Memo

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To: Joint Fact Finding Committee

From: Ascent Environmental

Subject: **Preliminary Approach for Estimating Watercraft Use and Emissions**

Introduction

The Joint Fact Finding (JFF) committee reviewed an October 27, 2016 memo that presented an initial approach to estimate watercraft use associated with moorings (buoys, boat houses, boat lifts, and slips), and an approach to estimate air pollution emissions from that boat use. This memo describes an updated approach based on comments from the JFF committee and additional data received since October 2016. This memo also presents initial work toward developing an estimate of watercraft use from launch facilities (i.e., boat ramps). The information is organized into three parts:

Part 1: Watercraft Use Associated with Moorings: This section presents an updated estimate of watercraft use associated with moorings. Key changes to the approach presented in October 2016 include: 1) a revised estimate of hours of use per day based on actual engine hours and numbers of trips recorded by Lake Tahoe marinas (rather than survey responses), 2) refined estimates of the percent of moored watercraft that are in use based on JFF comments and data provided by marinas, and 3) the addition of maps depicting the areas monitored by TRPA to assess watercraft use patterns (Attachment A).

Part 2: Composite Watercraft Emission Factors: This section expands on the approach described in the October 2016 memo by: 1) describing key attributes of the population of watercraft on Lake Tahoe and 2) presenting the results of the composite emissions calculations for vessels moored on Lake Tahoe and vessels active on Lake Tahoe.

Part 3: Watercraft Use Associated with Launch Facilities: This section describes potential approaches for estimating watercraft use that could result from new boat ramps. It presents two separate initial estimates of watercraft use based on different data sources. It also describes other possible data sources that the JFF committee may be able to obtain to refine the estimates.

The JFF Committee is asked to review the proposed approach, and provide input on the recommended methodology and data sources. Input from the JFF will be used to refine the proposed approach, which will then be used to evaluate the environmental effects of the Shoreline Plan alternatives in the environmental impact statement (EIS). The approach will also allow the Shoreline Policy Committee to understand the incremental emissions associated with each additional mooring and launch facility, which can inform the development of the Shoreline Plan. Please note that this memo addresses only those watercraft emissions associated with moorings and boat ramps. Emissions from rental watercraft will also be analyzed in the EIS, but are not addressed in this memo.

Part 1: Watercraft Use Associated with Moorings

Watercraft Use Levels

The levels of watercraft-generated exhaust emissions are a function of the number and duration of watercraft operating on the lake. Under the Shoreline Plan, increases in the number of moorings (i.e., buoys, lifts, slips, and boathouses) would result in changes in watercraft emissions. Therefore, an estimate of the boat-hours per mooring (i.e., the hours that watercraft supported by each mooring are in operation) is necessary to estimate the emissions that would result from watercraft use associated with additional moorings. To estimate the boat-hours per mooring, the daily number of hours of boat use per mooring, by mooring type, was established for holidays, peak weekend days, peak weekdays, off-peak weekend days and off-peak weekday days. This was calculated for each mooring type using the following equation:

M x U x H = Boat-hours

M = the average number of watercraft per mooring

U = the percent of watercraft moored on the lake that are in use

H = hours of use per day

Average Number of Watercraft per Mooring

The average number of watercraft per mooring was generated from boat use monitoring data collected by TRPA in the summers of 2014 and 2016 (TRPA 2016b). To measure the number of watercraft per mooring, TRPA divided the shoreline into grid cells and selected a series of cells as a representative sample of the shoreline (see attachment A). The TRPA boat crew then visited each of these cells during the morning hours. The data for the two years include peak holidays (including the Labor Day weekend and Fourth of July weekend), weekends (during the peak season of July 1 through Labor Day), weekdays (during the same peak season), off-peak weekends (during May, June, or after Labor Day – September 30), and off-peak weekdays (during the same off-peak period).

Within each grid cell, the total number of each type of mooring was counted, as well as the number of boats present on those moorings. This data was then summed for each type of day (e.g., weekend, weekday) to derive a percent occupied for each mooring type. The number of boat lifts, boathouses, and slips observed was relatively small, and the occupancy of these moorings are affected by lake levels, which were low during the survey periods. Therefore, a conservative estimate of 100 percent occupancy is proposed for these mooring types for all days. The resulting occupancy rates and average number of boats per mooring per type of day are presented in Table 1.

Table 1 - Average number of boats per mooring for each type of mooring and day.

