9. GLACIER HYDROLOGY

Objective: to learn about the production and drainage of glacial meltwater and the impact of meltwater on glacial processes.

You should be able to:
- Identify factors influencing the presence of meltwater in glaciers and list locations for water storage in glaciers;
- Discuss types of information scientists can collect on water flow through glaciers using different techniques;
- Outline the characteristics of different types of subglacial drainage networks;
- Describe the factors affecting normal pressure at the base of a glacier;
- Explain the relationship between normal pressure and basal water pressure and describe how this relationship affects glacial processes, and;
- Describe the seasonal progression of drainage network development and meltwater discharge.

Read:

1. List the sources of heat for melting ice. You may want to refer back to Assignment 3.

2. List ways in which water is stored in the following four locations.
   a. supraglacial
   b. englacial
   c. subglacial
   d. adjacent to the glacier

3. Techniques for studying glacier hydrology are listed below. Describe the information each technique can provide regarding glacier hydrology.
   a. dye-tracing experiments
b. analysis of meltwater quality

c. borehole studies

d. radar radio-echo sounding or ground-penetrating radar

e. examination of former glacier beds

4. Describe the impact a glacier’s thermal classification (warm, cold or polythermal) has on the presence of meltwater.
5. Summarize the four types of subglacial drainage systems identified in your textbook by filling in Table 9.1.

**TABLE 9.1 Characteristics of Glacier Drainage Systems**

<table>
<thead>
<tr>
<th>Description of drainage system characteristics</th>
<th>Distributed or discrete?</th>
<th>Widespread or localized?</th>
<th>Efficient or inefficient?</th>
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Equation 9.1 defines shear stress ($\tau$), the driving force behind glacial flow, as the product of density ($\rho$), height (glacier thickness, $h$), gravity ($g$) and the sine of the glacier slope ($\theta$), all of which we explored in assignment 7.

$$\tau = \rho \times g \times h \times \sin \theta$$  \hspace{1cm} (9.1)

Equation (9.2) defines normal pressure ($N$) as the product of density, height, and gravity:

$$N = \rho \times g \times h$$  \hspace{1cm} (9.2)

Substituting equation (9.2) into equation (9.1) gives:

$$\tau = N \times \sin \theta$$  \hspace{1cm} (9.3)

Normal pressure essentially equals the weight of the ice – the force applied to the underlying bed. The weight of the ice helps drive glacial flow but it also helps determine the amount of work done at modifying the underlying landscape. Two other factors affect normal pressure but are not accounted for in equation (9.2). These include the presence of water at the glacier base and flow over an irregular bed.

6. Explain how the presence of water at the base of a glacier affects normal pressure – does it cause normal pressure to increase or decrease? Why? [2]

7. Explain how glacial flow over an irregular bed affects normal pressure – does it cause normal pressure to increase or decrease? Why? [2]

8. Will the changes in normal pressure you described in questions 6 and 7 cause shear stress to increase or decrease? [1]

9. Describe the difference between “normal pressure” and “effective normal pressure.” [2]
10. Cavities provide one location for subglacial water storage (question 2 above). What is the relationship between normal pressure and cavity formation? [2]

11. List the three conditions conducive to basal cavity formation and state why each condition aids cavity formation. [3]

12. List the four factors controlling basal water pressure and describe how each factor influences basal water pressure. [4]

13. Describe three reasons for why an understanding of basal water pressure is important to the study of glaciers. [3]
14. Describe the characteristics of glacier drainage networks throughout the year. Include information on:

- the amount of ablation,
- water storage and meltwater discharge,
- the degree of network development, and
- the subglacial water pressure.

Early spring:

Late spring:

Early summer:

Late summer:

Autumn:

Winter:

15. During which of the six time periods listed in question 14 should glacier flow velocity be highest and during which should flow velocity be lowest? Why?