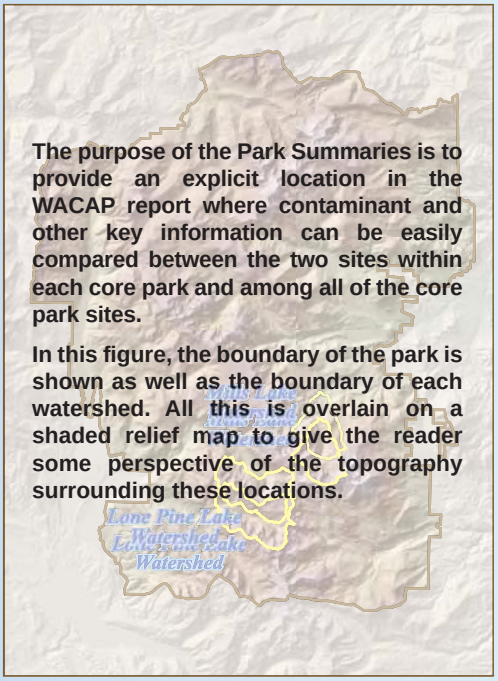
KEY

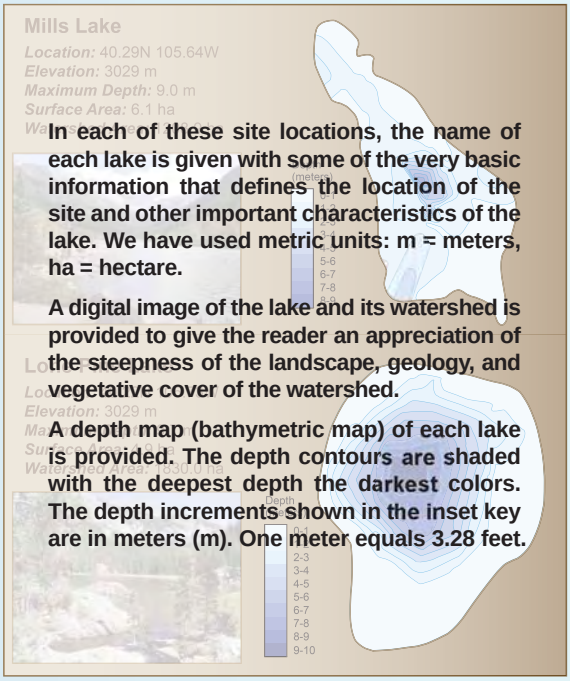
The Park Summaries that follow in this chapter have been prepared to provide the reader with a summary of selected contaminant results for each core WACAP national park. A set of reduced summaries for the secondary parks that contain only vegetation results follows the core park summaries, with a separate key. The Arctic parks GAAR and NOAT, with one lake site each, have been combined into one summary. These summaries contain a considerable amount of information, but do not represent all data and information available for the parks. This two-page Key provides explicit detail regarding each block of information the reader will encounter on the two-page graphical summaries and is intended to guide the reader through the summaries. Summaries for all parks are presented in the same format. The summaries are designed so the two lake sites within each park can easily be compared and the relative position of these sites within the context of all WACAP core parks can be visualized. The reader is encouraged to consult the other chapters of this report for more detailed information on the full range of WACAP results and their interpretation.

◆ Park and Lake Setting ◆



The purpose of the Park Summaries is to provide an explicit location in the WACAP report where contaminant and other key information can be easily compared between the two sites within each core park and among all of the core park sites.

In this figure, the boundary of the park is shown as well as the boundary of each watershed. All this is overlain on a shaded relief map to give the reader some perspective of the topography surrounding these locations.

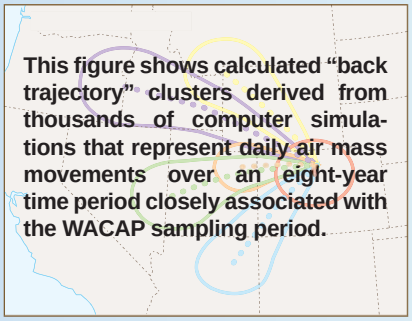


In each of these site locations, the name of each lake is given with some of the very basic information that defines the location of the site and other important characteristics of the lake. We have used metric units: m = meters, ha = hectare.

