Contemporary Limnological Sampling of Lake McDonald (Glacier National Park) Confirms Oligotrophic Status

Brooke G. Bannerman, Ashley P. Ballantyne, Chris Downs, James J. Elser

Lake McDonald, Glacier National Park

- Managed by NPS, but private inholding exist along the perimeter of the lake
- No long-term lake monitoring program in place

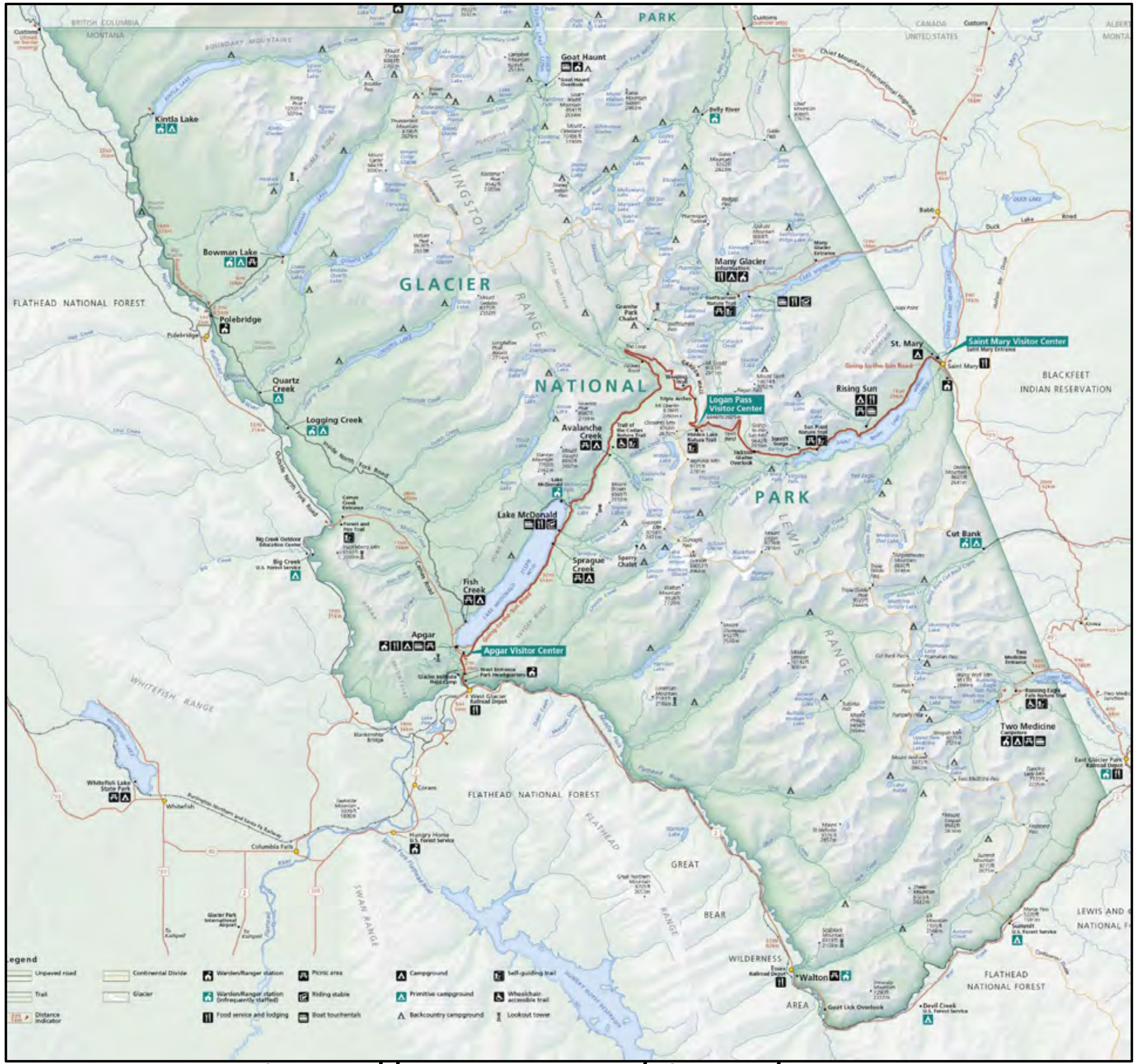
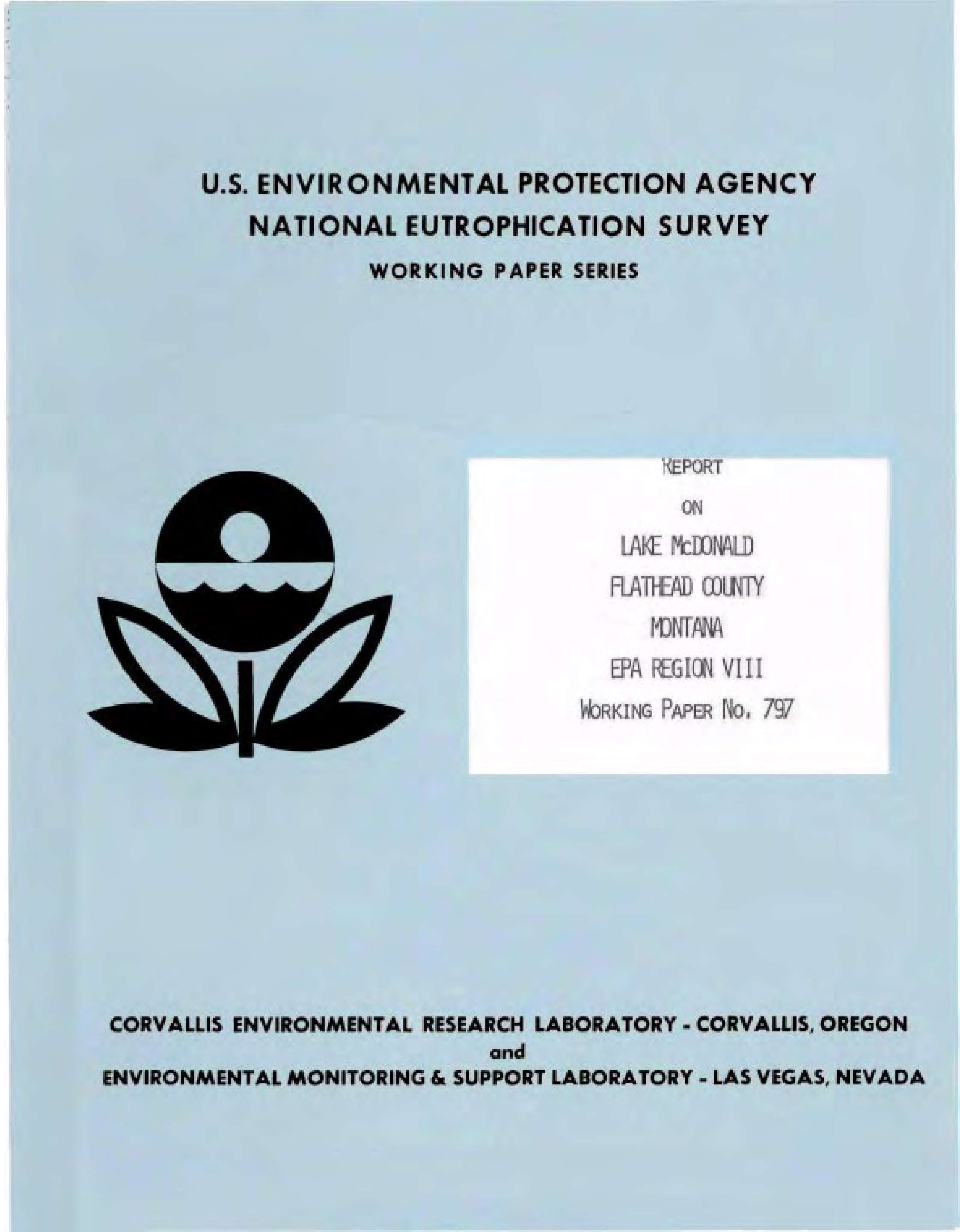


Image source: https://npmaps.com/glacier/

History of limnological surveys

- 1975: National Eutrophication Survey (NES)
- 1984-1990: Flathead Lake Biological Station
- 1996-2007: Volunteer monitoring program
- 2018: GNP-initiated survey



U.S. ENVIRONMENTAL PROTECTION AGENCY
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REPORT
ON
LAKE McDONALD
FLATHEAD COUNTY
MONTANA
EPA REGION VIII
WORKING PAPER No. 797

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

1974-1975 NES survey

- Led by the EPA with professional involvement from Montana Dept of Health and Environmental Sciences, Montana National Guard, and USGS
- Morphometry, trophic status, and nutrient loading
- Lake sampling June and July 1975
- Tributary sampling Oct 1974 – Sept 1975

