This version of the Reservoir Bathymetry Project completion memorandum is Draft and Provisional.

In summary:

- ***The results show close conformance between the original FIIP reservoir capacity curves and the updated WGM (Contractor) curves at mountain reservoirs and valley reservoirs with well-defined topographic margins – reservoirs where topographic and contour interpolation in the original FIIP work would be expected to have high fidelity with the terrain.***
- ***The conformance between the two sets of curves decreases for valley-floor reservoirs with less distinct topography. Without exception, the WGM curves indicate a decrease in storage compared to the original curves. This appears to be very reasonable given the potential for reservoir sedimentation, organic accumulation and vegetative encroachment in these settings, as well as the lower resolution in the original FIIP topographic work suggested by the original topobathymetric contour maps at certain reservoirs.***

Our review indicates that the WGM work meet the criteria for a recommendation for adoption at all reservoirs. However, we are providing a provisional and draft memorandum for full review prior to formalizing recommendations.

After review, the memorandum will be updated with input and a recommendation for next steps.

Executive Summary: CSKT – Montana Compact Implementation Team

Reservoir Topobathymetric Survey for Bureau of Indian Affairs

Flathead Indian Irrigation Project Reservoirs

Below, we report the finding of a topobathymetric survey completed over the 2018 – 2020 period at fourteen Flathead Indian Irrigation Project (FIIP) reservoir facilities. The work was completed by WGM Group with LiDAR data acquisition and processing completed by Quantum Spatial. The project was recommended for approval by the CSKT-Montana Compact Implementation Technical Team, with funds disbursed from Montana to the CSKT to administer the project.

The findings reflect a synthesis of Contractor work, with focus to address the primary project objective – to redevelop the reservoir storage elevation-capacity curves, compare them to the original FIIP work, and where appropriate recommend updates to the elevation-capacity curves.

Many of the FIIP reservoir facilities are at, or looking back at the century mark, and it is reasonable to anticipate that reservoir capacities would change. At the outset, we anticipated the mountain reservoirs would exhibit change due to progradation of sediment where inflowing streams discharge into a reservoir. In fact, the elevation-capacity curves for the mountain reservoirs exhibit minor changes between original and updated data. However, we found notable changes in valley reservoirs with shallow and indistinct marginal areas. It appears a combination of sedimentation, vegetative encroachment, and potentially lower resolution surveying in original work lead to observed changes.

Results are summarized at one elevation – the Standard Operating Procedure upper operating elevation (unless otherwise noted in memo) – in the table below.

Reservoir	*Type*	*Elevation, in feet*	*WGM capacity, in acre-feet*	*FIIP capacity, in acre-feet*	*Change*
Upper Jocko Lake Reservoir	**Mountain**	*4,440.0*	*5,039*	*5,200*	*-2.1%*
Lower Jocko Lake Reservoir	**Mountain**	*4,340.0*	*6,369*	*6,449*	*-1.2 %*
Tabor Reservoir	**Mountain**	*4025.6*	*23,755*	*23,483*	*+ 1.2%*
Mission Reservoir	**Mountain**	*3409.0*	*7,872*	*8,135*	*-3.2%*
McDonald Reservoir	**Mountain**	*3598.0*	*8,258*	*8,225*	*+0.4%*
Kicking Horse Reservoir	**Valley**	*3059.1*	*5,559*	*6,180*	*-10.0%*
Ninepipe Reservoir	**Valley**	*3010.0*	*10,742*	*14,857*	*-28.0%*
Lower Crow Reservoir	**Valley**	*2849.9*	*9,938*	*10,352*	*-4.0%*
Pablo Reservoir	**Valley**	*3211.0*	*22,974*	*28,400*	*-19.1%*
Twin Reservoir	**Valley**	*3090.5*	*833*	*899*	*-7.3%*
Lower Dry Fork Reservoir	**Valley**	*2858.0*	*3,606*	*4,020*	*-10.3%*
Upper Dry Fork reservoir	**Valley**	*2928.7*	*2,293*	*2,876*	*-20.3%*
Hubbart Reservoir	**Mountain**	*3219.0*	*12,449*	*12,125*	*+2.7%*
Little Bitterroot Lake	**Valley**	*3906.5*	*25,008*	*26,400*	*-5.3%*

To: **Project File**

From: **Seth Makepeace, CSKT Water Resources Program**

Re: **Results and Observations – CITT Reservoir Bathymetry Project, Flathead Indian Irrigation Project**

Date: **October 29, 2020**

Version: **Draft and Provisional Document Version 1 October 29, 2020**

Enclosures: **Appendices**

A reservoir topobathymetric (bathymetry) survey was completed for fourteen Flathead Indian Irrigation Project (FIIP) storage reservoirs in 2018-2020 with the objective to update the reservoir elevation-storage capacity (elevation-capacity) curves. This memorandum details that work effort and is organized as follows:

- **Background and Objectives,**
- **Project Approach,**
- **Details of the Survey Event,**
- **Accuracy Assessment for Survey Information (QA/QC),**
- **Observations, Results, and Recommendations,**
- **References Cited,**
- **Appendices.**

Background and Objectives

Reservoir elevation-capacity curves were developed for FIIP reservoirs around the time of each reservoir's completion, generally in the early 1900's. Elevation-capacity curves report the volume of water, in acre-feet, that can be stored at progressively increasing reservoir elevation levels, in feet. Reservoir topobathymetric maps were also developed around the same time for all or most reservoirs and presumably form the basis for the elevation-capacity curves. Curves span from either the low-point elevation in a reservoir, or the hydraulically accessible low elevation (typically gatehouse inlet invert elevation) up to a defined elevation, such as the reservoir spillway crest.

The current bathymetry project was planned and implemented to collect a survey-grade reservoir bed digital surface model to apply to redevelop the reservoir elevation-capacity curves, recognizing:

- Sedimentation and/or vegetation accumulation and encroachment may have occurred in some reservoirs, potentially reducing reservoir capacity, and
- Survey methods have improved over the last century and would be anticipated to lead to higher resolution results.

Also, while the original topobathymetric maps and capacity curves were developed with care, there is limited methods documentation other than final work products.

The project was administered by the Confederated Salish and Kootenai Tribes (CSKT), and is part of the overall scope of activities for the CSKT-Montana water rights Compact Implementation Technical Team (CITT). CITT members and irrigation project personnel were involved in the project formulation and completion. The bulk of the financial support for the project came from State of Montana appropriations dispersed to the CSKT to support activities of the CITT. Funds were disbursed via a task order process authorized through a Master Agreement between the State of Montana and the CSKT.

Specifically, the topobathymetric project was advanced to:

- Collect survey-grade data across the project extent using recognized industry practices,
- Process and analyze the data using a well-documented workflow,
- Collect and process data of a known accuracy,
- Include metadata documentation – information about the collection and analysis of the data,
- Prepare and archive electronic files of all raw and processed data,
- Redevelop the elevation-capacity curves at the fourteen primary FIIP reservoirs (Figure 1),
- Compare the updated curves with the original FIIP curves and make recommendations to adopt the updated curves where appropriate.

The above objectives were met. The seamed – survey points from ground and LiDAR data collection integrated into a surface model - survey-grade dataset has also been used for engineering design work at certain reservoirs and may see future applications.

Parts of this summary abstract from the Contractor reports, and these should be referenced for more detail (available in CSKT project files).

Project Approach

The project was contracted to WGM Group (Contractor), with the Light Detection and Ranging (LiDAR) data collection and processing subcontracted to Quantum Spatial (QSI). All work was completed under the direction of a Surveyor licensed to practice in Montana. At each reservoir, the survey extent spanned from the lowest point in the reservoir to a defined upper elevation – the maximum area/capacity (max a/c) elevation. The max a/c elevation varied between reservoirs, but generally was set at the reservoir spillway crest or one foot above the spillway crest. At all reservoirs, the max a/c was higher in elevation than the upper recommended operating elevation for the reservoir. At a number of reservoirs the lowest point, and a slice of the reservoir above that point, is below the reservoir gatehouse inlet elevation. This volume of water is hydraulically inaccessible, and is often termed the dead pool.

Survey coverage included both ground (upland areas above upper reservoir operating level to the max a/c) and reservoir bed topography (upper reservoir operating level down to lowest reservoir elevation, either ground or below-water at time of survey). LiDAR data acquisition extended beyond the max a/c and is available in project files.

Data were collected using:

- Green LiDAR – an airborne laser scanner pulse system capable of collecting ground and below-water topography down to a depth of approximately 1.5 Secchi depths, where Secchi depth is a visual indicator of water clarity.
- Ground survey data were collected using GPS/GNSS receivers, total station, and differential leveling approaches (WGM, 2020).

- Below-water data at depths greater than the green LiDAR observation depth were collected using GPS/GNSS hydrographic sonar deployed on a hydrodrone and, at larger reservoirs, on a motor-propelled boat. In certain heavily-vegetated shallow water settings, ground-based survey was completed to fill data gaps from the hydrographic portion of the survey.

Data collected via various approaches were integrated to produce a seamless surface dataset and topographic model depicting reservoir bed and ground topography up to the max a/c. Data were projected into the latest realization of the NAD83 horizontal datum projected into Montana State Plane coordinates and the NAVD88 vertical datum.

Once the NAD83/NAVD88-projected dataset was finalized, the data were projected from a grid elevation to a ground elevation unique to each reservoir (MDOT, 2005). Without this step, capacity curves would be based on State Plane grid coordinates at a zero elevation. The ground elevation was set to approximately two thirds full at each reservoir.

Finally, data were projected into what is termed for project purposes, the CSKT local datum. The correction from real world to local coordinates was done through transformations completed at control points and known reservoir gatehouse floor elevations, both established in the CSKT local datum. The horizontal transformation between coordinate systems was consistent between the reservoirs, but the vertical transformation varied by reservoir. Final elevation-capacity and elevation-area curves are reported in both coordinate systems projected to ground elevation.

The early development of the CSKT local datum is not well defined, but appears to have been set during reservoir construction, and it has carried forward to this date. The most consistent and enduring known local control points are the reservoir gatehouse floors. CSKT local datum's were monumented and documented in Morrison-Maierle/CSSA (1990). The coordinates described in this report, where found, were observed for the current project to complete the coordinate system transformations. Neither Morrison-Maierle/CSSA (1990) nor WGM (2020) were able to reconcile the variable differences in elevation between NAD83/NAVD88 datum's and CSKT local datum's that occur between each reservoir.

The existing FIIP elevation-capacity curves, reservoir Standard Operating Procedures, and reservoir operating criteria are described and reported in the CSKT local control, requiring the transformation from real world to local coordinates to meet project objectives.

We note that the original General Land Office surveys for the Reservation (digital and rectified versions of plan sheets available in CSKT files) were completed around the time the FIIP was being planned in the early 1900's. Although beyond the scope for this memorandum, there is a possibility that the CSKT local datum derives from the original GLO survey work.

Details of the Survey Event

The Contractor developed the data acquisition plan to optimize coverage using LiDAR. This increased both the efficiency for data collection and also led to higher accuracy results in shallow water areas. The overall work sequence was as follows:

- Late summer, 2018 – set survey ground control for LiDAR data acquisition and relocate and/or establish control points at individual reservoirs.

- September 24-26, 2018 – Complete LiDAR data acquisition. This period corresponded to a time with low cloud cover and low reservoir pool elevations. The data quality objective and mission settings were to produce a laser pulse setting ≥ 6 pulses/m^2 with opposing flight side-lap overlap of ≥ 50%, for a total overlap of 100% (QSI, 2019). The LiDAR flight area included a buffer around each reservoir project extent.
    - The LiDAR acquisition target for the average value of first returns – energy pulses emitted by the laser that return one echo to the receiver system – was 6 points/m^2 of terrain. The observed average value for first returns for the project was 29.5 points/m^2.
    - The average value for ground and bathymetric-classified data was 5.2 points/m^2 and the average value for bathymetric-only classified data was 4.5 points/m^2.
    - First returns may include top of vegetative canopy, ground, or bathymetric points. Classified returns remove returns from vegetative canopy, leaving ground and reservoir bed surface returns.
    - For reference, reporting returns of 4.5 points/m^2 indicates 4+ independent measurements of coordinate-referenced elevation occurred on average for each m^2 of LiDAR-collected terrain data.
- LiDAR data were fully processed and delivered in early 2019 and, based on the aerial extent of the LiDAR coverage, the Contractor developed a deep-water data acquisition plan.
- Ground-based data collection occurred over the May-October, 2019 period using a single-beam sonar system integrated with survey-grade GPS deployed from both a hydrodrone, and in larger reservoirs, a motor-propelled boat. In a few valley reservoirs, notably Kicking Horse Reservoir, heavily vegetated shallow water areas impeded use of boat-based data collection, and minor data gaps were filled with ground-based survey using a survey-grade GPS/GNSS data collector.
- Concurrent with ground-based bathymetric survey work, the Contractor collected QC points and coordinates at appurtenant structure features at each reservoir. These varied by reservoir, but included at a minimum spillway crest elevations.
- Data were processed over the fall and winter of 2019- 2020 and the final project was delivered in March, 2020. Data processing required point integration from the various sources to produce a seamless ground and reservoir bed surface model. Some point cloud thinning – reduction in the density of data points - was required to improve data processing. Also, some manual editing of sonar-bathymetric points was required at three valley reservoirs – Pablo, Ninepipe, and Kicking Horse Reservoirs. False reservoir bed returns, higher than the bed surface, were observed due to extensive submerged aquatic vegetation. Criteria for manual point editing included selection of the lowest elevation return and extensive comparison with adjacent LiDAR-bathymetric points.

At the outset, the Contractor anticipated some challenges in vegetated shallow water areas related to water clarity and the efficacy of Green LiDAR data acquisition in lower water clarity environments. As noted above, these were resolved through additional ground-based survey and manual point cloud editing.

Accuracy Assessment for Survey Information (QA/QC)

Accuracy is considered in terms of absolute accuracy – the consistency of the data with external data sources – and in terms of relative accuracy - the internal, or point to point consistency of the dataset. Accuracy results are summarized below but the actual reports, in particular the QSI report, should be referenced for an in depth discussion of accuracy standards and results.

LiDAR

Absolute accuracy was assessed using guidelines from the Federal Geographic Data Committee (FGDC) National Standards for Spatial Data Accuracy.

- 44 bare earth (non-vegetated) ground points with known elevations were withheld from the calibration and post-processing steps for absolute accuracy assessment. The median elevation spread between the points for the unclassified point cloud was 0.070 feet and, for the classified and gridded elevation model (DEM) data, the median spread was 0.005 ft.
- 836 known bare earth (non-vegetated) ground control points that were used in the classification and post-processing were compared to the DEM results and indicated a median spread of 0.010 ft.
- 186 bathymetric points were collected to assess below-water vertical accuracies. The median spread between points was 0.125 ft and the 95^{th} percentile spread was 0.357 ft.
- 66 wetted edge points were checked resulting in a median spread of 0.036 ft and a 95^{th} percentile spread of 0.251 ft.

Relative accuracy was assessed by comparing the ground surface model for each individual flight line to the adjacent flight line for overlapping areas. The median spread between points was 0.045 ft.

Ground-Based Survey

WGM Group evaluated the LIDAR vertical point accuracies with a random sample of 139 points (~ 10 per reservoir) using a survey grade GPS/GNSS receiver with an on-site base station. The LiDAR ground points had an accuracy of 0.12 ft. root mean square error (RMSE) and the bathymetric points indicated an RMSE accuracy of 0.20 ft.

Shallow water sonar was compared to survey grade GPS/GNSS receiver measurements and indicated an accuracy of +0.10 ft. Deep water sonar could not be checked for accuracy, but the manufacturer specification indicated accuracy of +0.20 ft or better.

