CAP

#18

September 19, 1966

Mr. David R. Brower
Sierra Club
1050 Mills Tower
San Francisco 4, California

Dear Dave:

Your Chapter 2 on the "Sedimental Journey" came in over the week-end.

I have just returned from Arizona and will try to find time to analyze this document at the first possible time.

Best regards,

lg

Morris K. Udall

The Honorable Morris K. Udall
House Office Bldg.
Wn., DC

Memo . . .

from DAVID R. BROWER
Sierra Club • 1050 Mills Tower
San Francisco 4

Dear Mo —

Here's Chapter 2 — comment on my "Sedimental Journey," flooding a few of my "facts" but not all. More anon when I bounce back with new worries.

Sincerely,

Dave

9-7-66

This man is sharp — and well-trained

C A Washburn
1429 Grove St. No.D
Berkeley, Cal.94709

Dear Dave,

Relative to our discussion last night on silting, this is what I tracked down today. I'll type up the sections "Facts" and "Interpretation" first, then read over your paper again and do "Conclusions".

FACTS

1. Data on sediment accumulation in L. Mead (ref. 1) which will be used as a basis for calculations.

   a) During the 14-yr period, 1935-48, 1,957 million tons of sediment were deposited in L. Mead in the delta formed by the Colorado--this was 97.2% by weight of the total sedimentation in Mead (p 195). Thus the Colorado's contribution was 140 million tons/yr. This value was calculated from the measured volume of sediment contributed by the Colorado, 1,392,000 ac-ft (p 196) and its avg. density (64.5 $\#/ft^3$)--both values are measured.

   b) The above annual tonnage should be compared with that passing Grand Canyon, as measured from water samples. This value is 142 million tons (p 196). The data seem very consistent, and from p 196 of ref. 1: "If the quantity of sediment carried in the bed load is appreciable, we would expect the total amount of sediment in the Colorado delta to be somewhat greater than the total suspended load passing the Grand Canyon station. Since this is not the case, it appears that the bed load of the Colorado is extremely small, and that practically all of the sediment carried by the Colorado River is carried in suspension. Thomas has cited evidence that the bed load of the Colorado upstream from Lake Mead is not great. The absence of significant quantitities of coarse constituents in the Colorado delat also suggests a small bed load." Note that the 1926-50 average suspended sediment passing Grand Canyon was 168 million tons/yr, while the '35-'48 rate was 142.

   c) Regarding aggradation (formation of topset beds), the topset beds in L. Mead (1948) had gradients of 1.2 to 1.3 ft/mile, averaging 1.25 (p 215). Using this slope from the permanent spillway crest (elev. 1205.4') and the profile of the river, the topset beds are expected to build up about 13.5 miles above the original head of the reservoir (to about mile 222) (p 216). This brings the top of the slime to elev. 1365'. The resulting sediment storage capacity above the perm-anent spillway level is about 6 million ac-ft--about

25% gain above Mead's capacity--USGS thus estimates Mead's total soil-storage capacity at 35.7 million ac-ft.

d) Sediment will compact--USGS estimates a filled reservoir density of 96.1 lbs/cu. ft. This gives storage for 74,700 million tons in the 35.7 million ac-ft. Mead's sediment is 45% sand and 55% clay and silt.

e) No specific data are given on sources of sediment, but a map on p 27 indicates they thought they thought the Little Colorado might contribute 7-9 % of the sediment in Mead with the Paria contributing about 1%. On p 28 they say: "Probably more than 95% of the sediment entering L. Mead passes through Grand Canyon." To get a bit ahead of the story, and to leave ref. 1, my estimates are that the L. Colorado would contribute about 11% with the Paria doing better than 4%.

2. THE INTERPRETATION (or how to make something out of a few pieces of data widely scattered in various Water Supply Papers)--if you want their numbers, come to me.

a) The river over-all. For times prior to '47, there just aren't good data on suspended sediment at any interesting points. (Research doesn't pay--the Sierra Club might try to use the results someday.) Using the data for 1948-59, inclusive, plus that for '62 (the '60 & '61 data has yet to be published--automation hit USGS in '62), I conclude by comparison of the main stream stations at Lees Ferry (samples taken above the mouth of the Paria) with the Grand Canyon station that:

1) about 99% of the water passing Grand Canyon passes Lees Ferry (i. e., channel losses about equaled Paria and Little Colorado inputs during this period--"normally" there's about a 400,000 ac-ft gain here (between Lees and the Grand). This agrees with the statement in ref. 2, p H11: "The sum of the average runoff of Colorado River near Cisco, Colo., Green River at Greenriver, Utah, and San Juan River near Bluff, Utah, constitutes about 97 % of the runoff computed at Lee Ferry."