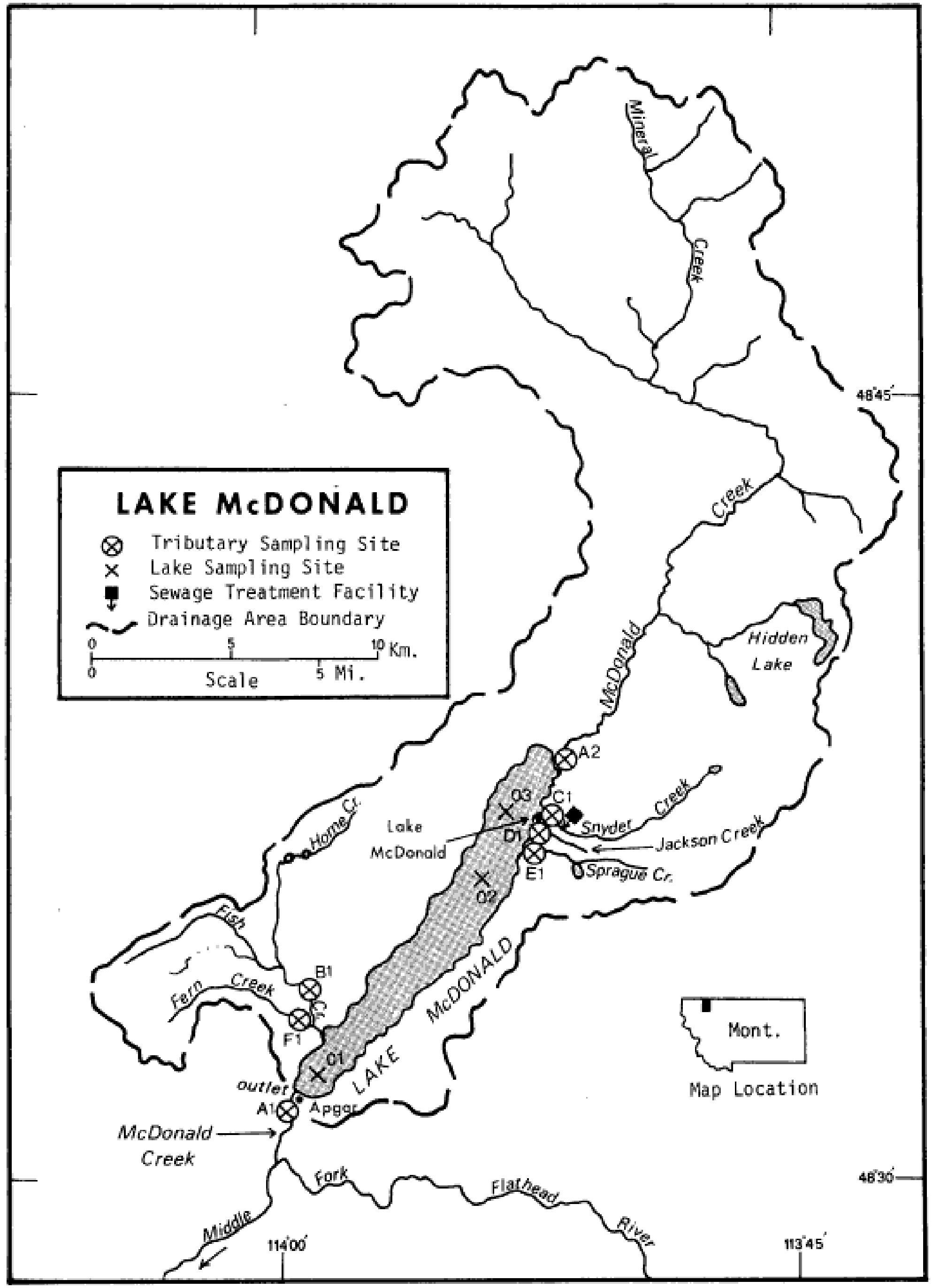


Image source: NES Report

Hydrologic setting

- Morphometry
  - Surface area: 32.63 km^2
  - Maximum depth: 142 m
  - Mean depth: 45.7 m
  - Volume: 1,491 x 10^6 m^3
- Hydrological inputs
  - 85% from McDonald Creek
  - Hydraulic retention time: 3.2 years