	Buoys		Slips, Boatlifts, and Boathouses	
Day Type*	**Percent occupied**	**Boats per mooring**	**Percent occupied**	**Boats per mooring**
Peak Holiday	63%	0.63	100%	1
Weekend	61%	0.61	100%	1
Weekday	59%	0.59	100%	1
Off-peak Weekend	48%	0.48	100%	1
Off-peak Weekday	22%	0.22	100%	1

*Boat use monitoring data was filtered to include only morning surveys that occurred prior to 11:00am, and afternoon surveys that occurred between 12:00pm and 3:00pm to reflect peak times of watercraft use. Holidays in the TRPA dataset were defined as statutory holidays and adjoining weekend days. July 4 fell on a Friday or Monday in both survey years.

Percent of Watercraft in Use

The percent of watercraft moored on the lake that are in use was derived from the same TRPA boat use monitoring data (TRPA 2016b). To measure the percent of the moored watercraft that were in use during each type of day, the TRPA boat crew revisited each grid cell during the peak time of day for boat use (noon – 3 pm). The difference between the number of boats observed in the morning and the number of boats observed during the afternoon period reflected the percent of boats in use for any given day. The observed percentage of boats in use for each mooring type and each type of day are presented below. The monitoring data did not include observations of the percentage of boats in slips that were in use each day. This value was assumed to be equal to the level of use observed for boat lifts, because the convenience of accessing each of these mooring types is relatively similar.

Table 2 - The average percentage of boats moored on Lake Tahoe that are in use.

Day Type	Buoys	Boat Lifts*	Boat Houses*	Slips
Peak Holiday	40%	36%	17%	36%
Weekend	40%	36%	17%	36%
Weekday	29%	16%	24%	16%
Off-peak Weekend	23%	3%	17%	3%
Off-peak Weekday	1%**	1%	1%	1%

*Where zero boat use was observed, the estimate was increased to 1 percent to reflect a conservative estimate of use.
** Insufficient data was available on watercraft use associated with buoys on off-peak weekdays therefore use was assumed to be consistent with other mooring types.

Hours of Use per Day

The average hours of boat operation per day were derived from private watercraft records maintained by four Lake Tahoe marinas and compiled by the North Tahoe Marina. These records include data on engine hours at the beginning of the season (as watercraft are prepared for the boating season) and at the end of the season (as watercraft are winterized). For watercraft stored at marinas, data are also available on the number of trips taken by each watercraft during the season. For the watercraft for which this information is available (n = 115), the total hours of engine operation during 2016 are 2,927 and the total number of trips is 1,467, resulting in an average of 2 hours of use per trip (North Tahoe Marina 2017).

Boat-hours per Mooring

The boat-hours per mooring were then calculated for each type of day based on the data and equation described above (see Table 3). The boat-hours per mooring for each type of day were then multiplied by the number of days within a typical boating season to generate the boating hours per mooring for the entire season, as shown in Table 4.

Table 3 - Hours of Watercraft Use per Mooring per Day

Day Type	Buoys	Boat Lifts	Boat Houses	Slips
Peak Holiday	0.50	0.71	0.33	0.72
Weekend	0.49	0.71	0.33	0.72
Weekday	0.35	0.33	0.47	0.32
Off-peak Weekend	0.22	0.06	0.33	0.06
Off-peak Weekday	0.01	0.02	0.02	0.02

Table 4 - Hours of Watercraft Use per Mooring per Type of Day and for the Boating Season				
Day Type	**Buoys**	**Boat Lifts**	**Boat Houses**	**Slips**
Peak Holiday	3.02	4.29	2.00	4.32
Weekend	7.65	11.22	5.24	11.31
Weekday	14.94	14.17	20.44	13.85
Off-peak Weekend	5.29	1.48	8.00	1.44
Off-peak Weekday	0.28	1.28	1.28	1.28
Entire Season*	31.18	32.44	36.96	32.21
*Boating Season is considered May 1 through September 30. It is assumed that each boating season includes 6 peak holidays, 16 weekends, 43 weekdays, 24 off-peak weekends, and 64 off-peak weekdays.				