2) during the 13 years mentioned above, suspended sediment passing the Grand Canyon station averaged 90 million tons annually while that passing Lees Ferry averaged 70.5 million tons. During these 13 years the flow at Lees Ferry averaged 11.6 maf vs. the long-term (51 yr) average of 12.9 and the 1930 to 1956 average of 11.2 maf. Thus the above suspended sediment values give 19.5 million tons annually that come in between Lees Ferry and Grand Canyon. This number should be pretty good--certainly good for ± 20%. But keep in mind the statement regarding the time-variable that isn't random, from p. H 12 of ref. 2:

"In the decade beginning in 1942 the annual sediment load reaching the reservoir (Mead) was 50 to 100 million tons less than would be expected on the basis of the sediment-runoff relation for years prior to 1941, and the change is believed to be, at least in large part, an effect of the Southwest drought. In the years 1942-51 there was approximately average streamflow from the principal water-producing areas in Colorado, Wyoming, and northern Utah, but reduced streamflow from the principal sediment-producing areas. The result was less sediment per unit of runoff in those years, as measured at Grand Canyon. From 1953 to 1956 there was a progressively greater sediment load per unit of runoff, because drought engulfed the entire Colorado River basin, and runoff was deficient in the principal water-producing areas as well as in the principal sediment-producing areas."

b) So we're left with 19.5 million tons a year to divide up between the Paria, the Little Colorado, and the "other". This problem is a good bit tougher than arriving at the 19.5 figure. We have records for the Paria for the same 13 years I talked about above ('47-59 plus '62). For these years the Paria averaged 3,090,000 tons/yr of suspended sediment--for the first 12 of those (flow data for '62 not available) years the Paria's flow averaged 18,100 acre-ft annually vs. the long term ([illegible] yr) average of 21, 940. But several good years were in there including '58 which ran over 39,000. So I think we can safely put the Paria's dirt load at 4,000,000 tons/yr ± 30%, say.

c) The Little Colorado is much tougher--here there are only 4 years of sediment records published ('57-59 plus '62) and we don't know the flow for '62. So using the '57-'59 data we get an average sediment load of 9,700,000 tons for the Little Colorado. This was blended with 131,000 acre-ft annually. This flow should be compared with the River's long term (17 yrs) average flow of 139,000. Thus for the Little Colorado about all we can do is put the sediment load at 10,000,000 tons/yr ± 40%. The station on the Little Colorado is at Cameron which is also the site for the proposed phreatophyte farm called Coconino.

d) So here's it in summary:

	suspended sed. 10^6 tons/yr
added Lees Ferry to Grand Canyon	19.5 ± 20%
added, Paria	4.0 ± 30%
added, Little Colorado	10.0 ± 40%

But the error limits aren't as bad as they seem--after all, we're worried about what ends up behind which dam & that shouldn't be so bad. The Paria's contributions should end up behind Paria and Marble, and all the rest should be behind Coconino and Bridge.

e) What's the tons/year convert to in terms of acre-feet per year?
For Coconino & Paria let's use the current (uncompacted) L. Mead density:

$$\frac{99{,}500 \text{ ac.ft}}{142{,}000{,}000 \text{ tons}} = 700 \frac{\text{acre-ft}}{10^6 \text{ tons}}$$

For Marble & Bridge let's reduce this by the density ratio 64.6/96.1 = 0.67, OR:

$$700 \times 0.67 = 470 \frac{\text{acre-ft}}{10^6 \text{ tons}}$$

f) So, each year, at Paria and Marble:

$4 \times 10^6 \times 700 = 2800$ ac.ft uncompacted

or $4 \times 10^6 \times 470 = 1880$ ac.ft compacted

g) and at Coconino and Bridge each year:

$15.5 \times 10^6 \times 700 = 10{,}800$ ac.ft uncompacted

or $15.5 \times 10^6 \times 470 = 7{,}300$ ac.ft compacted

with the realization that probably only about 2/3 of this comes from the Little Colorado so only this much can be behind Coconino.

Now I'll read over your piece and try to distribute these numbers around and get a comparison with your's.

3. CONCLUSIONS AND COMMENTS The easiest way seems to be to comment on your paper as I go through it, and wind up with my calculatio

Huber's statement that 1/3 of Mead's silt comes from the Little Colorado must have been a judgement value--I don't believe it could be near correct.