CSKT Review

A qualitative check was completed by CSKT to look at the consistency of the reservoir bed contour maps and the dataset in general. This review was consistent with expectations and did not indicate outliers or breaks in topographic continuity.

The CSKT, when comparing the FIIP and Contractor elevation-capacity curves, looked at the difference between the 1990 and currently observed control point elevations. Where there was an overlapping point in the reservoir gatehouses, the correspondence between points was acceptable.

Valley-floor reservoirs indicated varying degrees of departure between the original FIIP and Contractor-developed elevation-capacity curves. As a QC check, the CSKT completed more focused work on these reservoirs, and this review step is reported by reservoir below.

Observations, Results and Recommendations

Deliverables for the project are generally reported in both a real world and CSKT local coordinate system. A number of the results are large raw or processed digital files of the seamed raw and post-processed point information; these are available in the CSKT project files in various standard formats. The primary processed results include topobathymetric contour maps for each reservoir and elevation-capacity and area-capacity tables for each reservoir. The CSKT have also brought the data into an ArcGIS environment for spatial analysis and QC checks.

Information focused to the primary project objective – developing new elevation-capacity curves and comparing these to existing FIIP elevation-capacity curves - is reported below and in appendices for each of the fourteen project reservoirs. The information comes from a set of standardized spreadsheets available in the CSKT project files. An internal QC process was applied to the spreadsheets. A summary page from each reservoir spreadsheet is reported and contains a similar set of information, some of which is described below.

- The Contractor elevation-capacity data spans from the lowest point in the reservoir, in most instances below the hydraulic control for the reservoir, to the max a/c elevation. The FIIP elevation-capacity data generally initiates at the reservoir gatehouse inlet elevation or some other feature at the reservoir. The dead pool – the unmanaged lower portion of the reservoir - is well defined with the Contractor data.
- For comparison purposes, the WGM/FIIP elevation-capacity data need to initiate at the same elevation. This is reported in the summary sheets as the reconcile elevation. For most of the reservoirs, the Contractor acre-foot capacity value was reset to zero acre-feet at the reconcile elevation in order to correspond to the FIIP capacity data.
- The term SOP refers to the CSKT Safety of Dams Standard Operating Procedures for each reservoir. The SOP's contain an array of reservoir information, and also report the recommended upper operating elevation for each reservoir.
- The two datasets were compared graphically and by computing the relative percent difference (RPD) at the SOP upper elevation operating level.
- The Contractor deliverables include area-capacity tables. These are available, but not reported, since FIIP area-capacity tables are not available for many of the reservoirs.

Physically the reservoirs can be defined as one of two types:

- Mountain reservoirs in incised-valley settings with well-defined topography, and
- Valley-floor reservoirs, often with indistinct margins and shallow, vegetated marginal areas.

Reservoir	Type	On channel / Off channel
Upper Jocko Lake Reservoir	Mountain	On channel
Lower Jocko Lake Reservoir	Mountain	On channel
Tabor Reservoir	Mountain	On channel
Mission Reservoir	Mountain	On channel
McDonald Reservoir	Mountain	On channel
Kicking Horse Reservoir	Valley	Off channel
Ninepipe Reservoir	Valley	Off channel
Lower Crow Reservoir	Valley (well defined margins)	On channel
Pablo Reservoir	Valley	Off channel
Twin Reservoir	Valley	On channel
Lower Dry Fork Reservoir	Valley	On channel
Upper Dry Fork reservoir	Valley	On channel
Hubbart Reservoir	Mountain	On channel
Little Bitterroot Lake	Valley (well defined margins)	On channel

There is generally a close correspondence between the FIIP elevation-capacity data and the Contractor-developed reservoir capacity data in each mountain reservoir and the two valley reservoirs with well-defined margins. The correspondence between the two datasets decreases notably in the remaining valley reservoirs.

We provide a short discussion and recommendation for each reservoir. In the appendix, we provide a summary table and comparison curve, the Contractor elevation-capacity tables, the area-capacity tables, and specific graphics for certain reservoirs.

To be finalized:

Without exception, we recommend updating the elevation-capacity curves to the Contractor-developed curves. The general recommendation is based on the following:

- ***The survey dataset met quality control criteria for the work-type and was completed using industry-standard practices under the direction of a Surveyor licensed to practice in Montana.***
- ***The data and surface models represent current reservoir bed topography in each reservoir. In some instances the original FIIP topobathymetric work is over 100 years old, and we would expect some change over time.***
- ***The Contractor reservoir topobathymetric models and contours were developed with very dense point arrays, reducing the weight of any individual outlier data.***
- ***Where there was large discrepancy between Contractor-developed and FIIP elevation-capacity curves, the Contractor area and volume data were re-developed in a GIS work environment as a QC check. Recognizing the Contractor worked in a Civil 3D Cad environment and the checks were completed in GIS, the correspondence was close at each reservoir.***
- ***Further exploration was completed to compare the Contractor work and the FIIP topobathymetric work at certain reservoirs. This information is reported below, but corroborates the recommendations.***

Upper Jocko Lake Reservoir (Black Lake)

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to one foot above the spillway crest, an indistinct earthen feature on the east end of the reservoir. At this reservoir the Contractor had notable difficulty locating and then reconciling the CSKT local control points with their control survey points and had to partially rely on control point overlap at Lower Jocko Lake Reservoir. The two curves were reconciled at elevation 4,390.0 feet, the start of the FIIP elevation-capacity curve. The Contractor reported a dead pool volume of 264.4 acre-feet.

The elevation-capacity curves have similar shape, show close correspondence, and at the upper SOP operating elevation 4,440.0 feet, the Contractor capacity value is 2.1% lower than the FIIP capacity value; this equates to a reduction in storage of 161 acre-feet.

Lower Jocko Lake Reservoir

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to the dam crest on the west side of the reservoir. Lower Jocko Lake does not have a spillway, and the dam crest is well above the upper operating level for the reservoir. The two curves were reconciled at elevation 4,267.0 feet, the gatehouse inlet invert elevation; below this level the Contractor reported a dead pool volume of 1,298 acre-feet.

The elevation-capacity curves have a very similar shape, and at the upper SOP operating elevation 4,340.0 feet, the Contractor capacity value is 1.2% lower than the FIIP capacity value; this equates to a reduction in storage of 81 acre-feet.

Tabor Reservoir (St. Mary's Lake)

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to one foot above the flashboard pins (stanchions) in the spillway. The two curves were reconciled at elevation 3,911.5 feet, the gatehouse inlet invert elevation; below this level the Contractor reported a dead pool volume of 12,973 acre-feet.

The elevation-capacity curves have a very similar shape, and at the SOP upper operating elevation 4,025.6 feet, the Contractor capacity value is 1.2% greater than the FIIP capacity value; this equates to an increase in storage of 272 acre-feet.

Mission Reservoir

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to one foot above the flashboard pins in the spillway. The two curves were reconciled at elevation 3,341.0 feet, the gatehouse inlet invert elevation. The Contractor data indicates there is no dead pool volume.

The elevation-capacity curves have a very similar shape, and at the upper SOP operating elevation 3,409.0 feet, the Contractor capacity value is 3.2% lower than the FIIP capacity value; this equates to a reduction in storage of 263 acre-feet.

McDonald Reservoir

The Contractor-developed elevation-capacity data span from the lowest point in the reservoir to one foot above the spillway radial gates in the closed position. The two curves were reconciled at elevation 3,540.0 feet, the gatehouse inlet invert elevation. The Contractor data indicated a dead pool volume of 3,749 acre-feet.

The elevation-capacity curves have overlapping shape, and at the upper SOP operating elevation 3,598.0 feet, the Contractor capacity value is 0.4% greater than the FIIP capacity value; this equates to an increase in storage of 33 acre-feet.

Kicking Horse Reservoir

At Kicking Horse Reservoir, the Contractor placed the maximum a/c at elevation 3,060.0 feet, below the spill point for the facility. The Contractor point cloud and independent surveys for SOD work indicate the maximum a/c should be at 3,065.0 feet, corresponding to the low point elevation in Dike No. 3, in the northwest portion of the facility. Kicking Horse Reservoir does not have a spillway, but overtopping would occur at this location in Dike No. 3. In order to reflect the full range of reservoir stage, we extended the elevation capacity curve from 3,060.0 feet to 3,065.0 feet in a GIS work environment. We note that we did not encounter this issue at any other reservoir facility.

Area and volume were calculated for elevations below 3,060.0 feet, compared to the Contractor results, and based on the close correspondence, extended to 3,065.0 feet. The results are reported in the following table.

Elevation, in feet	Area, in acres			Volume, in acre-feet		
	Contractor	CSKT GIS	% difference	Contractor	CSKT GIS	% difference
3,027.0	0.5	0.4	18.3%	0.2	0.2	0.5%
3,032.0	2.5	2.2	13.6%	8.4	7.9	5.4%
3,037.0	4.6	3.9	16.2%	25.3	24.3	3.8%
3,042.0	9.5	7.7	18.7%	57.9	55.9	3.4%
3,047.0	161.9	159.0	1.8%	419.4	415.0	1.0%
3,052.0	396.3	396.9	0.1%	1,735.5	1,730.1	0.3%
3,057.0	585.3	587.2	0.3%	4,283.6	4,279.0	0.2%
3,060.0	648.2	641.0	1.1%	6,134.0	6,106.4	0.4%
3,061.0		650.7			6,749.4	
3,062.0		656.3			7,401.1	
3,063.0		660.4			8,059.3	
3,064.0		663.8			8,722.0	
3,065.0		665.7			9,387.4	

The difference in area and volume results for the overlapping elevations decrease to an acceptably small percent departure as area and volume increase. We did not expect 100% overlap, since the Contractor work was completed in Civil 3D CAD and our work was completed in GIS. This effort also provided an independent check of the Contractor data analysis steps.

Kicking Horse Reservoir is a valley-type reservoir that exhibited some discrepancies between the Contractor and FIIP elevation-capacity data. We identified the following points that may lead to the reported changes between the two curves.

- Kicking Horse Reservoir was constructed in 1930, so the intervening time span for capacity curve development is over 90 years. Sedimentation likely occurred in the intervening period, with the South Crow Feeder Canal a notable source of coarse sediment.
- Vegetation encroachment along the shore margins may also have occurred, reducing reservoir depth.
- Kicking Horse Reservoir is wide and shallow and inundated a number of depressional wetlands. The original topography was likely difficult to survey with ground-based methods, and some interpolation may have occurred.

The original FIIP topobathymetric map (FIIP plate F-4431, 1929) was rectified at public land survey corners and placed over a 2019 air photo image (Figure 2). The 3,050 and 3,060 foot contour intervals are plotted for both the Contractor and FIIP data. The FIIP contours indicate a deeper reservoir pool toward the South Crow Feeder inlet, and also suggest a lower level of overall survey resolution.

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to 3,060.0 feet. The Contractor point cloud was processed and the data were extended to 3,065.0 feet, the low point elevation on Dike No. 3. The two curves were reconciled at elevation 3,042.0 feet, the start of the FIIP capacity curve. We were unable to find a corresponding outlet works structure elevation for the start of the curves. The Contractor reported a dead pool volume of 59.7 acre-feet, and FIIP reported a dead pool volume of 70 acre-feet.

The elevation-capacity curves have a very similar shape, and at the upper SOP operating elevation 3,059.1 feet, the Contractor capacity value is 10.0% lower than the FIIP value; this equates to a reduction in storage of 621 acre-feet at this pool elevation.

Ninepipe Reservoir

Ninepipe Reservoir was originally constructed in 1911. The dam crest was raised to 3,018 feet in 1923 and 4 dikes were emplaced on the south margin of the reservoir at the time of the dam raise. The FIIP elevation capacity curve was developed from a 1921 topobathymetric map (FIIP plate F-517-B, 1921) prepared prior to the 1923 dam raise.

Ninepipe Reservoir is a valley-type reservoir that exhibited notable discrepancies between the Contractor-developed and FIIP elevation-capacity data. The reservoir has a wide and shallow marginal area, and there is potential that vegetation encroachment has reduced water depths and reservoir capacity in the 100 years since final reservoir construction; this observation has been noted by FIIP staff, especially in the south and east margins of the reservoir.

Two figures are prepared related to Ninepipe Reservoir.

- Figure 3 shows the reservoir pool at an elevation that corresponds to a pool elevation of 3,001.4 feet. This figure clearly shows the extensive shallow marginal areas. Also, as indicated in the figure text, we estimated the volume in the reservoir at 3,001.4 feet in a GIS work environment, and compared it to the Contractor and FIIP volumes at this elevation. We found close correspondence with the Contractor data as anticipated, but the calculated volume is over 50% lower than the FIIP volume at this elevation.

- Figure 4 compares specific contours from the Contractor data with the 1921 FIIP topobathymetric map. There is close correspondence at the 3,010.0 foot elevation, but a lower correspondence at lower elevations.

We found close correspondence between the Contractor elevation-capacity data and the QC check completed in a GIS environment; the greatest difference was 1.5% found at the lowermost check elevation.

Elevation, in feet	Volume, in af		% difference Contractor / GIS	FIIP volume, in af	% difference Contractor / FIIP
	Contractor	CSKT GIS			
2,966.4	8.5	8.4	1.5%	below curve	below curve
2,971.4	26.7	26.5	0.6%	below curve	
2,976.4	52.9	52.6	0.5%	below curve	
2,981.4	87.0	86.7	0.4%	below curve	
2,986.4	131.4	130.7	0.5%	20.0	>100%
2,991.4	259.7	256.8	1.1%	240.0	8.2%
2,996.4	579.7	574.1	1.0%	1,246.0	53.5%
3,001.4	1,855.5	1,854.9	0.03%	4,245.0	56.3%
3,006.4	6,326.2	6,326.4	0.0%	9,616.0	34.2%
3,010.0	10,742.0			14,857.0	28.0%
3,011.4	12,898.4	12813.4	0.7%	~16,472.0[1]	~22%

[1] – top of FIIP curve 3,011.0 feet at 16,472.0 af

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to the low point elevation on Dike No. 4, located on the south side of the reservoir. The two curves were reconciled at elevation 2,985 feet, the gatehouse inlet invert elevation; below this level the Contractor reported a dead pool volume of 117 acre-feet.

The elevation-capacity curves have a similar shape, and at the upper SOP operating elevation 3,010.0 feet, the Contractor capacity value is 28% lower than the FIIP capacity value; this equates to a reduction in storage of 4,115 acre-feet.

Lower Crow Reservoir

The Contractor-developed elevation-capacity data spanned from the lower point in the reservoir to the spillway crest elevation. The two curves were reconciled at elevation 2,800.0 feet, the start of the FIIP curve. At this elevation, both the FIIP and Contractor data indicate 0 acre-feet of storage.

The elevation-capacity curves have a very similar shape, and at the spillway crest elevation 2,877.0 feet, the Contractor capacity value is 4.0 % lower than the FIIP capacity value; this equates to a reduction in storage of 414 acre-feet.

Pablo Reservoir

Pablo Reservoir is a valley-type reservoir that exhibited some discrepancies between the Contractor-developed and FIIP elevation capacity data. Pablo Reservoir was initially constructed in 1912, it was raised in 1918, and it was finally completed in 1932. Safety of Dams upgrades occurred in 1993-1994 and 2004, but SOD upgrades did not affect reservoir capacity (SOD SOP, 2008). Six wetland cells were completed along the south and west margin of the reservoir at some time after final development of the FIIP elevation-capacity curve. Elevation-capacity curves were developed for each cell by the Contractor, and combined the wetlands store 546 acre-feet of water at the maximum a/c elevation 3,211.6 feet. We report Contractor data with and without the wetland cells to facilitate comparison.