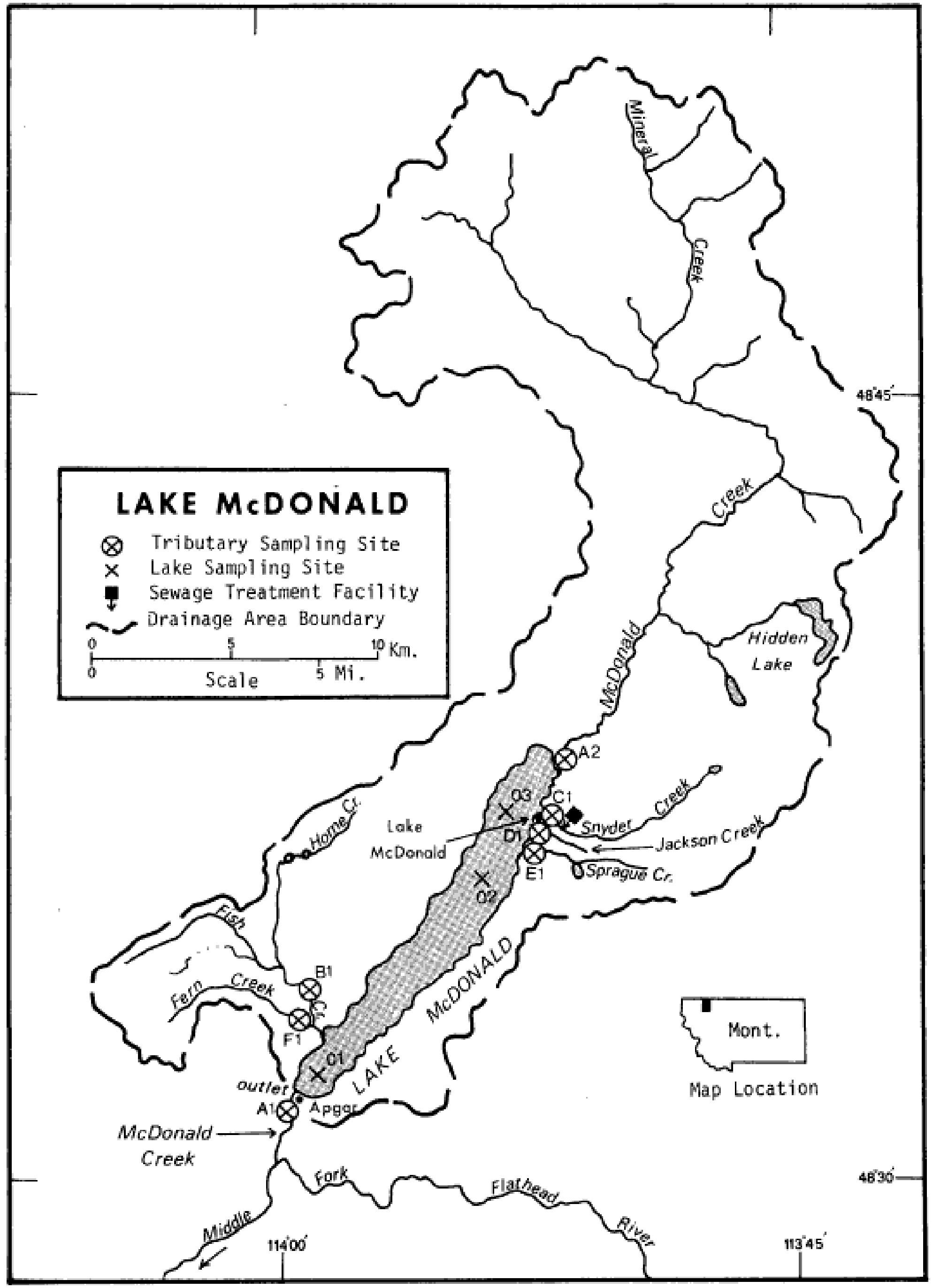
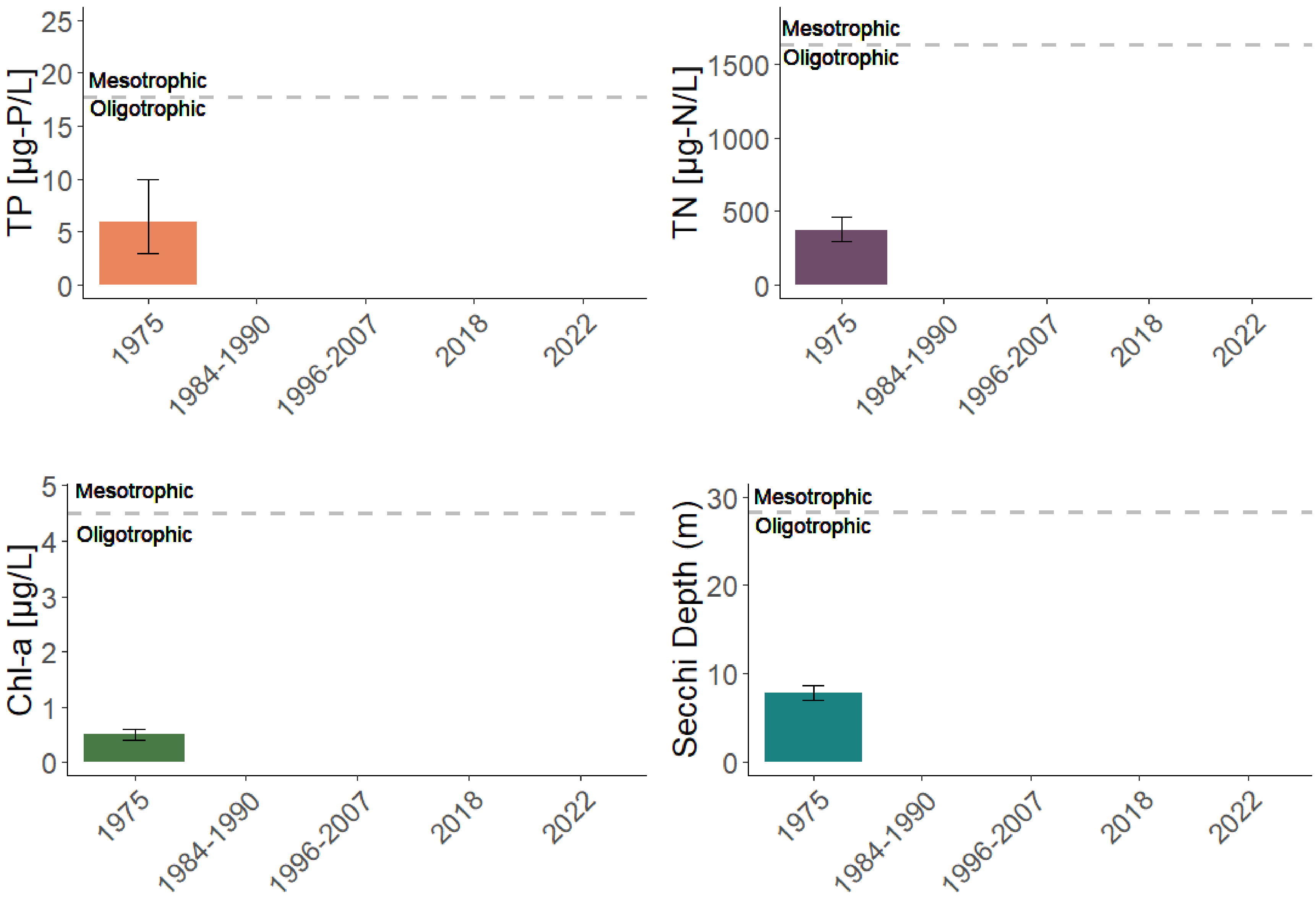
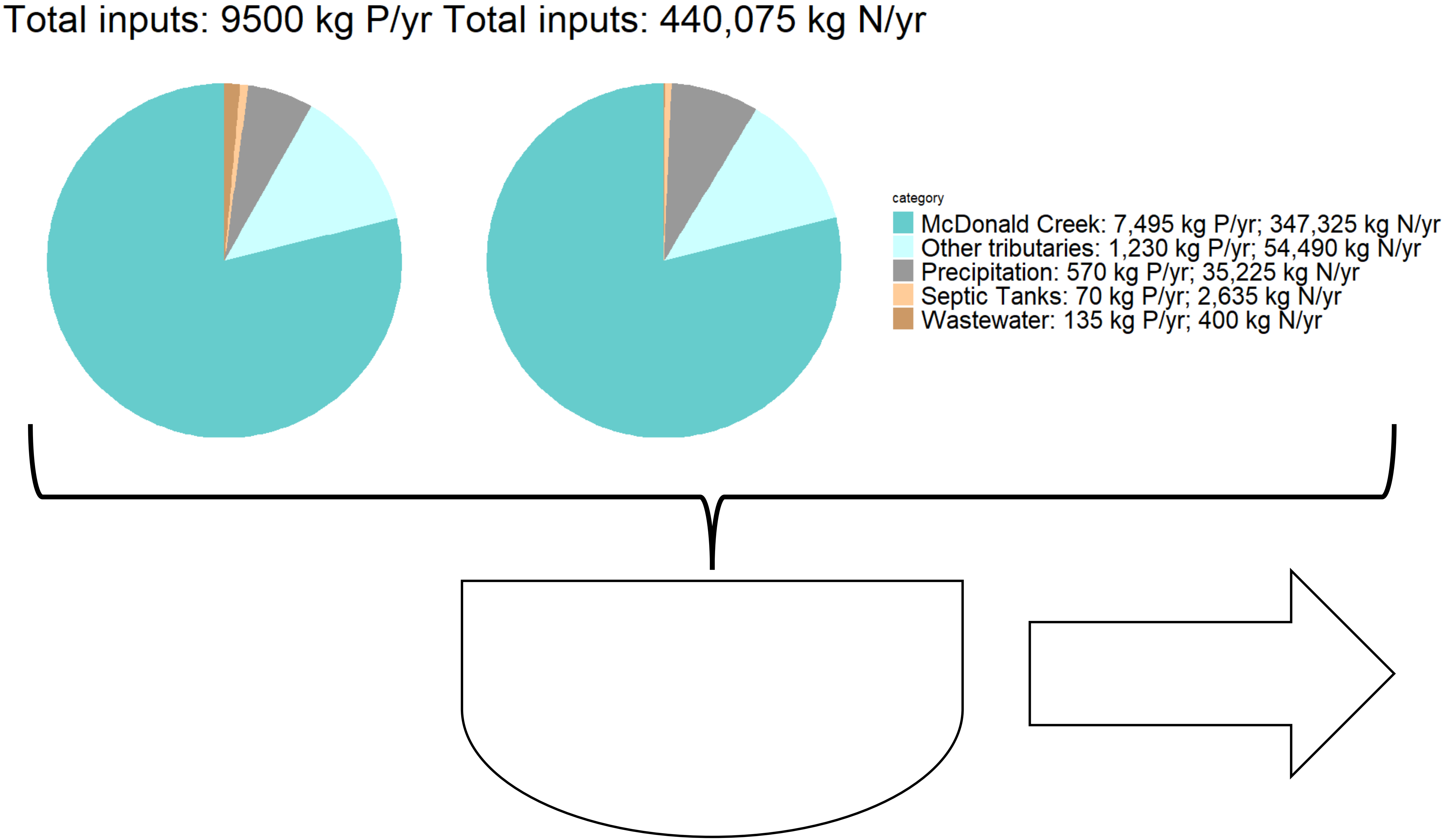


