Colorado River Historic High Water Level within the Grand Canyon

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December 3, 2018

Synopsis

The Colorado River historic high water level within the Grand Canyon is determined to be 80 feet above a base flow of 8000 cfs between Lee's Ferry and the confluence of the Little Colorado River(LCR), and 100 feet above the base flow from there to the Grand Wash Cliffs.   These elevations are based on calculated peak flows of 700,000 cfs and 860,000 cfs up and downstream of the LCR

This report was commissioned by the Grand Canyon Private Boaters Association (GCPBA) for the benefit of the private boater.

Purpose

The purpose of this report is to define the high water level's location, and thereby assist the private boater in recognizing the extent of the disputed boundary between the Park and Hualapai Tribal lands. The disputed boundary concerns the left side of the river starting at River Mile (RM) 164.5, extending for 109 miles to the Grand Wash Cliffs at RM 273.5. The Hualapai define the boundary to be at the middle of the river, while the U.S. Government defines it to be at the high water mark.

Introduction

The boundaries of Grand Canyon National Park, the adjoining Lake Mead, Glen Canyon National Recreation Areas and Tribal lands have a rich and complex history as they have evolved over time to their present day status. Certain sections of these boundaries have been in dispute since they were first delineated and these disputes continue to this day[1].

[1] Morehouse, Barbara, A Place Called Grand Canyon – Contested Geographies, University of Arizona Press, Tucson, 1990

The first boundary description of the Hualapai Reservation was written on July 1, 1881 at Whipple Barracks, Prescott, Arizona.   A week later, on July 8, 1881, general orders were issued, "…setting aside a tract of country, in the Territory of Arizona, …. as a military reservation for the subsistence and control of the Hualapai Indians….."[2]

Approximately 1½ years later, an Executive Order,[3] signed by then President Chester Arthur, was issued on January 4, 1883 formally establishing the Hualapai Reservation.   The Executive Order's boundary description is the same as first written on July 1, 1881:

"Beginning on a point on the Colorado River, five (5) miles eastward of Tinnakah Spring; thence south twenty (20) miles to crest of high mesa; thence south 40 ^{o} east twenty-five (25) miles to a point of Music Mountains; thence east fifteen (15) miles; thence north 50 ^{o} east thirty-five (35) miles; thence north thirty (30) miles along said river to the place of beginning; the southern boundary being at least two (2) miles south of Peach Spring, and the eastern boundary at least two (2) miles east of Pine Spring. All bearings and distances being approximate."

Although challenged, the Hualapai Reservation boundaries have been largely unchanged since first described in 1881, while the boundaries of Grand Canyon National Park have undergone many changes since the Park was first conceived. The last legislation establishing present day boundaries is Public Law 93-620, [4] better known as the 1975 Grand Canyon National Park Enlargement Act. The Act's boundaries are described in map number 113-20021B, dated December 1974, shown in Figure 1.

[2] Walapai Papers, Historical Reports, Documents and Extracts Relating to Walapai Indians of Arizona, Washington 1936.

[3] Executive Orders relating to Indian Reserves, May 14, 1885 to July 4, 1902, Government Printing Office 1902

[4] http://www.gpo.gov/fdsys/pkg/STATUTE-88/pdf/STATUTE-88-Pg2089.pdf

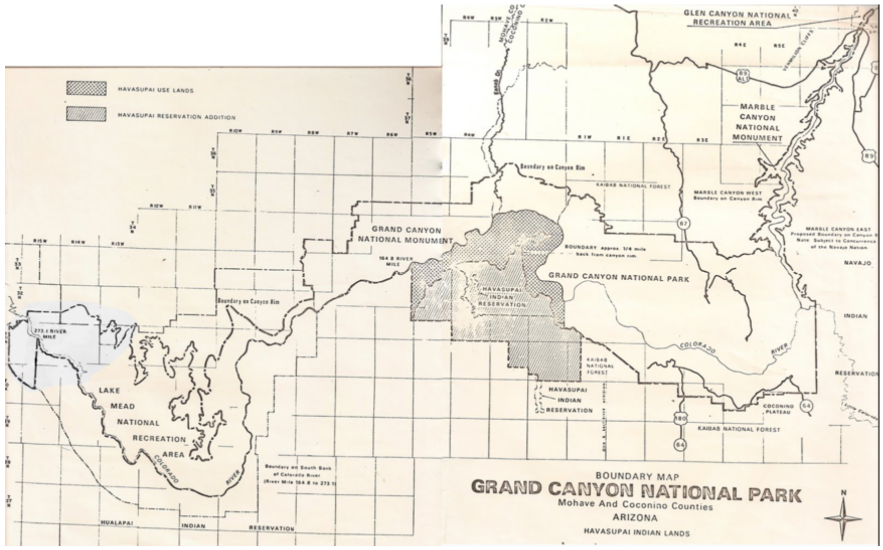

Figure 1, Grand Canyon National Park Boundaries, 1975 Enlargement Act

It should be emphasized that the Act refers to the map as a drawing. It is not a map by which stakes or survey monuments are identified – it only provides for a general location of the pertinent boundaries.