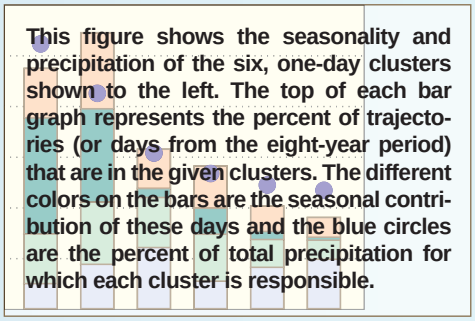
A digital image of the lake and its watershed is provided to give the reader an appreciation of the steepness of the landscape, geology, and vegetative cover of the watershed.

A depth map (bathymetric map) of each lake is provided. The depth contours are shaded with the deepest depth the darkest colors. The depth increments shown in the inset key are in meters (m). One meter equals 3.28 feet.

◆ Atmospheric Transport ◆

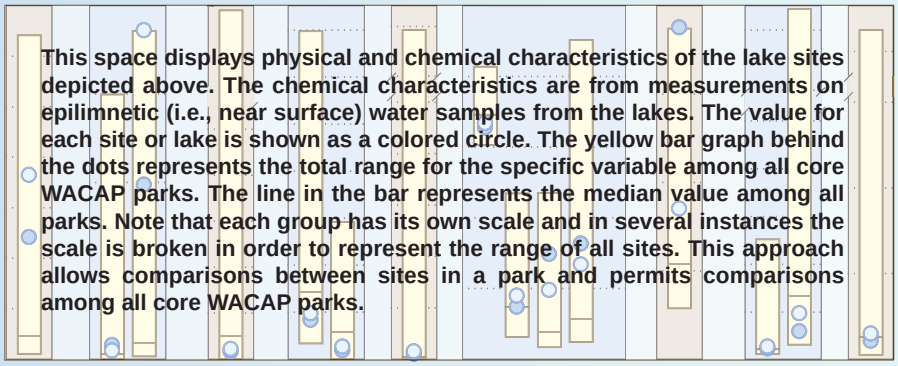


This figure shows calculated "back trajectory" clusters derived from thousands of computer simulations that represent daily air mass movements over an eight-year time period closely associated with the WACAP sampling period.



This figure shows the seasonality and precipitation of the six, one-day clusters shown to the left. The top of each bar graph represents the percent of trajectories (or days from the eight-year period) that are in the given clusters. The different colors on the bars are the seasonal contribution of these days and the blue circles are the percent of total precipitation for which each cluster is responsible.

◆ Physical and Chemical Characteristics ◆



This space displays physical and chemical characteristics of the lake sites depicted above. The chemical characteristics are from measurements on epilimnetic (i.e., near surface) water samples from the lakes. The value for each site or lake is shown as a colored circle. The yellow bar graph behind the dots represents the total range for the specific variable among all core WACAP parks. The line in the bar represents the median value among all parks. Note that each group has its own scale and in several instances the scale is broken in order to represent the range of all sites. This approach allows comparisons between sites in a park and permits comparisons among all core WACAP parks.

◆ Snow Contaminant Fluxes ◆

This figure shows the fluxes of the most prevalent semi-volatile organic compounds* (SOC) and five metals present in the annual snow pack samples taken over the three years of WACAP sampling. The different sites sampled in the park are represented by the colored dots. The three sample years are indicated by the placement of the dots in the width of the yellow bars: Spring 2003 is on the left edge, Spring 2004 is in the middle, and Spring 2005 is on the right edge. The yellow bar in back of the dots represent the total range of snow contaminant fluxes among all core WACAP parks and the line on each bar represents the median value for each contaminant. Note the vertical axis is in log units that range from 0.01 to 1,000,000 ng/m²/yr.

◆ Whole Fish Contaminant Concentrations ◆

Whole fish concentrations in ng/g wet weight of the most prevalent semi-volatile organic compounds* (SOC) and five metals are shown in this figure. The blue bars for contaminant concentrations show the maximum, minimum, and median (horizontal line) values of the five to ten fish analyzed from each lake. The yellow bar behind the fish data represents the total range for these contaminants among all core parks and the line in each bar represents the median value for all parks. Note the vertical axis is in log units that range from 0.0001 to 100,000 ng/g.