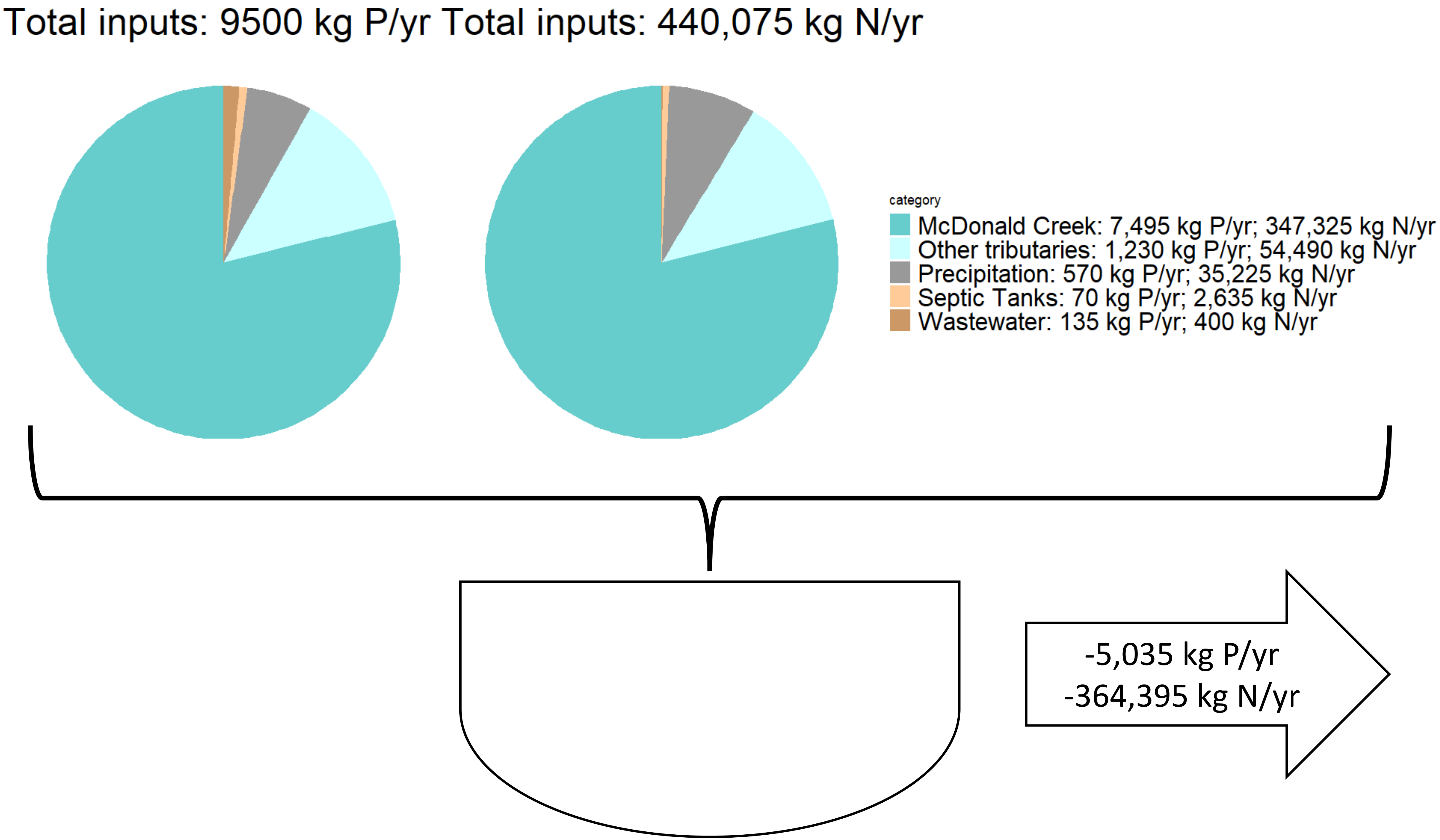
Image source: NES Report

NES findings

- Oligotrophic status
- EPA bioassay: primary P limitation, secondary N effect




Total inputs: 9500 kg P/yr Total inputs: 440,075 kg N/yr
category
McDonald Creek: 7,495 kg P/yr; 347,325 kg N/yr
Other tributaries: 1,230 kg P/yr; 54,490 kg N/yr
Precipitation: 570 kg P/yr; 35,225 kg N/yr
Septic Tanks: 70 kg P/yr; 2,635 kg N/yr
Wastewater: 135 kg P/yr; 400 kg N/yr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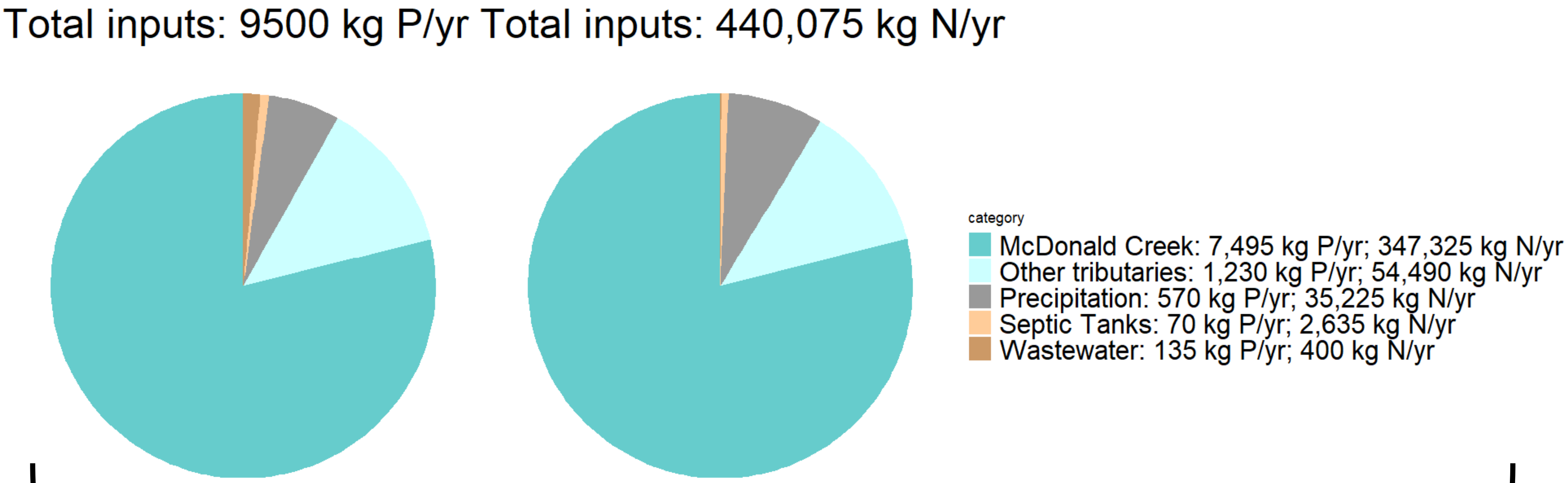
-364,395 kg N/yr



Outcomes:

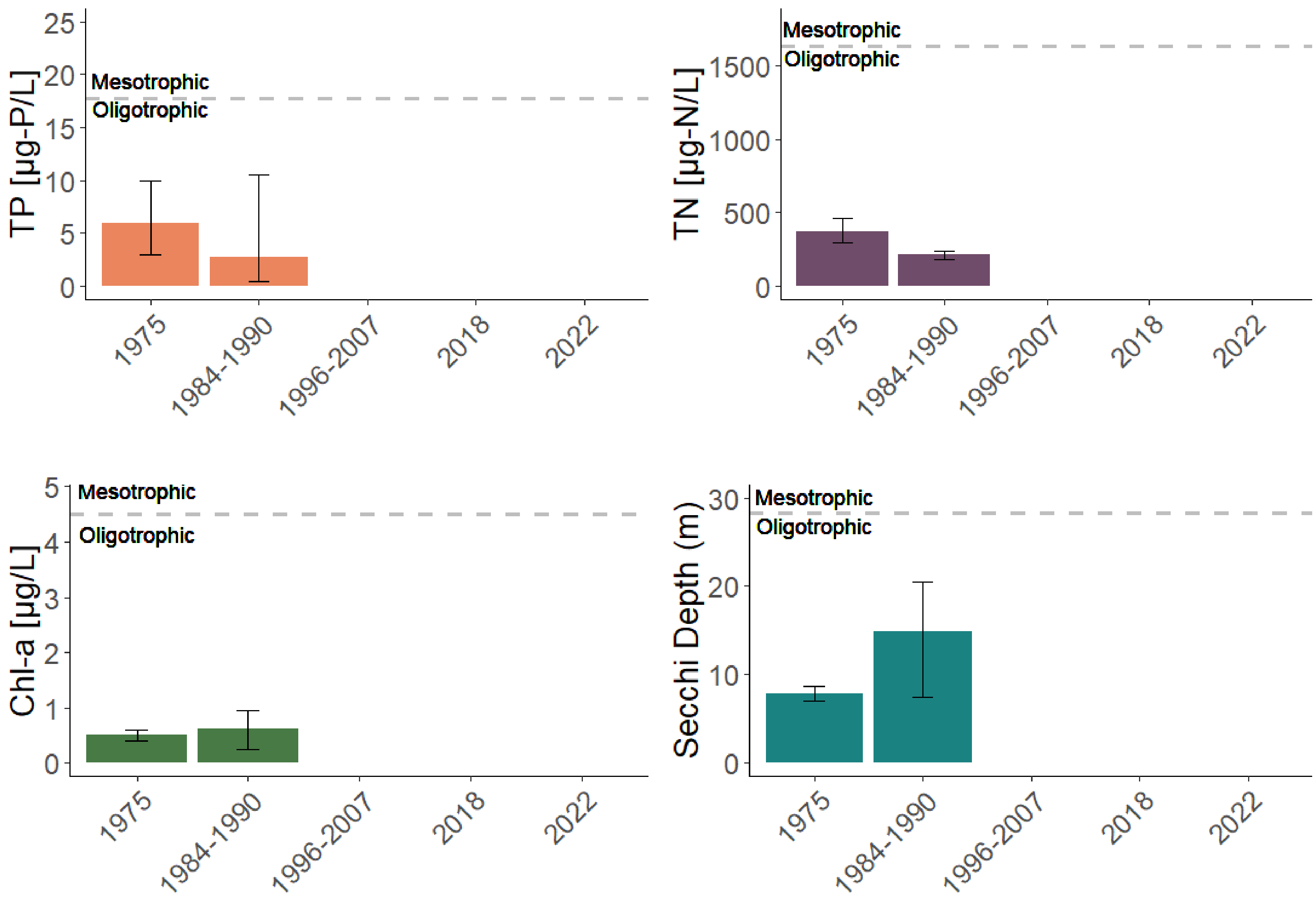
- Within "permissible" loading limits to maintain oligotrophic status
- Wastewater diverted to alterative treatment facility

