A COMPARATIVE HYDROLOGIC STUDY OF MELTWATER STREAMS FROM THE EAGLE, HERBERT AND MENDENHALL GLACIERS NEAR JUNEAU, ALASKA.

ANNE E. SAWYER
Department Of Geology, Carleton College
Faculty Sponsors: Professors Mary Savina And Dave Bice, Carleton College

INTRODUCTION

Runoff patterns in glaciated basins are highly complex due to a large number of variables. Variations in runoff are affected by glacial processes such as the formation of complex conduit systems within glacier ice and diurnal variations in ablation. Ablation is regulated by air temperature, wind patterns, air pressure, and precipitation (Te Chow, 1964). Other factors such as aquifer potential of glacial deposits in glaciated watershed valleys and hydraulic pressure under ice further complicate a hydrologic analysis in glaciated basins.

The purpose of this project was to analyze and compare fluctuations in discharge of the Herbert, Eagle, and Mendenhall Rivers to determine if runoff from these three glaciated basins fluctuated on the same temperature and precipitation schedule. By monitoring stage and discharge of these systems throughout the month of July, 2000, and examining historical discharge and climate data, I found that there may be differences between these systems that cannot be accounted for by variations in temperature and precipitation alone. My analysis of runoff patterns suggests that watershed size, percent ice and ablation zone cover are not always indicative of the amount of runoff from a glaciated basin. Results also suggest that there is a strong diurnal variation in meltwater discharge from the Eagle, Herbert and Mendenhall glaciers- strong enough to be detected up to 8 kilometers downstream from glacier termini. It is evident from these results that the Eagle, Herbert and Mendenhall systems are highly dynamic and can change their behavior on a daily and yearly basis.

METHODS

Discharge and stage were monitored on the Herbert, Eagle and Mendenhall Rivers throughout the month of July, 2000. Measurements were taken at highway bridges across each river to ensure safety and ease of access. A tag line was set up across each bridge to establish data collection stations across each stream on the side with the least amount of debris, which ranged from gravel bars to abandoned cars. Stage was measured at a designated point under each bridge.

Depth and velocity data were collected at each station along the tag lines. Depth was measured using a rope anchored with a weighted steel pipe. Velocity was measured using a General Oceanics Inc. current meter attached to the weighted rope. The current meter was placed at six-tenths depth of the water column for two minutes in order to obtain the average velocity for each section (Te Chow, 1964). When stream velocity was too great to use the pipe as an anchor, depth was calculated using streambed profiles and average velocity was calculated using the following formula: average velocity =(surface velocity)*0.86 (Mosely and McKerchar, 1993) Stage was measured before and after each depth/ discharge profile to obtain an average. A stage-discharge rating table was created for each system by correlating stage measurements and discharge calculations. Measurements were made approximately once or twice every two days for three weeks.

Twenty-four hour stage, air, and water temperature data were collected using a PDCR 1830-8388 Druck pressure transducer and two thermisters wired to a Campbell Scientific Inc. model 21X micro logger. Each stream was logged for the duration of one week. However, the data logger was placed in Mendenhall Lake rather than in Mendenhall River in order to correlate my data with those from the United States Geological Survey's (USGS) data collection station on Mendenhall Lake. The USGS correlated lake stage with downstream velocity measurements to obtain discharge. My stage and discharge results matched those of the USGS to within ten percent. Thus, for the remainder of the summer, I used USGS discharge data for the Mendenhall River to do a direct comparison with my data from the Herbert and Eagle Rivers.