Our review indicates the initial FIIP elevation capacity curve was developed in 1931 and updated in 1955. Figure 5 compares the original 1931 reservoir topographic map (FIIP plate – F-4495, 1931) with the Contractor-developed data at the 3,200 and 3,180 foot elevations. At other elevations from 3,190 feet up to 3,211 feet, there is close conformance between original and updated contours. At present, we do not have information related to the 1955 update to the elevation capacity curve, but note this update increased the capacity of the reservoir.

We redeveloped the Contractor capacity data in a GIS work environment as a QC check, and found very close agreement. This information, as well as a comparison between the Contractor results and the 1931 and 1955 FIIP curves are reported in the following table.

Elevation, in feet	Volume, in af		% difference	Volume, in af		% difference	
	Contractor w/o wetland cells	CSKT GIS		FIIP – 1931[1]	FIIP - 1955	Contractor/FIIP 1931	Contractor/FIIP 1955
3,180.0	1.4	1.0	35%	0.0	45.0	---	97%
3,182.0	28.0	26.4	65%	0.0	180.5	---	84%
3,184.0	143.5	141.3	2%	250.0	410.0	43%	65%
3,186.0	432.1	429.5	1%	950.0	814.0	55%	47%
3,188.0	954.9	950.8	0.6%	1,300.0	1,425.0	27%	33%
3,190.0	1,718.7	1,713.3	0.4%	2,300.0	2,349.0	25%	27%
3,192.0	2,713.0	2,706.2	0.3%	3,500.0	3,549.0	22%	24%
3,194.0	3,942.2	3,933.6	0.3%	5,000.0	4,961.0	21%	21%
3,196.0	5,407.7	5,396.8	0.2%	6,500.0	6,673.0	17%	19%
3,198.0	7,096.0	7,082.6	0.2%	8,000.0	8,595.0	11%	17%
3,200.0	9,006.0	8,990.6	0.2%	10,000.0	10,905.0	10%	17%
3,202.0	11,137.2	11,117.2	0.2%	12,000.0	13,330.0	7%	16%
3,204.0	13,434.6	13,412.6	0.2%	14,000.0	15,990.0	4%	16%
3,206.0	15,927.7	15,953.0	0.2%	16,500.0	19,350.0	3%	18%
3,208.0	18,615.3	18,743.9	0.7%	19,300.0	22,720.0	4%	18%
3,210.0	21,482.3	21,778.0	1.4%	22,200.0	26,510.0	3%	19%
3,211.0	22,974.7	23,391.9	1.8%	24,400.0	28,400.0	6%	19%

[1] – visually estimated from curve, table data not available

We found relatively high agreement between the Contractor data and the original 1931 FIIP data and much lower agreement between the Contractor data and the 1955 update to the FIIP data.

The Contractor-developed elevation-capacity data span from the lowest point in the reservoir to the dam crest near the outlet works. The Contractor curves, with and without the wetland cells, are compared with the FIIP-1955 data and are reconciled at elevation 3,179.0 feet, the gatehouse inlet invert elevation. The Contractor data indicate no dead pool storage.

The elevation-capacity curves have overlapping shape, and at the SOD upper operating elevation 3,211.0 feet, the Contractor capacity value is 19.1% lower than the FIIP capacity value; this equates to a reduction in storage of 5,426.0 acre-feet.

Twin Reservoir (Turtle Lake)

The Contractor-developed capacity curve spanned from the lowest point in the reservoir to the dam crest on the north side of the reservoir. The curves were reconciled at elevation 3,061.0 feet, the start of the FIIP curve and the approximate elevation of the gatehouse inlet invert elevation; below this elevation the Contractor reported a dead pool volume of 35.4 acre-feet.

The capacity curves for the two datasets share a similar shape and at the SOP upper operating elevation 3,090.5 feet, the Contractor capacity value is 7.3% lower than the FIIP capacity value; this equates to a reduction in storage of 66 acre-feet.

Lower Dry Fork Reservoir

Lower Dry Fork Reservoir was constructed in 1921 and raised approximately 11.5 feet in 1933-1934. Safety of Dams modifications were initiated in 2008, including construction of a wetland dike feature around 2012 intended to regulate the west arm of the reservoir. The impoundment behind the dike does not appreciably affect reservoir storage, instead it allows for independent regulation of the water level behind the dike.

The 1921 topobathymetric map (FIIP plate – F-3782, 1921) contains an elevation capacity curve on the map plate. Capacity values were estimated from the curve and compared to the currently utilized FIIP elevation-capacity curve. The values are very comparable and indicate the original 1921 capacity data are still employed by FIIP as the current rating table. We were unable to ascertain if the 1934 upgrade increased capacity or only increased reservoir freeboard. FIIP use of the original curve, and the lack of reference to outlet works modification, suggest the later.

We compared the 1921 topobathymetric map with the Contractor map at three contour intervals and generally found close correspondence between the contours (Figure 6).

Comparison of the elevation-capacity curves at Lower Dry Fork Reservoir indicated discrepancies between the Contractor and FIIP data. The Contractor elevation-capacity data were redeveloped in a GIS work environment and are compared below. The table also provides a comparison between the Contractor data and the FIIP elevation capacity data.

Elevation, in feet	Volume, in af		% difference Contractor / GIS	FIIP volume, in af	% difference Contractor / FIIP
	Contractor	CSKT GIS			
2,832.0	0.7	0.6	17.9%	20.0	97%
2,834.0	9.6	9.4	11.0%	75.0	87%
2,836.0	45.2	45.3	0.1%	160.0	72%
2,838.0	118.2	118.0	0.2%	278.0	57%
2,840.0	232.2	231.4	0.3%	435.0	47%
2,842.0	383.3	382.0	0.3%	636.0	40%
2,844.0	561.5	560.1	0.3%	880.0	36%
2,846.0	827.6	825.9	0.2%	1,180.0	30%
2,848.0	1,180.6	1,175.8	0.4%	1,550.0	24%
2,850.0	1,600.2	1,593.7	0.4%	2,000.0	20%
2,852.0	2,087.1	2,096.0	0.4%	2,510.0	17%
2,854.0	2,657.3	2,649.4	0.6%	3,090.0	14%
2,856.0	3,317.6	3,313.1	0.1%	3,745.0	11%
2,857.8	3,986.2	3,979.8	0.2%	4,420.0	10%

The Contractor-developed capacity curve spanned from the lowest point in the reservoir to the top of the spillway on the east side of the reservoir at elevation 2,857.8 feet. The curves were reconciled at 2,830.5 feet, the start of the FIIP curve and the approximate gatehouse inlet invert elevation.

The capacity values share a similar shape and at the max a/c elevation 2,857.8 feet, the Contractor capacity value is 10.3% lower than the FIIP capacity value; this equates to a reduction in storage of 414.0 acre-feet.

Upper Dry Fork Reservoir

Comparison of the elevation capacity curves at Upper Dry Fork Reservoir indicated discrepancies between the Contractor and FIIP data. The Contractor elevation-capacity data were redeveloped in a GIS work environment as a QC check and results are compared below. The table also provides a comparison between the Contractor data and the FIIP elevation-capacity data. The FIIP data come from the project elevation-capacity table for the reservoir. The values were compared to the elevation-capacity curve found on the original topobathymetric map for the reservoir (FIIP plate – F-5222, 1939). At elevations above 2,912 feet, the comparable elevation capacity values are very close, below this elevation the resolution on the original curve is low. This comparison indicates that it is unlikely that there was an update to the FIIP tables following the original work product.

Elevation, in feet	Volume, in af		% difference Contractor / GIS	FIIP volume, in af	% difference Contractor / FIIP
	Contractor	CSKT GIS			
2,902.0	0.1	0.12	-7.1%	4.0	98%
2,904.0	2.2	2.13	3.2%	14.0	84%
2,906.0	9.3	9.15	1.6%	32.0	71%
2,908.0	23.8	23.5	1.2%	72.0	67%
2,910.0	57.0	56.5	0.9%	136.0	58%
2,912.0	120.4	120.0	0.4%	225.0	46%
2,914.0	211.3	210.4	0.4%	343.0	38%
2,916.0	332.6	331.3	0.4%	493.0	33%
2,918.0	489.3	487.6	0.3%	693.0	29%
2,920.0	693.0	691.2	0.3%	943.0	27%
2,922.0	955.1	953.4	0.2%	1,259.0	24%
2,924.0	1,277.5	1,274.7	0.2%	1,651.0	23%
2,926.0	1,659.4	1,654.9	0.3%	2,117.0	22%
2,928.0	2,111.1	2,106.5	0.2%	2,658.0	21%

We also provide a map comparing the original FIIP topobathymetric map and Contractor-developed contours at the 2910, 2920, and 2,925 foot elevations (Figure 7). There is wide disparity between the two contour sets.

The Contractor-developed capacity curve spanned from the lowest point in the reservoir to one foot above the spillway elevation at elevation 2,929.9 feet. The curves were reconciled at 2,901.3 feet, the Contractor low point elevation.

The capacity curves share a similar shape, and at the SOD SOP upper operating elevation 2,928.7 feet, the Contractor capacity value is 20.3% lower than the FIIP capacity value; this equates to a reduction in storage of 583.0 acre-feet.

Hubbart Reservoir

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to one foot above the spillway crest. The two curves were reconciled at elevation 3,144.4 feet, the initial overlap elevation of the two data sources. The Contractor data indicates there is no dead pool volume; FIIP reports a dead pool volume of 9.0 acre-feet.

The elevation-capacity curves have an overlapping shape, and at the upper SOP operating elevation 3,219.0 feet, the Contractor capacity value is 2.7% greater than the FIIP capacity value; this equates to an increase in storage of 324 acre-feet.

Little Bitterroot Lake

The Contractor-developed elevation-capacity data spanned from the lowest point in the reservoir to one foot above the culvert spillway. The two curves were reconciled at elevation 3,897.98 feet, the start of the FIIP curve. The Contractor data indicated a dead pool volume of 332,464 acre-feet.

The elevation-capacity curves have an overlapping shape, and at the upper SOP operating elevation 3,906.48 feet, the Contractor capacity value is 5.3% less than the FIIP capacity value; this equates to a reduction in storage of 1,392.0 acre-feet.

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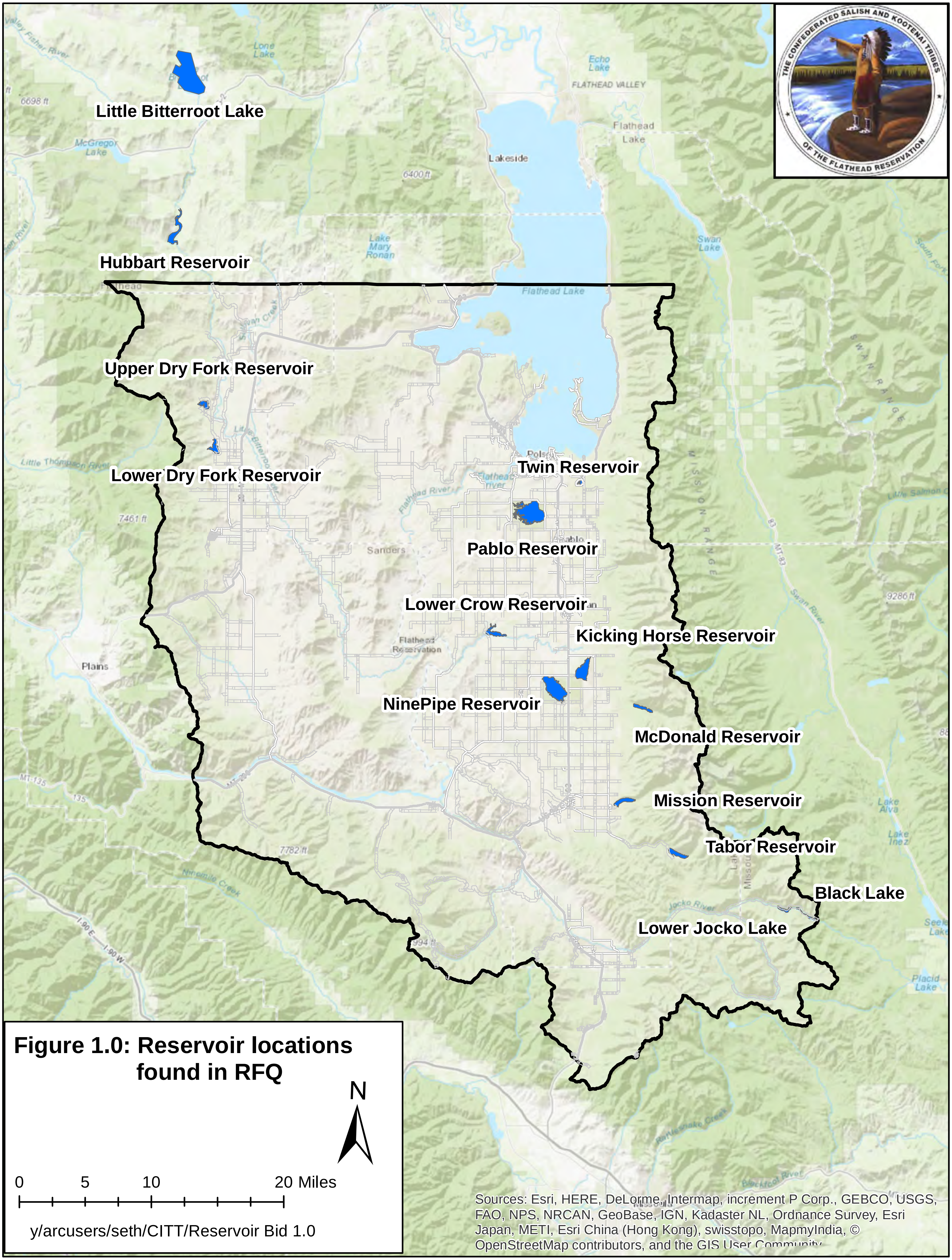