+4,465 kg P/yr
+75,680 kg N/yr

-5,035 kg P/yr
-364,395 kg N/yr

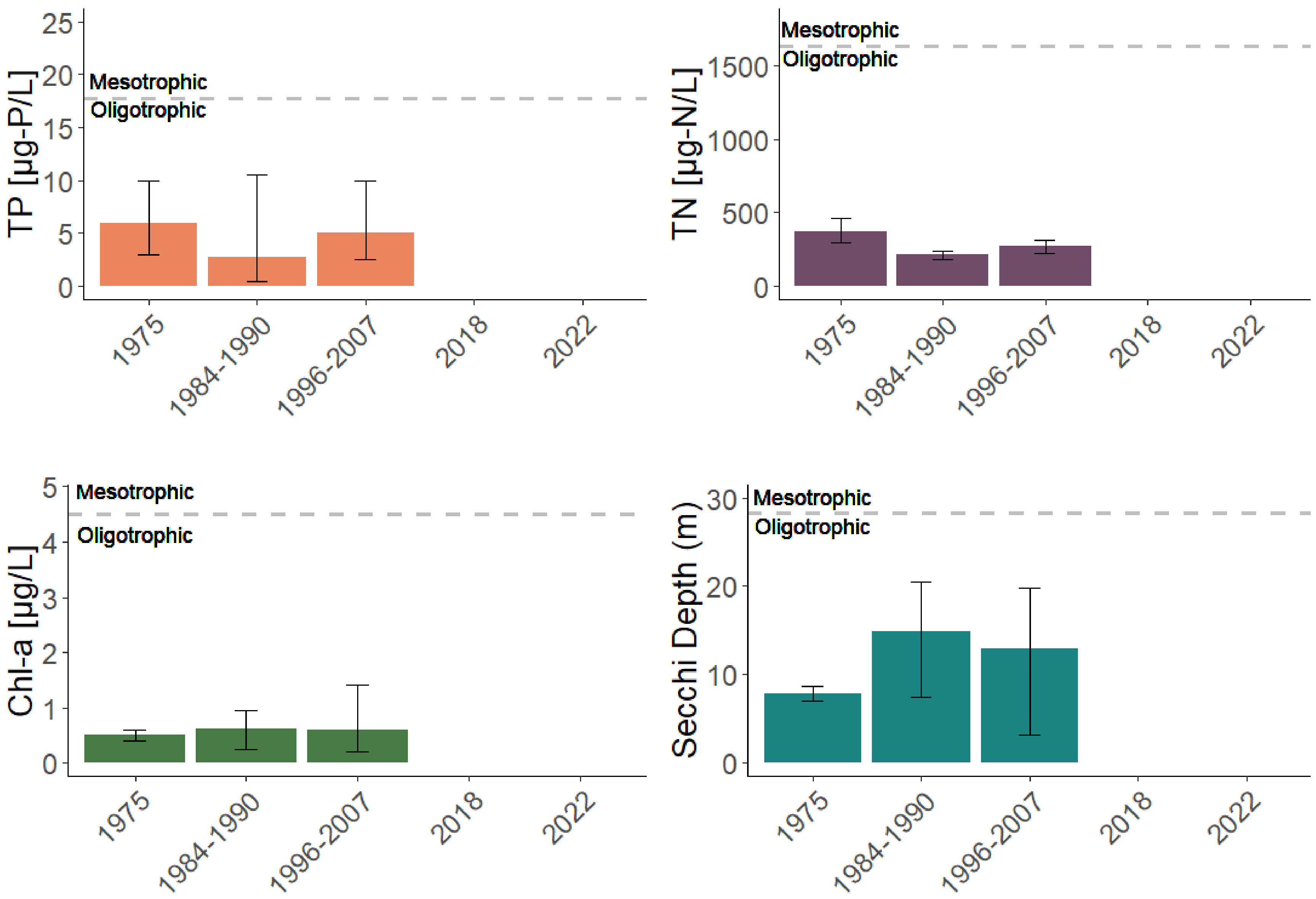
Surveys by the Flathead Lake Biological Station

- Initiated due to concerns about acidification and nutrient enrichment from atmospheric deposition
- July and September, 1984-1990
- Oligotrophic status



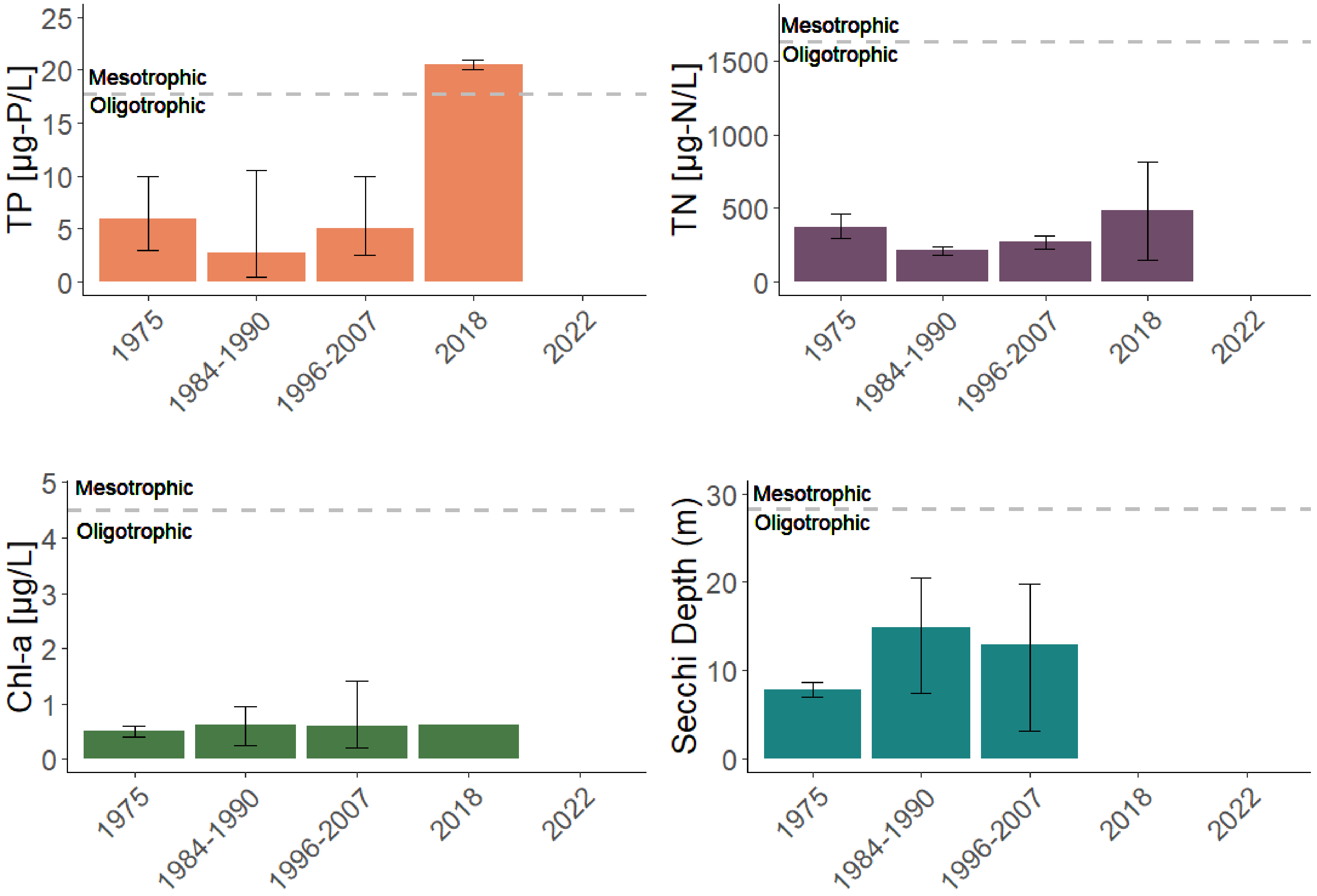
Volunteer Lake Monitoring Program

- Sampled 10x 1996 - 2007
- Oligotrophic status



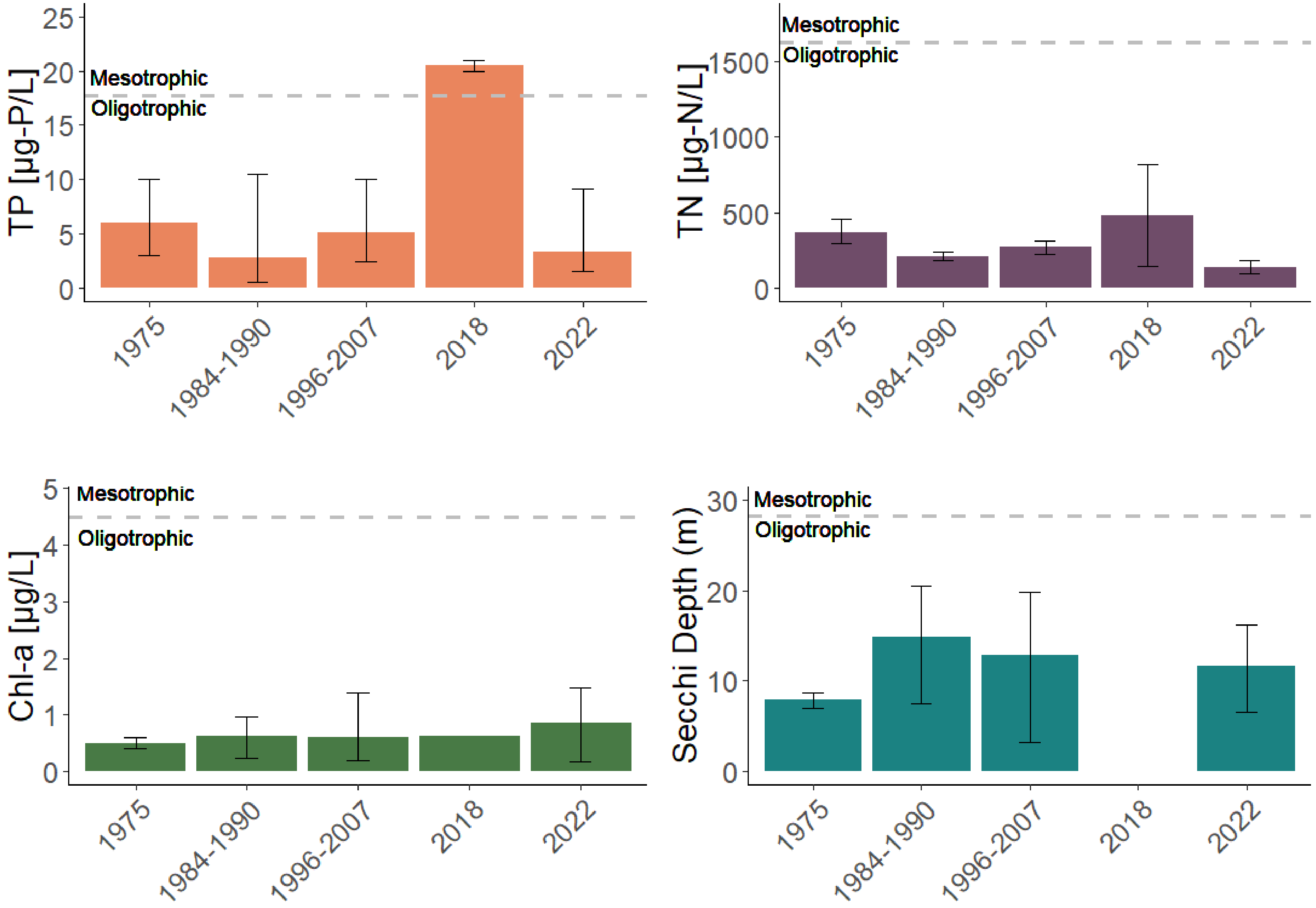
2018 GNP-initiated surveys

- July and Sept
- 4x [TP]
- 1.7x [TN]
- No change in chl-a



2022 findings

- [TP] back within historic range
- [TN] below historic levels



What caused the nutrient enrichment detected in 2018?