Contaminant health thresholds cited in the literature are shown on this graph for selected SOCs and mercury for humans and piscivorous mammals and birds. Human thresholds for SOCs (discussed in Section 5.4.3) are based on consumption levels for recreational and subsistence fishers. The human threshold for mercury (discussed in Section 5.4.1) is based on a consumption rate similar to the values for recreational fishers, and was converted from a fillet to whole-fish basis. The piscivorous mammal threshold (discussed in Section 5.4.2) is an average of the thresholds for otter and mink (Lazorchak et al., 2003).

**SOC groupings by compound class are listed in Table 4-1.*

◆ Vegetation Contaminant Concentrations ◆

The concentrations of the most prevalent semi-volatile organic compounds* (SOC) and total mercury in lichen and two-year old conifer needles are shown for core WACAP sites in this figure. Conifers were sampled along an elevation gradient shown by the colored dots on the right, above each contaminant name. The left-side shows the median value for a bulk lichen sample taken near the lake site. Lichens differ from conifer needles in that they cannot be aged and usually are expected to be more than two years old. The yellow bars behind the dots show the total range of contaminants among all core WACAP parks for the respective plants and the line in the bars represents the median value. Note these values are on a log scale – spanning a very broad range of concentrations from 0.001 to 1,000,000 ng/g (lipid weight for SOCs, dry weight for mercury).

◆ Sediment Organic Contaminant Fluxes ◆

Yearly focusing factor-corrected sediment fluxes of semi-volatile organic compounds* (SOC) are shown in this figure. Year (depth) is shown on the vertical axis. Given the expense of the SOC analyses, WACAP allocated approximately eight slices to be analyzed for each sediment core. The green lines are the year in which the individual SOC was registered with the US government. When present, the red dotted line is the date that use in the US was discontinued. An asterisk indicates that the value at that level in the core was below the detection limit. Profiles of the two lakes are shown side by side for each different contaminant.

◆ Sediment Contaminant Fluxes ◆

These figures are sediment profiles for each site. The top of the graph represents the surface of the sediment core; the dates on the vertical axis are derived from ^{210}Pb dating. Each point on a graph represents results of an analysis of a sediment slice having an average date represented by the circle.

Sediment flux is expressed as mass per unit area per year. Spheroidal Carbonaceous Particles (SCP) are microscopic "fly ash" materials formed only by high temperature combustion associated with fossil fuel (coal and oil) combustion. They are excellent indicators of local or regional sources of human industrial activities. Total Organic Carbon is a component of the sediment record derived from in-lake photosynthesis production or watershed sources and typically decreases with depth as a result of biogenic processes in the sediment.

Sediment Metals Enrichment: Results of the analysis of four metals in lake sediments for each of the two lakes are shown here. The units are expressed as Percent Enrichment from historical (pre-industrial) background values near ~1880. The results have been "normalized" to titanium, which removes much of the noise in the profiles related to watershed processes (e.g., weathering, avalanches). These profiles show the recent history of metal deposition to each lake system with respect to background.

Summary: Glacier National Park

Oldman and Snyder lakes share many physical characteristics. However, Oldman Lake has a much greater volume and greater maximum depth, as well as greater specific conductance, pH, and acid neutralizing capacity. Snyder Lake is more productive, with higher total phosphorus, nitrogen, and chlorophyll-*a*. At GLAC, air, vegetation, and snow had among the highest concentrations for current-use pesticides, compared with these media at the other parks. The source of these compounds probably was regional agriculture within a few hundred kilometers of the park.

Air

Compared to measurements at the other parks, high concentrations of SOCs detected in air include PAHs, dacthal, endosulfans, HCB, a-HCH, and g-HCH. Low concentrations of chlordanes and PCBs were also detected. Concentrations at Oldman Lake, east of the Continental Divide, were higher than those at Snyder Lake, west of the Continental Divide.

