

National Lake Assessment 2022

Survey Design

Target Population

For purposes of this survey, the target population of “lakes” includes natural and man-made freshwater lakes, ponds, and reservoirs greater than one hectare (approximately 2.5 acres), greater than 1,000 square meters of open water, greater than one meter in depth, non-saline due to salt water intrusion or tidal influence, and not used for aquaculture, disposal-tailings, mine-tailings, sewage treatment, evaporation or other unspecified disposal use that are within the conterminous U.S., excluding the Great Lakes.

Survey Design

NLA 2022 uses a spatially balanced survey design where lakes are viewed as a finite population (i.e., each lake is viewed as a point identified by the centroid of the lake polygon). The design is stratified by state. Within each state, lakes are selected using unequal probability categories based on lake area. In addition, the survey design includes a subsample of lakes sampled in NLA 2017 and a new sample of lakes for NLA 2022. The subsample of lakes from NLA 2017 are taken from the new lakes selected for NLA 2017. The reason for restricting the subsample to new lakes is that the sample frame for 2017 not only includes all lakes >1ha but also includes NHD high resolution lakes for 1-5ha. This sample frame more closely matches the sample frame for NLA 2022.

Unequal probability categories used for the NLA 2017 subsample are defined based on lake area: 1 to 4 ha, 4 to 10 ha, 10 to 20 ha, 20 to 50 ha and greater than 50 ha. For new NLA 2022 lakes, the unequal probability categories are 1 to 4 ha, 4 to 10 ha, 10 to 50 ha and greater than 50 ha. The collapsing to four lake area categories reflects that no differences in percent of non-target lakes nor in landowner access were found. Given that weight adjustment on all evaluated sites is likely to use lake area categories, having fewer categories will result in more stable weight adjustments since they will be based on more evaluated lakes within a category.

Fish Tissue Study: A subset of the lakes selected using the above survey design will have fish sampled for the analysis of fish tissue contaminants. The subsample is approximately 2/3 of the base lakes selected for the main NLA 2022 survey. Approximately 50% of the lakes will be from the subsample of NLA 2017 lakes and 50% from new lakes selected for 2022. These lakes will be assigned to panels that will identify them.

The survey design has five base and two over sample panels:

- **NLA22_17RVT2FT** – Panel of lakes originally sampled in NLA 2017. These lakes will be sampled twice in NLA 2022 for all indicators except for fish tissue which will be sampled for only one of the two visits.

- **NLA22_17BaseFT** – Panel of lakes originally sampled in NLA 2017 and will be sampled once in NLA 2022 for all indicators as well as fish tissue.
- **NLA22_17Base** – Panel of lakes originally sampled in NLA 2017 and will be sampled once in NLA 2022 for all indicators except fish tissue.
- **NLA22_22BaseFT** – Panel of new lakes to be sampled once in NLA 2022 for all indicators including fish tissue.
- **NLA22_22Base** – Panel of new lakes to be sampled once in NLA 2022 for all indicators except fish tissue.
- **NLA22_17Over** – Over sample lakes to be used as replacements for NLA22_17RVT2FT or NLA22_17BaseFT or NLA22_17Base lakes when they cannot be sampled for any reason. If the lake being replaced was scheduled to be sampled for fish tissue, then the replacement lake will be sampled for fish tissue.
- **NLA22_22Over** – Over sample lakes to be used as replacements for NLA22_22BaseFT or NLA22_22Base lakes when they cannot be sampled for any reason. If the lake being replaced was scheduled to be sampled for fish tissue, then the replacement lake will be sampled for fish tissue.

See below for description of the lake replacement process when a base lake cannot be sampled for any reason.