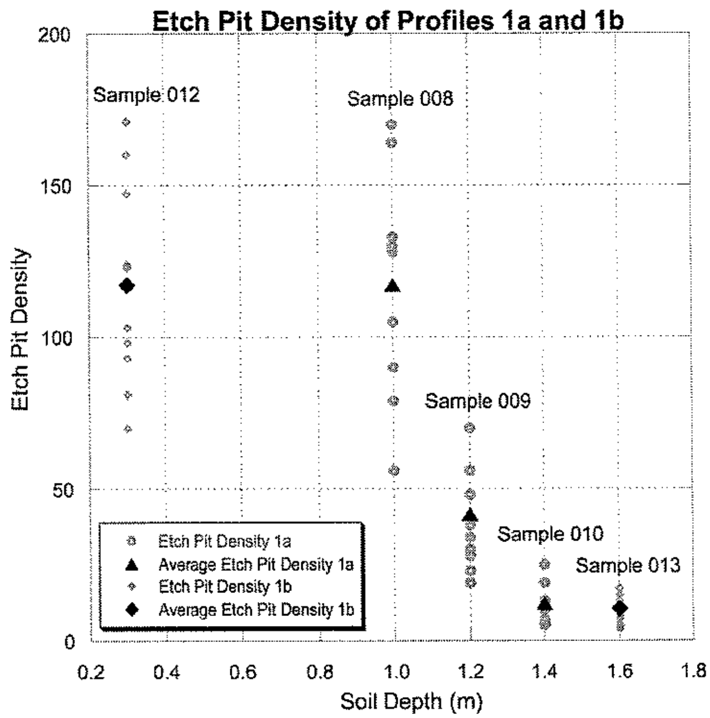

Figure 4. 'Etch pit density' refers to the number of etch pits counted on the weathered faces of feldspar grains with the use of the SEM. The etch pits were counted in a randomly selected 10 cm x 15 cm area on feldspar mineral grains under 1000x magnification and an accelerating voltage of 25kV. Please note that soils were sampled from the mid-section of each horizon.

grains must be typical of weathering in this climate zone over this duration of time. Some weathering of feldspar grains has taken place, but not enough to rid the soils of the feldspars completely. In fact, the original structure of most feldspar grains is still evident throughout the profile. The Herbert Glacier must have less weathered soils than those of the Mendenhall, because of the lower organic accumulation and slower soil reaction rates that are due to less rainfall and cooler temperatures (Crocker and Dickson, 1957). However, the Herbert soils developed for a much longer period of time than those on the Mendenhall moraines, so the differing soil morphologies must also be the product of drainage class. The dense Herbert tills must inhibit the continuous flushing of freshwater through the soils, and consequently the chemical weathering processes are lengthened in the poorly drained soils.

REFERENCES CITED:

Alexander, E.B. and Burt, R., 1996, Soil development on moraines of Mendenhall Glacier, Southeast Alaska. Part 1: The moraines and soil morphology: Geoderma, 72: 1-17.

Berner, R.A. and Holdren, G.R., 1977, Mechanism of feldspar weathering: Some observational evidence: Geology, 5: 369-372.

Berner, R.A. and Holdren G.R., 1979, Mechanism of feldspar weathering – II. Observations of feldspars from soils: Geochimica et Cosmochimica Acta, 43: 1173-1186.

Calkin, P.E. and Wiles, G.C., 1991, Little Ice Age glaciation in Alaska: A record of recent global climatic change: International Conference on the Role of Polar Regions in Global Change, Proceedings 1990, 2: 617-623.

Chandler, R.F., 1943, The time required for podzol formation as evidenced by the Mendenhall Glacier deposits near Juneau, Alaska: Soil Science Society of America, Proceedings 1942, 7: 454-459.

Cremeens, D.L., Darmody, R.G. and Norton, L.D., 1992, Etch-pit size and shape distribution on orthoclase and pyriboles in a loess catena: Geochimica et Cosmochimica Acta, 56: 3423-3434.

Crocker, R.L. and Dickson, B.A., 1957, Soil development on the recessional moraines of the Herbert and Mendenhall Glaciers, Southeast Alaska: Journal of Ecology, 45: 169-185.

Dearman, W.R. and Baynes, F.J., 1979, Etch-pit weathering of feldspars: Proceedings of the Ussher Society Conference, 390-401.

Lamb, H.H., 1977, Climate: present, past and future, vol. 2: Methuen, London, 835p.

Lawrence, D.B., 1950, Glacier fluctuation for six centuries in Southeastern Alaska, and its relation to solar activity: The Geographical Review, 40: 191-223.

Lee, M.R. and Parsons, I., 1995, Microtextural controls of weathering of perthitic alkali feldspars: Geochimica et Cosmochimica Acta, 59: 4465-4488.

Stevens, M.E., 1963, Podzol development on a moraine near Juneau, Alaska: Soil Science Society of America, Proceedings 1963, 27: 357-8.

