C/P Index against Orientation. Label and Title this graph, and identify each constructional form by number or code (i.e., provide a key). (5 marks)

5. On the squared graph paper provided, plot the C/P Index (x-axis) against Beach Length (y-axis). Label and title this graph, and identify each constructional form by number or code (i.e., provide a key). Draw a line of best fit through the points. (5 marks)

Answer Summary Question 4.

Deliverables:

Submit Table 1, Figure 4, Figure 5, Figure 6 and answers to the Summary Questions.

Table 1: Characteristics of beaches near Chezzetcook, Nova Scotia

#	Feature Name	Grid Coordinates	Chord (C)	Perpen-dicular (P)	C/P Index	Orienta-tion	Length (L) (in m)
1	Cow Bay Beach	650395					
2	Fox Point	708428					
3	Lawrencetown	730432					
4	Masseys Beach	773428					
5	Grand Desert	810475					
6	Long Beach	840476					
7	Martinique Beach	900485					
8	Oyster Pond	954479					
9	Cape Antrim	805470					
10	Miseners Island	826467					
11	Gaetz Lake[1]	795454					
12	Ball Island[1]	783428					
13	Terminal Beach[1]	750425					

[1] Deposition material is not marked on the map for these beaches. Measure the chord length between the headpoints for each of these beaches.

Figure 4: Sketch map of the Atlantic Coast near Chezzetcook, Nova Scotia

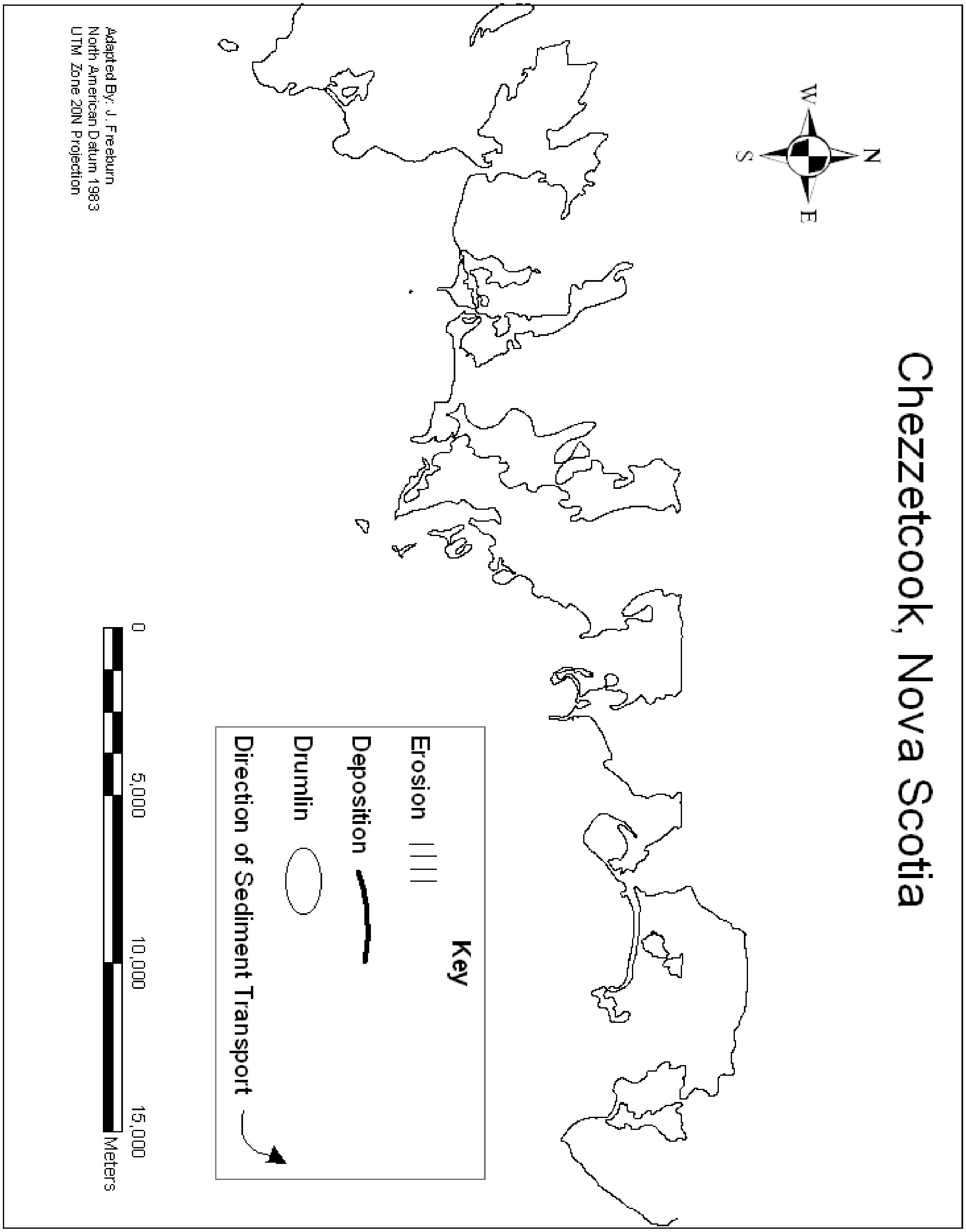


Figure 5: Circle graph of chord length/perpendicular ratio and orientation of beaches near Chezzetcook, Nova Scotia