Figure 1.0: Reservoir locations found in RFQ

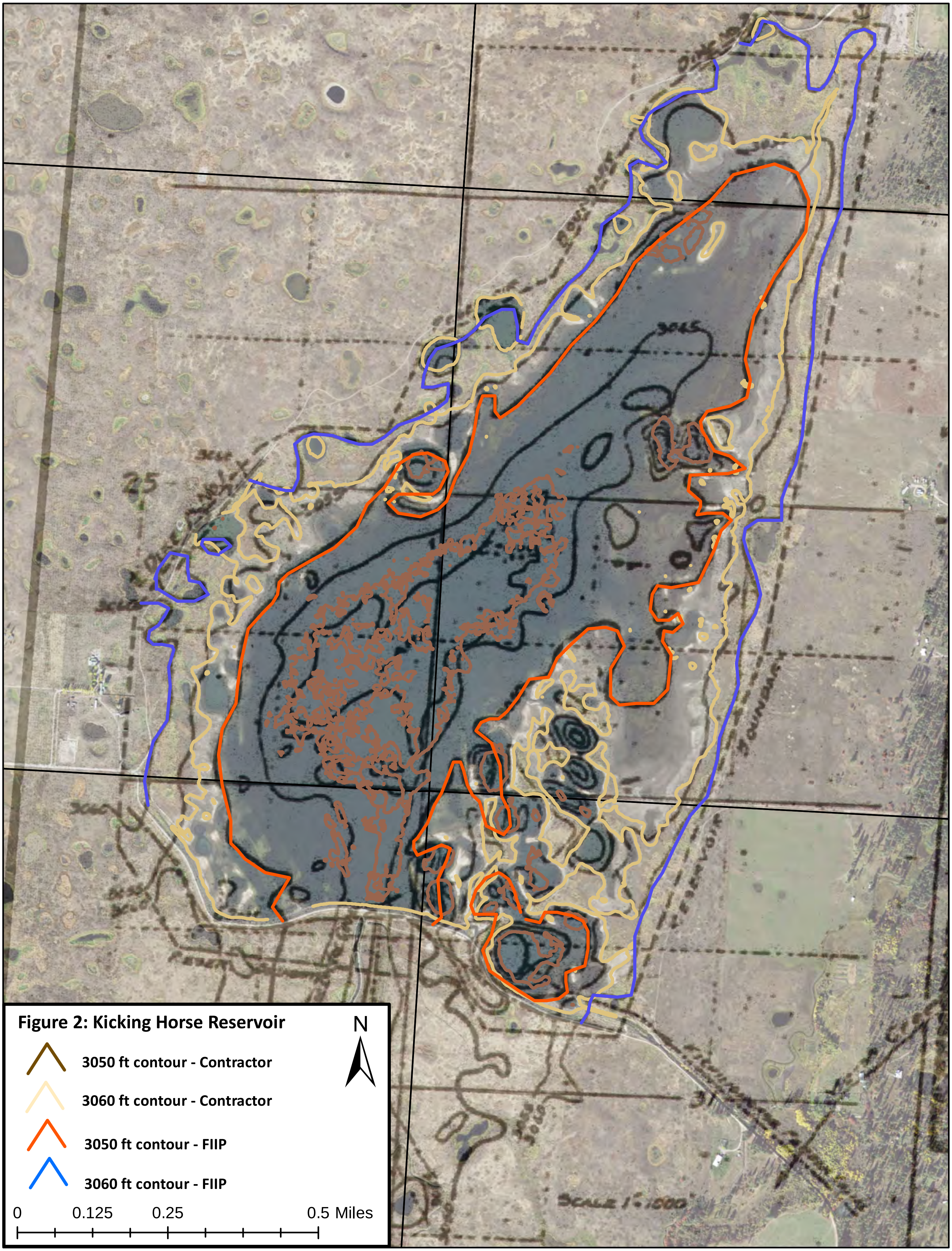


Figure 2: Kicking Horse Reservoir
3050 ft contour - Contractor
3060 ft contour - Contractor
3050 ft contour - FIIP
3060 ft contour - FIIP
0
0.125
0.25
0.5 Miles
N

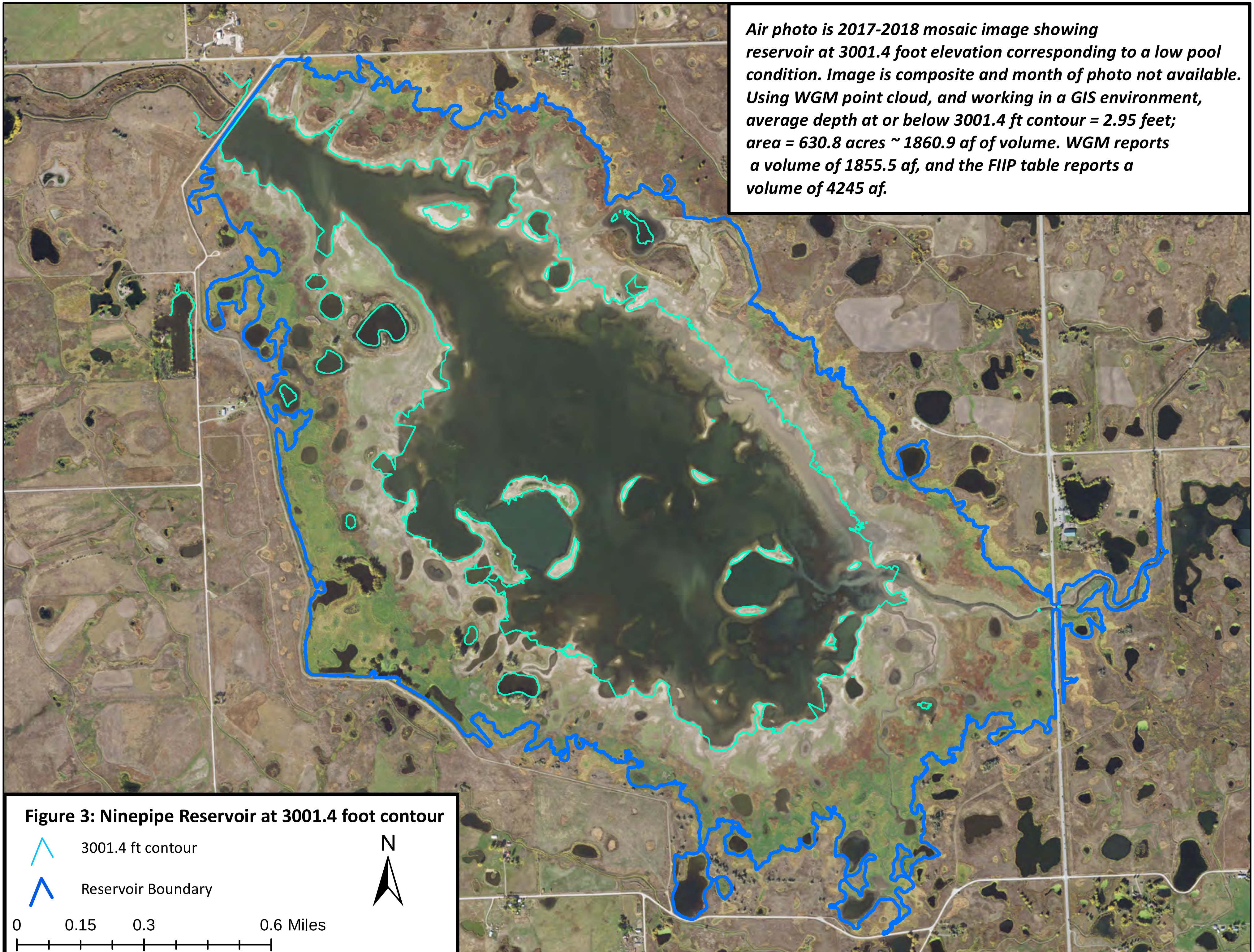


Figure 3: Ninepipe Reservoir at 3001.4 foot contour

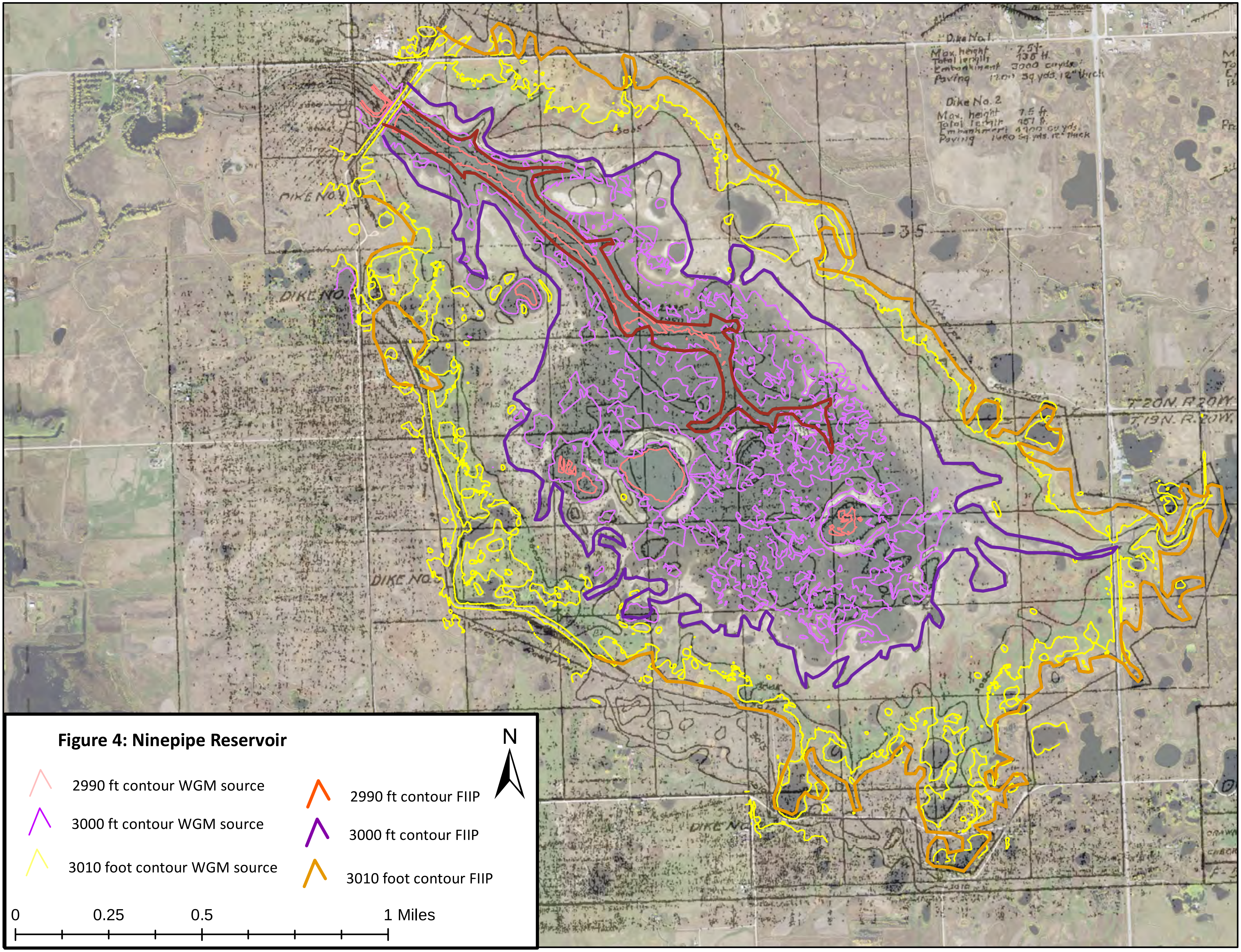


Figure 4: Ninepipe Reservoir
2990 ft contour WGM source
3000 ft contour WGM source
3010 foot contour WGM source
2990 ft contour FIIP
3000 ft contour FIIP
3010 foot contour FIIP
N
0
0.25
0.5
1 Miles

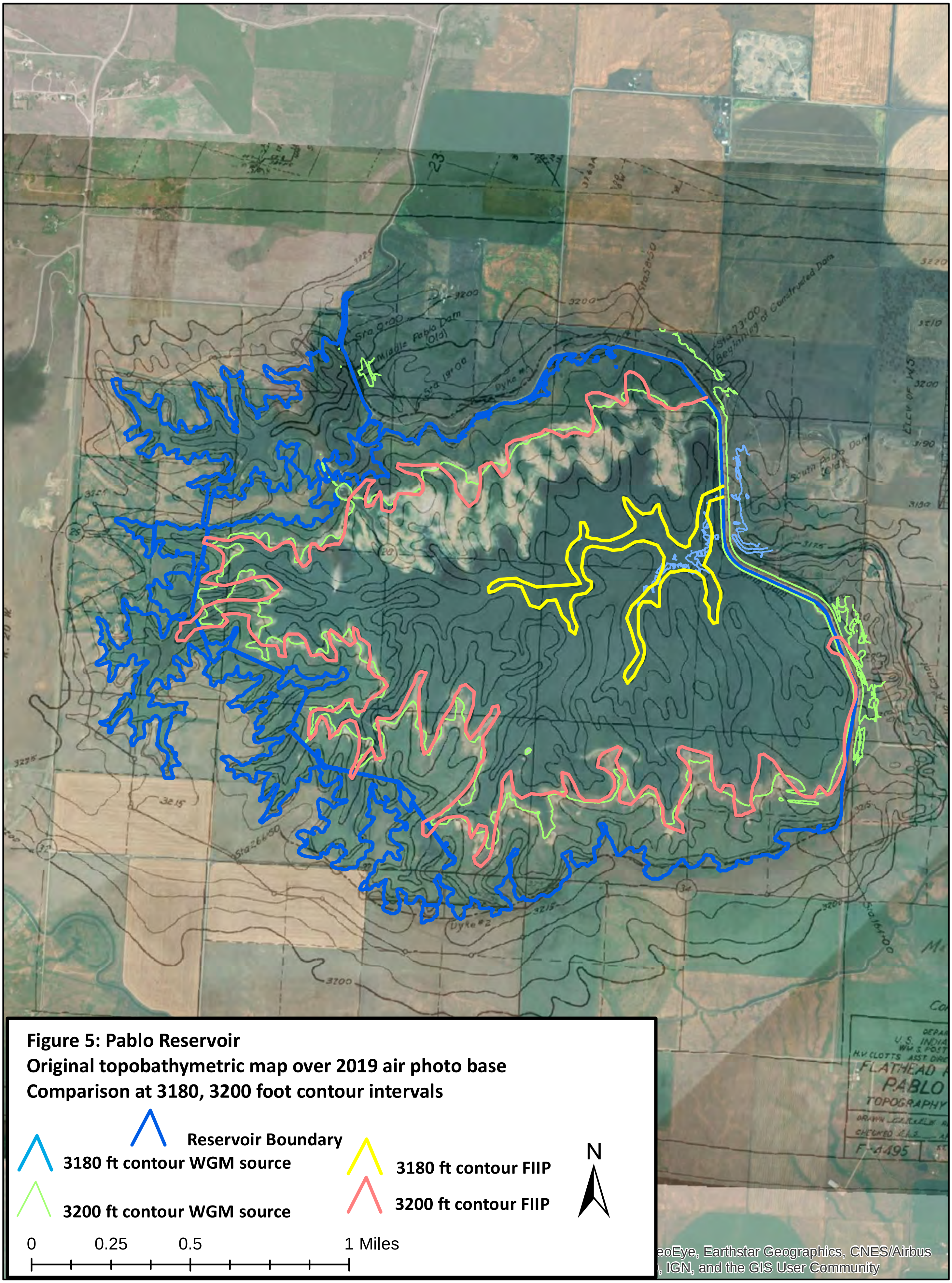


Figure 5: Pablo Reservoir
Original topobathymetric map over 2019 air photo base
Comparison at 3180, 3200 foot contour intervals

Figure 6: Lower Dry Fork Reservoir
Original topobathymetric map over 2019 air photo base
Comparison at 2840, 2850, 2855 foot contour intervals

N

- 2840 ft contour WGM source
- 2850 ft contour WGM source
- 2855 ft contour WGM source
- 2840 ft contour FIIP
- 2850 ft contour FIIP
- 2855 fft contour FIIP