Ugolini, F.C., 1968, Soil development and ecological succession in a deglaciated area of Muir Inlet, Southeast Alaska: Ohio State University Institute of Polar Studies Report no.20, part 3: 39-59.

Glacier ablation was estimated using ablation stakes on Mendenhall Glacier. Four sticks of known length were emplaced in the ice perpendicular to the ice surface and the length of each stick above the ice was measured. The location of each stick was recorded with a Trimble GeoExplorer3 Global Positioning System (GPS) unit. The change in surface height of the ice was measured for a period of three days.

While in Juneau, I obtained historical stage, discharge, and climate data for both the Herbert and Mendenhall rivers for July and August 1969 to 1979 from the USGS Water Resources Division office. I used this historical data as another method of comparison between Herbert and Mendenhall Rivers and as a comparison of changes in system behavior over a period of three years.

Watershed area and percent ice cover in each watershed (Figure 1) was calculated in ArcView GIS 3.2 based on 15' USGS quadrangle maps. Watershed area was used to calculate the amount of runoff in millimeters per day from each watershed. Ablation zone area was estimated with ArcView using 1995 equilibrium line data (Ramage, 1998). Hydrographs, which included runoff, rainfall, and temperature, were created in KaleidaGraph using USGS historical and present-day data and my data for July 2000 (Figure 2). MatLab 5.2, a spectral analysis program, was used to identify diurnal variations in streamflow. Spectral analysis uses a Fast Fourier Transform to decompose a given curve into component sine and cosine functions. The transform outputs a power value for each frequency and the frequencies associated with higher power values represent the most significant cycles in the data (Jensen, 1999). Due to the close proximity of Eagle and Herbet cross section locations to the ocean, I had to determine whether there was a tidal influence reflected in my data. In order to separate the diurnal and tidal cycles from larger cycles such as rainfall I had to run a band pass filter on my data. I used a Band Pass Filter to eliminate cycle frequencies greater than one day and less than six hours in order to eliminate noise and isolate the diurnal and tidal cycle frequencies. Figure 3 shows an example of filtered 2000 data, in which the diurnal cycle is very strong, and Figure 4 shows the results of a Fast Fourier Transform run on the filtered data.

KaleidaGraph was used to analyze the Eagle, Herbert and Mendenhall hydrographs. Total runoff and precipitation during any specific hydrologic event was calculated by integrating the hydrograph in KaleidaGraph. Runoff from the Eagle, Herbert and Mendenhall watersheds was compared on an event-by-event basis and an overall basis. Using runoff calculations for days where ablation was measured, I computed the amount of melted ice in the ablation zone necessary to produce the amount of runoff seen from the watershed per day. I then compared that result to the ablation estimates from the Mendenhall Glacier to determine how much water was being generated from ablation alone.

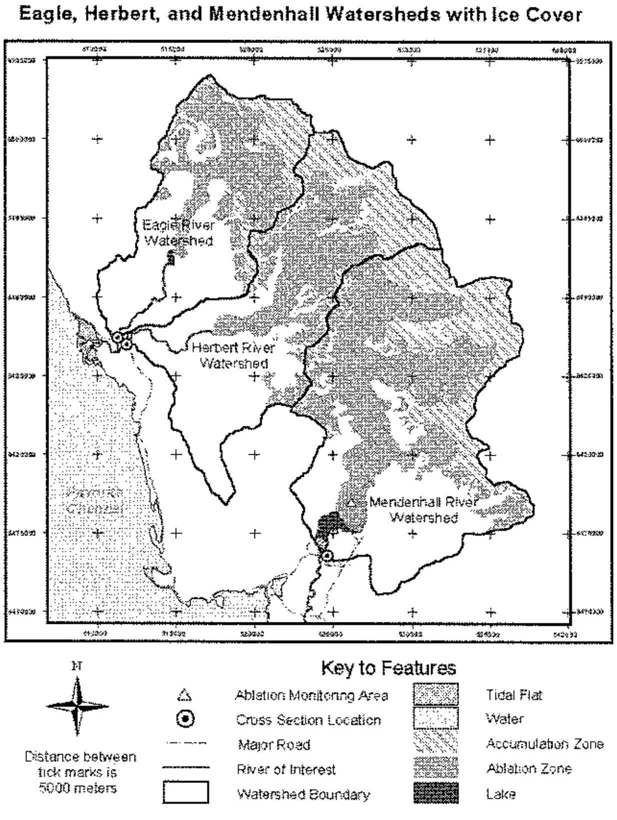

Figure 1: Field area map

RESULTS

- Using a spectral analysis, I was able to determine that the Mendenhall, Eagle and Herbert watersheds all have obvious diurnal fluctuations reflected in runoff (Fig. 2, 3 and 4). The Eagle and Herbert rivers show a weak twelve-hour tidal cycle that is insignificant when compared to the diurnal variation. There is no tidal influence at the Mendenhall River monitoring location.

