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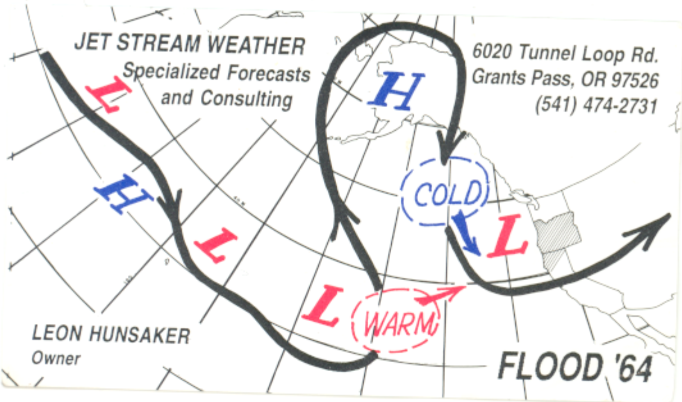



LEON HUNSAKER
Owner

FLOOD '64

4/23/13

Mike,

Enclosed is a Copy of our final report.

We really appreciate your willingness to add it to your list of internet reports. Looking forward to learning more about your water plan!

Jenn

# JANUARY 1862 SUPERFLOODS

In view of the recent levee and Folsom Dam upgrades, we are concerned that the citizens of Sacramento and environs do not understand the destructive potential of a repeat of the 1861 – 62 flood series. This report presents compelling evidence that there were two superfloods in January 1862 – – less than two weeks apart. We call them superfloods because they were both larger than the recent major floods of February 1986 and January 1997. Our report also details why the official peak flow estimate of 320,000 CFS for the January 10, 1862 superflood at Folsom/Fair Oaks is ~ 40% too low.

Based upon the above information, and more, this report outlines a "common sense scenario" describing Sacramento's flood potential in the event of a repeat of the currently underrated 1861 – 62 flood series.

# INTRODUCTION

A review of our report: Step by Step Estimate of The Peak Flow on The American River @ Folsom for Record Flood: 1/10/1862, dated June 10, 2011, shows only minor changes in our thinking between then and now regarding the magnitude of our peak flow estimate. However, there is a significant difference. Today's estimate is supported by a much stronger foundation. A good example is what we call the "Snell Factor" contribution to the 3-day flow. Two years ago our estimate of 10% was based mainly on supposition. A similar estimate today is based upon a series of well-founded calculations that include Dr. Snell's 1861 – 62 Sonora rainfall measurements. Our report vindicates Dr. Snell for his much maligned weather observation of 30 inches of rain in Sonora during the 10 day period January 14, 1862 through January 23, 1862.

A second major item that makes the foundation of our estimate much stronger, is some unpublished research by Robert Collins. For many years he was the district hydrologist for the Sacramento District of the Army Corps of Engineers. Following my presentation at the June 2010 Extreme Precipitation Symposium held at the University of California at Davis, Mr. Collins made this statement: "Assuming that the precipitation amounts were about equal because of the extra low-level snow melt, the heaviest 3-day January 1862 flow on the American River at Folsom/Fair Oaks was ~ 30% larger than the 3-day flow for either the February 1986 or January 1997 floods.'' The storm and watershed research in our book "Lake Sacramento", along with the findings in this report, strongly support this conclusion.

Other storm and watershed factors capable of increasing river flows, previously overlooked, have been researched and are listed below:

1. The water holding capabilities of fresh snow and how this can dramatically add to peak flows produced by heavy warm storms.
2. How the early January 1862 cold spell increased the runoff during the heavy warm flood producing storm of January 9 – 11, 1862.
3. How the three heavy storms of late December 1861 made a runoff contribution to the flood producing storm of January 9 – 11, 1862.

**Note: In the conclusions of this report (page 17) we briefly discuss how a rapid sequence of major flood events similar to the 1861 – 62 series, would affect levee systems and flood control operations.**

WHY THE EARLY JANUARY 1862 FLOOD WAS SIGNIFICANTLY LARGER THAN EITHER THE FEBRUARY 1986 OR JANUARY 1997 FLOODS ON THE AMERICAN RIVER AT FOLSOM/FAIR OAKS

A. EXTRA LOW LEVEL SNOW MELT: Robert Collins retired district hydrologist for the Sacramento District of the Army Corps of Engineers had this to say following my presentation at the June 2010 Extreme Precipitation Symposium held at the University of California at Davis. "Assuming that the precipitation amounts were about equal, because of the extra low level snow melt, the heaviest 3-day January 1862 flow on the American River at Folsom/Fair Oaks was ~ 30% larger than the 3-day flow for either the February 1986 or January 1997 floods." This conclusion is supported by snow profiles 2, 8 and 9 in our book: "Lake Sacramento". Mr. Collin's statement may be heard on the following website: www.cepsym.Info
Then click on the following: Proceedings
2010 conference
Scroll down to Hunsaker
(last name on the list)
Select audio – visual

B. EXPANDING SCALE OF NRC's FIGURE 3.1: We need to choose the optimum range of fresh snowpack depths that will make the greatest contribution to the peak flow. To avoid any controversy, we are going to use the same range of depths that existed on the ~ 51 mi.$^2$ South Yuba River watershed above Cisco just prior to the late January 1963 flood producing storm. This range of snow depths *(4 inches to 30 inches) was one of the main factors responsible for the record-breaking peak flow of 18,400 CFS that occurred at Cisco late the 31st of January 1963. *Refer to **Exhibit A** for details on how the water holding capabilities of fresh snow can dramatically increase the magnitude of the peak flow by delaying the runoff.*

**<u>*Note:</u> This estimate of the existing snowpack depth range was made using measurements taken at the Big Bend Ranger station and Soda Springs 1E. Both of these measurement stations are located within the boundaries of the ~ 51 mi.$^2$ South Yuba River watershed above Cisco.**

A storm comparison of the percentage of Yuba watershed area covered with a blanket of fresh snow 4 inches to 30 inches deep above Smartville, tells the story. On January 7, 1862 ~ 42% of the Yuba watershed was covered with a blanket of fresh snow 4 inches to 30 inches deep just prior to a record breaking flood. *See snow profile-2 in "Lake Sacramento".* Just prior to the major flood producing storm of January 1997 a similar range of snow depths covered less than 25% of the Yuba watershed. *See prolile-9.* The only major flood in the 20th century with a larger snowpack in the 4 inch to 30 inch depth range, prior to the onset of a flood producing storm, was *December 1964 with an area coverage of ~ 37%. *See profile -7.*

**<u>*Note:</u> Our research indicates the December 1964 flood peak of 171,700 CFS on the Yuba River at Englebright Dam was the highest peak flow that would have occurred at this location since January 1862.**

Since a large percentage of the Yuba watershed in early January 1862 was covered with fresh snow in the 4 inch to 30 inch depth range, we made the assumption that the late January 1963 snowpack on the South Yuba River watershed above Cisco was proportionately similar to the snowpack that blanketed the American River watershed in early January 1862. Then we compared the peak flows for each flood on the South Yuba River at Cisco – – 15,000 CFS for January 1997, 18,400 CFS for January 1963. The January 1963 peak flow was 23% higher than the January 1997 peak flow.