In the 14 years prior to '48, Mead got just about 100,000 acre-feet per year *silt from the Colorado. This was only about 85 % of what the average '26-'50 would lead you to expect, but since '48 it has averaged only about 65,000 acre-feet/year (90 million tons over 140 million tons times 100,000 acre-feet). As the water goes, so goes the silt. Note that Daines value (175,000 tons/yr) was too high--by nearly 3X currently. Note that the density value you assumed, 2.65, is about right for the particle densities but way too high for the bulk. This stuff just doesn't pack--the Mead studies showed densities of less than 62.4 (dry weight of solids divided by wet volume), with a heavily packed density of about 1.5X this. The 147 million tons BLM put in their Appendix to PSWWP is thus about the long-term average--using a density of 62.4 this comes to about 100,000 ac-ft/yr, which is the L. Mead experience value. Your density of 2.65 gave you 45,000.

Your 90% water-60% silt value fits just above the San Juan's mouth--at Lees Ferry it's about 99% water-80% of the silt coming from above.

USGS makes reservoir studies after the fact: e. g., L. Mead, L. Pillsbury. Now that you bought your cow, see if it's alive.

Your estimate of Little Colorado's flow, 1,503,000 ac-ft is over ten times too big--records show 139,000.

Ha! my estimate for the Paria 2,800 ac-ft/yr is only 55% of the Bureau's figure for the sediment from Glen to Marble. Reason being that mine is based on 90.0 million tons/yr passing Grand, their's on the long-term average of 168: 90/168 = 53.5%. Depending on whether you believe in wet years again, maybe you should double my values --but remember the Paria and Little Colorado flows during the sample period I used for sedimentation were quite close to the long-term average flows. This factor of 2X represents the transport rule acting on the uncertainty in river flow of 20%. I will carry on with my numbers--halve the number of years I calculate if you believe in water. My value makes the Paria about 12% solids, not 20.

Note that for the Little Colorado, using my value of 10 million tons/yr and the average flow of 139,000 ac-ft comes out to be about 5% solids. The factor of 10 difference you mention on pg 5 of your work is attributed to the wrong value of the Little Colorado flow.

Carrying on with my low value of 19.5 million tons/yr converted to uncompacted sediment of 13,700 acre-feet/yr, I would have the 6¼ maf capacity of the 4 dams silted up in 450 years, not 62.5. Even if you believe in rain and double my silt rate (I don't see how it could be multiplied by seven or eight), appreciation

you still get 225 years of go. This isn't too far from your, 180 under your 'best case'. My best case would be to add 25% to my times to give espected lives of 300 to 500 years. Can USGS top that?

Regarding the flood business, there is some evidence in the flow records that how recently the area has been washed down is as important as the carrying-power--flow relation in determining sediment carry-off. Leopold (ref. 3) says (p 72-73): "Let us consider now the different importance of frequent and infrequent events when viewed in terms of the sediment load directly, apart from the water discharge. This difference derives from the fact that in many instances the sediment is not carried during the times of maximum discharge." He then refers to a table comparing sediment flows for given times on the Colorado (Grand Canyon), Rio Puerco, Cheyenne, and Nicbara Rivers. Continuing, he says: "For all four of the streams, 98-99% of the total load is carried during events which occur more frequently than once in 10 years." I thus conclude a huge flood wouldn't do much to the averages, especially with the reservoirs. Even if the reservoirs were full of water, they should furnish a relative slack area for sedimentation.

I agree with you on the phreatophyte problem--the silt reservoirs, normally being empty of water, will have it long before they are filled with mud.

Also you're right on bank storage becoming unavailable because of sedimentation.

According to ref. 1, p 100, L. Mead's bank storage was 13.2% when full. I'm not sure what kind of experience they had with this returning. However, p. 102 of ref. 1 indicates it does come back on the year-year operating cycles. During the drawdown from Sept. '41 to Sept. '46 following the '41 filling, they apparently got 910,000 ac-ft back (out of 3,300,000).

Well, I think Dan & I have converted you to a full-fledged engineer. Let me know what you think of this.

Sincerely,

Chuck

REFERENCES

1. W. O. Smith, C. P. Vetter, G. B. Cummings, et. al. USGS Prof. Paper #295, "Comprehensive Survey of Sedimentation in Lake Mead, 1948-49" (1960).

2. H. E. Thomas USGS Prof. Paper 372-H "General Summary of Effects of the Drought in the Southwest." (1963).

3. Luna B. Leopold, M. Gordon Wolman, John P. Miller, FLUVIAL PROCESSES IN GEOMORPHOLOGY. Freeman (1964).