Part 2: Composite Watercraft Emission Factors

Existing Watercraft Population and Fleet Mix

The population is the total number of vessels that operate on Lake Tahoe during a year. The watercraft population during 2015 is estimated to be 13,617, based on the number of registration stickers issued by TRPA's Aquatic Invasive Species (AIS) inspection program (Kasman, pers. comm., 2016). A database developed using vessel registration and AIS inspection data consisted of 12,688 records, where each record represents a vessel that received a unique Blue Boating sticker number from the AIS inspection program (TRPA 2016a). This database was used to derive the fleet mix. The database of 12,688 records was refined to remove records with duplicate state registration identification numbers and/or duplicate Blue Boating sticker numbers, resulting in 12,406 unique records (or a sample size of 91.1% of the total population).

The fleet mix refers to the breakdown of the watercraft population by the following characteristics:

- engine type (i.e., inboard, outboard, jet, auxiliary, personal watercraft [e.g., jet ski], electric, and none),
- engine size (in horsepower [hp]), and
- model year of engine.

Approximately 54 percent of the 12,406 records from the database were complete, meaning they included values for the engine type, engine size, and vessel model year, which are necessary to estimate emission factors. This represents a sample size of 49 percent of the total population of 13,617 vessels estimated to have operated on Lake Tahoe at any point during 2015. The distributions by engine type, engine size, and model year data are presented in Tables 5, 6, and 7, respectively. These factors are based on the available sample of 49 percent of all vessels and were used to develop the composite emission factors described below.

Table 5 - Distribution by Engine Type	
Engine Type	**Distribution (%)**
Outboard	54%
Inboard	22%
Jet	22%
Auxiliary – Sailboat	1%
Total	100%

Table 6 - Distribution by Engine Size	
Engine Size (hp)	Distribution (%)
1 to 15	4%
16 to 25	1%
26 to 50	2%
51 to 120	9%
121 to 175	16%
176 to 250	23%
251 to 500	44%
> 500	1%
Total	100%

Table 7 - Distribution by Model Year	
Model Year	Distribution (%)
2001 or older	43%
2002	4%
2003	5%
2004	6%
2005	7%
2006	7%
2007	6%
2008	4%
2009	2%
2010	1%
2011	1%
2012	2%
2013	3%
2014	4%
2015	4%
2016	0.2%
Total	100%

Emission Factors

Detailed emission factors (i.e., a representative value that relates the quantity of a pollutant released with an activity associated with the release of that pollutant) were provided by David Chou of the California Air Resources Board (ARB) (ARB 2016). These emission factors consist of values differentiated by engine type, engine size (hp), and model year. All exhaust emission factors are provided in units of grams per break horsepower-hour (g/bhp-hr), which is a measure of the power at which an engine is operating rather than a measure of the total horsepower that an engine can produce. Emission factors were available for vessel model years starting from 2001, so model years prior to 2001 were combined into one group. Consistent with the ARB methodology, ROG emission factor is calculated from ROG conversion from total hydrocarbon (THC), and methane (CH_4) emission factor is calculated from CH_4 conversion from total organic gases (TOG) (ARB 2014).

Load Factors

Because the exhaust emission factors are expressed in units of g/bhp-hr, load factors need to be accounted for when estimating emissions. The load factor refers to the level of power at which the engine operates. For example, a 100 hp engine operating with a load factor of 32 percent would be equal to a break horsepower of 32. Estimates of exhaust emissions will be based on the following load factors published by ARB (ARB 2014:10).

Table 8 - Load Factor by Watercraft Type	
Watercraft Type	**Load Factor (%)**
Outboard	32%
Personal Watercraft	40%
Sterndrive	21%
Inboard	21%
Jet Boat	21%
Auxiliary Sail	35%
Source: ARB 2014:10.	

Composite Emission Factors for Existing Population of Watercraft

Watercraft data from 2015 registration and AIS inspection records (TRPA 2016a), and the emission factors and load factors from ARB were used to develop composite emission factors for motorized watercraft operating on the lake under existing conditions. The composite emission factors are calculated as an average of all the vessel emission factors, weighted by key attributes including engine type, engine size, and model year.

Two sets of composite emission factors were estimated and are summarized in Table 9. One set of composite emission factors represents all vessels on Lake Tahoe, and a second set represents only those vessels that are moored on Lake Tahoe (i.e., vessels kept on buoys, boat lifts/houses, or slips). As shown in Table 9, the emission factors for vessels moored at Lake Tahoe are similar to, and 4 to 8 percent higher, than the emission factors for the all vessels, depending on the pollutant.