The Act did not define the boundary in question. In fact, the Hualapai Tribe is never mentioned. The only reference regarding the boundary is described on only the map: "Boundary on South Bank Colorado River River Mile 164.8 to 273.1."

Because the Act did not address it, a request was made by the Assistant Solicitor, Parks and Recreation, for a legal analysis of the boundary dispute. A February 6, 1976 memorandum[5] from the San Francisco Field Solicitor found that, by virtue of the Executive Order of 1883, "…. the reservation was established at the high water level of the Colorado River while the title to the bed of the River remained in the United States until 1912, when it passed to State upon Arizona's admission to the Union…."

As such, the Government's position is that lands below the high water level are within the National Park - recreationists, whether private or commercial passengers, having paid park entrance fees, are allowed to visit and camp following the Park's strict guidelines for doing so.

[5] United States Department of the Interior, Office of the Solicitor, San Francisco Field Office, Feb. 6, 1976, Hualapai Indian Reservation, Grand Canyon National Park, Boundary at Colorado River

Conversely, the Hualapai Tribe[6] "…. has continued to maintain constant cultural and historical affiliation with the territory, water, riparian and riverine resources of the Colorado River and the Grand Canyon. Hualapai ancestral homelands and resources extended from the Colorado River's junction with the Little Colorado River on the northeast, downriver to the southwestern confluence of the Bill Williams and Santa Maria Rivers. Resources, trade and social relationships extended in the East to Flagstaff, west to the Pacific coast and south down into Baja California. Both in Hualapai tradition and in the exercise of contemporary territorial sovereignty with respect to Tribal resources and properties, the Hualapai Tribe has consistently maintained its riverine boundary line as always being in the mid-stream of the Colorado River."

The January 2001 Management Plan of the lower Grand Canyon River Corridor, prepared under contract by the Hualapai, states, in part:

- The Hualapai Tribe has jurisdiction over the lands and waters of the Colorado River in Grand Canyon from river mile 165.0L to 276.7L. Nothing in this plan forfeits the Hualapai Tribe's sovereignty.

- "The Hualapai Tribe seeks to further develop additional Memorandums of Understanding with the National Park Service and other Federal and State entities for future management of the lower Colorado River corridor and the resources that it supports." And reaffirms "the permitting abilities of the Hualapai Tribe for the use of tribal resources by river recreationists along the lower Colorado River corridor."

<u>So, Where Are We Today?</u>

The foregoing provides the private boater with a brief background on the two opposing positions – which have existed for decades. It has been a disagreement that has been dormant for a similar length of time. It recently sprang to life when the Hualapai posted "NO TRESPASSING" signs at the entrance of National Canyon (RM 167) and issued public notices stating that permits are required for utilization of camps or beaches on left side of the river along the adjoining tribal lands.

This report does not side with one position or the other. At this time, knowing the history, it is inconceivable that one side would acquiesce to the other's

[6] About the Hualapai Nation, 2nd Edition © April 2010, Hualapai Department of Cultural Resources

position. Adjudication of this dispute is the least desirable path forward for reasons that need not be enumerated here. A cooperative agreement for administration of the disputed land, building on past cooperation[7] between the two parties, is the only viable option and much more desirable.

In the meantime, what should the private boater do? There are three options:

1) Contact the Hualapai and arrange for a permit and provide the approximate date when camps are anticipated to be occupied and pay the appropriate fees. The Hualapai Game and Fish Department can be contacted at: Phone: 928.769.2227, Fax: 928.769.111 or at gamefishhualapaitribe@yahoo.com

2) Camp on the left side of the river and stay below the high water level. Park entrance fees have been paid and camps may be utilized following Park rules. Use discretion if confronted by Hualapai law enforcement. Know that Tribal jurisdiction over nonmembers is extremely limited. For more information, see: "Congressional Research Service, Tribal Jurisdiction over Nonmembers – a Legal Overview, by Jane M. Smith, November 26, 2013.

3) Avoid all visitation/camps on the left side and utilize the right side of the river exclusively.

<u>The High Water Mark</u>

Given the foregoing options, it is clear that the location of the high water mark is critical to delineating the extent of the disputed boundary. Are you above or below it? It is generally assumed that the camps are below the high water mark even though its location is undefined. The National Park Service and Hualapai Tribe most likely have some opinion as do others[8] regarding the dispute and/or the high water mark's location.

It is beyond the scope and purview of the Solicitor General to define the high water mark's location on the ground. The only definition the Solicitor provides is that it applies prior to the operation of Glen Canyon Dam. Hence, the reference to 'historic' as used in this report.