Expected Sample Size

For NLA 2022, 904 lakes will be sampled with 96 of the lakes sampled twice for a total of 1000 lake visits. Consequently, 904 unique sites will be sampled with 808 sampled only once and 96 sites being sampled twice during 2022 resulting in 1000 ($808 + 2 \cdot 96$) total site visits. Reporting will be nationally as well as for nine aggregated ecoregions (CPL, NAP, SAP, UMW, NPL, SPL, TPL, WMT and XER). Approximately, 100 lakes will be sampled in each aggregated ecoregion. For each aggregated ecoregion, the number of lakes assigned to each state within the ecoregion will be proportional to the number of lakes in the sample frame within the state. The total lakes for a state will be the sum across all ecoregions in the state. In addition, the minimum number of lakes for a state will be 8 and the maximum will be 50. With these constraints and with proportional allocation, two states (TX and MN) are allocated more than 50 lakes and 13 states (AZ, CT, DE, IA, MD, NH, NJ, NM, NV, RI, TN, VT, WV) have 8 or fewer. For these states, lakes in the sample frame are allocated by ecoregion within each state to get minimum of 8 and maximum of 50. Then the remaining states are re-allocated lakes by ecoregion to satisfy the total sample size. The final allocation by state and aggregated ecoregion is given in Table 1. Approximately 50% of the lakes will be lakes sampled in NLA 2017. The survey design does not select lakes based on aggregated ecoregions; only the total number of lakes for a state is specified in the survey design. For new lakes, approximately an equal number of lakes by the four lake area categories are selected with unequal probability within each state. For new lakes sampled in 2017, the lakes selected are the first lakes evaluated in 2017 to meet the sample size requirement for 2017 lakes to be resampled in 2022. Note that these are the expected number of lakes and not the final number of lakes selected by the survey design (see section “Final Survey Design Summary”).

Table 1. Number of lakes to be sampled by state and aggregated ecoregion.

St	CPL	NAP	NPL	SAP	SPL	TPL	UMW	WMT	XER	Total	2017	New
AL	6	0	0	8	0	0	0	0	0	14	7	7
AR	5	0	0	5	0	0	0	0	0	10	5	5
AZ	0	0	0	0	0	0	0	2	6	8	4	4
CA	0	0	0	0	0	0	0	16	32	48	24	24
CO	0	0	0	0	4	0	0	11	4	19	10	9
CT	0	8	0	0	0	0	0	0	0	8	4	4
DE	7	0	0	1	0	0	0	0	0	8	4	4
FL	11	0	0	0	0	0	0	0	0	11	6	5
GA	16	0	0	17	0	0	0	0	0	33	16	17
IA	0	0	0	0	0	8	0	0	0	8	4	4
ID	0	0	0	0	0	0	0	8	8	16	8	8
IL	0	0	0	0	0	17	0	0	0	17	8	9
IN	0	0	0	3	0	16	4	0	0	23	12	11
KS	0	0	0	0	10	10	0	0	0	20	10	10
KY	0	0	0	6	0	3	0	0	0	9	4	5
LA	13	0	0	0	0	0	0	0	0	13	6	7
MA	1	8	0	0	0	0	0	0	0	9	4	5
MD	5	0	0	3	0	0	0	0	0	8	4	4
ME	0	15	0	0	0	0	0	0	0	15	8	7
MI	0	0	0	0	0	1	28	0	0	29	14	15
MN	0	0	0	0	0	6	44	0	0	50	25	25
MO	0	0	0	4	0	10	0	0	0	14	7	7
MS	11	0	0	0	0	0	0	0	0	11	6	5
MT	0	0	30	0	0	0	0	15	0	45	22	23
NC	3	0	0	9	0	0	0	0	0	12	6	6
ND	0	0	31	0	0	7	0	0	0	38	19	19
NE	0	0	3	0	23	3	0	0	0	29	14	15
NH	0	8	0	0	0	0	0	0	0	8	4	4
NJ	3	2	0	3	0	0	0	0	0	8	4	4
NM	0	0	0	0	2	0	0	3	3	8	4	4
NV	0	0	0	0	0	0	0	1	7	8	4	4
NY	0	29	0	1	0	0	0	0	0	30	15	15
OH	0	6	0	4	0	3	0	0	0	13	6	7
OK	1	0	0	3	27	4	0	0	0	35	18	17
OR	0	0	0	0	0	0	0	13	8	21	10	11
PA	0	8	0	5	0	0	0	0	0	13	6	7
RI	0	8	0	0	0	0	0	0	0	8	4	4
SC	3	0	0	5	0	0	0	0	0	8	4	4
SD	0	0	31	0	0	9	0	0	0	40	20	20
TN	2	0	0	6	0	0	0	0	0	8	4	4
TX	15	0	0	0	34	0	0	0	1	50	25	25
UT	0	0	0	0	0	0	0	5	9	14	7	7
VA	2	0	0	9	0	0	0	0	0	11	6	5
VT	0	8	0	0	0	0	0	0	0	8	4	4
WA	0	0	0	0	0	0	0	15	12	27	14	13
WI	0	0	0	0	0	3	24	0	0	27	14	13
WV	0	0	0	8	0	0	0	0	0	8	4	4
WY	0	0	5	0	0	0	0	11	10	26	13	13
Sum	104	100	100	100	100	100	100	100	100	904	451	453