Table 9 - Composite Emission Factors			
Pollutant	**All Vessels (g/boat-hour)**	**Moored Vessels (g/boat-hour)**	**Difference (%)**
PM_{10}	4.49	4.83	8%
$PM_{2.5}$	4.49	4.83	8%
ROG	585.51	610.26	4%
NO_X	264.12	275.81	4%
CO_{2e}	40,357.13	43,265.89	7%
*Assumed that emission factors for PM_{10} = $PM_{2.5}$.			

Projected Composite Emission Factors for Build Out of the Shoreline Plan

Ascent will next develop a projected composite emission factor for the watercraft fleet assumed to be operating on Lake Tahoe upon build-out of the Shoreline Plan (tentatively assumed for 2035). The mix of engine types and sizes and age distribution of the fleet will be assumed to be the same as under existing conditions. For example, it will be assumed that the proportion of watercraft are one, five, and ten years old, are the same as under existing conditions. However, because this age distribution will be estimated for a future build-out year, it will require the use of emission factors for newer model-year engines than under existing conditions. The build-out composite emission factor will also be expressed in average grams per hour of boat operation (g/boat-hour).

Part 3: Watercraft Use Associated with Launch Facilities

The Shoreline Plan could authorize construction of new boat ramps, which could result in increases in watercraft use and associated environmental effects. Thus, it will be necessary to estimate the changes in watercraft use that would result from new boat ramps. Such use would need to be estimated for both the peak day and the entire season to support the analysis of criteria air pollutant emissions and greenhouse gas emissions, respectively.

Because new boat ramps would increase the maximum launch capacity at Lake Tahoe, new boat ramps would likely increase watercraft use on Lake Tahoe to some extent. It would be reasonable to assume that watercraft use associated with new boat ramps would be typical of that at existing boat ramps.

Estimating watercraft use that would result from new boat ramps is challenging because it is affected by a number of factors that are unknown at this time, including: the launch capacity of new boat ramps (which would be affected by the location, design, parking capacity, and accessibility of individual future boat ramps); the extent to which launching activities at new boat ramps would constitute "new" watercraft use versus watercraft activity that would otherwise occur at other launch sites; and the overall future demand for watercraft use on Lake Tahoe. If we assume that new boat ramps would result in new watercraft use at levels comparable to existing boat ramps, this would be a conservative approach that could be used for the EIS. The following equation could be used to calculate boat-hours of use associated with a new ramp for a peak day and for the entire season.

L x H = Boat-hours

L = watercraft launches per ramp

H = hours of use per day

Watercraft Launches per Ramp

To develop reasonable assumptions about the typical annual and peak day watercraft use (i.e., number of launches) at existing boat ramps, we recommend developing multiple estimates based on different data sources. These multiple estimates of watercraft use could then be combined or averaged to develop a composite estimate that would reduce the potential for error that could result from any one data source. Watercraft use estimates at existing boat ramps have been developed using two separate data sources: a watercraft use survey, and a boating fact sheet that includes information reported by boat ramp operators. The JFF committee is asked to review these two approaches and provide any additional information that could be used to develop additional estimates, as described below.

<u>Watercraft use survey data:</u> An estimate of the typical watercraft use at existing boat ramps can be generated from the 2015 boat registration data compiled by TRPA (TRPA 2016a). These data include information on 12,406 of the estimated 13,617 vessels that operated on Lake Tahoe during any point in 2015, which vessels were used for day use (i.e., launched from a boat ramp rather than moored on Lake Tahoe), and the number of days the vessel was used during the boating season, as reported by the vessel

operator. By adding the total number of days each vessel launched from boat ramps was used, the data show 29,944 total launches from boat ramps in 2015. Because this only includes 12,406 (or 91.1%) of the estimated 13,617 separate vessels that operated on Lake Tahoe, the estimate of 29,944 launches should be increased by 8.9% to account for launches that would occur from other vessels not included in the data. This results in an estimated 32,609 launches during 2015.

The total number of launches can then be divided by the number of public of quasi-public boat ramps that were operational during 2015 to generate an estimate of average annual launches per boat ramp. During 2015, a total of 13 public or quasi-public boat ramps were open for all or part of the boating season (TRPA 2016c) resulting in an average of 2,508 launches per boat ramp.

Based on the observed trends in use patterns during various days of the season (see Tables 3 and 4, above), any one peak holiday day accounts for approximately 1.74% of the total boat use during a season. By applying that percentage to the estimated 2,508 launches per boat ramp, an estimated average of 44 launches would be expected to occur per boat ramp on a peak day.