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[7] Jeff Ingram, Celebrating the Grand Canyon, Hualapai – NPS CORE Team Meetings Summary, January 11, 2012, gcfutures.blogspot.com

[8] Celebrating the Grand Canyon, Jeff Ingram, gcfutures.blogspot.com

It is given that a river has fluctuating levels and that its high water mark therefore defines its boundary. Wikipedia provides a couple of definitions;

"A high water mark is a point that represents the maximum rise of a body of water over land. Such a mark is often the result of a flood, but high water marks may reflect an all-time high, an annual high (highest level to which water rose that year) or the high point for some other division of time."

"One kind of high water mark is the ordinary high water mark or average high water mark, the high water mark that can be expected to be produced by a body of water in non-flood conditions. ... Likewise, many states use similar definitions of the OHWM for the purposes of their own regulatory programs."

With respect to ocean shores, the high water mark[9] is defined as: *"That part of the shore of the sea to which the waves ordinarily reach when the tide is at its highest."*

Determination of the High Water Mark

Determination of the peak historic flow is requisite to the determining the corresponding high water mark. USGS Professional Paper #1677[10] by Topping, et al., provides an in-depth analysis of recorded flows at Lee's Ferry. The reader is encouraged to access this publication as it contains rare photographs of the gage as well as high water marks associated with historic flood events.

From this publication, four data points are presented in Figure 2 of peak flows having return periods of 1, 10, 100 and 1000 years in a log-log plot format, i.e. both the horizontal and vertical axes use a logarithmic scale.

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[9] A Law Dictionary, Adapted to the Constitution and Laws of the United States. By John Bouvier, 1856. 13 Oct. 2018

[10] Computation and Analysis of the Instantaneous-Discharge for the Colorado River at Lee's Ferry, Arizona, May 8, 1921, through September 30, 2000, By Topping, Schmidt, Vierra.

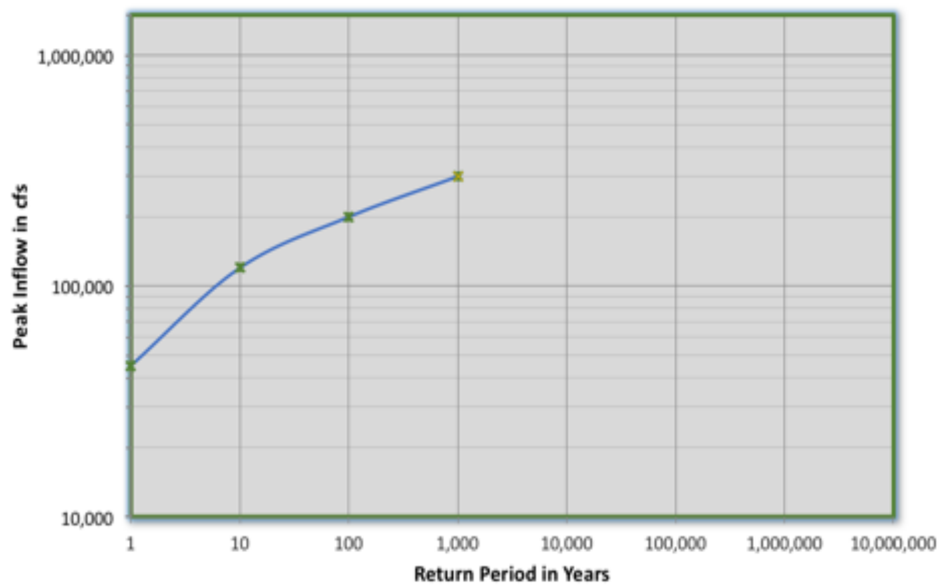

Figure 2, Historic Peak Inflow vs. Return Period pre Glen Canyon Dam

The USGS publication cites the 1994 Paleo flood[11] study by O'Connor et al. This study examined deposits 50 feet above the river, 2 miles downstream from Lee's Ferry, at a location referred to as Axehandle Alcove. The deposits were carbon dated and found to have been deposited 1200 years ago as a result of an estimated peak flow of more than 500,000 cubic feet per second (cfs). The USGS, upon review, downgraded the study's estimated peak flow to 300,000 cfs corresponding to a 1000-year return period.

Referring back to Figure 2, a return period of 1 year corresponds to a peak flow of 45,000 cfs. Meaning that, in any given year, there is a 100 percent probability of this flow occurring. Similarly, a 100-year flood corresponds to peak flow of 200,000 cfs, having a 1 per cent probability of occurring in any given year. Using the results of the Paleo flood study, the USGS was able to extend the observed/measured data beyond 100 years to a little over 1000.

The data in the Figure 2 can be further extended by calculating the Probable Maximum Flood (PMF). A PMF is a combination of the most severe meteorological and hydrologic conditions that are reasonably possible. For high hazard dams, such as Hoover and Glen Canyon, the PMF is design criteria for sizing the outlet works. The outlet works should be of such capacity, so that the

[11] Jim E. O'Connor, Lisa L. Ely, Ellen E. Wohl, Lawrence E. Stevens, Theodore S. Melis, Vishwas S. Kale and Victor R. Baker, "A 4500-Year Record of Large Floods on the Colorado River in the Grand Canyon, Arizona," The Journal of Geology, Vol. 102, No. 1 (Jan., 1994), pp. 1-9

PMF can be safely passed without overtopping the dam. PMF studies[12] conducted by the United States Bureau of Reclamation (USBR) resulted in peak inflows of 693,000 cfs and 1,130,000 cfs at Glen Canyon and Hoover Dams, respectively. The studies, dated September 1990, took 3 years to conduct at a cost of $ 1 million.