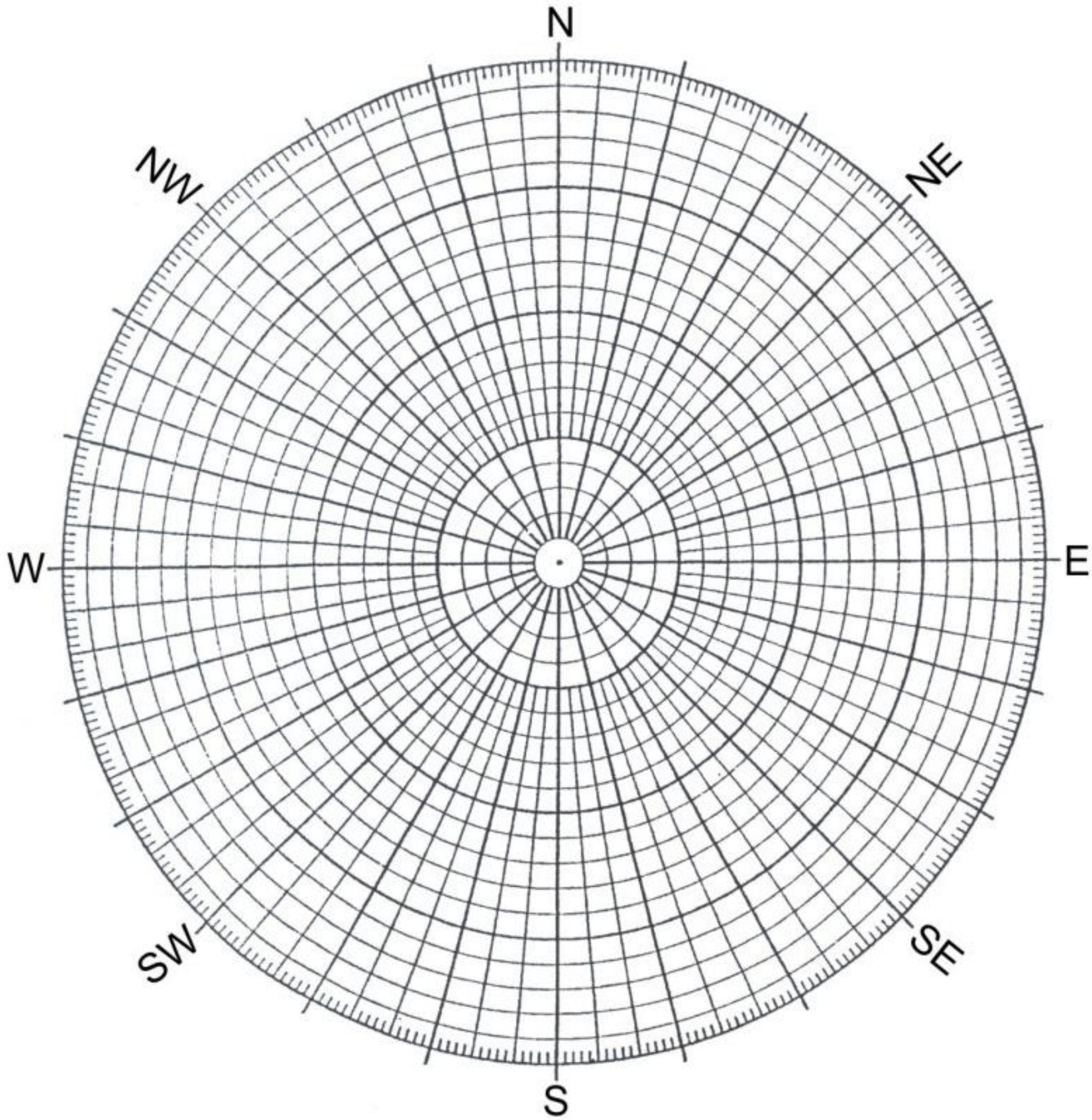


Figure 6: Linear plot of chord length/perpendicular ratio and length of beaches near Chezzetcook, Nova Scotia.

Lab #9 Summary Questions

1. Focusing on the area depicted on the Tracadie mapsheet, and associated information related to coastal sediment transport in figures 1 and 2, identify the main source of **coastal** sediment nourishing the barrier system. Write a short paragraph describing the source and direction of flow of coastal sediment into the Tracadie and Pokemouche compartments. (3 marks)

2. Explain why the artificial breakwater is maintained to (only) the south of Old Gully. What effect does the artificial breakwater have on the 'natural' construction of the barrier islands and the flow of coastal sediment to the north and south of Old Gully? (4 marks)

3. The North Gully and Pokemouche Gully gaps are unprotected yet they remain open. What other natural forces keep these gaps open? (2 marks)

4. Write an analysis of the plots developed.

    a) Is there a relationship between C/P Index and Orientation? (3 marks)

    b) Is there a relationship between length and C/P Index? (3 marks)

    c) Are the constructional features (beaches) on this coastline in equilibrium? If not suggest why, bearing in mind the likely coastal history of this region. (4 marks)