- The Eagle River has smaller diurnal peaks than both the Mendenhall and Herbert Rivers. The Herbert River shows the strongest diurnal variations both historically and in July 2000. It is possible that the lakes at the front of the Mendenhall and Eagle Glaciers dampen the diurnal or event signal.
- Historically and presently, both the Herbert and Mendenhall Rivers respond quickly to rainfall. However, the Mendenhall River tends to have higher runoff peaks in response to precipitation events relative to the Herbert. The Herbert appears to drop back to baseflow more quickly than does the Mendenhall, which may respond slowly due to a dampening effect from Mendenhall Lake.
- As temperature increases, diurnal peaks become more obvious. As rainfall increases, the diurnal signal tends to be overwhelmed and the hydrograph becomes more complex. It appears that rainfall onto ice surfaces causes ablation to increase.
- Ablation data were inconclusive due to a number of factors including, but not limited to, difficulties in estimation of system response to rainfall events and lack of ablation data for days when the Eagle River was monitored with the data logger.
- My data show that the Eagle watershed has more runoff than the Herbert watershed relative to the amount of ice and ablation zone cover per watershed. The Herbert River watershed has 20% more ice and ablation zone cover than the Eagle River watershed, yet runoff from the Herbert River was 1/3 less than that from the Eagle River within a 30 minute time interval (Fig. 2).
- The Herbert and Mendenhall Rivers show stark differences in behavior with respect to each other on a yearly basis. Thus, the short amount of time I had in the field was not enough to make general assumptions about stream behavior.

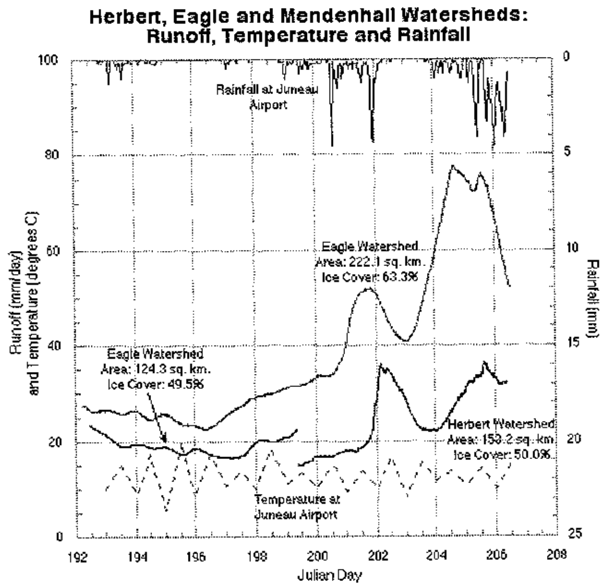

Figure 2: Hydrograph of Herbert, Eagle, and Mendenhall Rivers for July 10-24, 2000.

CONCLUSIONS

The Mendenhall, Eagle, and Herbert Rivers do not appear to behave in similar fashions, although all three streams show strong diurnal signals. I believe that the Eagle watershed, and possibly the Herbert and Mendenhall, experience water influx from sources other than local ablation or meteoric input. One possibility is water influx from the Juneau Icefield may enter the glacier basins under considerable hydraulic pressure. Another possibility is that there is a larger aquifer potential and groundwater influx than previously assumed. I can also conclude that were I to do further research on the Herbert, Eagle and Mendenhall Rivers, I would conduct a more thorough study over a number of years and with data loggers at glacier termini and downstream locations.