Maury Roos Chief Hydrologist for the California Department of Water Resources estimated a peak flow on the American River at Folsom/Fair Oaks during the major flood of January 1997 of 295,000 CFS. If we increase the Roos' estimate at Folsom by 23% we get a preliminary estimate of *365,000 CFS for the peak flow on January 10, 1862 at Folsom.

**<u>*Note:</u> Rounded off to the nearest 5,000 CFS.**

A similar peak flow estimate (~ 365,000 CFS) can be obtained by using our *modified version of figure 3.1* from the 1999 National Research Council report: Improving American River Flood Frequency Analyses.

<u>Step No.1</u>: Take the 200,000 CFS estimate of the greatest 3-day January 1862 flow at Folsom from the February 23, 1999 DWR report: Analysis of 1862 Precipitation and Runoff. Locate its position along the Y axis of our **modified figure 3.1*.

<u>Step No. 2</u>: Then move in a horizontal direction toward the right until you intersect the extended regression line.

Step No. 3: At this point drop vertically downward to the X axis. This also gives an estimated January 1862 peak flow of 365,000 CFS at Folsom.

***Note: The NRC's figure 3.1 was modified to include the DWR's estimated maximum 3-day January 1862 flow data. This modification was made by Holger Sommer. Professor Sommer taught fluid mechanics at Carnegie Melon University in Pittsburgh, Pennsylvania.**

This modification expands the scale of *figure 3.1* and allows us to estimate peak flows beyond the limits of the original graph. By increasing the January 1997 3-day flow at Folsom/Fair Oaks by 30%, as stated by Robert Collins, gives an average 3-day flow for January 9, 10 and 11, 1862 of ~ 213,000 CFS. Then using our *modified version of figure 3.1* we obtain an estimated peak flow of ~ **414,000 CFS**.

Do we have any information suggesting that runoff from the early January 1862 flood producing storm was delayed by a fresh snowpack? *See figure 1*. The hourly rate of increase in water level, (carefully measured –*words used in news report*) at Seventh and P streets in Sacramento between 7 AM and 9 PM on January 10th, sheds light on this possibility. Take note of the rapid rate of increase in hourly rates between 2 PM and 4 PM. We are confident that this rapid increase in water level was not due to a nearby levee break along the American River. A statement on page 15 of California History (spring of 1979 edition) says: " On January 9, 1862, the *upstream* levee at Rabel's Tannery again gave way, despite attempts to strengthen the line since the last break. The river levels were even higher than they had been in December." (*upstream* added for clarity) Nor do we subscribe to the idea that it was due primarily to an extra heavy burst of rain. ***See item 2 in Exhibit F.*** In Item 2 it states: At this writing (9 PM January 10, 1862 in Placerville ~ 40 miles to the east) it (the rain) seems to be coming down in torrents – – rivulets are turned into rivers which sweeps everything before them. According to the information we have from Seventh and P streets in Sacramento, the peak flow was reached at about the same time – – around 9 PM on January 10, 1862. This indicates that if the peak flow had been driven primarily by the rainfall that it would have occurred later the night of the 10th or morning of January 11, 1862.

Given the snow conditions that existed in the mountains along with continued heavy rain, we are prepared to say the sudden rise in water level, as shown in *figure 1*, is a result of a widespread collapse of the snowpack (across a substantial area of the watershed) over a period of just a few hours. This scenario is described very well in a Special Weather Summary in the Weather Bureau publication "Climatological Data, Oregon, December 1964".

**Conclusion: As indicated above, the runoff delay caused by the fresh snowpack would have significantly increased the peak flow on the American River at Folsom. This fact lends support to our 414,000 CFS peak flow estimate based upon Robert Collin's January 1862 3-day flow estimate of 30% larger than either January 1997 or February 1986.**

C. DR. PEREZ SNELL'S 1861-62 RAINFALL MEASUREMENTS FOR SONORA STRONGLY SUGGEST THE JANUARY 1862 PRECIPITATION ON THE AMERICAN RIVER WATERSHED HAS BEEN UNDERESTIMATED

Because of the unusual magnitude of Snell's measurements, their accuracy has been called into question. However, our extensive in-depth review has caused us to think otherwise. ***Exhibit B*** is a data sheet that lists Dr. Snell's Sonora precipitation measurements along with January 1862 daily observations from Sacramento and Grass Valley. It also includes daily amounts for January 10 and 11, 1862 measured at *Red Dog by W. A. Bigoli.

***Note*: Red Dog is ~ 7 miles ESE of Nevada City. Elevation: 2800 feet.**

In order to make maximum use of Dr. Snell's Sonora data we divided the January precipitation measurements into two 10 day periods. The first 10-days covers the period January 2 through January 11, 1862. The second 10-days covers the period January 14 through January 23, 1862--the same time frame in which Dr. Snell reported 30 inches of rain in Sonora. These two 10-day periods account for over 95% of the precipitation that fell during the month of January 1862 at both Grass Valley and Sacramento. Another item of interest: There are two major storms in each 10-day period. In each case the precipitation that fell during the final three days was from heavy warm storm activity.

My estimate of the location of the jetstream (storm track), during both heavy warm storms, has it coming out of Southern California and extending in a northerly direction generally parallel to the Sierra. However, the storm track across Southern California during the warm phase of the second 10-day period was farther south and east and impinged upon the San Gabriel Mountains. *See figure 2*. This development produced a peak flow on the Santa Ana River over three times larger than the peak of 100,000 CFS that occurred during the devastating flood of 1938 in the same area.

## D. EVIDENCE OF SIMILARITIES BETWEEN THE TWO SUPER FLOOD PRODUCING STORMS OF JANUARY 1862

According to rainfall data, from the Sacramento – Grass Valley region, the precipitation was uniformly widespread and the amounts were proportional. If we divide the 10-day precipitation for the second storm period into the 10-day amount for the first storm period, at both Sacramento and Grass Valley, the results are surprisingly uniform – – 79.6% in Sacramento, 79.9% in Grass Valley. Assuming these same conditions prevailed as far south as Sonora, suggests that reasonably accurate estimates can be made for the missing data at Sonora. For example: We have no measurement of how much precipitation fell in Sonora during the first 10-day period (January 2 through January 11, 1862). Using Sacramento precipitation as a guide if we multiply Dr. Snell's precipitation amount for the second 10-day period (30 inches by 79.6%) we get an estimate of **23.9 inches** at Sonora for the first 10-day storm period of January 1862.

A comparison of the magnitudes of the two 3-day flood producing storms of January 1862 at Sonora will require several additional estimates. The 3-day total rainfall for Sacramento (January 9, 10 and 11, 1862) was 3.16 inches compared with 3.15 inches during the 3-day period (January 20, 21 and 22, 1862). Now if we divide 3.16 inches by the first 10-day Sacramento storm total of 6.55 inches we get 48%. Following the same procedure with the second 10-day storm period, gives an answer of 38%. In summary these percentages represent that portion of the total 10-day precipitation produced by warm storm activity. If we multiply the total estimated precipitation for the first 10-day period (23.9 inches by 48%), we get an estimated 3-day warm storm total at Sonora of **11.47 inches**. Using data from the second 10-day period (30 inches multiplied by 38%) gives a similar three-day estimate at Sonora of **11.4 inches**. This is another example of the proportional distribution of the precipitation that existed throughout the region.