0 0.125 0.25 0.5 Miles

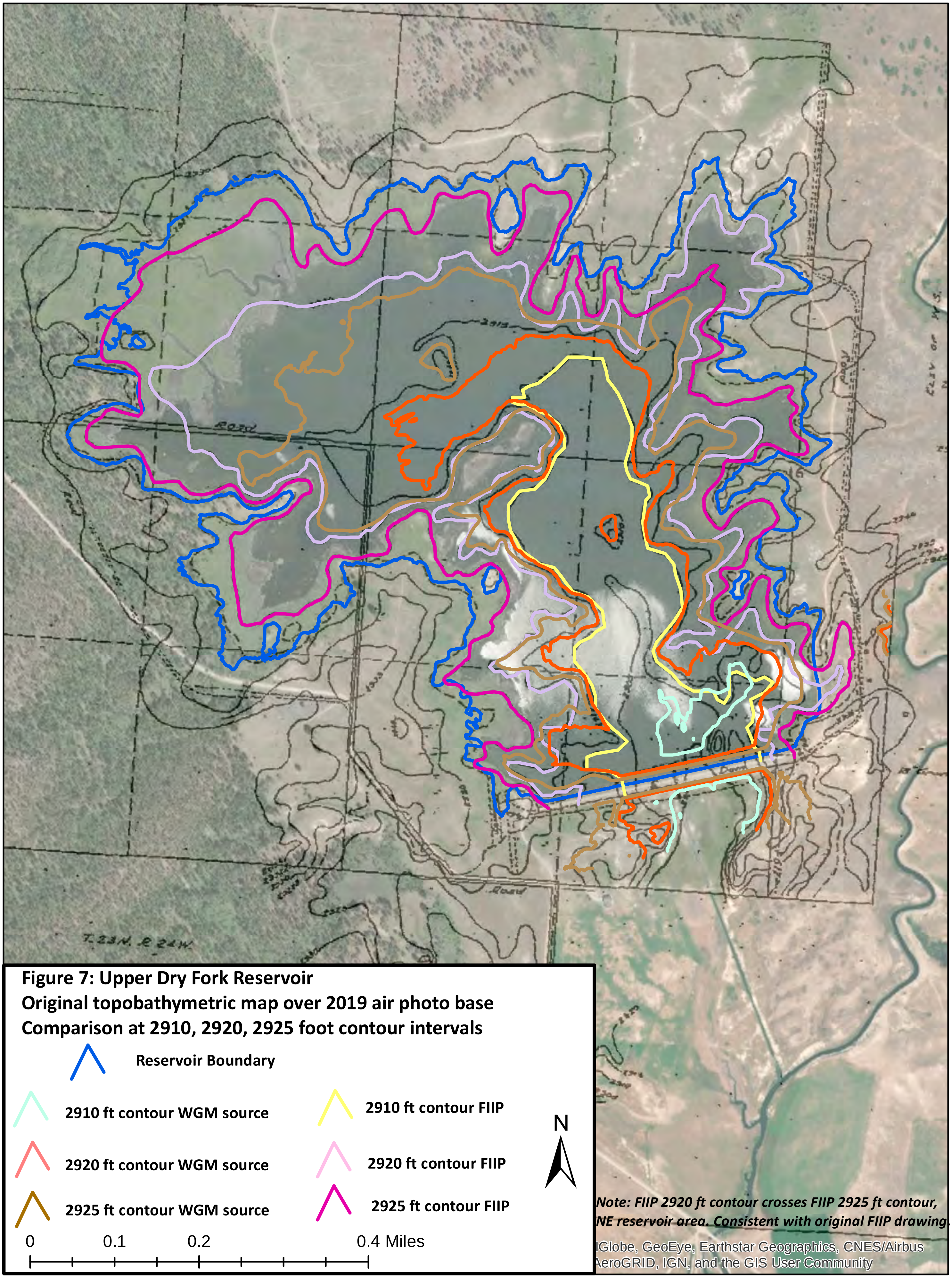
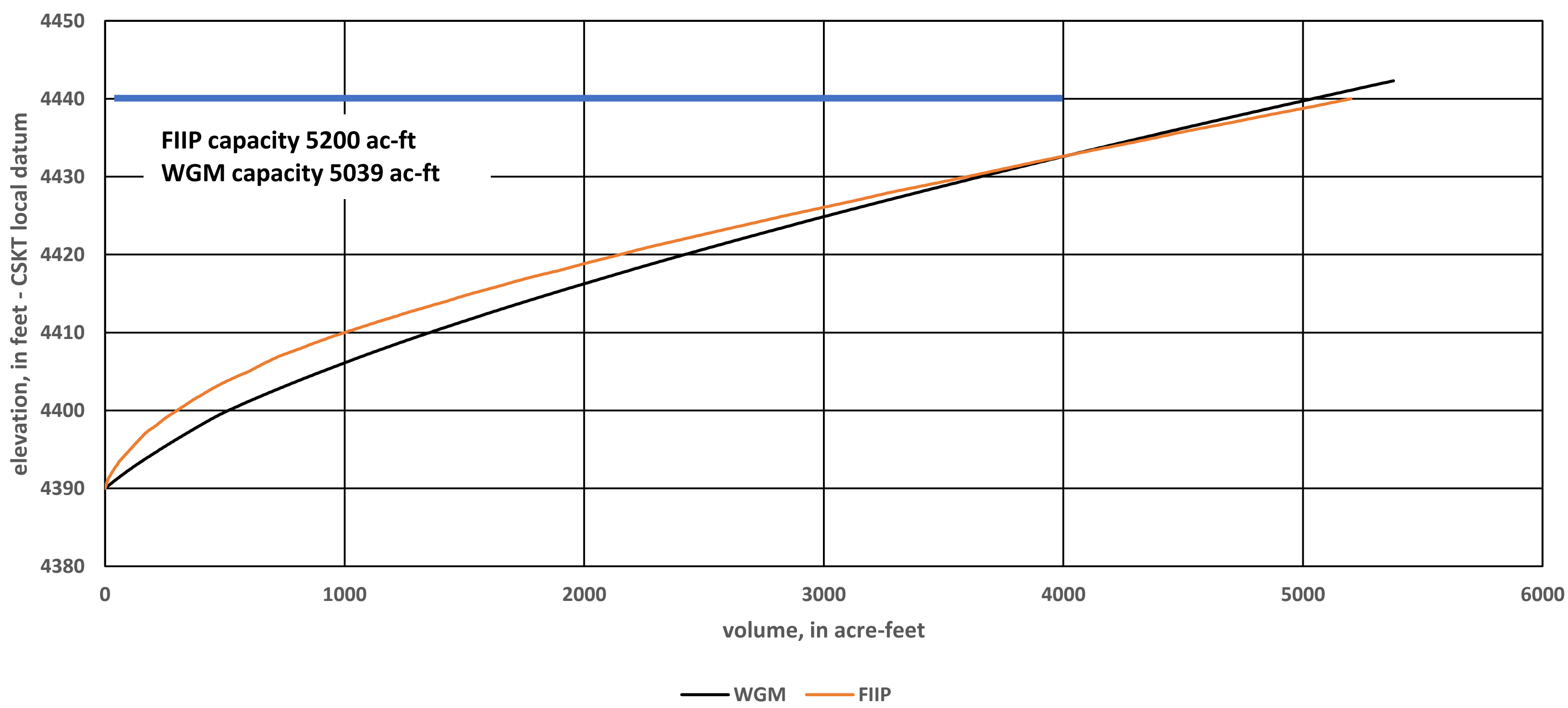
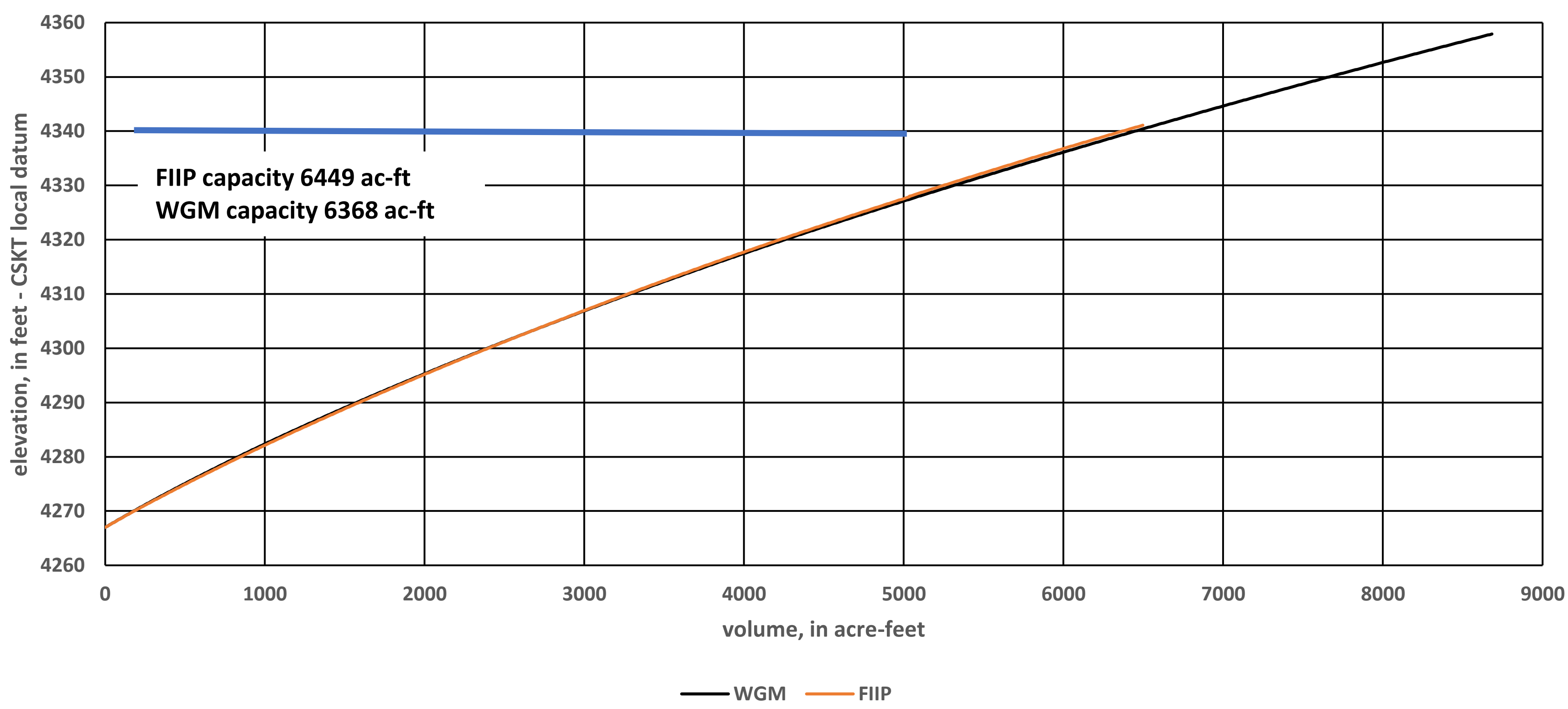


Figure 7: Upper Dry Fork Reservoir
Original topobathymetric map over 2019 air photo base
Comparison at 2910, 2920, 2925 foot contour intervals

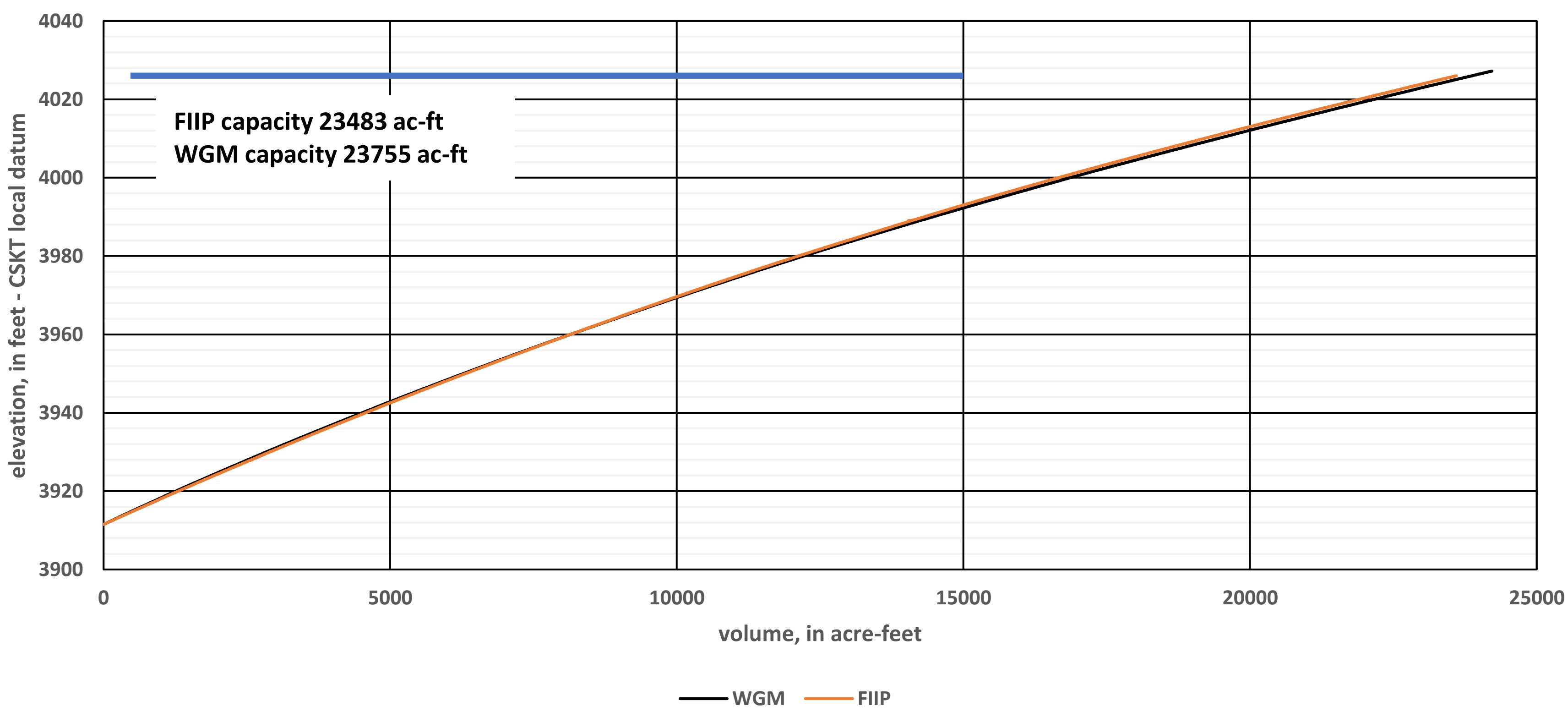
Upper Jocko Lake (Black Lake)	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	4442.30 ft / 5377.80 ac-ft / above top of FIIP curve
Maximum a/c feature	1.0 ft above top of spillway crest
Lowest reservoir elevation WGM	4378.70 ft
WGM/FIIP curves reconciled at elevation	4390.0 ft
WGM/FIIP reconciled at feature	start of FIIP capacity data (SOP indicated gatehouse invert = 4393.0 ft)
SOP upper operating elevation	filling restriction at 4423.0 ft removed, use 4440.0 ft
SOP upper operating elevation feature	undefined, top of FIIP curve
WGM curve range	4378.70 ft to 4442.30 ft / 0 ac-ft to 5646.1 ac-ft
FIIP curve range	4390.0 ft to 4440.0 ft / 0 ac-ft to 5200 ac-ft
volume below reconcile feature (WGM / FIIP)	264.40 ac-ft / 0.0 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	4448.48 ft / 4450.0 ft, WGM point - metal sill to gatehouse
Relative difference WGM / FIIP at SOP upper operating level	2.10%