The blue and yellow horizontal lines shown in Figure 3 represent the PMF for Glen Canyon and Hoover Dam. The PMF is a maximum, i.e. it represents the upper limit of peak flows for a given drainage basin. If the historic data and PMF are correctly calculated, the relationship between the two should be a smooth curve going from 1 to 10 million years. In this case, the curve intersects the PMF at a return period of approximately 3 million years. This is indicative, that both the historic data and the PMF were correctly determined. Although a PMF is not a statistically derived storm, based on the author's experience, a PMF is typically associated with a return period of 1 to 2 million years.

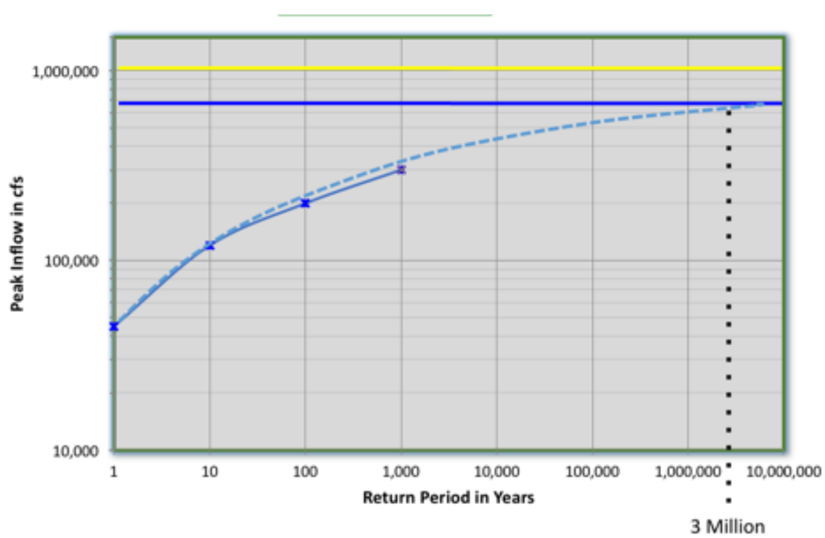

Figure 3, Historic Peak Flows Extrapolated showing PMF limit

The primary driver of a PMF is the amount of rainfall – or the maximum probable precipitation (PMP). The difference in a PMP and a 1,000-year rainfall event may only be one or two inches, e.g. 30 inches of rainfall in a 72-hour time period versus 32 inches.

It should be noted that a Log-Pearson Type III distribution is the default methodology for hydrologic analyses to determine flows for any given return

[12] Colorado River Basin Probable Maximum Floods – Hoover and Glen Canyon Dams, United States Department of the Interior, Bureau of Reclamation, September 1990.

period. Instead, the curve shown in Figure 3 can be reliably used to determine Glen Canyon Dam inflows at return periods from 1000 to 3 million years. The published data by the USGS and USBR in Figure 3 complement one another and more than adequately serve this purpose

The disputed boundary lies between the two dams – or the applicable peak flow between the two PMF values. Rather than averaging the two, the applicable peak flow was determined as shown in Figure 4. This figure shows the USBR's calculated PMF values of 693,000 and 1,130,000 cfs in relation to the location of the disputed boundary.