All of these comparisons are suggesting that the impact of the two storms on the region was similar. Do we have any runoff data that supports this conclusion?

<u>In Sacramento</u> we have the following information:

1. The flood of January 1862 reached its highest point at Seventh and P about 9 PM on the 10th--a rise of 69.5 inches since 7 AM. *<u>Source:</u> The floods of 1861-62 at and near Sacramento, compiled from daily newspapers by City Engineer's Grunsky and Given.*
2. On page 15 of California History (The magazine of the California Historical Society), for the spring of 1979: "By the morning of January 10th, the southern part of Sacramento was under two and a half feet of water."
3. January 22, 1862: Water in the city is 5 inches above December 9, 1861 and 15 inches below January 10th. *<u>Source</u>: same as in item number one above. <u>Location</u>: believed to be the same as in item one.*

<u>Summary:</u> Based upon the above information, we can draw the following conclusions:

1. At 9 PM on January 10, 1862, the depth of the water at Seventh and P in Sacramento was ~ 100 inches.
2. During the flood of January 22, 1862, the maximum depth of the water at Seventh and P was ~ 85 inches.

<u>At Nelson's Point</u> (~ 10 miles south of Quincy) on the middle fork of the Feather River, a gold miner named Plug sent the following information to the editor of the Plumas Standard:

1. A letter from Plug dated January 15, 1862 stated: "About Saturday noon January 11, 1862 the water reached its highest mark, which was some 28 feet above its ordinary level."

2. A second letter from Plug (10 days later) stated: "We are just now recovering from another deluge—our third great flood. The river reached the height of 26 feet above ordinary low water mark."

<u>Discussion and Conclusions:</u> A two foot difference in peak flows appears to be reasonable. This can be explained, at least in part, by the **more**

**favorable watershed runoff conditions** that existed prior to the heavy warm storm of January 9, 10 and 11, 1862. The same line of reasoning can be used to at least partially explain the difference in the water levels at Seventh and P streets in Sacramento. Another argument to consider is presented in the following section -- section E.

## E. EVIDENCE OF DIFFERENCES BETWEEN THE TWO SUPER FLOOD PRODUCING STORMS OF JANUARY 1862

Looking in a northerly direction, there is a bend in the Sierra toward the east as it crosses the American River watershed and is the reason much of the Western section has a *southerly aspect.* This becomes discernible on a relief map when the elevation of Placerville (at 1,890 feet) is compared with other higher elevation precipitation measurement stations farther north, such as Iowa Hill (at 2,930 feet), also located near the same longitude. This combination of geographical features provides a *channel for the strong southerly winds which accompany heavy warm storms. *See* ***Exhibit C.*** It also appears to make it possible to use (what we call) **orographic lift factors** to make reasonable estimates of rainfall amounts at higher elevations (such as Blue Canyon) when using data from a low-level upwind station like Placerville.

**<u>*Note:</u> The existence of channeling is indisputable! A comparison of the 3-day rainfall totals at Deer Creek powerhouse (elevation 3,700 feet--located just below Blue Canyon along the same longitude line as Iowa Hill) and Blue Canyon shows they are similar. This is true even though the elevation at Blue Canyon ranged from 1,000 feet higher than Deer Creek before 1945 on up to 1,600 feet higher after 1945. Without the channeling effect, the 3-day totals at Blue Canyon (5,280 feet elevation) would have undoubtedly been larger than Deer Creek.** *For more information on channeling in this region, see* ***Exhibit D.***

In both January 1862 warm storm cases the channeling of the southerly upslope winds, along this segment of the Sierra, appears to be similar. <u>But there is a subtle difference.</u> As we mentioned earlier, the southerly jetstream that was in play during the second warm storm was located farther south and east. *See figure 2.* We know this is true in Southern California because of the record-breaking peak flow of 317,000 CFS that occurred on the Santa Ana River January 22, 1862. Toward the

North, a comparison of the 3-day Grass Valley rainfall amounts for both January warm storms indicate the winds aloft over the Grass Valley-Nevada City area were more southeasterly during the second storm. The 12.2 inches that fell in Grass Valley on January 9-11 compares favorably with the estimated 11.47 inches recorded in Sonora during the same period of time. The Grass Valley amount is larger due in part to its higher elevation. On the other hand, a comparison of the 3-day total that fell at Grass Valley (*8.92 inches) and the estimated 11.4 inches that fell in Sonora during the second warm storm defies similar logic because the comparison is reversed.

We have concluded this disparity was caused by a rain shadow that developed over the Grass Valley-Nevada City area during the second warm storm. A close examination of our large relief map backs this conclusion. Just east of Grass Valley and Nevada City, there is a bend in the Sierra ridgeline toward the northwest. It is our opinion that this bend caused the wind which was already blowing from the southeast to become even more southeasterly with a down slope component. Comparatively speaking this caused a sharp decrease in Grass Valley rainfall. *See **Exhibit C.***

***Note: A review of the available precipitation reports at the beginning and ending of the 3-day period, suggests the actual 72 hour rainfall in Grass Valley during the second warm storm was closer to 8.5 inches.**

TRANSITION: There was likely minor rain shadow interference in the Grass Valley-Nevada City area during the first superflood producing storm. However, it wasn't enough to drop the 3-day storm total for Grass Valley below that of Sonora. This places the January 9 – 11, 1862 storm in the same general category as the major storms of the 20th century because in all cases the 3-day and 10-day precipitation amounts were larger in Grass Valley than Sonora. This indicates that the atmospheric dynamics for the early January 1862 storm and the major flood producing storms of the 20th century were similar. As a result the two heaviest storms of the 20th century -- February 1986 and January 1997 were selected to be tested to see which one had the precipitation producing dynamics that compared best with the precipitation producing dynamics that prevailed during the January 9–11, 1862 storm.

## F. DETERMINING WHICH 20TH CENTURY STORM COMPARED BEST WITH THE JANUARY 9–11, 1862 SUPER STORM

Before we run a test, we need to establish a **standard of comparison.** The DWR in their February 23, 1999 report made two 3-day 1862 rainfall estimates for Blue Canyon. One was for **20 inches** the other **21 inches** and will be the standard used to select which of the two heaviest 20th century storms comes closest to matching the January 9 –11, 1862 storm. These estimated 3-day rainfall totals for Blue Canyon were the **cornerstones** of two different methods used by the DWR to estimate the maximum 3-day January 1862 flow on the American River at Folsom/Fair Oaks. Since no 1862 rainfall data are available for Blue Canyon, a 3-day rainfall (warm storm) relationship was developed between the Grass Valley – Nevada City area and Blue Canyon using 20th century data. *See figure 3.*

Our goal is to estimate the Blue Canyon rainfall for the January 9 – 11, 1862 storm using January 1862 rainfall data from the Grass Valley-Nevada City area as the starting point. We chose Red Dog. It is located ~ 7 miles ESE of Nevada City (elevation 2800 ft.) and is within ~ 8 air miles of Iowa Hill – – another key station used in our analysis. Fortunately a resident of Red Dog by the name of W. A. Bigoli, measured the rainfall for the two heaviest days – – the 10th and 11th. The total for the two days in Red Dog was 11.32 inches compared with 9.43 inches in Grass Valley. Since the observation times of these two measurements were only three hours apart, using ratio and proportion along with the 2.77 inches of rain that fell in Grass Valley on January 9th, should give a fairly accurate answer. Our estimate of the precipitation that fell at Red Dog on the 9th is 3.33 inches—making the estimated 3-day total for Red Dog **14.65 inches.**

Since our test involves estimating the 3-day January 9-11, 1862 storm total for Blue Canyon, we need to calculate (what we call) <u>the 3-day orographic lift factors</u> between Iowa Hill and Blue Canyon for both the February 1986 and January 1997 flood producing storms. After making adjustments for differences in elevation, combining these results with the 14.65 inch estimated storm total for Red Dog will give a final 3-day estimate at Blue Canyon for both 20th century storms.