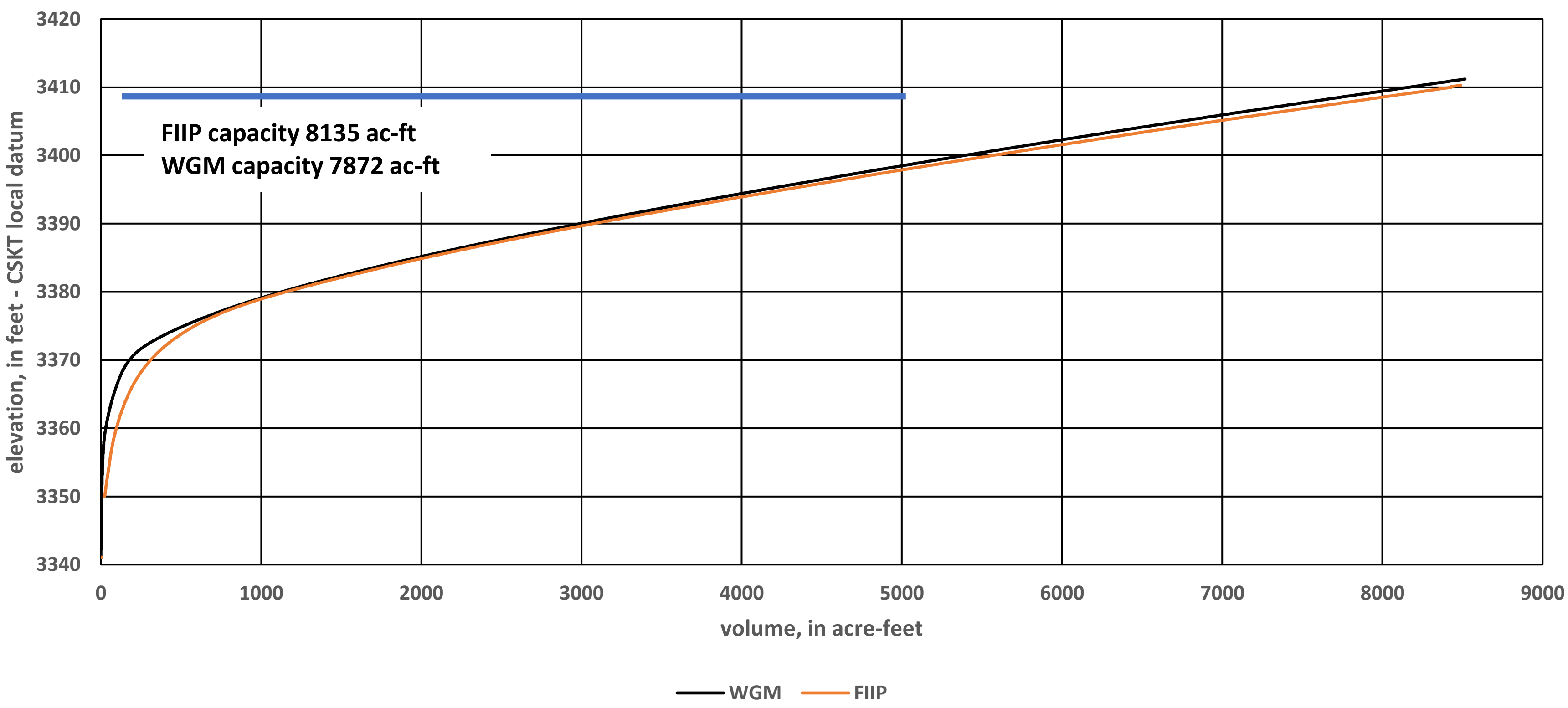
Lower Jocko Lake Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	4357.90 ft / 8682.80 ac-ft / above top of FIIP curve
Maximum a/c feature	dam crest on west side of dam, well above operating range
Lowest reservoir elevation WGM	4231.70 ft
WGM/FIIP curves reconciled at elevation	4267.0 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	4340.0 ft
SOP upper operating elevation feature	undefined
WGM curve range	4231.70 ft to 4357.90 ft / 0 ac-ft to 9980.7 ac-ft
FIIP curve range	4267.0 ft to 4341.0 ft / 0 ac-ft to 6497.0 ac-ft
volume below reconcile feature (WGM / FIIP)	1297.80 ac-ft / 0.0 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	4359.92 ft / 4360.0 ft
Relative difference WGM / FIIP at SOP upper operating level	1.20%



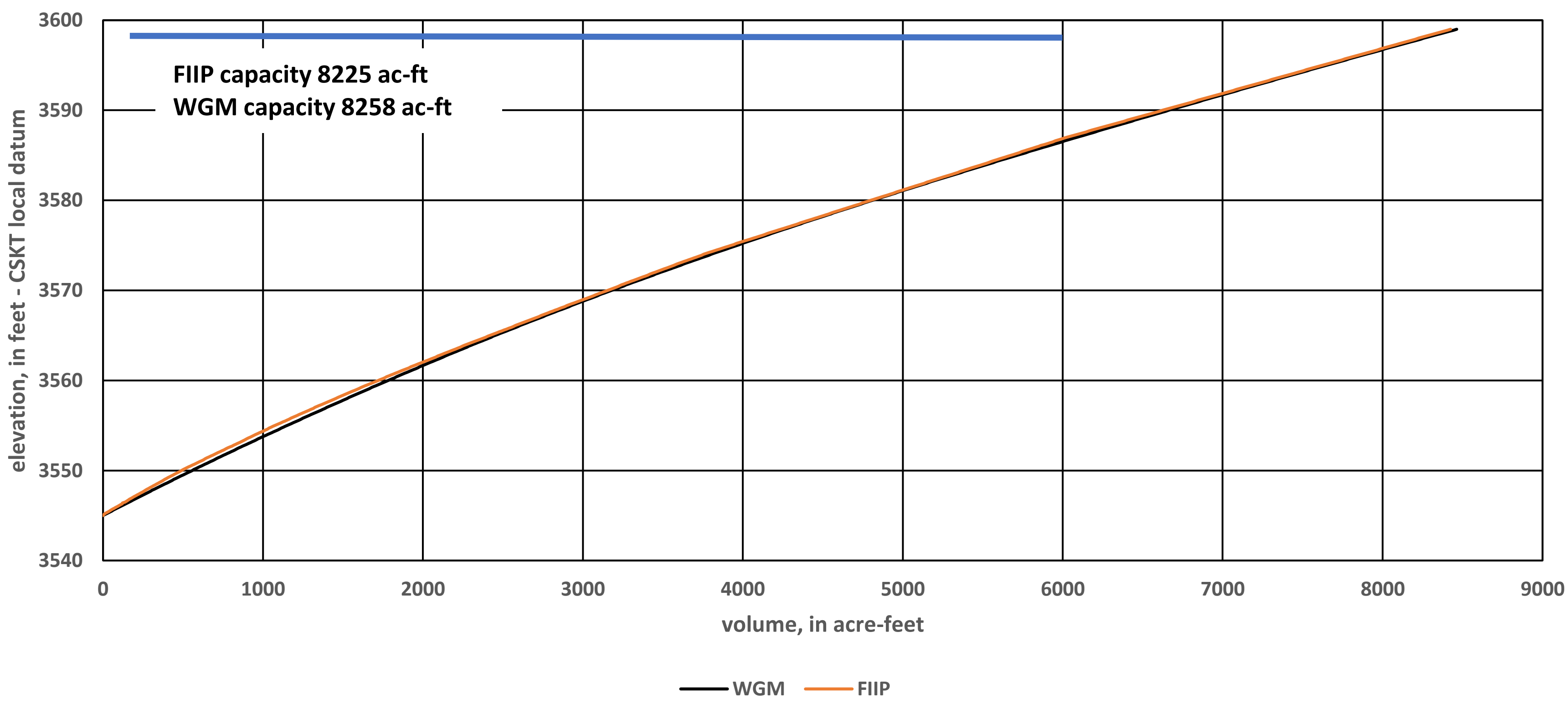
Tabor Reservoir (St. Mary's Lake)	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	4027.20 ft / 24218.20 ac-ft / above top of FIIP curve
Maximum a/c feature	1.0 ft above top of pin in spillway (pin - spillway flashboard stanchion)
Lowest reservoir elevation WGM	3752.20 ft
WGM/FIIP curves reconciled at elevation	3911.50 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	4025.6 ft
SOP upper operating elevation feature	1.0 ft above spillway concrete sill
WGM curve range	3752.20 ft to 4027.20 ft / 0 ac-ft to 37190.9 ac-ft
FIIP curve range	3911.50 ft to 4026.0 ft / 0 ac-ft to 23597 ac-ft
volume below reconcile feature (WGM / FIIP)	12972.7 ac-ft / not reported
gatehouse floor elevation (WGM / 1990 MM Report)	4027.24 ft / 4027.24 ft
Relative difference WGM / FIIP at SOP upper operating level	1.20%



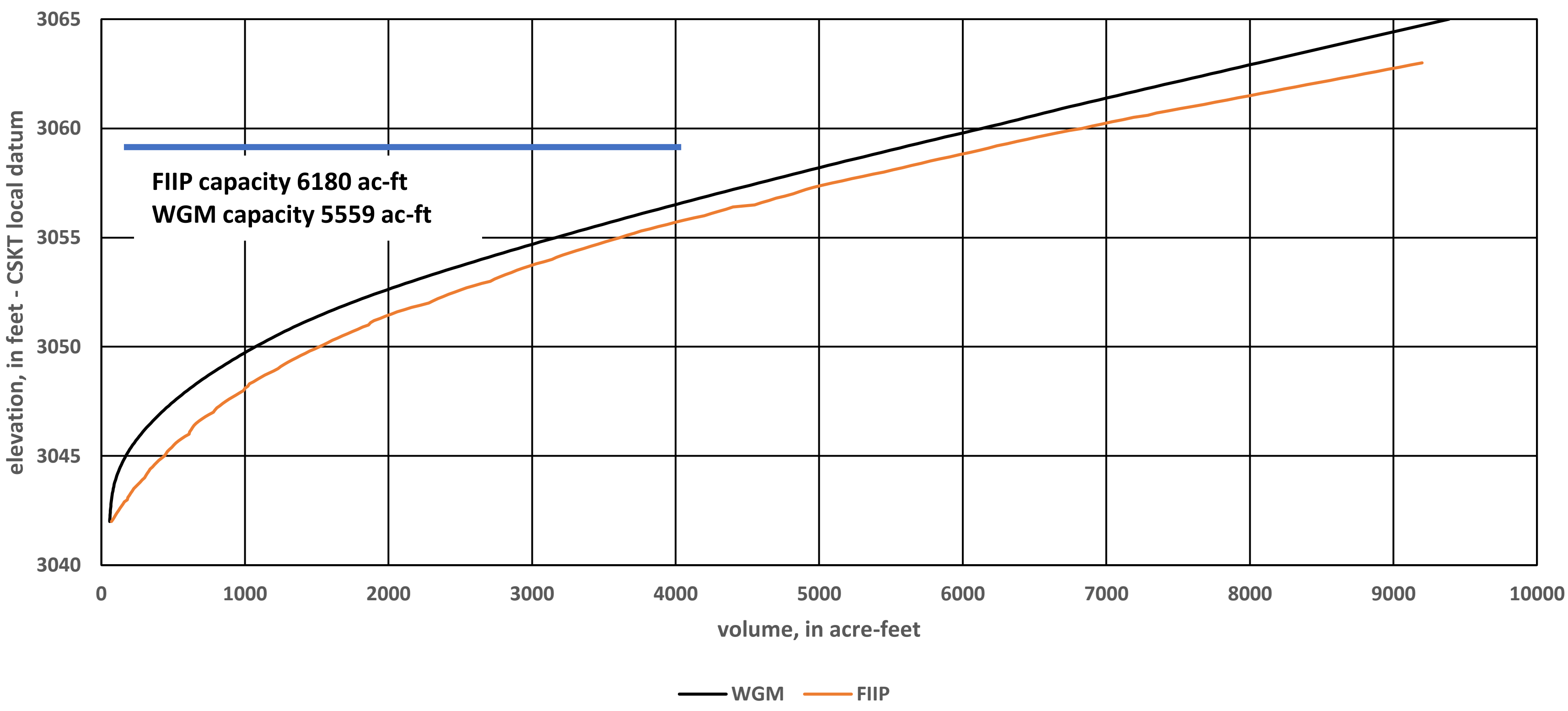
Mission Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3411.20 ft / 8519.50 ac-ft / above top of FIIP curve
Maximum a/c feature	1.0 ft above top of pin in spillway (pin - spillway flashboard stanchion)
Lowest reservoir elevation WGM	3339.68 ft
WGM/FIIP curves reconciled at elevation	3341.0 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	3409.0 ft
SOP upper operating elevation feature	spillway weir crest (concrete base, not metal weir blade)
WGM curve range	3339.70 ft to 3411.20 ft / 0 ac-ft to 8515.9 ac-ft
FIIP curve range	3341.0 ft to 3410.0 ft / 0 ac-ft to 8430.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0.00 ac-ft / 77 ac-ft (reported in SOP, not FIIP capacity table)
gatehouse floor elevation (WGM / 1990 MM Report)	3419.00 ft / 3419.00 ft
Relative difference WGM / FIIP at SOP upper operating level	3.20%



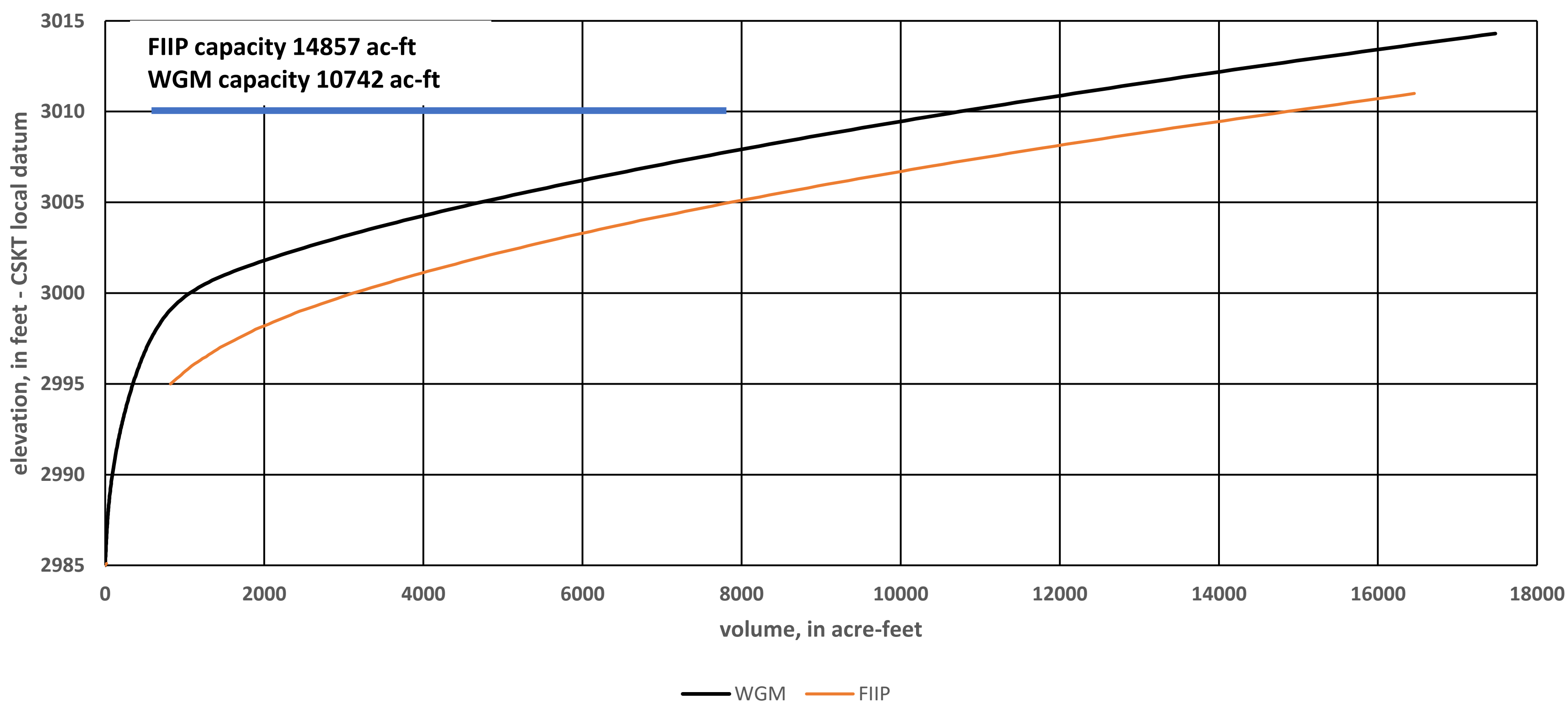
McDonald Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3599.0 ft / 8463.3 ac-ft / 8425 ac-ft
Maximum a/c feature	1.0 ft above closed radial spillway gate
Lowest reservoir elevation WGM	3488.8 ft
WGM/FIIP curves reconciled at elevation	3545.0 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	3598.0 ft
SOP upper operating elevation feature	top of spillway gates closed position
WGM curve range	3488.8 ft to 3599.0 ft / 0 ac-ft to 12222.8 ac-ft
FIIP curve range	3540.0 ft to 3600.0 ft / 0 ac-ft to 8645.0 ac-ft
volume below reconcile feature (WGM / FIIP)	3748.7 ac-ft / not reported
gatehouse floor elevation (WGM / 1990 MM Report)	3604.1 ft / 3604.0 ft
Relative difference WGM / FIIP at SOP upper operating level	0.40%