The total number of lakes sampled in NLA 2022 will equal the expected total sample size for each state. The number of lakes expected from NLA 2017 and from new lakes for each state may differ from the expected sample size depending on the outcome of the site evaluation process, although the expectation is that they will match. The number of lakes sampled by aggregated ecoregion are expected to differ, since the survey design does not stratify by aggregated ecoregion and the lake replacement process does not replace lakes within the same aggregated ecoregion.

State Level Assessments

Five states requested a sample size large enough to complete a state-level assessment. The five states are ID, OR, VT, WA, and WI. The states did not request any change from the NLA 2022 survey design. Consequently, for those states the over sample size was increased to ensure at least 50 lakes could be evaluated and sampled.

Final Survey Design Summary

While the expected sample size and survey design, provides the survey design requirements, the final number of sites depends on the lake selection. The numbers may differ due to the use of unequal probability categories in the survey design which does not guarantee the expected number of lakes in each category. It also differs since the survey design includes lakes from new lakes selected for NLA 2017. That design, while similar to the NLA 2022 new lake survey design, was different. In particular, it selected more lakes in small lake area categories than large area categories with the expectation that more of the smaller lakes would be non-target or not have landowner access. The tables below summarize the “base” lakes.

Table 2. Number of lakes in Base sample by lake area category and aggregated ecoregion.

	(1, 4]	(4, 10]	(10, 50]	>50	Sum
CPL	58	32	38	18	146
NAP	33	27	23	10	93
NPL	32	19	16	7	74
SAP	38	12	18	13	81
SPL	31	20	25	12	88
TPL	45	35	30	10	120
UMW	32	25	34	15	106
WMT	46	26	33	14	119
XER	30	16	17	14	77
Sum	345	212	234	113	904

Table 3. Number of lakes in Base sample by aggregated ecoregion and state.

	CPL	NAP	NPL	SAP	SPL	TPL	UMW	WMT	XER	Sum
AL	11	0	0	3	0	0	0	0	0	14
AR	7	0	0	3	0	0	0	0	0	10
AZ	0	0	0	0	0	0	0	4	4	8
CA	0	0	0	0	0	0	0	25	23	48
CO	0	0	0	0	9	0	0	8	2	19