## <u>ORIGINAL THREE-DAY OROGRAPHIC LIFT FACTORS</u> FOR FEBRUARY 1986 AND JANUARY 1997

| February 1986 | Station | January 1997 |
|---|---|---|
| 18.64 in. | Blue Canyon 5,280 ft. | 16.10 in. |
| 12.64 in. | Iowa Hill 2,930 ft | 12.89 in. |
| 9.04 in. | Placerville 1,890 ft. | 8.28 in. |

**Note: A more accurate adjustment for the difference in elevation between Red Dog and Blue Canyon, is obtained when the difference in 3 -day rainfall amounts between Iowa Hill and Blue Canyon is expressed in thousandths of an inch per 100 feet.**

February 1986: Difference in 3-day rainfall totals (Iowa Hill – Blue Canyon): 6 in. divided by 23.5 = .255 in./100 ft.
January 1997: (Following the same procedure) = .136 in./100 ft.
Difference in elevation between Red Dog and Iowa Hill – – 130 ft..

Orographic lift factor for February 1986: 1.3 x .255 = .33 in.
Orographic lift factor for January 1997: 1.3 x .136 = .18 in.

Blue Canyon 3-day estimate using the original February 1986 lift factors

14.65 in. Red Dog 3-day total
6.00 in. lift factor (Iowa Hill – Blue Canyon)
.33 in. elevation adjustment (Red Dog – Iowa Hill)
**20.98 in.**

Blue Canyon 3-day estimate using the original January 1997 lift factors

14.65 in. Red Dog 3-day total
3.21 in. lift factor (Iowa Hill –Blue Canyon)
.18 in. elevation adjustment (Red Dog – Iowa Hill)
**18.04 in.**

**As you can see the 3-day 20.98 inch estimate, using the orograhic lift factor from the February 1986 storm, compares very well with the DWR's 3-day estimates of 20 and 21 inches.**

G. ADJUSTING BLUE CANYON OBSERVATION TIME TO MATCH IOWA HILL AND PLACERVILLE

At this juncture we made a decision to adjust the Blue Canyon 24-hour precipitation observation time from midnight to 8 AM. This was done to make our analysis more compatible with the 24-hour precipitation amounts measured at Placerville and Iowa Hill. Both of these stations have 8 AM observation times. This was relatively easy to accomplish since Blue Canyon measures the precipitation in hourly increments.

However the observation time adjustment increased the heaviest 3-day rainfall total at Blue Canyon for the February 1986 storm from **18.64** inches to **19.69** inches. As a result a new lift factor calculation was made between Iowa Hill and Blue Canyon along with a new 130 foot elevation adjustment estimate between Red Dog and Iowa Hill. The Red Dog to Iowa Hill adjustment increased from **.33** of an inch to **.39** of an inch while the original orographic lift factor between Iowa Hill and Blue Canyon increased from **6** inches to **7.05** inches. This gives an adjusted 3-day estimate for Blue Canyon, following the Red Dog – Iowa Hill – Blue Canyon route, of **22.09 inches.** *See **Exhibit E** for more details on the final Red Dog –Iowa Hill – Blue Canyon calculations.*

## H. ESTIMATING BLUE CANYON RAINFALL ALONG A SONORA – PLACERVILLE – IOWA HILL – BLUE CANYON ROUTE.

In view of these promising results we decided to estimate the 3-day rainfall total for Blue Canyon following along a Sonora – Placerville – Iowa Hill – Blue Canyon route. We took our 11.47 inch (January 9 – 11, 1862) storm estimate for Sonora and projected it northward toward Placerville near the southwestern boundary of the American River watershed. First, we should point out that the elevations of Sonora and Placerville are similar, ~ 1,800 feet for Sonora compared with 1,890 feet at Placerville. In addition, there doesn't appear to be any serious terrain impediments to southerly airflow between the two points. **This suggests that the 3-day rainfall amounts, at Sonora and Placerville were essentially equal (11.47 inches)** – –at least for the first warm storm (January 9, 10 and 11, 1862). This may not have been true for the second warm storm because of an increasing chance of a rain shadow as you move northward from the vicinity of Placerville toward the Grass Valley – Nevada City area. The 3-day rainfall of 12.2 inches in Grass Valley supports our Sonora estimate of 11.47 inches.

**Are you ready for this?** The estimated 3-day rainfall at Blue Canyon is **22.12 inches** for the January 9 – 11, 1862 storm when following the Sonora – Placerville – Iowa Hill –Blue Canyon route. *See **Exhibit C.*** This is essentially the same estimate **(22.09 inches)** obtained from the Red Dog – Iowa Hill – Blue Canyon route. See ***Exhibit E** for proof of this assertion. See **Exhibit F** for reports that discount the role that rain shadows may have played during the January 9–11, 1862 storm along the western and southern sections of the American River watershed.*

Note: At this point it is time to stop and review what has been accomplished. There are no January 1862 rainfall measurements available for Blue Canyon. The method generally used to solve this problem involves developing a 3-day heavy warm storm relationship between the Grass Valley-Nevada City area and Blue Canyon using 20th Century data. *See figure 3.* Then using the DWR's January 1862 3-day estimate of **14.7 inches** for Nevada City gives a 3-day estimate for Blue Canyon of **~ 21 inches**. To successfully develop this type of a relationship requires a larger storm sample than just one case. However using (what we call) **orographic lift factors**, we have managed to successfully develop and test another method of estimating the 3-day January 9-11, 1862 rainfall total for Blue Canyon. It allows us to make use of Dr. Snell's 1861-62 Sonora rainfall measurements. *The details of this method are outlined in **Exhibit E.***

I. USING THREE-DAY LIFT FACTOR INCREASES FOR FEBRUARY 1986 STORM TO ESTIMATE THREE-DAY RAINFALL TOTALS AT BLUE CANYON FOR THE JANUARY 9 – 11, 1862 STORM

| **February 1986** | Station | Elevation |
|---|---|---|
| **25.05 in.** | **Blue Canyon** | **5,280 ft.** |
| **(56% increase)** | | |
| **16.06 in.** | Iowa Hill | 2,930 ft. |
| **(40% increase)** | | |
| **11.47 in.** | Placerville | 1,890 ft. |

**Conclusion: The difference in the Blue Canyon rainfall totals, that correspond with the adjusted February 1986 lift factor and the lift factor increases as indicated by the heavier three-day rainfall in 1862, is 25.05 in. – *22.12 in. = 2.93 in. This difference represents a rainfall**

**increase of <u>13.3%</u> at Blue Canyon when compared with the adjusted February 1986 storm total.**

<u>*Note</u>: This estimate comes from Route "B": Sonora – Placerville – Iowa Hill –Blue Canyon and is based upon Dr. Snell's January 1862 rainfall measurements in Sonora.