Snow

Snow water equivalents, contaminant concentrations (except PAHs), and contaminant flux to the snowpack in GLAC were similar to those at the other parks. For PAHs, the concentrations and fluxes at Snyder Lake were substantially higher than those at Oldman Lake. Mercury flux to the snowpack was near average among parks, but fish concentrations of mercury were below average, indicating low rates of mercury methylation and bioaccumulation, similar to rates at ROMO. SOC concentrations in snow varied considerably among the sites sampled. However, within the same year, the range for all contaminants in GLAC was typically within an order of magnitude. PAH concentrations in snow at Snyder Lake were always higher than at the other sites, and among the highest at all parks.

Vegetation

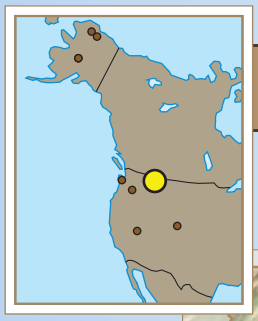
Numbers and concentrations of PAHs detected were highest at GLAC than at other parks. Proximity to an aluminum smelter suggests a local source of PAHs contributing to the high concentrations. Other SOCs (endosulfans, dacthal, DDTs, g-HCH, a-HCH, HCB, triallate, chlorpyrifos, and PCBs) were in the mid to upper ranges compared to those at other parks. Dacthal, endosulfans, HCB, a-HCH, chlorpyrifos, DDTs, PCBs, and PAHs were higher on the west side of the park, attributable to precipitation and temperature. Triallate, chlorpyrifos, and g-HCH were higher on the east side of the park, probably because of agricultural intensity. Enhanced nitrogen and sulfur deposition related to regional agricultural intensity is of concern. Many rare but not highly toxic elements were higher in lichen at GLAC than in lichen at other parks. Because forest productivity is high, pesticides scrubbed from the air by vegetation probably contribute significant contaminant loads to the ecosystem via canopy through-fall and needle litter-fall.

Fish

Pesticide concentrations (dacthal, g-HCH, HCB, dieldrin, and chlordanes) in fish in Oldman Lake were higher than those in Snyder Lake, possibly related to agricultural intensity. One fish from Oldman Lake exceeded contaminant health thresholds for piscivorous birds (kingfishers) for chlordanes, and the median concentration of DDTs from Oldman Lake exceeded the contaminant health thresholds for piscivorous birds. Fish in both lakes exceeded kingfisher thresholds for Hg. Lake average dieldrin and p,p′-DDE fish concentrations in Oldman Lake exceeded contaminant health thresholds for subsistence fishers. Dieldrin concentration in one fish from Oldman Lake exceeded the contaminant health threshold for recreational fishers. Mercury increased with increasing age of fish in Snyder Lake. Kidney and/or spleen macrophage aggregates were significantly related to mercury and age at both lakes. All fish appeared reproductively normal, but elevated concentrations of estrogen-responsive protein were found in males from both lakes. One intersex male was found at Oldman Lake. These data suggest endocrine disruption.

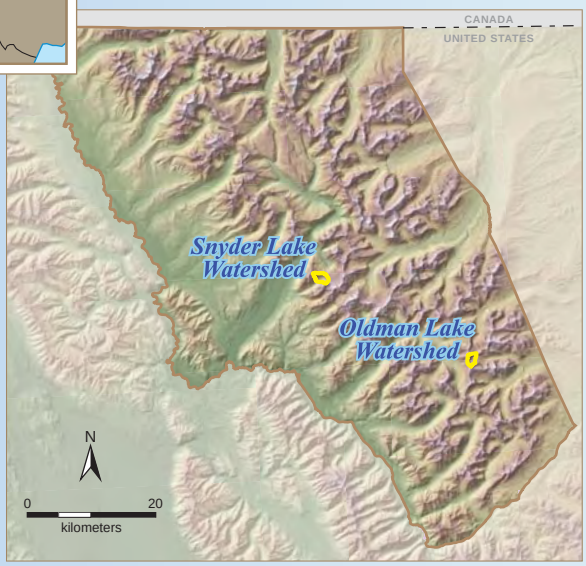
Sediment

SOC profiles are consistent with the first usage of these chemicals in the United States, but most have not decreased since use ceased. Snyder Lake profiles generally show greater contaminant flux than Oldman Lake profiles. PAHs in Snyder Lake indicate some decline in the recent sediments since approximately 1990. Lead, cadmium, and mercury profiles increase from approximately 1875 and decrease beginning in the 1960s. These profiles suggest a common historic source that might have been affected by reductions in emissions related to the Clean Air Act. This relationship is supported by the pattern observed in SCPs.