CT	0	8	0	0	0	0	0	0	0	8
DE	7	0	0	1	0	0	0	0	0	8
FL	11	0	0	0	0	0	0	0	0	11
GA	22	0	0	11	0	0	0	0	0	33
IA	0	0	0	0	0	7	2	0	0	9
ID	0	0	0	0	0	0	0	10	6	16
IL	0	0	0	1	0	15	1	0	0	17
IN	0	0	0	2	0	16	5	0	0	23
KS	0	0	0	0	5	14	0	0	0	19
KY	0	0	0	8	0	1	0	0	0	9
LA	13	0	0	0	0	0	0	0	0	13
MA	1	7	0	0	0	0	0	0	0	8
MD	6	0	0	2	0	0	0	0	0	8
ME	0	15	0	0	0	0	0	0	0	15
MI	0	0	0	0	0	1	28	0	0	29
MN	0	0	0	0	0	3	48	0	0	51
MO	2	0	0	5	0	7	0	0	0	14
MS	11	0	0	0	0	0	0	0	0	11
MT	0	0	28	0	0	0	0	17	0	45
NC	5	0	0	7	0	0	0	0	0	12
ND	0	0	23	0	0	15	0	0	0	38
NE	0	0	0	0	24	5	0	0	0	29
NH	0	8	0	0	0	0	0	0	0	8
NJ	4	0	0	4	0	0	0	0	0	8
NM	0	0	0	0	2	0	0	2	4	8
NV	0	0	0	0	0	0	0	0	8	8
NY	1	28	0	1	0	0	0	0	0	30
OH	0	4	0	3	0	6	0	0	0	13
OK	2	0	0	5	23	5	0	0	0	35
OR	0	0	0	0	0	0	0	15	6	21
PA	0	7	0	6	0	0	0	0	0	13
RI	1	8	0	0	0	0	0	0	0	9
SC	8	0	0	0	0	0	0	0	0	8
SD	0	0	18	0	0	21	0	1	0	40
TN	4	0	0	4	0	0	0	0	0	8
TX	26	0	0	0	23	0	0	0	1	50
UT	0	0	0	0	0	0	0	6	8	14
VA	4	0	0	7	0	0	0	0	0	11
VT	0	8	0	0	0	0	0	0	0	8
WA	0	0	0	0	0	0	0	20	7	27
WI	0	0	0	0	0	4	22	0	0	26
WV	0	0	0	8	0	0	0	0	0	8
WY	0	0	5	0	2	0	0	11	8	26
Sum	146	93	74	81	88	120	106	119	77	904

Lake Use and Replacement

Each lake selected to be sampled is given unique site identification (SITE_ID). Site identification numbers have the form NLA22_ST-nnnnn where ST is two letter state code and nnnnn is a number between 10001 and 99999. It is critical this lake ID be used in its entirety to make sure that the lakes are correctly identified. Lakes evaluated for potential sampling must have all SITE_ID's from the largest to the lowest number evaluated within a state and within a PANEL_USE level:

For PANEL_USE panels NLA22_17RVT2, NLA22_17Base and NLA22_17Over

- Within a state, the two lakes in panel NLA22_17RVT2FT must be evaluated and sampled if possible. If a lake in the panel cannot be sampled, then the lowest SITE_ID from NLA22_17BaseFT that can be sampled within the state must be sampled twice. If none are available to be sampled within NLA22_17BaseFT then the lowest SITE_ID from NLA22_17Base must be sampled twice. If none are available to be sampled within NLA22_17Base, then the lowest SITE_ID from NLA22_17Over that can be sampled within the state must be sampled twice.
- Within a state, lakes in panel NLA22_17BaseFT and NLA22_17Base must all be evaluated and sampled if possible. If a lake in the panel cannot be sampled, then the lowest SITE_ID available within the state from NLA22_17Over must be evaluated. If the lake is from NLA22_17BaseFT panel, then the replacement lake must be sampled for fish tissue if possible. If no fish tissue sample is possible, then no fish tissue will be collected.

Note that for these panels, the NLA 2017 siteID is provided along with the 2017 evaluation status. Even if the lake was evaluated in 2017 and could not be sampled, it should be evaluated again in 2022 to determine if the evaluation status changed for NLA 2022. Within a state, it is possible that after all lakes in panels NLA22_17RVT2FT, NLA22_17BaseFT, NLA22_17Base and NLA22_17Over are evaluated, additional lakes must be evaluated to ensure that the number of lakes in NLA22_17RVT2FT, NLA22_17BaseFT and NLA22_17Base can be sampled. If not, then the remaining lakes required to be sampled will be added to the number of lakes in NLA22_22Base to ensure that the total number of lakes required for the state are sampled.

For PANEL_USE panels NLA22_22BaseFT, NLA22_22Base and NLA22_22Over

- Within a state, lakes in panel NLA22_22BaseFT must all be evaluated and sampled if possible. If a lake in the panel cannot be sampled, then the next available lowest SITE_ID within the state from NLA22_22Over must be evaluated and sampled for all indicators including fish tissue.
- Within a state, lakes in panel NLA22_22Base must all be evaluated and sampled if possible. If a lake in the panel cannot be sampled, then the next available lowest SITE_ID within the state from NLA22_22Over must be evaluated and sampled for all indicators excluding fish tissue.