## J. OTHER FAVORABLE WATERSHED CONDITIONS THAT CONTRIBUTED TO THE RUNOFF PRODUCED BY THE HEAVY WARM STORM OF JANUARY 9, 10 AND 11, 1862

In late December 1861 three significant storms hit the Northern and Central Sierra. The first two storms had a snow line of ~ 4,600 feet on the Yuba watershed and produced heavy amounts of snow above 5,500 feet. The third storm in the series was warmer with rain at times as high as 6,000 feet. As a result, the lower lip of the snowpack (a product of the two previous colder type storms) was the recipient of approximately 4 to 5 inches of rain. Our rough calculations indicate that the precipitation from this warmer storm along with the accompanying snow melt would have saturated or nearly saturated the snowpack up to a depth of ~ 8 inches by New Year's Day. The elevation at which the snowpack was ~ 8 inches deep was ~ 5,300 feet. At the same time, we also estimate a 200 foot rise in elevation of the snowpack lip--up to 4,800 feet.

The weather turned unusually cold in early January 1862 and by the morning of the 4th, we estimate the minimum temperature at 5,000 feet was close to 0°F. Temperatures this low would turn the nearly saturated 500 foot wide blanket of snow into a sheet of ice or icy snow. In addition we estimate a minimum temperature of 8°F at an elevation of 4,200-4,300 feet. A reading this low suggests that the watershed soil was frozen to a depth of several inches.

During the afternoon and evening of January 5th, a heavy snowstorm dumped up to a foot of snow as low as the foothills with lighter amounts near the valley floor. Higher up the snowfall amounts were greater, ~ 3 feet fell between 4,000 and 5,000 feet. This heavy snow episode was followed by heavy warm flood producing rains on January 9, 10, and 11, 1862.

After an examination of the above sequence of weather events along with our estimate of the watershed conditions just prior to the warm flood producing storm, **we have reached the following conclusions:**

1. The ~ 4,800 foot elevation mark, was the lower edge of a 500 foot elevational band of ice and icy snow.
2. Below 4,800 feet we estimate several inches of frozen watershed soil, as low as 3,300 feet. <u>Early on freezing rain was also likely</u>!
3. Because of the sheet of ice and icy snow along with a layer of frozen soil several inches thick as low as 3,300 feet, runoff from ~ 20 to 25% of the watershed above Smartville, during the heavy warm storm of January 9–11, 1862 was significantly greater than it otherwise would have been.
4. In addition the snowpack was deep enough above 5,500 feet that most of the 4-5 inches of rain that fell as high as 6,000 feet, during the last storm of December 1861, remained in the snowpack--thus increasing the density. Because of this when the heavy rains of January 9–11 hit, the threshold density of the snowpack was reached earlier and drainage from the snowpack below 6,000 feet started sooner which increased the runoff. As a result another ~ 8% of the watershed area contributed extra water to the flood.

**<u>Additional Comments:</u>**

**1. Since the above Yuba watershed assessment was made near the northern boundary of the American River watershed, we believe our findings are reasonably representative of the December 1861 – January 1862 conditions that existed on the American River watershed.**
**2. Because of limited data, admittedly the above estimates of the watershed conditions are rough approximations. However, we believe they give an adequate description of the conditions that existed just prior to the onset and during the early stages of the heavy warm flood producing storm of January 9 – 11, 1862.**

## K. FINAL PEAK FLOW ESTIMATE ON AMERICAN RIVER @ FOLSOM/ FAIR OAKS ON JANUARY 10, 1862

1. **Principal Items Used To Make Final Peak Flow Estimate**
   a. Collins Estimate: January 9 – 11, 1862 flow **30% larger** than the 3-day maximum flows of either the February 1986 or January1997 floods. *See page 1 of the Main report.*
   b. Our Estimate (using Dr. Snell's 1862 Sonora precipitation data): The 3-day precipitation at Blue Canyon for the storm (January 9 – 11, 1862) has been underestimated ~ 13.3 %. *See section I of the Main report.*

**Note: Before any runoff calculations can be made, we need to convert the 13.3% underestimate of the January 9 – 11 Blue Canyon precipitation to an acceptable runoff percentage. As a result we selected the same precipitation/runoff ratio of 1.7 used by the DWR in their calculations of the runoff produced by the January 9— 11, 1862 storm. The 3-day January 1862 precipitation estimates for Blue Canyon were the cornerstone of the methods used by the DWR to estimate the 3-day 1862 runoff at Folsom/Fair Oaks. Therefore we are assuming it (the heaviest 3-day Blue Canyon precipitation) was considered to be an index representative of the entire American River watershed.**

**Calculations:** If our interpretation of a 1.7 precipitation/runoff ratio is correct it means that for every 1.7 inches of rain that falls there will be 1 inch of runoff. Stating it another way: It also means that ~ 60% of the rain that falls will result in runoff. Following this definition, the underestimate of 13.3% in the precipitation that fell at Blue Canyon on January 9 – 11, 1862 amounts to **~ 8% more runoff.**

**Combining the Collins Estimate with Our Estimate** and calculating the peak flow on the American River at Folsom/Fair Oaks January 10, 1862.

Step No. 1: Take the official maximum 3-day flow for the February 1986 flood on the American River @ Folsom/Fair Oaks (166,000 CFS) and multiply it by 38%. **Result:** 63,080 CFS
Step No. 2: Add (63,080 CFS) to the 3-day February 1986 (166,000 CFS) flow for a total of **229,080 CFS**. This is the estimated maximum 3-day flow on the American River at Folsom/Fair Oaks produced by the storm of January 9-11, 1862.
Step No. 3: Now referring to our modified version of NRC's figure 3.1 we obtain an estimated peak flow of **~ 468,000 CFS.**

2. **Secondary Items Considered In Making Peak Flow Estimate**
    a. The water holding capabilities of fresh snow and how this can dramatically add to peak flows produced by heavy warm storms.
    b. How the early January 1862 cold spell increased the runoff during the heavy warm flood producing storm of January 9 – 11, 1862.
    c. How the three heavy storms of late December 1861 made a runoff contribution to the flood producing storm of January 9 – 11, 1862.

<u>Note:</u> **All three of the above secondary items were researched as outlined in *Section J* of this report and in our opinion did make a meaningful contribution to the runoff produced by the superstorm of January 9 – 11, 1862. There are two questions that need to be addressed: 1) Did the use of the DWR's 1.7 precipitation/runoff ratio include these items? 2) if not, how much did they add to the 3-day flow?**

**<u>Discussion:</u>** A statement in the DWR's February 23, 1999 report: Analysis of 1862 Precipitation and Runoff says an estimated runoff volume for 1862 was made using the 1997 precipitation/runoff ratio of 1.7. Then it goes on to say this was done because the 1862 event had wet antecedent conditions like the 1997 event. However, an investigation shows that none of the special 1862 watershed factors (listed above) were equaled or exceeded during the 1996 – 97 flood. This indicates that the antecedent watershed contribution to the runoff during the early January 1862 flood exceeded the antecedent watershed contribution to the January 1997 flood.