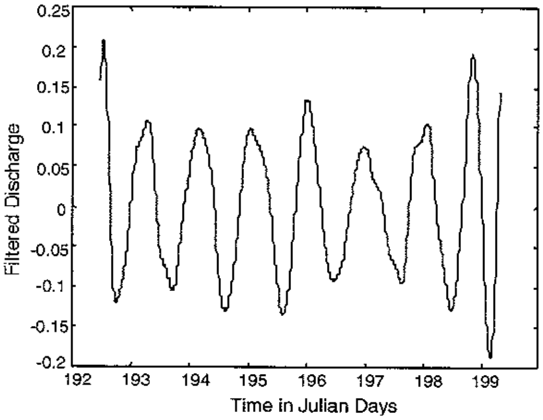

Figure 3: Eagle River discharge data after filtering out frequencies larger than 2 hours and smaller than 10 hours.

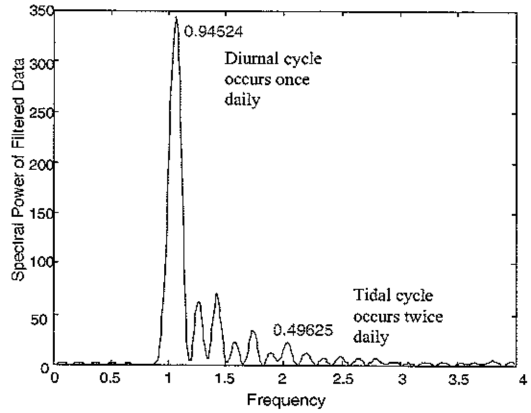

Figure 4: Spectral Analysis of Eagle River discharge. Larger peaks indicate stronger influence of the cycle on the system.

ACKNOWLEDGEMENTS

I would like to thank the Keck Geology Consortium and the National Science Foundation for funding this project. I would also like to thank Ed Neal at the USGS Water Resources Division office in Juneau for allowing me to ruffle through old files and spend two hours photocopying them and for all of the data he has provided. I would like to thank Joan Ramage for the equilibrium line data. I'd also like to thank Dave Bice for teaching me how to use MatLab. And of course, this one goes out to my mother.

SOURCES

Jensen, J., 2000, Direct Dating of Milankovitch Cycles: Evidence for a 123 and 95 Kyr eccentricity cycles at Monte dei Corvi, Italy, [Undergraduate Thesis]: Carleton College, 36p.

Mosely, M. P., and McKerchar, A. I., 1993, Streamflow, *in* Maidment, D. R., ed., Handbook of Hydrology: New York, McGraw-Hill, 8.1-8.39.

Ramage, J. M., 2001, Satellite Remote Sensing of Daily, Seasonal, and Annual Changes on Southeast Alaskan Glaciers 1986-1998, [Ph.D. Dissertation]: Cornell University, 283p.

Te Chow, V., 1964, Handbook of Applied Hydrology: New York, McGraw-Hill Publishing Company, 876.

U.S. Department of Commerce, 1969-1971, Local Climatological Data: Annual Summary With Comparative Data 1969-1971 Juneau, Alaska, USGS Water Resources of Alaska, Juneau, personal photocopying of unpublished documents, 2000.

U.S. Geological Survey Water Resources of Alaska, 2000, Mendenhall River Near Auke Bay Real-Time Provisional Data, July 4-26.

U.S. Geological Survey Historical Discharge Data for Herbert River Near Auke Bay, Alaska, and Mendenhall River Near Auke Bay, Alaska, 1969-1971. USGS Water Resources of Alaska, Juneau, personal photocopying of unpublished documents, 2000.

DEFORMATION HISTORY OF THE COAST STEEP ZONE, PRINCE RUPERT, BRITISH COLUMBIA

FACULTY

Cameron Davidson, Beloit College
Christopher Bailey, The College of William and Mary
Steve Ballou, Beloit College
Anu Gupta, Biosphere 2 Center

STUDENTS

Daniel Alvarado, Trinity University
Eric Butler, Beloit College
Laura E. Clor, The College of Wooster
Kenneth J. Davis, The College of William & Mary
Nicole Granger, Bates College
Katherine Rodriguez, St. Norbert College
Deborah Roth, The Colorado College
John Singleton, Pomona College
Carl H. Tape, Carleton College

VISITING FACULTY SPONSORS

Allen Dodsen, The College of Wooster
Dykstra Eusden, Bates College
Tim Flood, St Norbert
Steve Weaver, Colorado College