Sample Frame

The sample frame was derived from the National Hydrography Dataset (NHD) High Resolution data layer. Once the initial GIS layer that included all lake objects in NHD was prepared, additional attributes were created to identify lakes included in the sample frame and other properties used to construct the survey design. First, lakes that were less than or equal to 1 hectare were excluded. Next lakes were included or excluded based on the NHD FTYPE.

Lakes included were FTYPEs:

Lake/Pond

Lake/Pond: Hydrographic Category = Perennial
 Lake/Pond: Hydrographic Category = Perennial; Stage = Average Water Elevation
 Lake/Pond: Hydrographic Category = Perennial; Stage = Date of Photography
 Lake/Pond: Hydrographic Category = Perennial; Stage = Normal Pool
 Lake/Pond: Hydrographic Category = Perennial; Stage = Spillway Elevation
 Stream/River: Hydrographic Category = Perennial
 Lakes excluded were FTYPES:
 Estuary
 Playa
 Inundation Area: Inundation Control Status = Not Controlled
 Lake/Pond: Hydrographic Category = Intermittent
 Lake/Pond: Hydrographic Category = Intermittent; Stage = Date of Photography
 Lake/Pond: Hydrographic Category = Intermittent; Stage = High Water Elevation
 Lake/Pond: Hydrographic Category = Perennial; Stage = Normal Pool
 Reservoir
 Reservoir: Construction Material = Earthen
 Reservoir: Construction Material = Nonearthen
 Reservoir: Reservoir Type = Aquaculture
 Reservoir: Reservoir Type = Cooling Pond
 Reservoir: Reservoir Type = Decorative Pool
 Reservoir: Reservoir Type = Disposal
 Reservoir: Reservoir Type = Disposal; Construction Material = Earthen
 Reservoir: Reservoir Type = Disposal; Construction Material = Nonearthen
 Reservoir: Reservoir Type = Evaporator
 Reservoir: Reservoir Type = Evaporator; Construction Material = Earthen
 Reservoir: Reservoir Type = Filtration Pond
 Reservoir: Reservoir Type = Settling Pond
 Reservoir: Reservoir Type = Sewage Treatment Pond
 Reservoir: Reservoir Type = Tailings Pond
 Reservoir: Reservoir Type = Tailings Pond; Construction Material = Earthen
 Reservoir: Reservoir Type = Water Storage
 Reservoir: Reservoir Type = Water Storage; Construction Material = Earthen; Hyd*
 Reservoir: Reservoir Type = Water Storage; Construction Material = Earthen;
 Hydrographic Category = Intermittent
 Reservoir: Reservoir Type = Water Storage; Construction Material = Earthen;
 Hydrographic Category = Perennial
 Reservoir: Reservoir Type = Water Storage; Construction Material = Nonearthen
 Reservoir: Reservoir Type = Water Storage; Hydrographic Category = Perennial
 Reservoir; Reservoir Type = Treatment
 Swamp/Marsh
 Swamp/Marsh: Hydrographic Category = Intermittent
 Swamp/Marsh: Hydrographic Category = Perennial"

Note that excluding lake objects that are coded “Reservoir” by NHD does not exclude run-of-the-river reservoirs or constructed ponds.

The total number of lake objects in NHDPlus High Resolution is 596,565 with 450,925 being included in the NLA 2022 sample frame (Table 4) with 145,640 lake objects being excluded (Table 5).

Table 4. Number of lake objects included in NLA 2022 sample frame (subset of all lake objects in NHDPlus High Resolution)

	Lake area category (ha)				
	(1, 4]	(4, 10]	(10, 50]	>50	Sum
ECO	100771	21152	10853	2592	135368
CPL	19855	6105	4689	1940	32589
NAP	23490	4387	2312	660	30849
SAP	36741	5066	2259	722	44788
SPL	34932	6056	2889	669	44546
TPL	50852	10582	6239	1811	69484
UMW	29708	10836	9773	4061	54378
WMT	16576	4888	2830	968	25262
XER	8993	2307	1619	742	13661
Sum	321918	71379	43463	14165	450925

Table 5. Number of lake objects excluded from NLA 2022 sample frame that were lake objects in NHDPlus High Resolution.