**<u>Conclusion</u>:** In answer to the second question: How much did the secondary items listed above contribute to the three day flow? Of course the answer is simple: we do not have the kind of data needed to make such a determination. However, in view of the research contained in *section J* of this report, we feel comfortable in adding 1 1/2% to the final three day runoff of **229,080 CFS**.

<u>Step No. 1</u>: Multiply 229,080 CFS by 1 1/2% = 3,436 CFS.
<u>Step No. 2</u>: Add 229,080 and 3,436CFS = 232,516 CFS
<u>Step No. 3:</u> Referring to our modified version of NRC's figure 3.1 we obtain a **final estimated peak flow of <u>~ 475,000 CFS</u>**.

## L. FINAL OBSERVATIONS AND CONCLUSIONS

**After over eight years, punctuated with intense periods of research and study, it is hard for us to imagine how Sacramento will escape the onslaught of a storm and flood series similar to that of December 1861 – January 1862.**

**To be more specific about Sacramento: Assuming a sequence of storm and flood activity as occurred in 1861 – 62, the current levee upgrades and the admirably bold flood control plan that calls for lowering the storage levels in Folsom Lake to ~ 400,000 acre feet ahead of the flood has a reasonable chance of saving Sacramento from the first superflood. The high volume flows that began when the first major flood hit, ~ 30 days before the first superflood, will continue until the second superflood takes over ~ 10 to 12 days later. This extended period of high flows will weaken the levees and only add to the flood control problems a second superflood will bring. With the superfloods occurring less than two weeks apart, we expect this will be the final straw and breaks will develop in the Sacramento levee system.**

**Several years ago we made a preliminary analysis of a few of the 50 heaviest consecutive days of runoff on the American River at Fair Oaks. Specifically we compared the 50 heaviest consecutive days of runoff during the December 1996 – January 1997 flood event with our rough estimate of what the 50 heaviest consecutive days of runoff would have been during the 1861-62 series. Our estimate of the runoff in 1861-62 was ~ 45% greater. Conclusion: Extended high flows will increase stress on the levees.** *Lake Sacramento's Diagram B is proof of high flows.*

**A Few Additional Comments Regarding The First Superflood: If the flood control plan is properly executed, Sacramento will likely be saved. But it is hard to visualize the Delta remaining dry with what Professor Jeffery Mount described as ~ 1100 miles of fragile levees. The record or near record flows that will be occurring on rivers draining into the Sacramento and San Joaquin Valleys will overwhelm the Delta levees.**

**Leon Hunsaker, MS (MIT)**
**with**
**Claude Curran, Ph D (U of Oklahoma)**
**April 10, 2013**

## EXHIBIT "A"

This exhibit explains how the water holding capabilities of fresh snow can dramatically increase the magnitude of the peak flow in nearby streams and rivers. Walter U. Garstka and several other scientists from the Bureau of Reclamation conducted a laboratory experiment in Denver, Colorado on December 20, 1951 to determine what happens when water is sprinkled on a fresh snowpack. It wasn't until years later that Frederick A. Bertle, a hydraulic engineer for the Bureau of Reclamation, presented the results to the Western Snow Conference held in Colorado Springs April 1965.

Mr. Bertle's introductory remarks were as follows: "Adequate design of the spillway for a major storage reservoir requires the estimation of a synthetic maximum probable flood hydrograph. This maximum probable flood must represent a realistically critical combination of the major causative hydrological factors. In many areas of the Western United States, the maximum floods occur as a result of an extreme rain falling on a relatively fresh snow cover. The snowpack will absorb the rainfall from the early part of the storm and release it later. As a result of the release of stored water from the snowpack, in addition to the melting of snow and rainfall itself, the runoff peak flow may be considerably more severe than would occur from the rainfall alone."

*Note: The data contained in Mr. Bertle's paper were expanded and published in June 1966 as a water resources technical publication -- Engineering Monograph No. 35-- Bureau of Reclamation.*

At this same April 1965 Snow conference in Colorado Springs, H. Riesbol (Chief Hydrologist, Bechtel Corporation), L. Hunsaker (Senior Meteorologist, PG&E Co.) and D. Mahoney (Engineer Trainee, PG&E Co). also presented a paper. The title: Role of Snowmelt and Snowpack Storage in Production of Runoff on Feather River Basin During December 1955 Flood. The results showed significant amounts of water stored in the snowpack at the end of the storm. There was ~ 24% and 33% liquid water by weight at the 6,000 and 7,000 foot levels respectively thus supporting Mr. Bertle's conclusions. The prevailing wisdom at the time is stated on page 183 of Hydrology For Engineers, by Lindsley, Kohler and Paulhus in Mcgraw-Hill's 1958 edition. It says: "Runoff from snowmelt water retained in the snowpack is not effective. Limited data indicate that snow can retain from 2 to 5% liquid water by weight." **A new concept is born! The water holding capability of fresh snow has been proven to be substantial.**

## EXHIBIT "B "

Exhibit B is a data sheet that lists daily precipitation amounts for January 1862 at Sacramento and Grass Valley. It also includes a couple of daily measurements (January 10 and 11) made at Red Dog. In addition there are several precipitation reports for Sonora given to newspapers by Dr. Snell. The content of these documents and reports are listed below:

A. SONORA

1. Sacramento Union, Tuesday, January 21, 1862: TREMENDOUS RAINFALL – The Stockton Independent says that a rain gauge, carefully kept and registered by Dr. Snell of Sonora, Tuolumne County, shows that from the 11th of November 1861, to the 14th of January 1862, 72 inches of water fell at that place.

2. Nevada Democrat, Thursday, January 23, 1862: The amount (of rain) that fell at Sonora, according to a gauge by Dr. Snell up to the 14th instant was 72 inches.

3. Sacramento Union, February 7, 1862: Rain in Tuolumne. – Dr. Snell of Sonora, a gentleman who has the reputation of making correct meteorological observations, reports that from November 10,1861 to January 23,1862, 102 inches of rain had fallen.

B. RED DOG

1. Source: Page 30 of the Hand-Book Almanac under section titled-Notabilia of The Floods of 1861-62

2. Data: 24-hour rainfall ending at 9 AM January 10th-5.82 inches.
" " " " " 11th -5.50 "

C. GRASS VALLEY

1. Source: Grass Valley National Newspaper, Volume 9, Number 78, February 6, 1862, page 2. Observation time: Noon

2. Daily Precipitation for January 1862 (in inches)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | .05 | .23 | | .20 | 1.55 | .13 | .13 | 2.77 | 5.10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 4.33 | .09 | | 1.42 | .03 | 1.28 | 2.30 | 3.75 | .43 | 3.60 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| .70 | 3.30 | 1.32 | | | | .20 | | .21 | .90 |
| 31 | | | | | | | | | |