Boating fact sheet: California State Parks and the California Tahoe Conservancy have prepared a boating fact sheet to support the Kings Beach State Recreation Area General Plan and Pier Rebuild Project (CSP and CTC 2016). This fact sheet includes estimates on the average annual number of launches at four public boat ramps on the North Shore (Kings Beach/Coon Street, Tahoe Vista Recreation Area, Lake Forest, and Sand Harbor), as reported by the agencies that operate each ramp. Average annual launches (for recent years when the ramps are operational) range from 210 to 8,940. This fact sheet reflects an annual average of 4,474 launches per ramp, when averaged across the four ramps included in the fact sheet. By applying the 1.74% of total use estimated to occur on a peak day to the estimated 4,474 launches per boat ramp, an estimated average of 78 launches at each boat ramp would be expected on a peak day.

Other data: Due to the uncertainty in the estimates described above, we recommend that the JFF assist in identifying additional information on the number of launches at existing boat ramps during a peak day and during a year, and the proportion of total launches that occur on a peak day. One additional data source is a time-lapse youtube video showing 106 launches at the Lake Forest boat ramp over the course of 5 hours on July 3, 2009 - a peak holiday (available at: https://www.youtube.com/watch?v=ho1705vkc-k). Other possible data sources could include direct observations or records from boat inspectors stationed at ramps, or launch fee records from ramp operators.

Hours of Use per Day

As described under Part 1 of this memo, the average hours of watercraft engine operation per day for vessels moored on Lake Tahoe was derived from private watercraft records maintained by four Lake Tahoe marinas (North Tahoe Marina 2017). The data show that watercraft stored on Lake Tahoe averaged 2 hours of engine use per trip. In general, launching a vessel at a boat ramp requires more time and effort than accessing a watercraft that is already moored on the lake. In some cases, vessels launched at boat ramps are towed from areas outside of the Lake Tahoe Basin to be used during a vacation in the region. Because of the additional time and effort involved in launching a vessel from a boat ramp, it is reasonable to assume that users would operate their vessels for a longer period of time per trip so as to increase the recreational value of each launch. While no measurements of actual engine operation per trip are available for day-use watercraft that are not stored on Lake Tahoe, the 2015 boat registration data (TRPA 2016a) provides survey responses on the number of hours per trip as reported by watercraft operators for both watercraft moored at Lake Tahoe and launched at boat ramps but not stored on the lake. When the average reported trip duration for vessels moored on Lake Tahoe (n=2,515) is compared to the average reported trip duration for day use vessels launched at boat ramps (n=2,959), the average trip duration for day-use vessels launched from boat ramps is 11 percent higher than for vessels moored on Lake Tahoe. Thus, it is reasonable to assume that the average hours of engine operation would be 11 percent higher for vessels launched from boat ramps, or 2.22 hours per trip.

Proposed Next Steps

The following steps are proposed to complete the estimates of watercraft emissions associated with moorings:

1. Develop the composite emissions factors (g/boat-hour), described above, for the buildout year (assumed to be 2035).
2. Develop a peak day and seasonal estimate of emissions per mooring for 2015 and 2035 based on the estimate of boat-hours per mooring multiplied by the composite emission factors. This estimate of emissions per mooring could be applied to the inventory of existing moorings to provide a baseline estimate. It could also be used by the Shoreline Policy Committee to assist in the development of potential mooring caps in the Shoreline Plan.
3. Develop a composite estimate of launches per peak day and per year at a typical boat ramp. This would involve analyzing additional data sources on launch activity identified by the JFF committee, and developing an average estimate from multiple estimates developed from different data sources.
4. Develop an estimate of evaporative emissions (i.e., emissions released from watercraft engines in storage, and "hot soak" emissions, which occur after shutting down an engine that has been run). This estimate will require an analysis of the proportion of the watercraft fleet that is stored in the Tahoe Air Basin while not in use.
5. Develop a separate estimate of rental watercraft activity. Because the use patterns and fleet mix of rental watercraft are likely different than other watercraft, Ascent recommends developing a separate estimate of use hours and a separate composite emission factor for rental watercraft. This estimate can be based on an existing inventory of rental watercraft, augmented by use data from rental providers.
6. Seek ARB review of the composite emission factors methodology, and other assumptions described in this memo.
7. Determine whether any changes in use patterns would be expected by the buildout year (e.g., would the season be extended due to climate change, or new dredging provisions). This could involve an assessment of overall boating demand in the Lake Tahoe Basin to evaluate whether watercraft use estimates, as described in this memo, are consistent with expected demand for watercraft use.