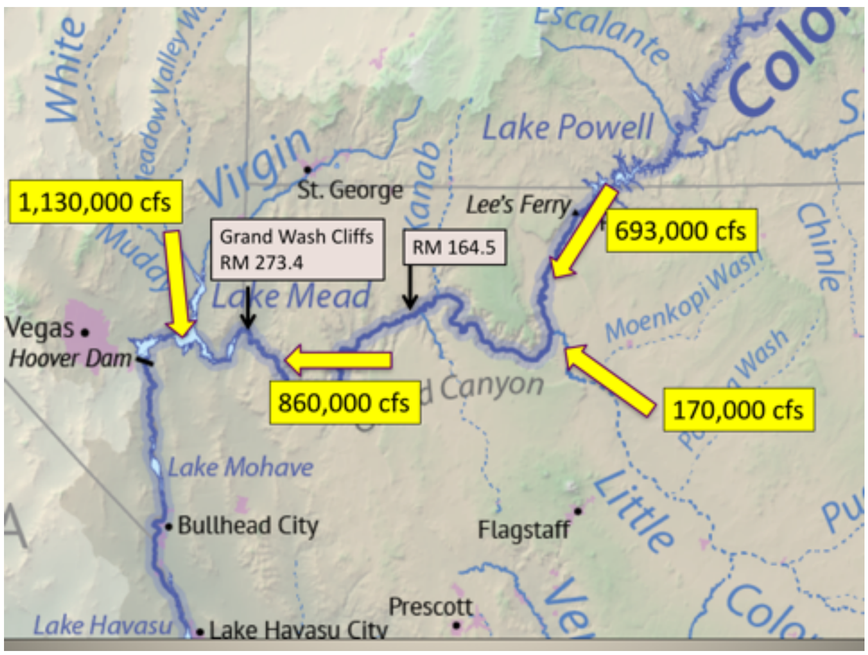

Figure 4, Drainage Area Affecting the Peak Flow at the Disputed Boundary

The Little Colorado River (LCR), having a drainage area of 26,500 square miles[13], has a far greater influence on the peak flow along the boundary than the many side streams, such as the Paria, Bright Angel, Kanab, etc. A conservative peak value is therefore determined by only considering the LCR. Using the ratio of 6.4 cfs per square mile for Glen Canyon Dam's drainage area and PMF, and applying it to the LCR, results in a peak flow of 170,000 cfs.

The gage on the LCR (USGS #09402000 located at Cameron), recorded a peak flow of 120,000 cfs on September 20, 1923. This recording is supportive of the estimated PMF by virtue of it being lower – as it should be. Combining the LCR and Glen Canyon PMF values results in a rounded down total of 860,000 cfs.

[13] Little Colorado River - Wikipedia

The foregoing historic peak flows are calculated values and correspond to a return period of approximately 3 million years. A return period is way of communicating probability or a measure of an event's occurrence in any one year. It should not be construed as the length of time needed for such an event to occur. A good analogy is that a person may experience one or two 100-year-rain storms in his or her lifetime. Yet, one doesn't need to have lived 100 years to experience such an event.

To further put the concept of return period in context, consider the following[14]:

> The odds of winning the mega millions jackpot is 1:300,000,000
> The odds of being attacked by a shark is: 1:11,500,000
> The odds of being struck by lighting during one's lifetime is: 1:14,600

Jackpots are won, shark attacks happen and people are struck by lighting. Similarly, given the age the Grand Canyon of 6 – 70 million years[15], it is highly likely that the foregoing peak flows occurred – perhaps multiple times.

<u>Quick Summary of Applicable Peak Historic Flows</u>

From Glen Canyon Dam to the LCR: 700,000 cfs (rounding up 693,000).
From the LCR to the Grand Wash Cliffs: 860,000 cfs (rounding down 863,000).

<u>Corresponding High Water Levels</u>

Having determined values for the peak historic flows, the corresponding high waters levels are estimated next. The analyses in USGS Publication 2008-5075[16] by Magirl, et al. was drawn upon for that purpose.

Magirl et al. modeled the river corridor from Lee's Ferry to Diamond Creek by solving the equations for conservation of energy and continuity by analyzing 2680 cross sections of the river channel. High-resolution digital topography of the

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[14] Megamillions.com, Weather.gov, Floridamuseum.ufl.edu
[15] Ranney, Wayne, How Old Is the Grand Canyon, Geoscience News and Information, Geology.com
[16] Magirl, et al., "Modeling Water-Surface Elevations and Virtual Shorelines for the Colorado River in Grand Canyon, Arizona, Report 2008-5075, USGS, 2008.

ground, for base flows of 8000 cfs, was used to define the cross sections.

Shorelines for flows up to 210,000 cfs were determined at a number of locations. Figure 5 shows the rise in elevation for flows above 8000 cfs at the Grand Canyon Gage (USGS #09402500 located just above Phantom Ranch.) The rise in elevation corresponds to 32 feet for a flow of 210,000 cfs.

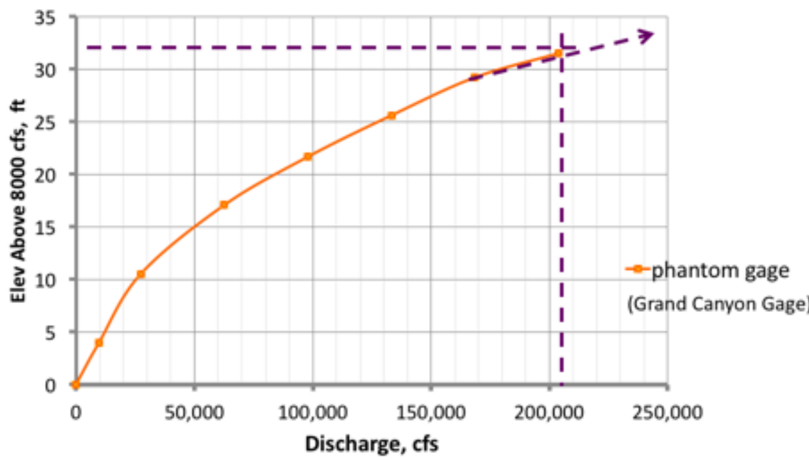

Figure 5, Grand Canyon Gage - Water Elevation Above 8000 cfs vs Discharge

The data provided for the Grand Canyon Gage was judged to be the most reliable as its bathymetry is monitored and cross sectional area is representative of most of river's corridor.