D. SACRAMENTO

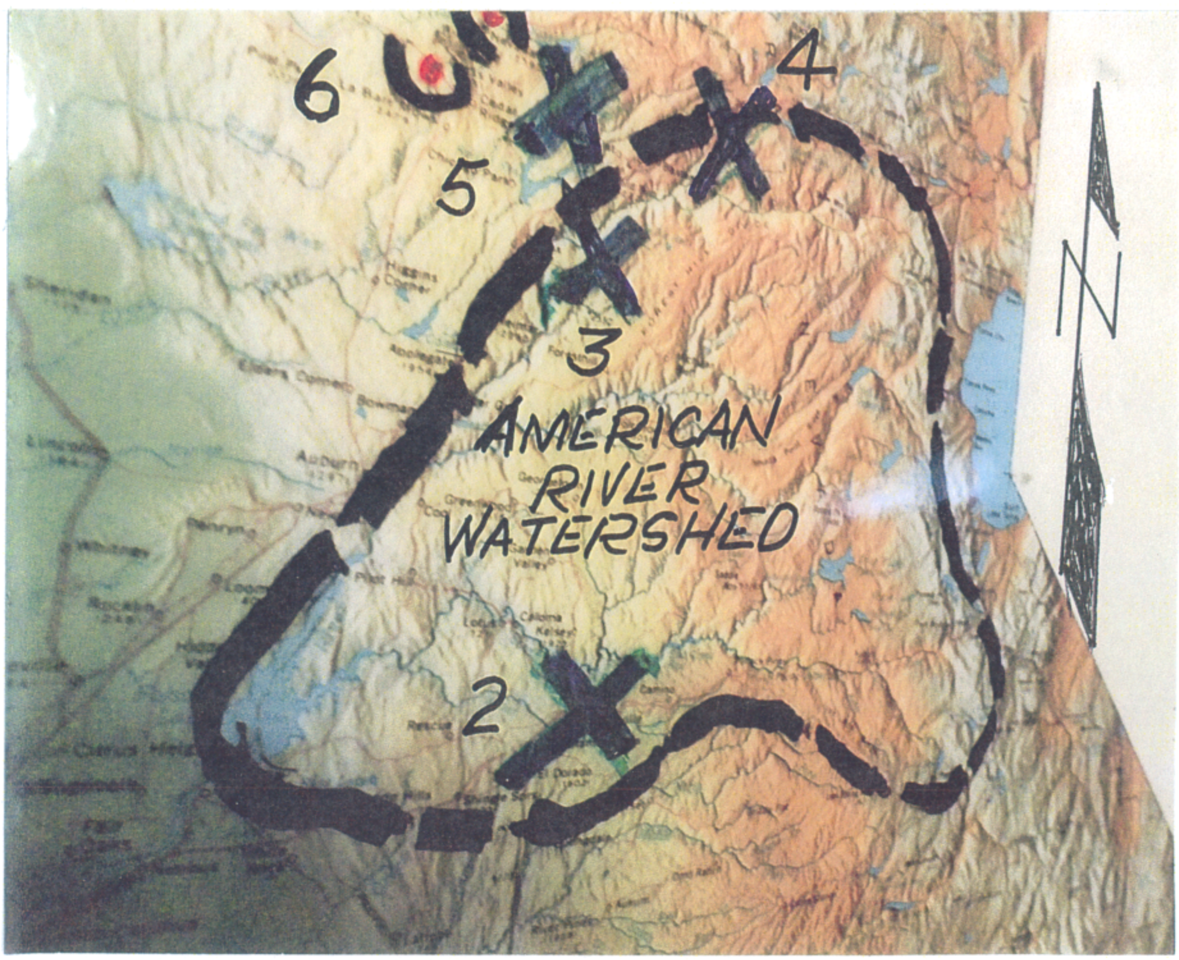
1. <u>Source</u>: State Climatological Files: *CA Rain*
2. <u>Daily Precipitation for January 1862 (in inches)</u>

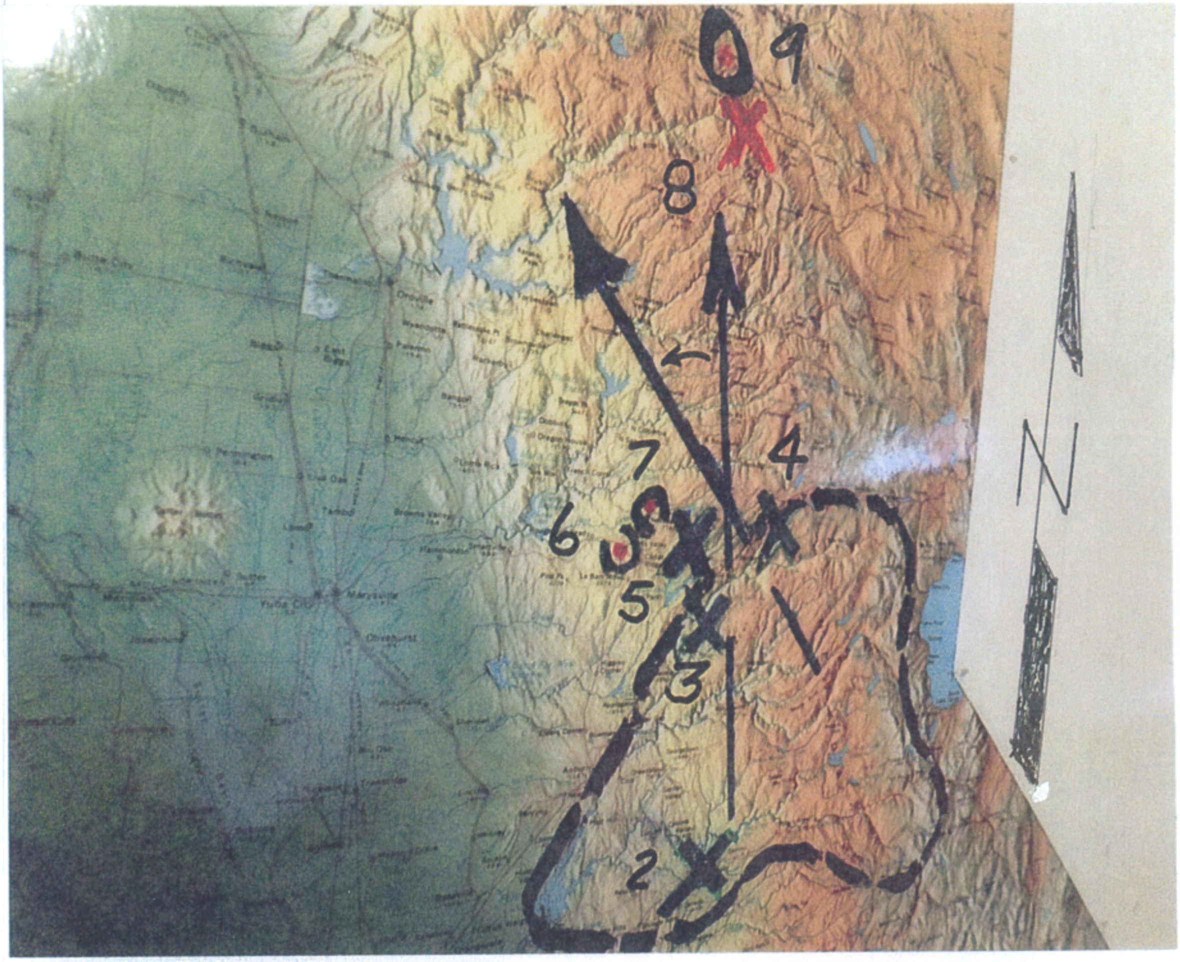
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | .02 | | 2.08 | .61 | | .68 | 1.40 | .76 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1.00 | | | .68 | | 3.15 | 1.25 | | | 1.65 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| .80 | .70 | | | | | | | .25 | |
| 31 | | | | | | | | | |