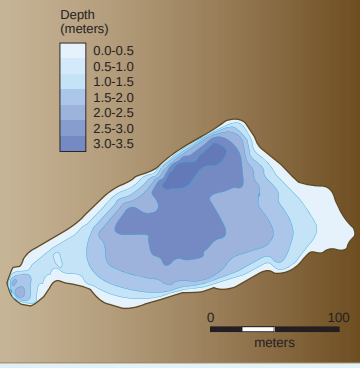
GLAC

Glacier National Park: *Site Characteristics*



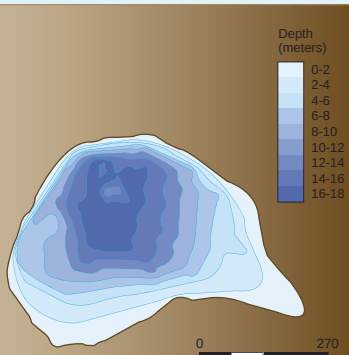
Snyder Lake

Location: 48.62N 113.79W
Elevation: 1597.2 m
Maximum Depth: 3.5 m
Surface Area: 2.6 ha
Watershed Area: 303.7 ha

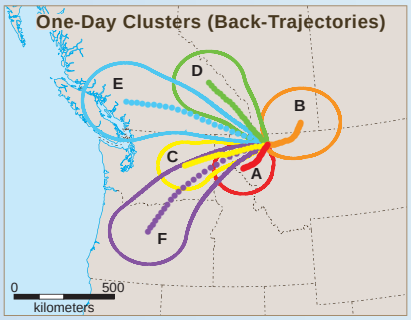


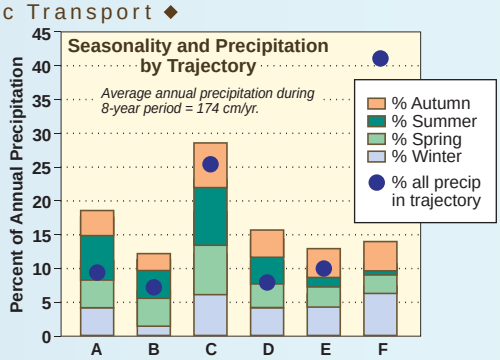
Oldman Lake

Location: 48.50N 113.46W
Elevation: 2025.7 m
Maximum Depth: 17.0 m
Surface Area: 18.2 ha
Watershed Area: 230.3 ha