Human causes:

- Methodological error
- Septic

Environmental:

- Nutrient deposition
- Glacial meltwater
- Wildfire

Image source: https://www.researchgate.net/figure/Fig-4-3-Water-sampling-from-the-lake-and-type-of-bottles-used-for-samples_fig4_317179279

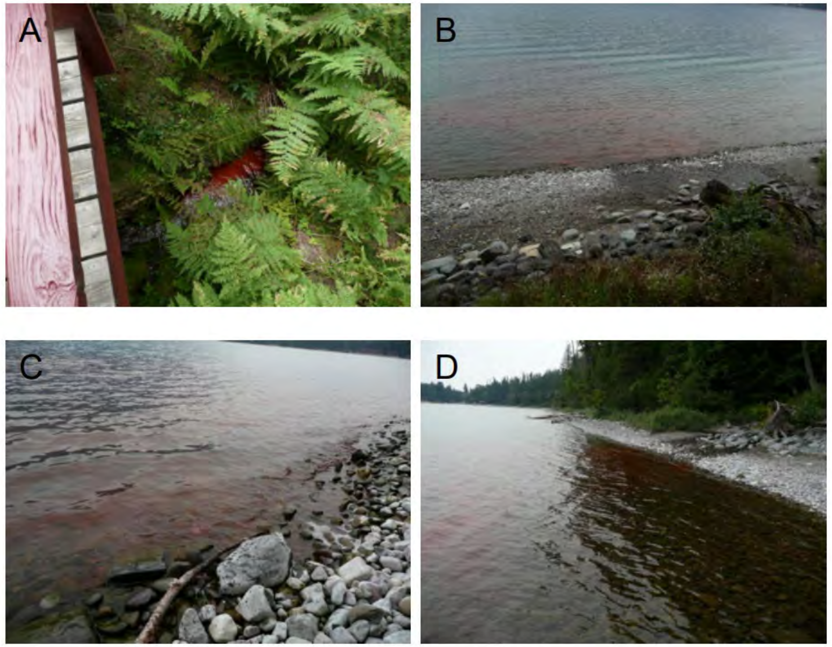


Figure 15. A). Tracer Dye as it appeared in creek running near septic field breakout. B). Tracer Dye at shoreline of lake at creek entrance to the McDonald Lake shoreline. C) Tracer Dye along shoreline in front of failed septic system. D) Tracer Dye extending onto McDonald Lake showing creek entrance along shoreline.

Image source: https://flatheadbeacon.com/galleries/howe-ridge-fire/

Dust mediated transfer of phosphorus to alpine lake ecosystems of the Wind River Range, Wyoming, USA

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Melting Alpine Glaciers Enrich High-Elevation Lakes with Reactive Nitrogen

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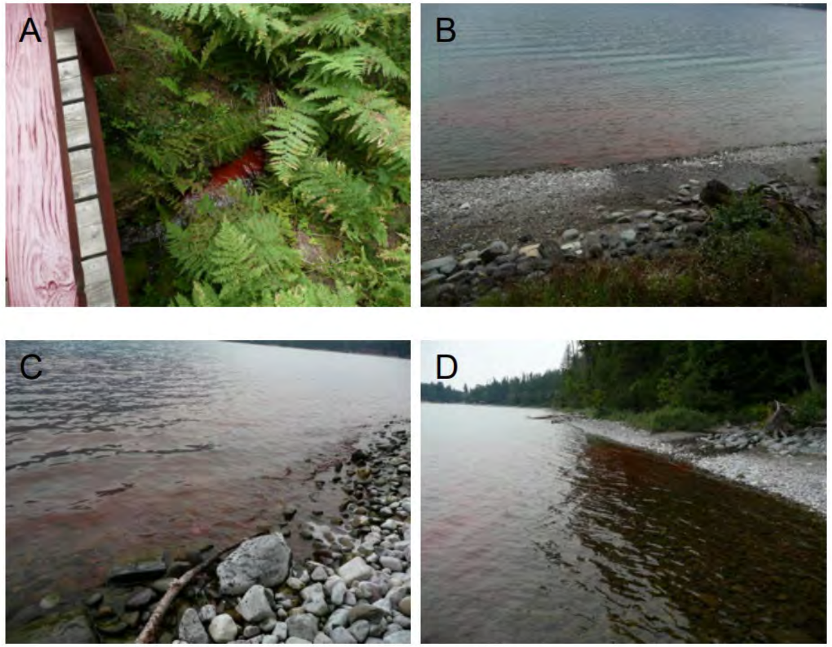

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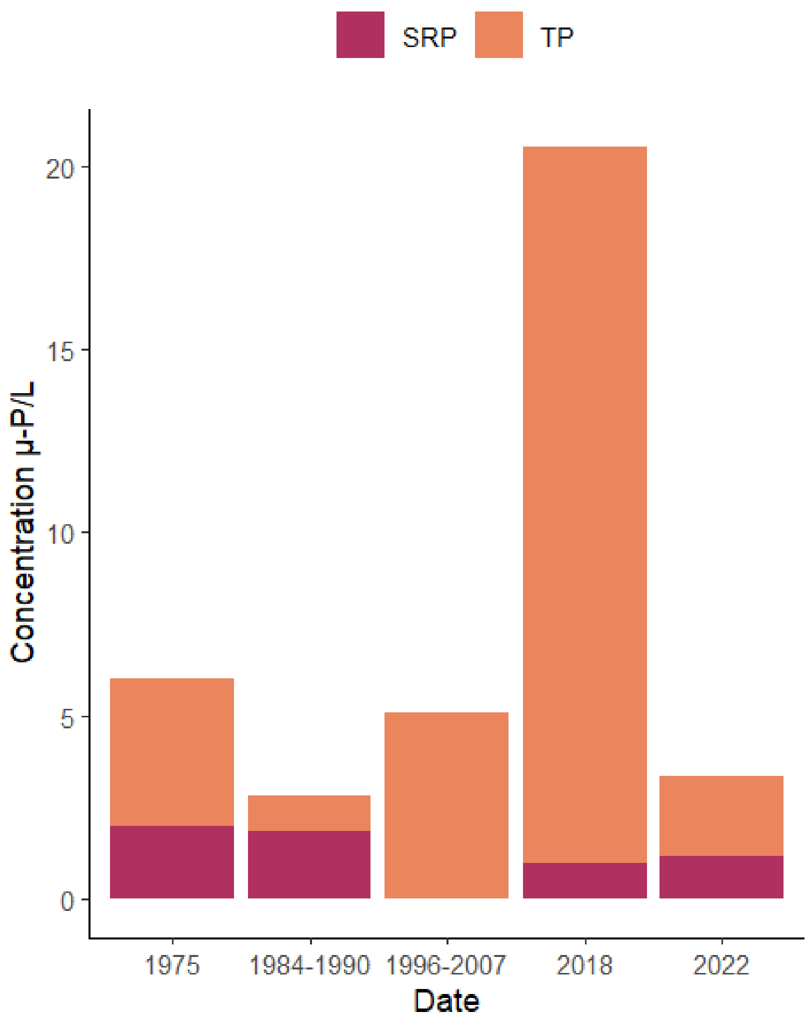