Note that the slope of the curve in Figure 5 becomes less steep with increasing flows. At 200,000 cfs, this slope is 0.1 feet per 1000 cfs, i.e. for every increase in flow of 1000 cfs, the river rises 0.1 feet. The same slope was found for the data presented by Greenbaum[17] et al. who conducted a paleo flood study on the Upper Colorado near Moab, Utah. In that study, a peak flow 325,000 cfs having a return period of 500 years was determined.

To extrapolate the rise in elevation for flows greater than 200,000 cfs, and thereby determine the high water mark, the intercept of 32 feet and slope of 0.1 ft/1000 cfs are used in the following linear equation:

Elevation, ft = 32ft + 0.1ft * (Flow – 200,000 cfs)/1000 cfs

[17] Greenbaum, N. et al., A 2000 Year Natural Record of Magnitudes and Frequencies for The Largest Upper Colorado River Floods Near Moab, Utah, AGU Publications, Water Resources Research

For a 100-year event of 200,000 cfs, the rise in elevation is 32 feet; for a peak historic flow of 700,000 cfs, the rise in elevation is 82 feet and 98 feet for 860,000 cfs, i.e. applicable historic peak flows above and below the LCR, respectively.

The high water marks apply to both the U-shaped portions of the canyon as well areas where the river widens out. These areas are typified by stagnant or water having very little flow/velocity – sometimes referred to as slack water.

This may seem counterintuitive to some. To reconcile this, one needs to consider the principle of conservation of energy of flowing water in which the square of the velocity is inversely proportional to the rise in elevation. This is better explained in the referenced USGS publication as well text books on hydraulic engineering of open channel flow.[18]

High Water Mark Influence on Early Settlement of the Unkar Delta

There is a significant amount of archeological evidence of early settlement in and around the Grand Canyon.[19] Of interest is the early occupation of the Unkar Delta (RM 72.5). Surely, these folks were in tune with their environment and were well aware of the river's seasonal fluctuations.

An archeological investigation of the delta was carried by Schwartz, et al.[20] starting in 1967. Figure 6 shows the outline of a dwelling, which is the front cover of their book. Based on carbon dating of pottery shards and their distinctive decorations, the delta was estimated to have been occupied over three 20-year periods from 900 to 1300 A.D.

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[18] USBR, Water Measurement Manual, Chapter 2, Basic Concepts Related to Flowing Water and Measurement, https://www.usbr.gov/tsc/techreferences/mands/wmm/chap02_10.html

[19] Balsom, Janet R. "Inclusion in NPS Management at Grand Canyon: Tribal Involvement and Integration, Crossing Boundaries in Park Management: Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands (ed. By David Harmon); Hancock, Michigan: The George Wright Society, 2001, pp. 249-252

[20] Schwartz, D. W., et al. Archeology of the Grand Canyon: Unkar Delta, School of American Research Press, © 1980.

Figure 6 Schwartz, et. al, Unkar Delta

A number of dwellings were excavated and mapped. Their locations were transferred to Google Earth shown as pins in Figure 7. The green, yellow and orange pins are 80, 72 and 222 feet above the river. The yellow pin represents the location shown in Figure. 6. Using the linear equation, the elevation of 72 feet corresponds to a flow of 600,000 cfs, and an approximate return period of 100,000 years.

Figure 7, Google Earth View – Unkar Delta

Thus, one can assume, given the level of flood protection, that they were keenly aware of the river's flood potential. No doubt they were able to determine the river's rise given the line of driftwood as they returned each season to grow their crops. Some of the dwellings still had sizeable pieces of drift wood in place.

One can see the vegetation on the river's right side in the lower middle of Figure 7. The elevation difference between the river and where the vegetation dies out as it borders the Dox formation is 33 feet. This vegetation is similar to that seen along the Unkar drainage as well as the mouth of the drainage channel at the river's edge. The presence of vegetation is evidence of periodic flooding. Again, a rise in elevation of 33 feet translates to a 100-year flood event of 200,000 cfs, which, based on the presence of vegetation, must have regularly occurred.

<u>Coming Full Circle</u>

We now revisit the Paleo flood study done by O'Connor et al. at Axehandle Alcove – 3 kilometers below Lee's Ferry, located on river left. Recall that the 1200–year old deposits were located 50 feet above the river level. It had been estimated that these deposits were as a result of a peak flow of 500,000 cfs. This estimate of flow, upon review by the USGS, was lowered to 300,000 cfs at a corresponding return period of 1000 years.

An elevation of 50 feet, using the linear equation, corresponds to a flow of 380,000 cfs. This flow falls directly on the smooth curve at the carbon dated age of 1200 years as shown in Figure 8. "JOG" stands for the Journal of Geology and represents the data point for 500,000 cfs at the same return period and is shown for comparison purposes.