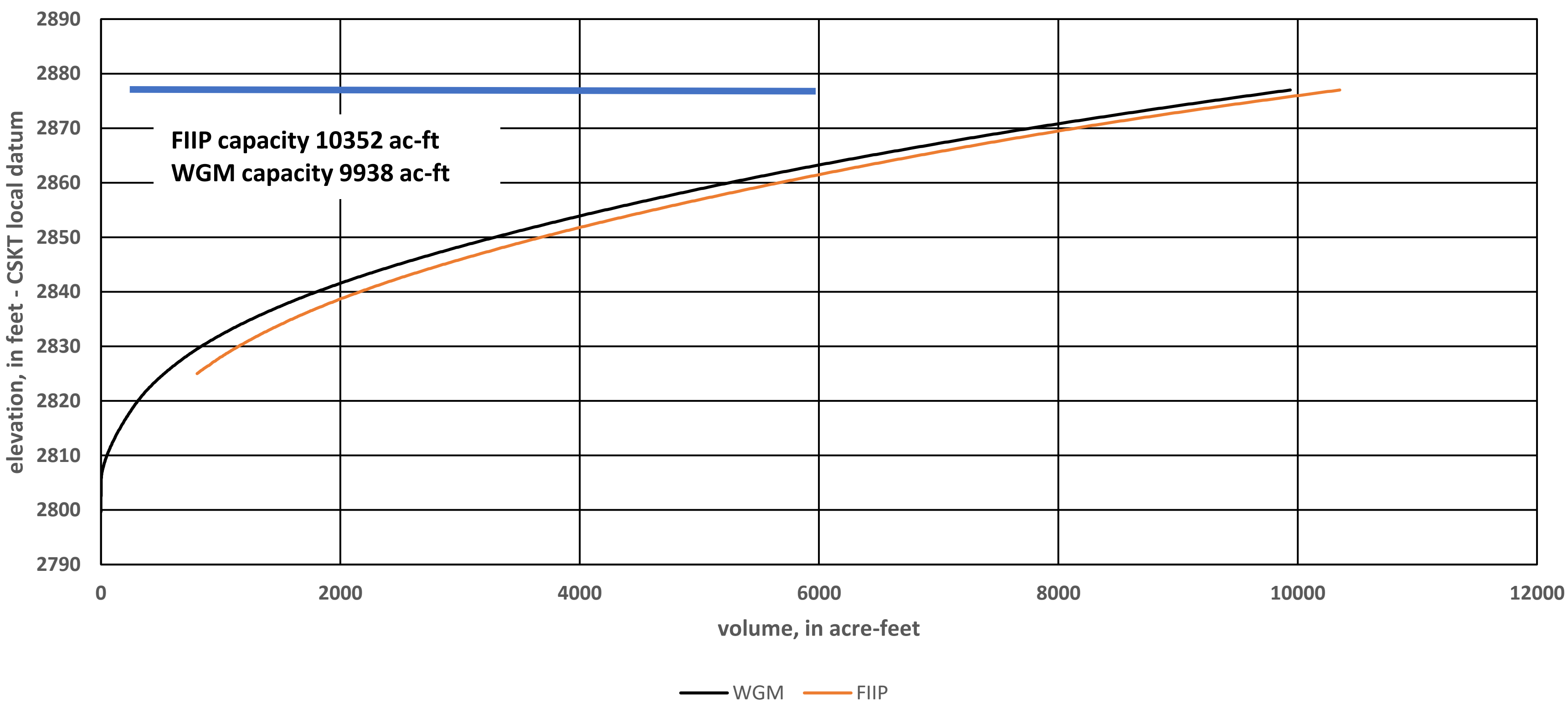
Kicking Horse Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	extended to 3065.0 ft / 9387.4 ac-ft / above top of FIIP curve
Maximum a/c feature	lowest point on Dike No. 3, northwwest side reservoir
Lowest reservoir elevation WGM	3025.9 ft
WGM/FIIP curves reconciled at elevation	3042.0 ft
WGM/FIIP reconciled at feature	start of FIIP curve / feature not known
SOP upper operating elevation	3059.1 ft
SOP upper operating elevation feature	SOP filling restriction
WGM curve range	3025.9 ft to 3060.0 ft, extended to 3065.0 ft / 0 ac-ft to 9387.4 ac-ft
FIIP curve range	3042.0 ft to 3063.0 ft / 70.0 ac-ft to 9200.0 ac-ft
volume below reconcile feature (WGM / FIIP)	59.7 ac-ft / 70 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	3068.02 ft / 3068.0 ft
Relative difference WGM / FIIP at SOP upper operating level	10.0%



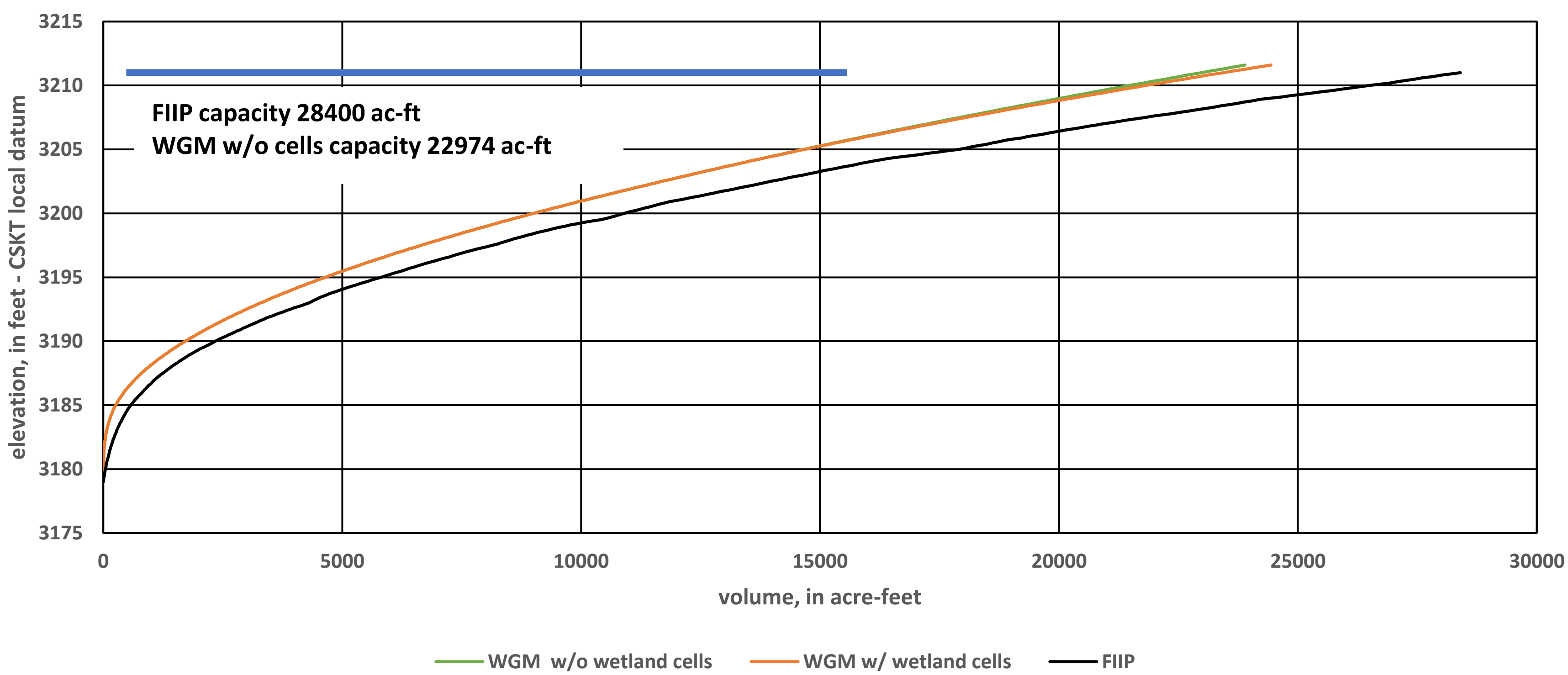
Ninepipe Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3014.3 ft / 17593.1 ac-ft / above top of FIIP curve
Maximum a/c feature	Low point on Dike No. 4, south side reservoir
Lowest reservoir elevation WGM	2961.6 ft
WGM/FIIP curves reconciled at elevation	2985.0 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	3010.0 ft
SOP upper operating elevation feature	undefined, top of reported high water on FIIP curve
WGM curve range	2961.6 ft to 3014.3 ft / 0 ac-ft to 17593.1 ac-ft
FIIP curve range	2985.0 ft to 3011.0 ft / 15.0 ac-ft to 16472.0 ac-ft
volume below reconcile feature (WGM / FIIP)	117.1 ac-ft / 15 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	3019.84 ft / 3019.78 ft
Relative difference WGM / FIIP at SOP upper operating level	28%



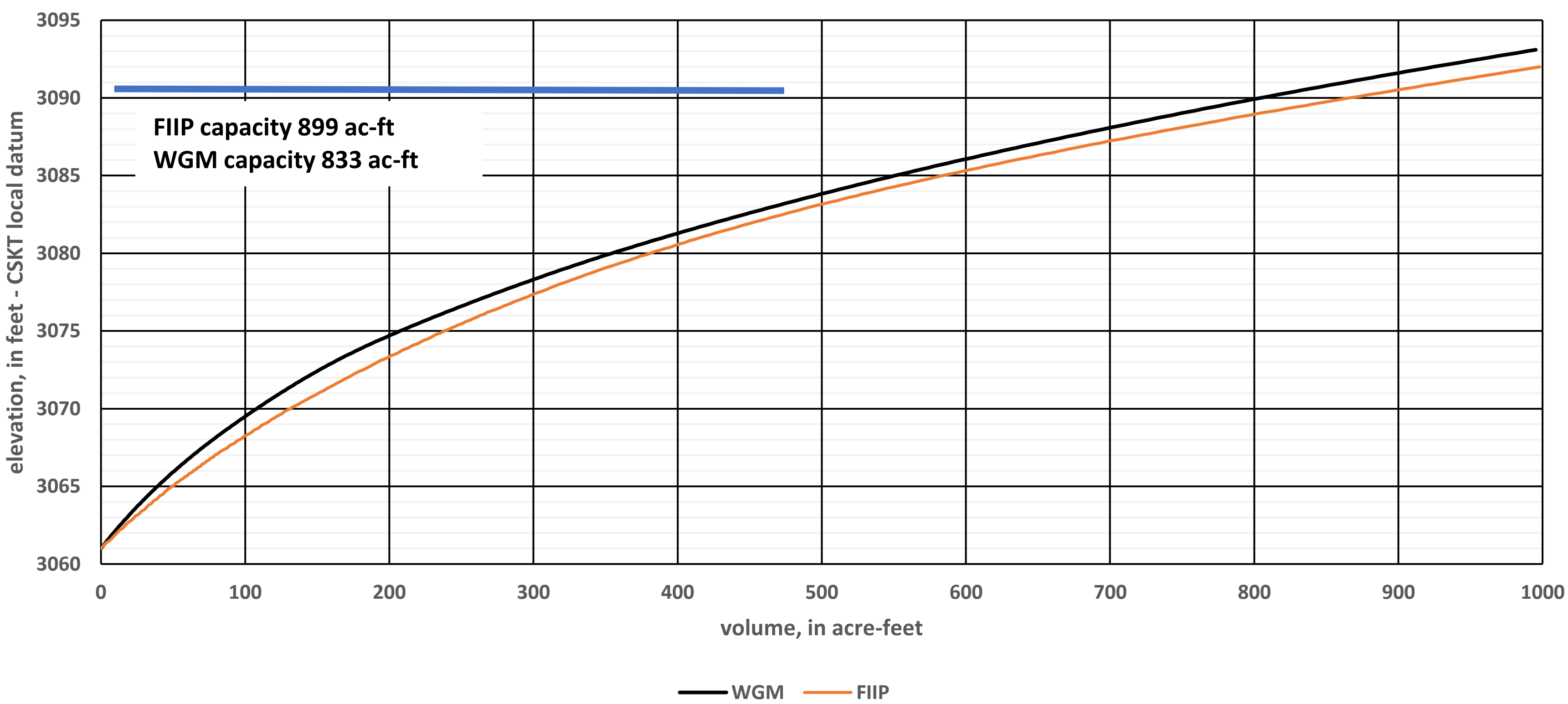
Lower Crow Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	2877.0 ft / 9938.2 ac-ft / 10352.0 ac-ft
Maximum a/c feature	spillway crest elevation
Lowest reservoir elevation WGM	2799.7 ft
WGM/FIIP curves reconciled at elevation	2800.0 ft
WGM/FIIP reconciled at feature	13 feet below top of grizzly, start of FIIP curve
SOP upper operating elevation	2849.9 ft
SOP upper operating elevation feature	filling restriction through construction
WGM curve range	2799.7 ft to 2877.0 ft / 0 ac-ft to 9938.2 ac-ft
FIIP curve range	2800.0 ft to 2877.0 ft / 0 ac-ft to 10352.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0.0 ac-ft / 0.0 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	2882.59 ft / 2882.50 ft
Relative difference WGM / FIIP at 2877.0 ft, spillway crest	4.0%