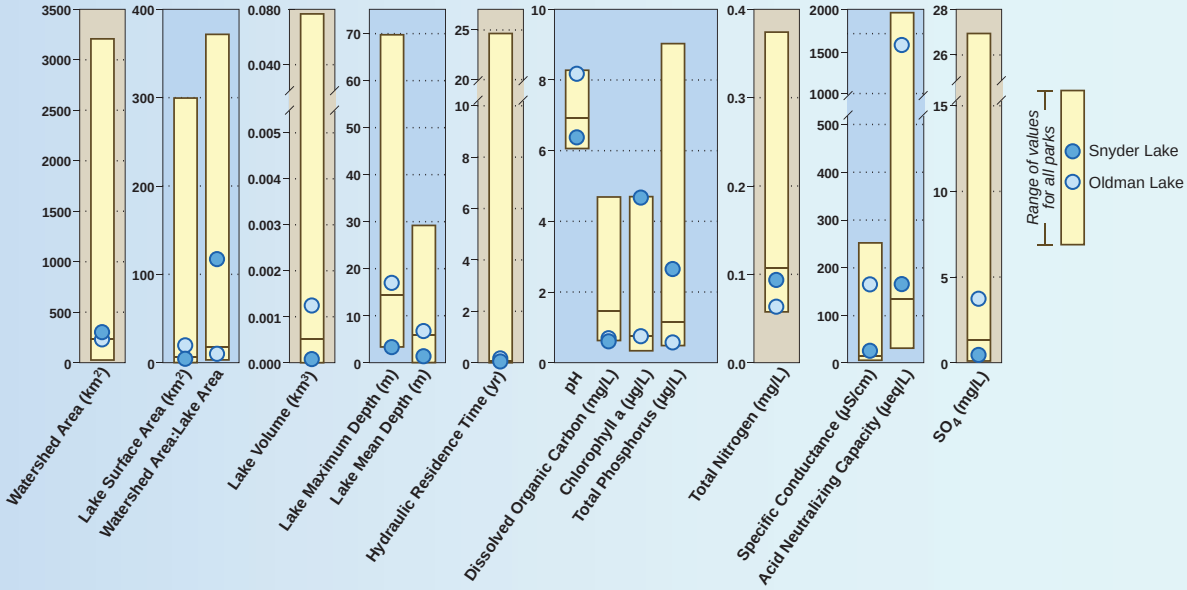


◆ Atmospheric Transport ◆

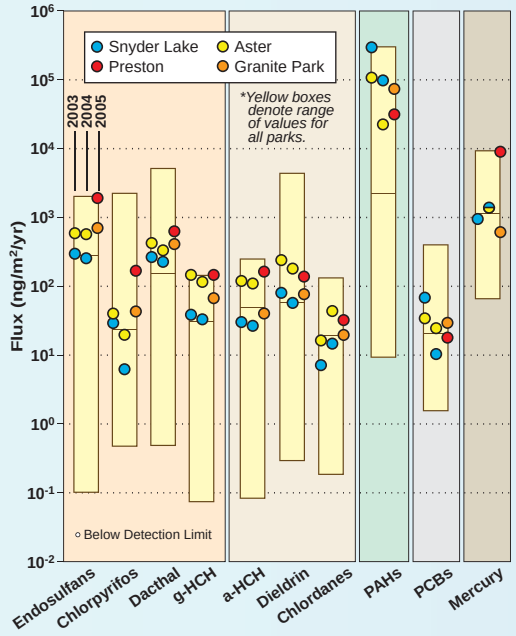




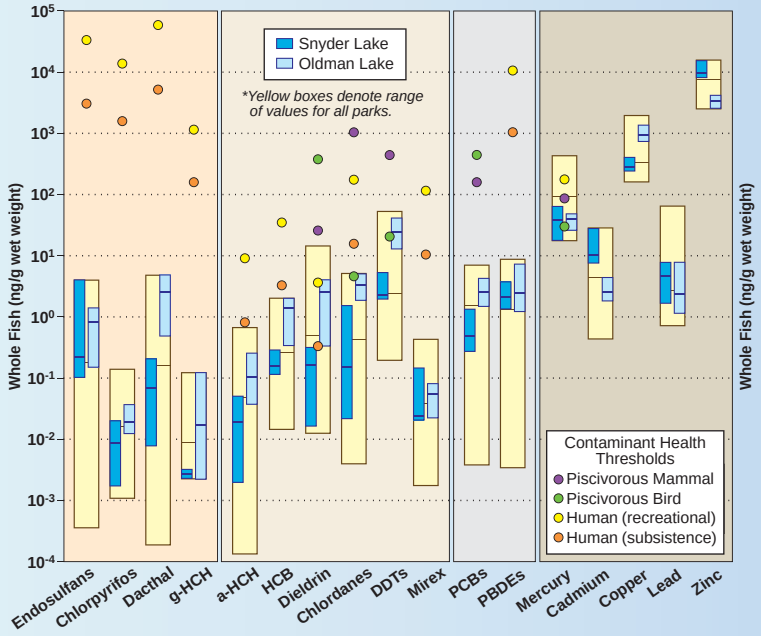
◆ Physical and Chemical Characteristics ◆