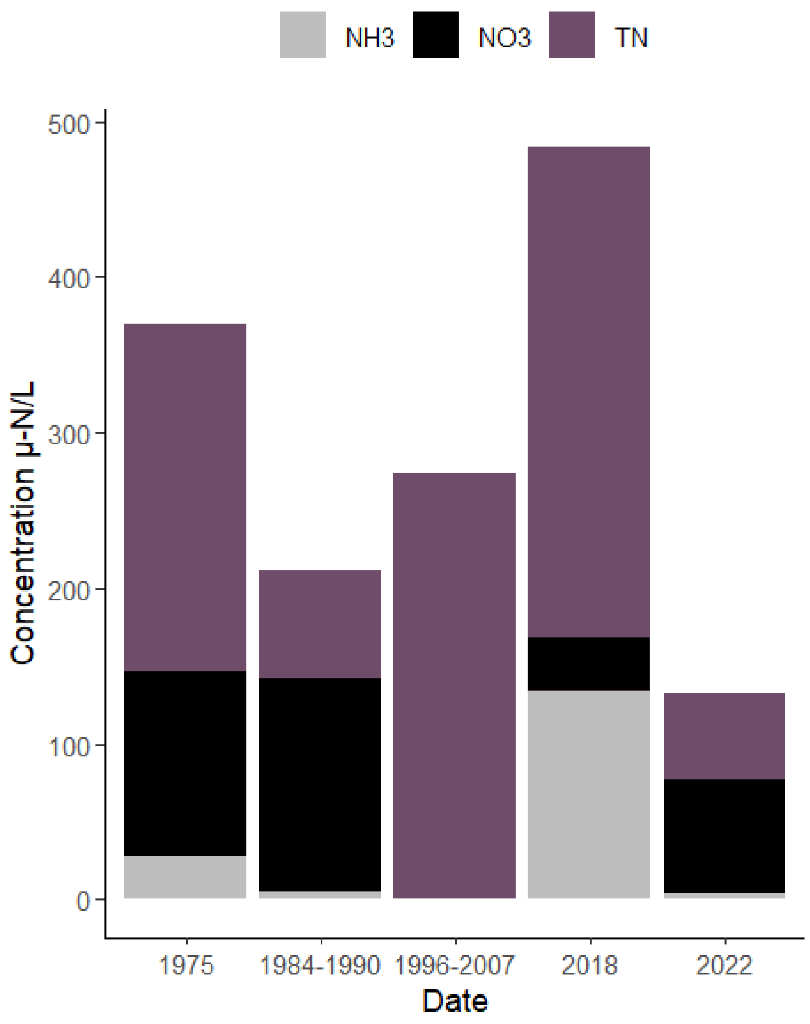

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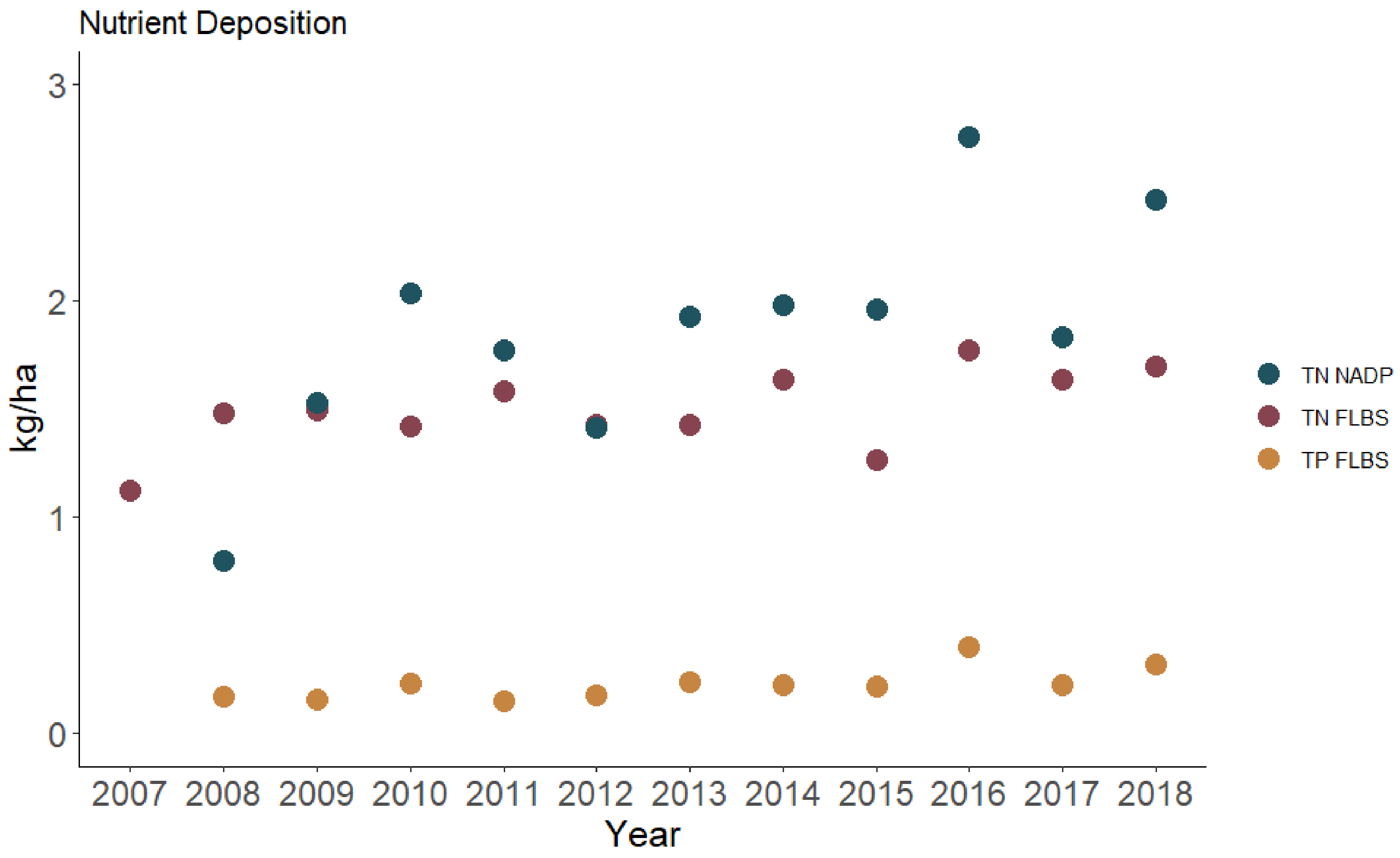

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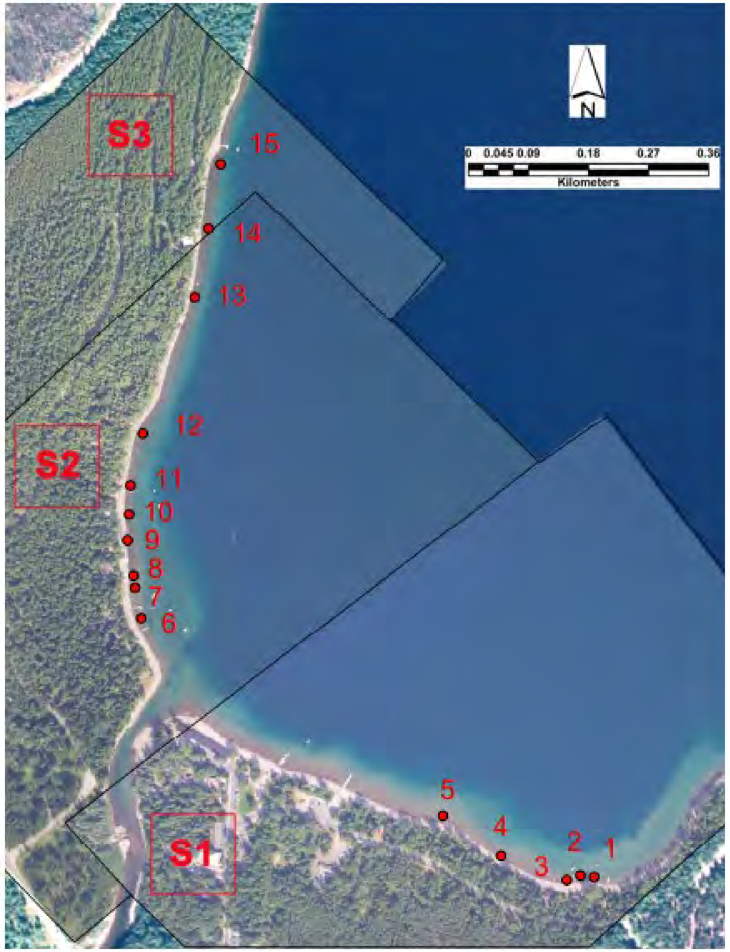

Figure 2. South Lake McDonald with high resolution digital multispectral images georeferenced to the base image. Numbers and red dots correspond to sampling sites. Sectional photos at higher resolution are in Appendix A.