	Lake area category (ha)				
	(1, 4]	(4, 10]	(10, 50]	>50	Sum
ECO	31403	7821	3652	632	43508
CPL	333	75	72	35	515
NAP	23592	4170	1564	215	29541
SAP	1147	292	207	43	1689
SPL	13825	5229	2757	213	22024
TPL	19615	3497	1373	211	24696
UMW	928	297	142	31	1398
WMT	3215	701	392	145	4453
XER	12438	2909	1854	615	17816
Sum	106496	24991	12013	2140	145640

Comparison to NLA 2017 Sample Frame

The NLA 2017 sample frame is summarized by aggregated ecoregion and lake area categories for comparison (Table 6 and Table 7). A total of 586,678 lake objects are in NHD source for the sample frame with 465,901 being included in the sample frame. This compares to 596,565 lake objects in NHDPlusHR for 2022 with 450,925 being included and 120,777 being excluded from the sample frame. Note that the newer NHDPlusHR includes 9,887 more lake objects than NHD used for 2017. The number of lake objects included in the NLA 2022 sample frame includes 450,925 compared to 465,901 for NLA 2017. Hence even though NHDPlusHR includes more lake objects fewer of them are included in the sample frame compared to NLA 2017.

Table 6. Number of lake objects from NHD included in NLA 2017 sample frame by aggregated ecoregion and lake area categories.

	(1, 4]	(4, 10]	(10, 50]	>50	Sum
CPL	117535	23614	11070	2731	154950
NAP	18837	5658	4324	1877	30696
NPL	23288	5257	2138	496	31179

SAP	35568	4747	1973	641	42929
SPL	37927	6625	2712	607	47871
TPL	44383	9921	5160	1562	61026
UMW	30895	11761	9653	3872	56181
WMT	17911	5042	2687	898	26538
XER	10264	2319	1320	628	14531
Sum	336608	74944	41037	13312	465901

Table 7. Number of lake objects from NHD excluded from NLA 2017 sample frame by aggregated ecoregion and lake area categories.

	(1, 4]	(4, 10]	(10, 50]	>50	Sum
CPL	10716	2670	1340	358	15084
NAP	265	60	39	16	380
NPL	23946	5265	1824	188	31223
SAP	678	188	131	17	1014
SPL	15969	5465	2473	201	24108
TPL	22362	4997	1749	146	29254
UMW	446	321	192	68	1027
WMT	2827	677	406	125	4035
XER	10699	2104	1379	470	14652
Sum	87908	21747	9533	1589	120777

The source for the NLA 2022 sample frame was integrated with the source for the NLA 2017 sample frame by intersecting overlapping polygons. This resulted in 99,715 lake objects being added (Table 8). These lake objects were included in the overall GIS layer to ensure that the additional attributes added to NHDPlus High Resolution were also added for these lake objects. These added lake objects were not included in the NLA 2022 sample frame. Their addition was to ensure that the same GIS data layers were used to define these attributes for NLA 2022 new lakes and for NLA 2017 lake objects that were to be evaluated for resampling in 2022. Note that most of the additional lakes are 1-4 ha lake objects. Given that approximately, 100,000 lake objects were added and the difference between the sample frame sources for 2017 and 2022 only differed by approximately 8,000 lake objects, the new NHDPlusHR also did not include approximately 100,000 lake objects from the earlier NLA 2017 snapshot of NHD sample frame source.

Table 8. Number of lake objects that were in NLA 2017 sample frame source but are not lake objects in NHDPlus High Resolution.

	(1, 4]	(4, 10]	(10, 50]	>50	Sum
CPL	32482	7308	3334	750	43874
NAP	3026	495	225	42	3788
NPL	3780	966	265	14	5025
SAP	5186	573	185	16	5960
SPL	9852	1889	483	23	12247
TPL	10888	2276	639	66	13869
UMW	4529	1032	380	80	6021
WMT	2969	519	167	37	3692

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XER	3877	800	442	120	5239
Sum	76589	15858	6120	1148	99715