◆ Snow Contaminant Fluxes ◆

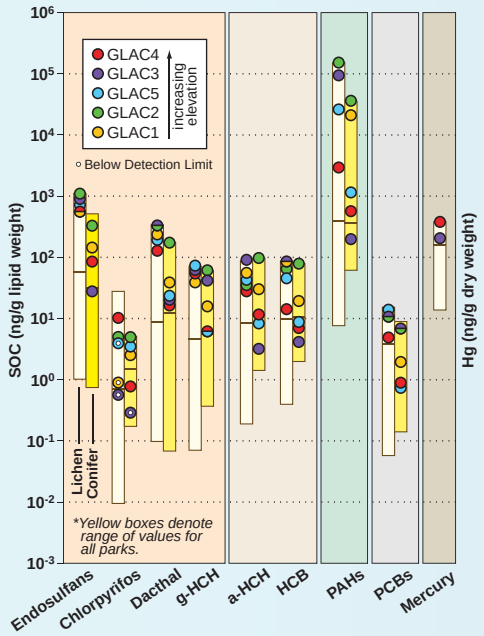


◆ Whole Fish Contaminant Concentrations ◆

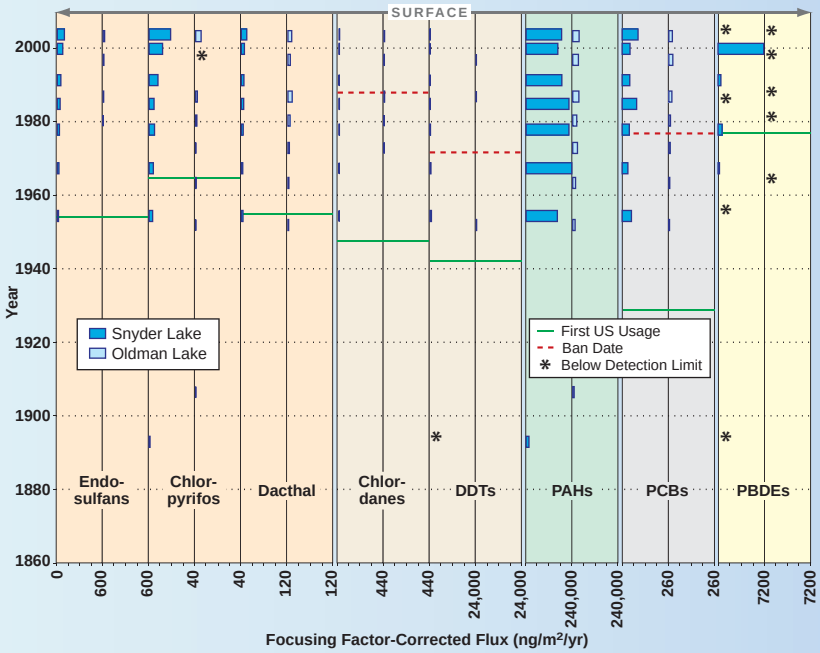


Current-Use Pesticides | Historic-Use Pesticides | Combustion By-products | Industrial Compounds | Metals | Current-Use Chemical

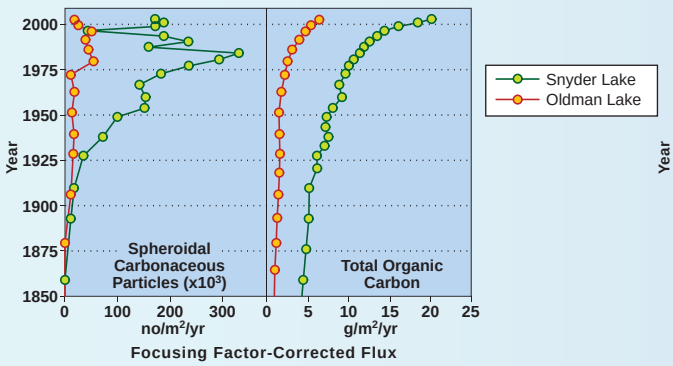
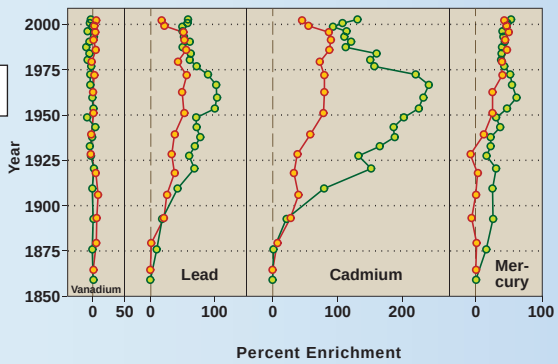
◆ Vegetation Contaminant Concentrations ◆



◆ Sediment Organic Contaminant Fluxes ◆



◆ Sediment Flux ◆



◆ Sediment Metals Enrichment ◆