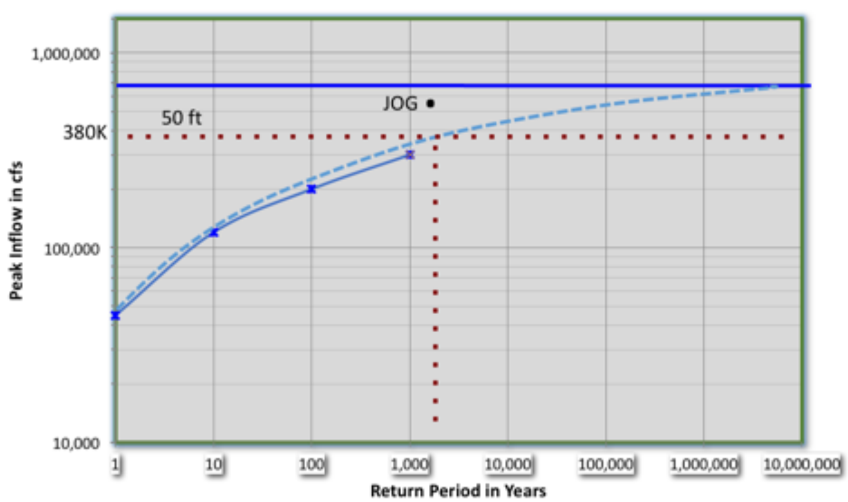

Figure 8, Paleo flood study – peak flow and corresponding return period

Figure 9 below shows a river view of Axehandle Alcove with the 50 ft elevation and corresponding flow superimposed.

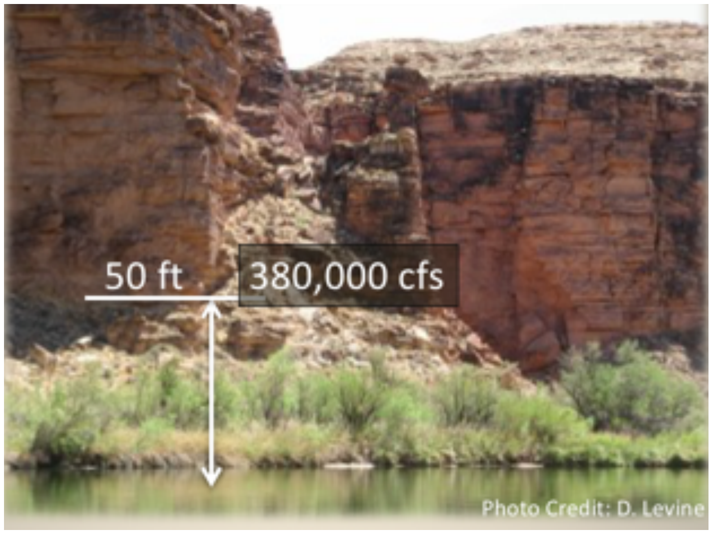

Figure 9, Paleo Flood Study, Axehandle Alcove, Photo Credit: D. Levine

Coming full circle validates a number of key results: carbon dating of the deposits, USGS's analyses of the historic data, the USBR's calculation of the PMF inflow at Glen Canyon and Hoover Dams, and the linear equation used to determine historic high water mark's elevation. Furthermore, although not definitive, the results appear to be in concert with early occupation of the Unkar Delta. The foregoing provides a degree of confidence in locating the high water marks along the disputed border

<u>Locating the High Water Marks along the Disputed Border</u>

For areas below the LCR and along the disputed border, a peak historic flow of 860,000 cfs translates to an elevation of 98 feet above the river given a base flow of 8,000 cfs. The elevation increase is rounded up to 100 feet to avoid a suggestion that the estimated increase is accurate to within a foot.

The following locations were examined using Google Earth; National Canyon (RM 167), Granite Park (RM 209), Diamond Creek (RM 225) and Quartermaster (RM 262). For each of these locations, pins are shown for elevations 32 and 100 feet above the river. Lines associated with these elevations are also shown.