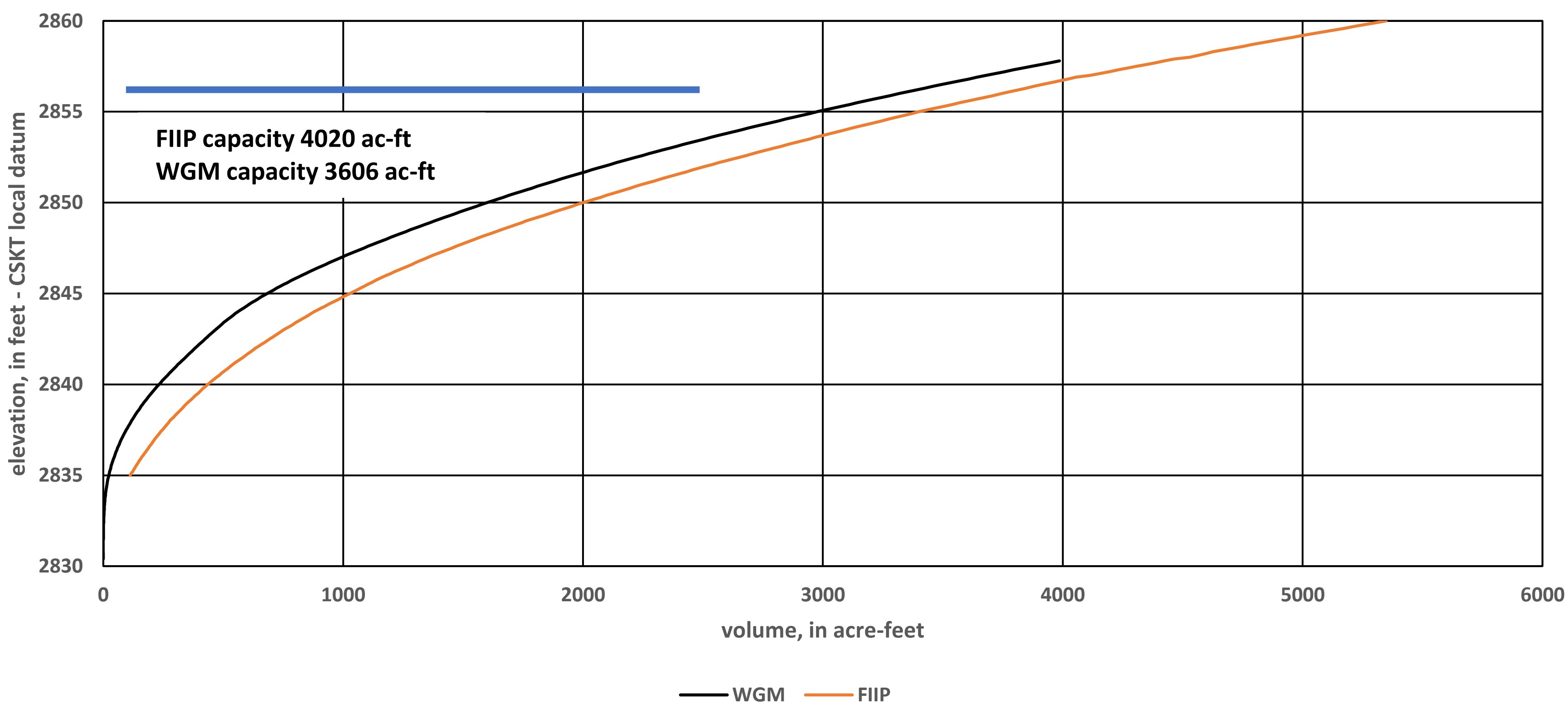
Pablo Reservoir	
Maximum a/c elevation / (WGM capacity)	3211.6 ft / 23891.4 ac-ft w/o wetlands cells / 24437.3 ac-ft w/ cells
Maximum a/c elevation / (FIIP Capacity)	3211.0 ft / 28400 ac-ft
Maximum a/c feature WGM	dam crest east end of reservoir
Lowest reservoir elevation WGM	3177.6 ft
WGM/FIIP curves reconciled at elevation	3179.0 ft
WGM/FIIP reconciled at feature	gatehouse inlet invert elevation
SOP upper operating elevation	3211.0 ft
SOP upper operating elevation feature	undefined, SOP and top of FIIP curve
WGM curve range	3177.6 ft to 3211.6 ft / 0 ac-ft to 23891.4 ac-ft / 24437.3 ac-ft wetland cells
FIIP curve range	3179.0 ft to 3211.0 ft / 3.0 ac-ft to 28400.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0.0 ac-ft / not reported
gatehouse floor elevation (WGM / 1990 MM Report)	3219.81 ft / 3220.0 ft
Relative difference WGM / FIIP at SOP upper operating level	19.1% w/o wetland cells , 17.5% w/ wetland cells



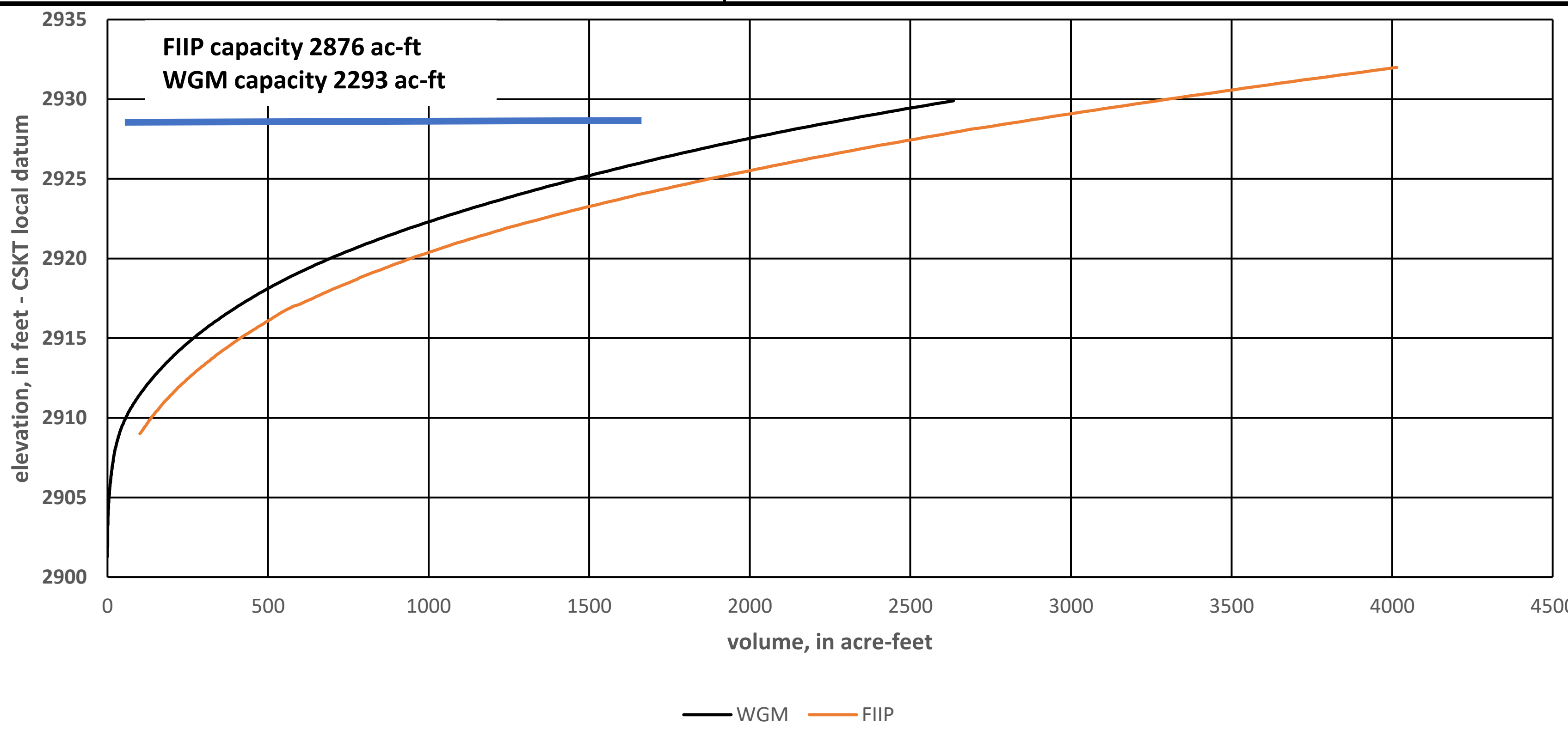
Twin (Turtle Lake) Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3093.1 ft / 1030.7 ac-ft / not reported
Maximum a/c feature	dam crest north side of reservoir
Lowest reservoir elevation WGM	3051.0 ft
WGM/FIIP curves reconciled at elevation	3061.0 ft
WGM/FIIP reconciled at feature	start of FIIP curve / ~ inlet invert elevation
SOP upper operating elevation	3090.5 ft
SOP upper operating elevation feature	feature not reported / SOP identifies spill into secretarial ditch at 3091.6
WGM curve range	3051.0 ft to 3093.1 ft / 0 ac-ft to 1030.7 ac-ft
FIIP curve range	3061.0 ft to 3092.0 ft / 0 ac-ft to 998.0 ac-ft
volume below reconcile feature (WGM / FIIP)	35.4 ac-ft / not reported
gatehouse floor elevation (WGM / 1990 MM Report)	3100.29 ft / 3100.00 ft
Relative difference WGM / FIIP at SOP upper operating level	7.30%



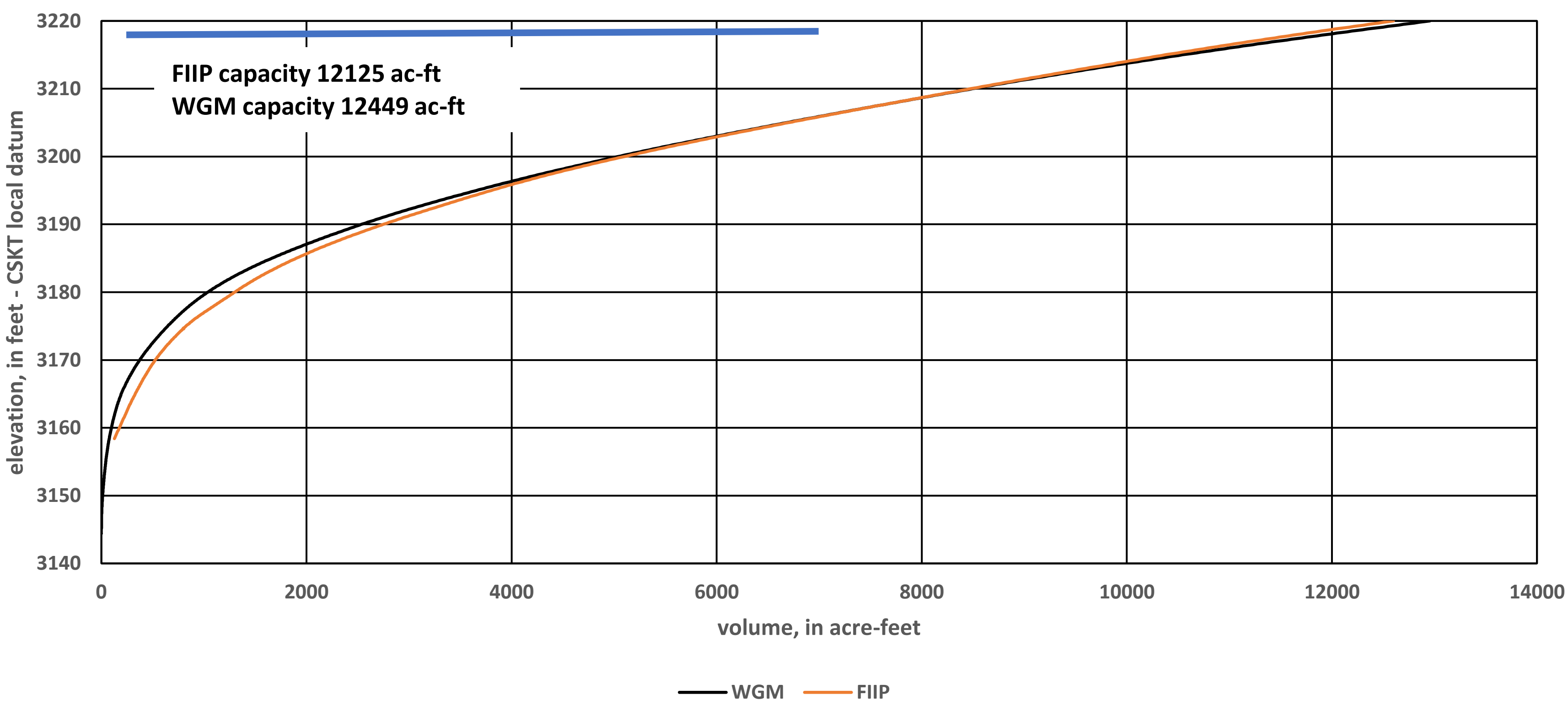
Lower Dry Fork Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	2857.8 ft / 3986.2 ac-ft / 4426 ac-ft
Maximum a/c feature	top of spillway crest east side of reservoir
Lowest reservoir elevation WGM	2830.5 ft
WGM/FIIP curves reconciled at elevation	2830.5 ft
WGM/FIIP reconciled at feature	start of FIIP curve / ~ inlet invert elevation
SOP upper operating elevation	2858.0 ft
SOP upper operating elevation feature	SOP-reported spillway elevation
WGM curve range	2830.4 ft to 2857.8 ft / 0 ac-ft to 3986.2 ac-ft
FIIP curve range	2830.5 ft to 2860.0 ft / 0 ac-ft to 5348.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0 ac-ft
gatehouse floor elevation (WGM / SOD SOP)	2863.41 ft / 2863.5 ft reservoir rebuilt starting 2008 new gatehouse
Relative difference WGM / FIIP at 3056.8 ft, 1.0 ft < spillway	10.3%



Upper Dry Fork Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	2929.9 ft / 2634.1 ac-ft / 3267 ac-ft
Maximum a/c feature	1.0 ft above top of spillway
Lowest reservoir elevation WGM	2901.23 ft
WGM/FIIP curves reconciled at elevation	2901.3 ft
WGM/FIIP reconciled at feature	start of WGM curve / WGM-reported low point elevation
SOP upper operating elevation	2928.7 ft
SOP upper operating elevation feature	crest of spillway
WGM curve range	2901.3 ft to 2929.9 ft / 0 ac-ft to 2634.1 ac-ft
FIIP curve range	2900.0 ft to 2932.0 ft / 0 ac-ft to 4015.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0 ac-ft / 0 ac-ft
gatehouse floor elevation (WGM / 1990 MM Report)	2935.15 ft / 2935.0 ft
Relative difference WGM / FIIP at SOP upper operating level	20.30%



Hubbart Reservoir	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3220.0 ft / 12955.1 ac-ft / 12600 ac-ft
Maximum a/c feature	1.0 ft above spillway crest
Lowest reservoir elevation WGM	3143.6 ft
WGM/FIIP curves reconciled at elevation	3144.4 ft
WGM/FIIP reconciled at feature	first overlap point WGM - FIIP curves / 0.8 ft above WGM low point
SOP upper operating elevation	3219.0 ft
SOP upper operating elevation feature	spillway crest
WGM curve range	3143.6 ft to 3220.0 ft / 0 ac-ft to 12955.1 ac-ft
FIIP curve range	3140.40 ft to 3220.0 ft / 0 ac-ft to 12600.0 ac-ft
volume below reconcile feature (WGM / FIIP)	0 ac-ft / 9.0 ac-ft
crest of concrete spillway (WGM / 1990 MM Report)	3218.97 ft / 3219.0 ft
Relative difference WGM / FIIP at SOP upper operating level	2.7%



Little Bitterroot Lake	
Maximum a/c elevation / (WGM capacity / FIIP Capacity)	3910.0 ft / not reported / not reported
Maximum a/c feature	1.0 ft above culvert spillway
Lowest reservoir elevation WGM	3641.4 ft
WGM/FIIP curves reconciled at elevation	3897.98 ft
WGM/FIIP reconciled at feature	1.0 ft below outlet sill elevation, start of FIIP curve
SOP upper operating elevation	3906.48 ft
SOP upper operating elevation feature	SOP - reservoir rim elevation (may relate to a recreational level)
WGM curve range	3641.4 ft to 3906.5 ft / 0 ac-ft to 357471.9 ac-ft
FIIP curve range	3897.98 ft to 3906.88 ft / 0 ac-ft to 28000 ac-ft
volume below reconcile feature (WGM / FIIP)	332,464 ac-ft / not reported
gatehouse floor elevation (WGM / 1990 MM Report)	no overlapping control / no 1990 datum points
Relative difference WGM / FIIP at SOP upper operating level	5.30%