

## Glacier Lakes Ecosystem Experiments Site (GLA)

The Glacier Lakes Ecosystem Experiments Site (GLA) was established in the late 1980's where research and monitoring could be conducted in high elevation alpine and subalpine aquatic and terrestrial ecosystems in the upper treeline ecotone. Research and monitoring are determining the amount of air pollutants deposited in alpine and subalpine ecosystems, and the impact of this deposition on the terrestrial and aquatic components of these ecosystems. The GLA is a remote area and is considered to be relatively pristine with low amounts of deposition. Long-term physical, chemical, and biological monitoring is important at GLA to determine change in atmospheric environment and climate, and the impact of any change on the ecosystem. Documentation of any increase in anthropogenic deposition can be monitored at the GLA; and data from the GLA can be compared to other western U.S. high elevation sites that are already impacted by anthropogenic pollutants. Alpine ecosystems represented by GLA are highly sensitive to climate change, air pollutants, and chemical deposition. The GLA is similar to many wilderness ecosystems in the western U.S. and has a history of grazing and light recreation use.

Integrated ecosystem level research conducted involves the disciplines of meteorology, biology, hydrology, soils, geology, limnology, ecology, plant physiology, biogeochemistry, and snow chemistry and physics. Current research includes studies on long term trends in deposition, effects of nitrogen deposition on subalpine meadow and on riparian systems, effects of winter recreation on air quality, the cycling of nitrogen through riparian ecosystems, the dynamics of disturbance in subalpine ecosystems, and the development and testing of techniques for monitoring of Air Quality Related Values (AQRVs) in wilderness ecosystems.



East (left) and West (right) Glacier Lakes, GLA, from the top of the Snowy Range ridge.

**Site characteristics:** The GLA is a 600 ha wilderness-like watershed in complex mountainous terrain containing small, alpine to subalpine catchments that include persistent snowfields, glacial cirque lakes, first and second order streams, wetlands, and forest. The GLA is located at 3200-3500 m elevation on the Laramie Ranger District, Medicine Bow National Forest in the Snowy Range in the Medicine Bow Mountains of SE Wyoming, 55 km west of Laramie, and 15 km NW of Centennial, Wyoming. Research and monitoring at the GLA is managed by the USDA Forest Service, Rocky Mountain Research Station. Most aquatic research at the GLA is conducted at two adjacent (120m distant) alpine lakes, East and West Glacier Lake, having similar surface area and depth, but differing in catchment area, inflow patterns, turnover rates, stratification, snowcover, deposition input, water chemistry and aquatic biota. They are ice-covered 7-8 months of the year. Almost 200 phytoplankton species have been identified in the GLA lakes. The lakes have low buffering capacity and are sensitive to atmospheric deposition.

The site became de-glaciated 15,200 years ago, with glacial cirque basins and lakes now dominating the upper reaches of the three main catchments. A permanent snowfield exists at the top of one of the basins. Bedrock at the site is primarily slow-weathering Medicine Bow Peak quartzite. Talus slopes and scree fields are common. Glacial till is present in some areas of the watershed. Soils are shallow, immature, and minimally developed with low base saturation, formed over quartzite bedrock that is crossed by weatherable mafic intrusions of amphibolite.

The GLA is located at the ecotone between alpine and subalpine. Alpine and subalpine vegetation is composed of more than 300 vascular plant species in 14 distinct plant associations. Dominant landscape

types are alpine, subalpine meadow, Engelmann spruce/subalpine fir forest, shrub, krummholz [wind deformed conifer trees], exposed bedrock, and scree. Included are old-growth forests with trees more than 700 years old. The GLA is a harsh environment with a short growing season having high winds and low temperatures. The GLA is accessible year round, by snow machine in the winter.

Meteorological observations are monitored at two locations, one at an alpine/subalpine ecotone location (Glacier Lakes) and the other in the subalpine (Brooklyn Lake). Data loggers receive, process, and store data every 15 minutes, including air and soil temperature, surface wetness, relative humidity, wind speed and direction, solar radiation, and precipitation. Average winter high temperature at the GLA is  $-6^{\circ}\text{C}$ , average winter low is  $-12^{\circ}\text{C}$ . Summer highs average  $14^{\circ}\text{C}$ , summer lows average  $6^{\circ}\text{C}$ . Mean air temperature at the GLA is  $-0.5^{\circ}\text{C}$ . Average wind speed in winter is  $13\text{ km hr}^{-1}$ , with average minimum of  $7.6\text{ km hr}^{-1}$  and average maximum of  $19\text{ km hr}^{-1}$ . Winter gusts greater than  $72\text{ km hr}^{-1}$  are common. Summer average wind speed is  $9\text{ km hr}^{-1}$ , with average minimum at  $3.2\text{ km hr}^{-1}$  and average maximum at  $15.5\text{ km hr}^{-1}$ . Annual precipitation averages 124 cm with 75-85% deposited as snow. Extensive snow cover exists from November through June and averages about 2 m snow depth at maximum winter accumulation. Hydrological monitoring at the GLA includes stream flow from four Parshall flumes and periodic snow core surveys. Lake, stream, soil, and snow chemistry are monitored at the GLA.

Databases exist on physical, biological, and environmental characteristics of the GLA. An extensive collection of meteorology, hydrology, air and water quality, water chemistry, snow chemistry, wet and dry deposition volume and chemistry, geology, soils, snow cover, landscape habitat, aquatic, floristic, and topographic information exists in the GLA database. A network of terrestrial field plots, hydrological sites, and permanent vegetation and aquatic sampling plots exist. An extensive herbarium collection of vascular plant species is housed at the GLA, with a duplicate set archived at the University of Wyoming Herbarium, Laramie, Wyoming. Checklists of terrestrial vascular plant species, phytoplankton,



**Lost Lake, a glacial cirque basin along the Snowy Range ridge at the GLA.**

periphyton, zooplankton, and macroinvertebrates have been assembled. Detailed soils descriptions are available. Maps are available of GLA topography, vegetation habitats, geology, and soils. Wet deposition chemistry is monitored at two NADP sites, WY00 located at West Glacier Lake and WY95 located at Brooklyn Lake. Dry deposition chemistry and ozone are monitored at CASTNet site CNT169, Brooklyn Lake. A SNOTEL site is located less than 0.5 km south of the GLA for remote sampling of precipitation, minimum, maximum and average temperature, snow depth, and water content. An AMERIFLUX site also is located at the GLA for monitoring carbon dioxide and heat and energy fluxes.

Laboratory, storage, lodging, and kitchen facilities are available for researchers in Centennial, Wyoming, approximately 10 km from the GLA. Information on the GLA is summarized in the publication: USDA Forest Service General Technical Report RM-249. The Glacier Lakes Ecosystem Experiments Site. 1994, available on-line from the GLA Website: <http://www.fs.fed.us/rm/landscapes/Locations/GLA/GLA.shtml>. The GLA database is being migrated to the RMRS archive database ([http://www.fs.fed.us/rm/data\\_archive/](http://www.fs.fed.us/rm/data_archive/)). Data from the national monitoring networks, NADP, CASTNet, SNOTEL, and AMERIFLUX, are available at their websites.