References

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CSP and CTC. *See* California State Parks and California Tahoe Conservancy.

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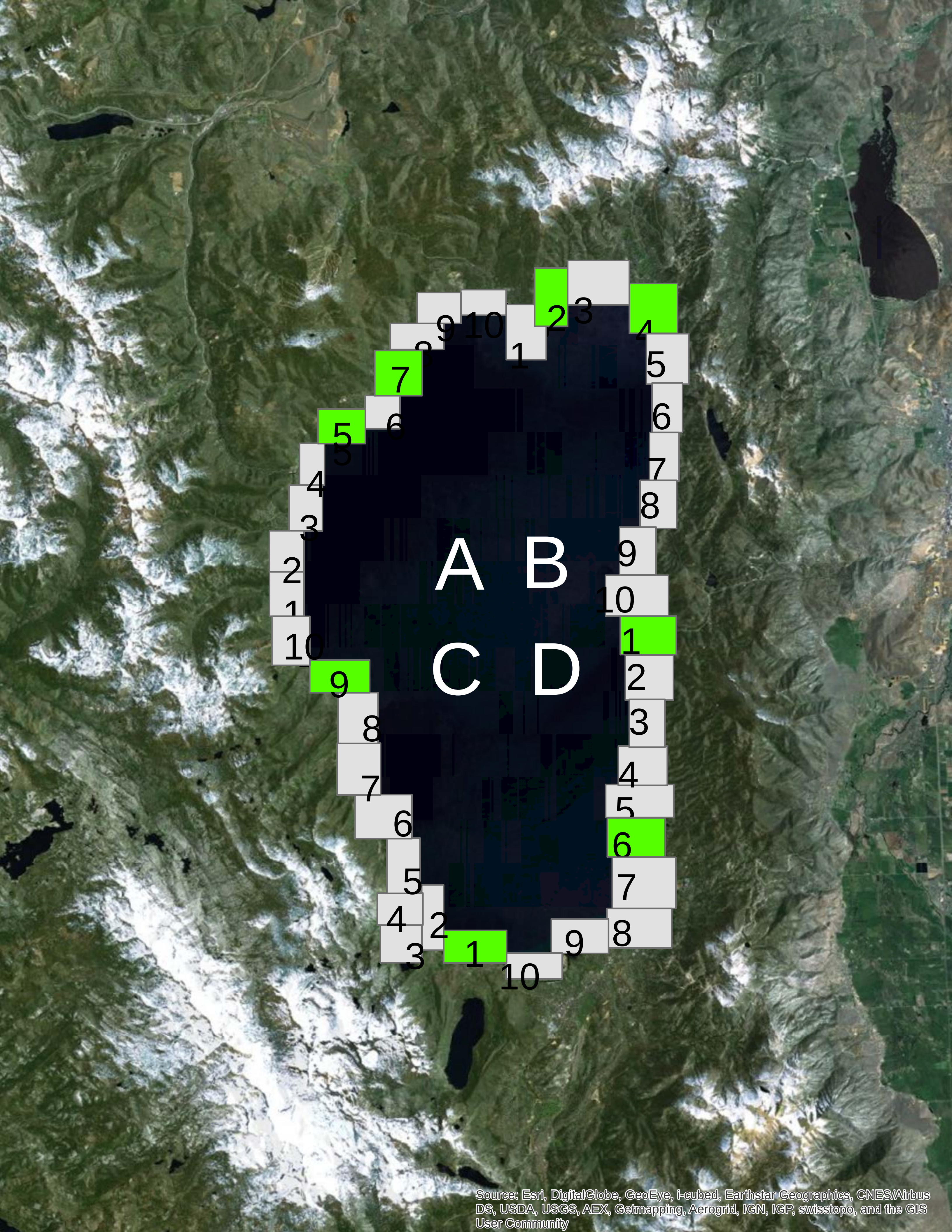
______. 2016c. Summary of Water Access for Marinas and Public Boat Ramps. Data on 2015 conditions compiled by TRPA.

TRPA. *See* Tahoe Regional Planning Agency.

Attachment A

TRPA Watercraft Use Monitoring Sample Sites


A B
C D
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community