Figure 10, National Canyon – Google Areal View, Location of Water Elevation

Figure 11, National Canyon – Google Street View with Lines of Water Elevations

Figure 12, Granite Park – Google Areal View with Water Elevation

Figure 13, Diamond Creek – Google Areal View with Water Elevations

Figure 14, Docks at Quartermaster – Google Street Vie

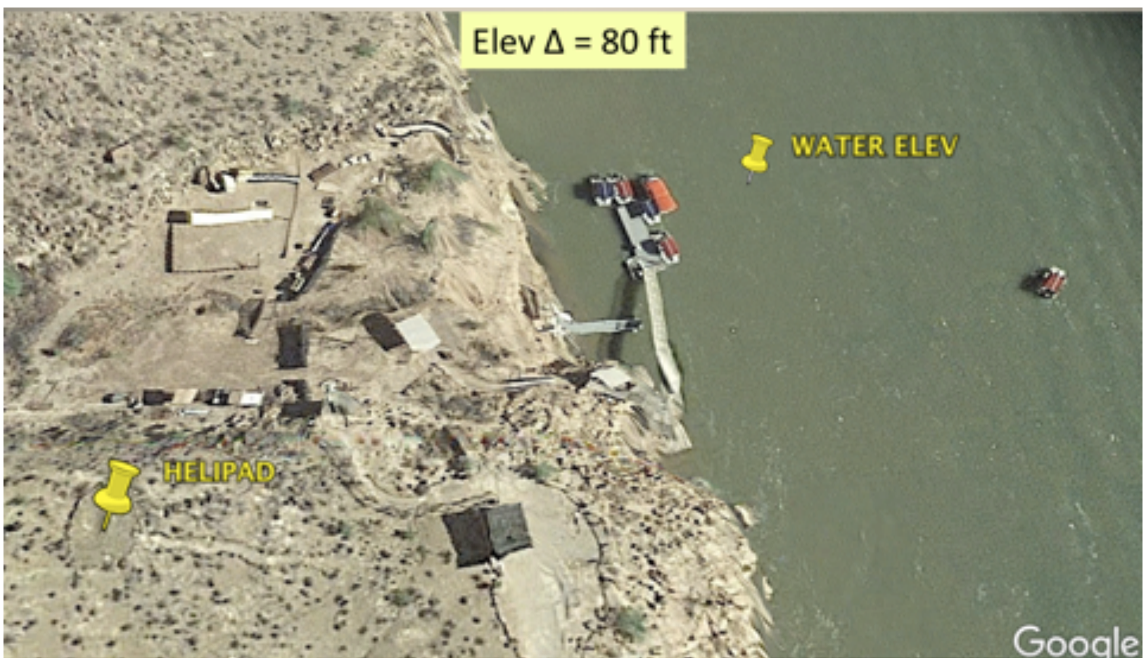

Figure 15, Docks at Quartermaster – Google Areal View – 80 feet Elevation difference between Helipad and River Level

The foregoing figures demonstrate the value of Google Earth for this kind of a study. Although it does not have the benefit of high-resolution digital topographic data, Google Earth is sufficiently accurate for the purposes of a study like this. In addition to elevation, latitude and longitude are similarly tracked as one moves the cursor.

This software, in conjunction with hand-held devices such as a Garmin inReach, allows one to reliably locate a point of interest on the ground. Most private boaters, as well as backpackers, packrafters and canyoneers have such a device in their party. Locating the high water mark is pertinent if one choses to explore the side canyons – the camps and beaches are all below the 100-year water level and certainly well below the peak historic high water mark. Having this technology readily available obviates the need to mark any perceived boundary location with a sign, such as the one shown in Figure 16.

Placement of this kind of a sign suggests to the author that the Hualapai underestimate the extent to which this is an affront to recreationists visiting Grand Canyon National Park. It is certainly counter to the Hualapai's stated intent to care for the land and provide for a positive visitor experience.

Figure 16, Hualapai "No Trespassing" sign at National Canyon – Photo obtained from posting on Facebook - photo credit unavailable

Locating the Middle of the River

At first blush, the Hualapai's position regarding boundary as the middle of river might be dismissed as easily determined. It is not. The Hualapai have not defined this location as representing current or historic conditions. If historic, or prior to operation of Glen Canyon Dam, the determination of the boundary's location is problematic. The river channel has shifted over time since the dam's operation by precluding the periodic flood flows from removing the alluvial materials deposited at mouth of every tributary.

This can be clearly seen at the Google view of Granite Park in Figure 12 – flow is from top to bottom. Here, the river channel has been pushed to river right absent the historic flood flows removing the island of alluvial materials. If these were removed, the channel would return to its original location, 700 feet towards the its left bank. One doesn't a degree in geomorphology to appreciate this.

Wrapping It Up

As mentioned earlier, the purpose of this report was to define the high water mark's location, and thereby assist the private boater in recognizing the extent of the disputed lands along the 109-mile length of the boundary between the Park and Hualapai Tribe. Knowing and having documentation is better than assuming.

Adjudication of the dispute may have serious negative consequence for the Hualapai given the high water mark's location at Diamond Creek and Quartermaster. Likewise, for the Park Service and private boater.

Lastly, it is hoped that defining the limits of the disputed boundary will facilitate arriving at a joint agreement between the Hualapai and Park Service for administering the areas in question.

This report was commissioned by the Grand Canyon Private Boaters Association for the benefit of private boating community and is hereby respectfully submitted. Not easy reading – but the engineering detail and rationale provided were necessary to establish the basis for the findings of this report.

Witness my seals below,

About the Author

John Vrymoed is a registered Civil and Geotechnical Engineer in California. Currently retired, he oversaw engineering projects and varied administrative functions as manager with the California Department Water Resources. He is a published author on topics related to earthquake engineering and dam performance, served on a panel of experts for the US Army Corps of Engineers and given presentations at various conferences.

A private boater, he has been down various rivers in the Western US and completed numerous trips down the Colorado River thru the Grand Canyon. He currently serves as Vice President of the Grand Canyon Private Boaters Association. He can be contacted at vrymoed@gmail.com