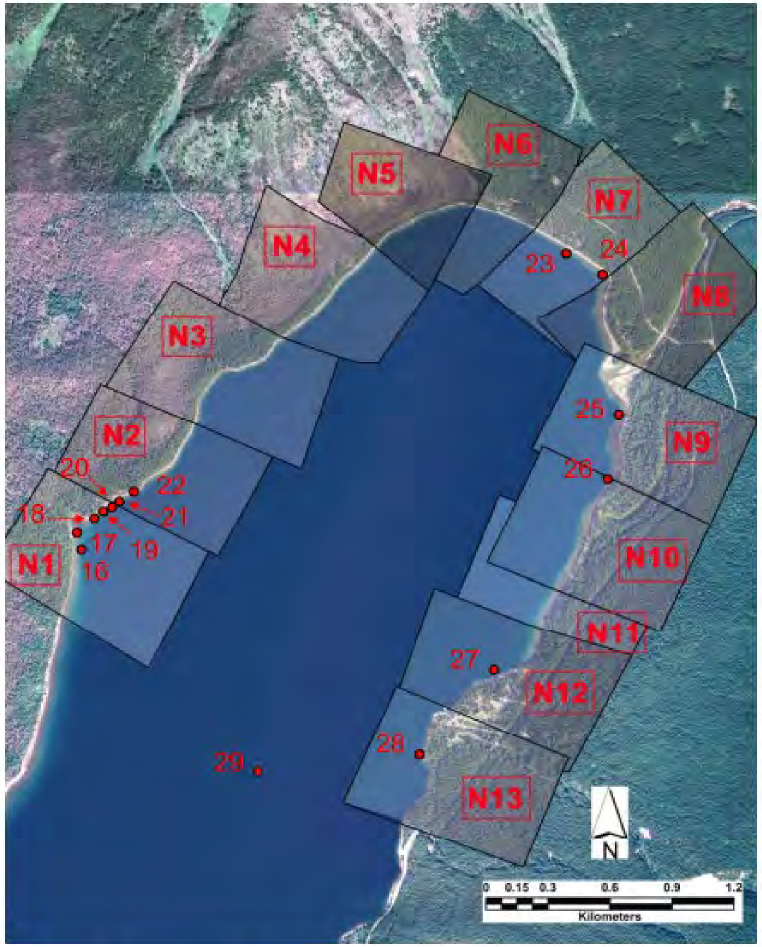

Figure 3. North Lake McDonald with high resolution digital multispectral images georeferenced to the base image. Numbers and red dots correspond to sampling sites. Sectional photos at higher resolution are in Appendix A.

What caused the nutrient enrichment detected in 2018?

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Environmental:

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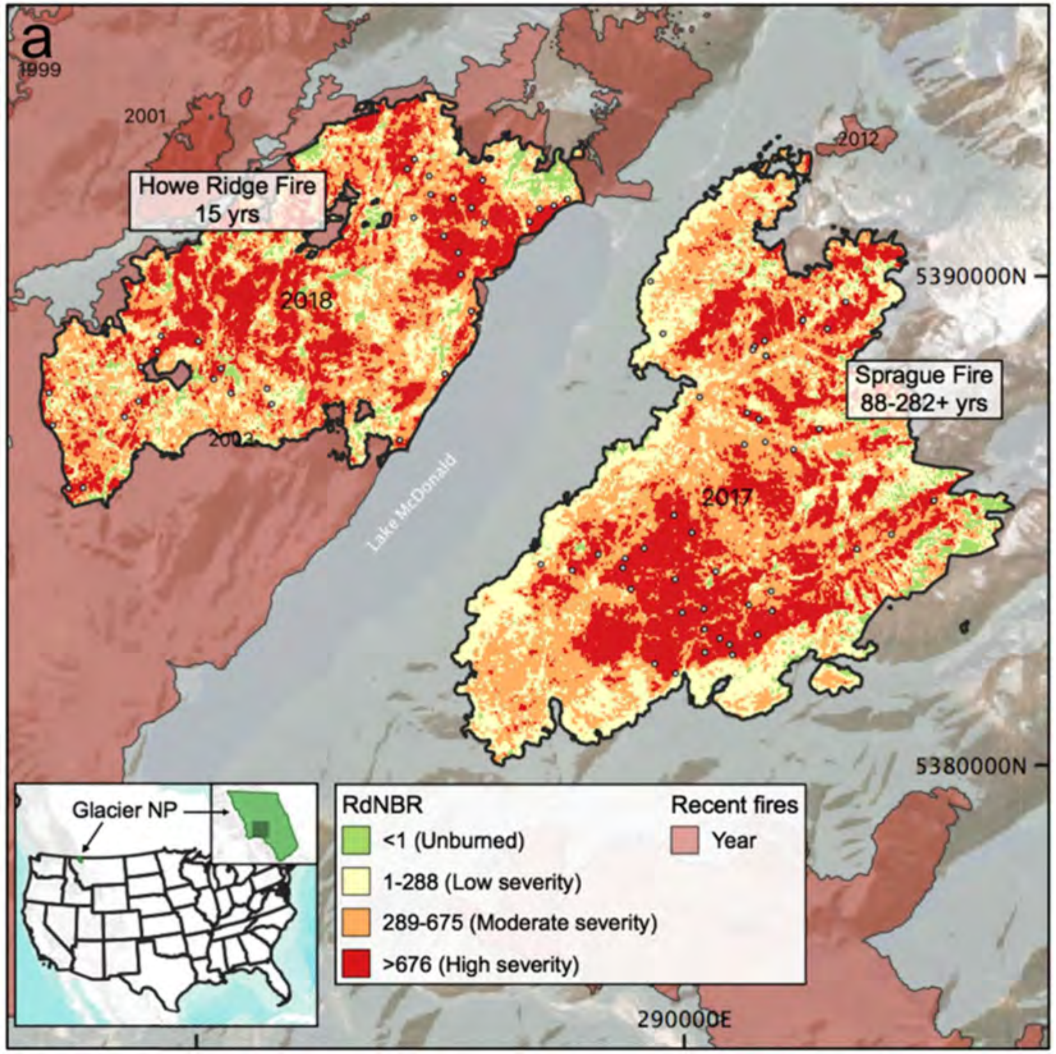


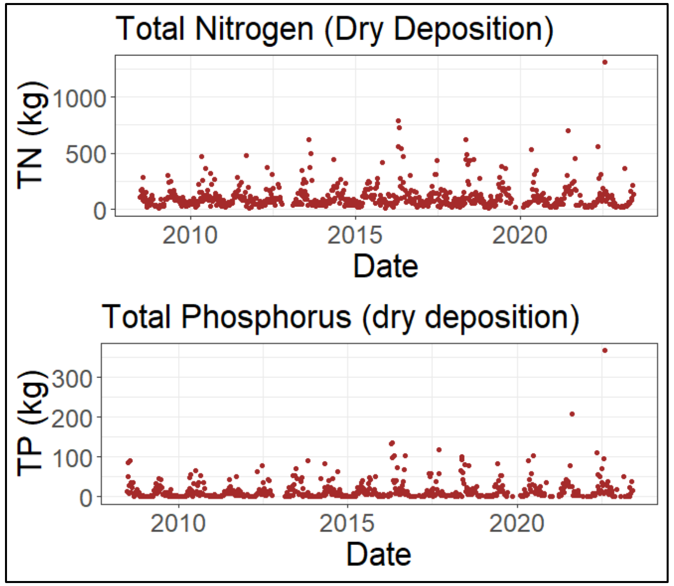
Image source: Hoecker, Tyler .J., and Monica G. Turner. 2022. A short-interval reburn catalyzes departures from historical structure and composition in a mesic mixed-conifer forest. Forest Ecology and Management 504: doi: https://doi.org/10.1016/j.foreco.2021.119814

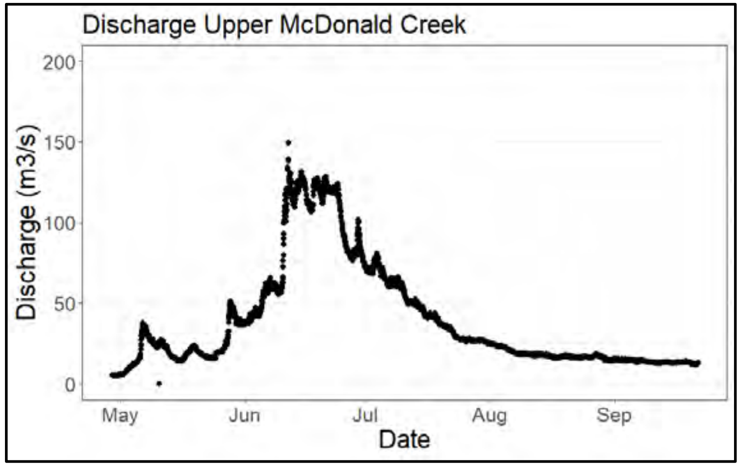




Image sourceshttps://flatheadbeacon.com/galleries

Contemporary Nutrient Budget = gains - losses





Thank you to GNP, the GNP Conservancy, the Freshwater Research Lab at FLBS, and all those who generously volunteered their time to help me with field and lab work. Questions?

Parameter	1975	1984-1990	1996-2007	2018	2022
Secchi	7.9 (7-8.7)	14.8 (7.5-20.5)	12.9 (3.2 – 19.8)	--	
Total P (µg-P/L)	6 (3-10)	2.97 (<0.1 – 10.5)	5.1 (2.5 – 10.0)	20.5 (20 – 21)	3.35 (1.5 – 9.1)
SRP (µg-P/L)	2 (2-2)	1.86 (<0.4 – 1.4)	—	1.00	1.2 (1.1 – 1.3)
Total N (µg-N/L)	369.5 (300-460)	205.42 (182 – 244)	274 (226 – 314)	483.5 (147 – 820)	133.05 (97.4 – 181)
NO_3^- + NO_2^- (µg-N/L)	146.5 (100-180)	141.79 (100.2 – 158.0)	—	50	76.66 (38.9 – 100)
NH_3 (µg-N/L)	28 (20-100)	5.38 (2.2 – 8.6)	—	134 (18-250)	3.31 (1.5 – 5.2)
Chl-a (mg/m3)	0.5 (0.4-0.6)	0.612 (0.24 – 0.956)	0.6 (0.2-1.4)	0.621	0.73 (0.18 – 14.8)