## EXHIBIT "C"

There are three segments of a relief map showing the orientation of the Sierra ridgeline as it extends from just south and east of Sonora northward across the American River watershed as far north as Quincy. Geographical locations of interest are identified by number. Refer to the following locator key:

1. Sonora
2. Placerville
3. Iowa Hill
4. Blue Canyon
5. Red Dog
6. Grass Valley
7. Nevada City
8. Nelson's Point
9. Quincy





9
8
7
4
6
5
3
2
N
Marysville


Roseville
Elverta
Antelope
Rio Linda
North Highlands
Orangevale
Fair Oaks
Carmichael
W Sacramento
SACRAMENTO
Rancho Cordova
Nimbus
White Rock
2
Florin
Freeport
Clarksburg
Sloughhouse
Bridge House
Sheldon
Elk Grove
Wilton
Franklin
Hood
Courtland
Pt Pleasant
Twin Cities
Herald
Clay
Galt
Vorden
Walnut Grove
Ryde
Thornton
Collierville
Woodbridge
Lodi
Victor
Lockeford
Clements
Isleton
Terminous
Henderson Village
1

**EXHIBIT "D"**

The heaviest consecutive three day rainfall amounts for 10 of the heaviest warm storms during the period 1907 through 1964 were selected to illustrate the effects of channeling in the Grass Valley – Nevada City – Deer Creek –Blue Canyon – Lake Spaulding – Bowman Dam region. Channeling occurs in this region when the strong southerly winds, associated with heavy storm activity, interact with terrain features that are more open toward the north. The following cross-section illustrates this point:

*Note: The three day rainfall amounts listed below, are for three stations at different elevations located near the same latitude line.*

| | | STATION | |
|---|---|---|---|
| Latitude | 39 deg. 13 min. No. | 39 deg. 18 min. No. | 39 deg. 19 min. No. |
| Date | Grass Valley | Deer Creek | Lake Spaulding |
| mo./yr. | (2,400 ft.) | (3,700 ft.) | (5,150 ft.) |
| Mar. 1907 | 10.2 in. | 14.0 in. | 14.2 in. |
| Jan. 1909 | 13.6 in. | 20.2 in. | 12.8 in. |
| Mar. 1928 | 10.2 in. | 14.0 in. | 13.3 in. |
| Dec. 1929 | 8.0 in. | 13.4 in. | 10.2 in. |
| Dec. 1937 | 10.8 in. | 13.4 in. | 14.2 in. |
| Nov. 1950 | 11.4 in. | 16.4 in. | 14.6 in. |
| Dec. 1955 | 12.8 in. | 18.8 in. | 18.8 in. |
| Oct. 1962 | 18.0 in. | 20.4 in. | 18.6 in. |
| Jan. 1963 | 12.6 in. | 18.8 in. | 16.2 in. |
| Dec. 1964 | 14.2 in. | 19.8 in. | 20.0 in. |
| **Average:** | **12.2 inches** | **16.9 inches** | **15.3 inches** |

Note: Above information taken from a graph. Accuracy of each reading within ~ 1/10 of an inch. Blue Canyon latitude: 39 deg. 17 min. No.
" " elevation: 5,280 ft.

**Discussion and Conclusions:**

1. The 1909 three-day total at Bowman Dam (13.59 in.) supports the three-day total of 12.8 in. at Lake Spaulding.
2. The 1962 three-day rainfall total at Nevada City (19.04 in.) supports the three-day total of 18.0 in. at Grass Valley.
3. The generally larger rainfall amounts at Deer Creek are due to the stronger winds caused by channeling. It also suggests that Blue Canyon is close enough to be included in the outer edge of this increased flow.

**EXHIBIT "E"**

Verifying estimated rainfall totals for superflood producing storm of January 9, 10 and 11, 1862 at Blue Canyon. Estimates were made along two different routes. Route "A": Red Dog – Iowa Hill – Blue Canyon.
Route " B": Sonora –Placerville – Iowa Hill – Blue Canyon.

Route "A": Red Dog – Iowa Hill – Blue Canyon

Section I: Estimated 3-day rainfall (January 9 – 11, 1862) for Red Dog

Step No.1: Refer to Exhibit B for a copy of rainfall data.

| | Red Dog | Grass Valley |
|---|---|---|
| January 9 | no data | 2.77 in. |
| January 10 | 5.82 in. | 5.10 in. |
| January 11 | 5.50 in. | 4.33 in. |
| Two Day Total : | 11.32 in. | 9.43 in. |

Step No. 2: Using ratio and proportion to estimate rainfall amount for Red Dog on January 9th.

$$\frac{9.43 \text{ in.}}{11.32 \text{ in.}} :: \frac{2.77 \text{ in.}}{X} \qquad X = \frac{11.32 \times 2.77}{9.43} = \mathbf{3.33 \text{ in.}}$$

Step No. 3: Daily rainfall (January 9 – 11, 1862) at Red Dog.

3.33 in. January 9, 1862 estimate
5.82 in. January 10, 1862
5.50 in. January 11, 1862
**14.65 in. Final 3-day estimate for Red Dog**

Section II: Estimating 3-day (January 9 – 11, 1862) rainfall for Blue Canyon.

Step No. 1: Combining 3-day adjusted orographic lift factor (Iowa Hill – Blue Canyon) for February 1986 storm with Red Dog's 3-day rainfall total. *See page 11 of Main report.* 14.65 in. + 7.05 in. = 21.70 in.

Step No. 2: Make adjustment for the 130 foot difference in elevation between Iowa Hill (2,930 feet) and Red Dog (2,800 feet).

1.3 x .30 in./100 feet = .39 in.

Step No. 3: **Final Blue Canyon estimate along Route "A":**
21.70 in. + .39 in. = **22.09 in.**

Route "B": Sonora – Placerville – Iowa Hill – Blue Canyon

Section I: Estimated 3-day rainfall (January 9 – 11, 1862) for Sonora.

Step No.1: Estimate precipitation total for the first January 1862 10-day storm period at Sonora (January 2 through January 11, 1862) using Sacramento data as a guide. Divide first 10-day storm period total in Sacramento (6.55 in.) by the total for the second 10-day storm period (8.23 in.). **Result: 79.6%**

Step No. 2: Assuming the same proportional distribution of the precipitation in the Sonora area, multiply Dr. Snell's (30 in.) total for the second 10-day period by (79.6%). **The result: 23.9 in.** which is the estimated total at Sonora for the first 10-day storm period.

Step No. 3: Estimating 3-day rainfall total for Sonora (January 9 – 11, 1862), using Sacramento precipitation distribution as a guide. Divide the first 10 day Sacramento storm total (6.55 in.) into the 3-day warm storm total (3.16 in.). **Result: 48%.**

Step No. 4: Multiply 23.9 in. by .48 = **11.47 in**. This is the estimated 3-day total at Sonora for the January 9 – 11, 1862 storm.

Section II: Estimated 3-day rainfall (January 9 – 11, 1862) for Blue Canyon along Route "B": (Sonora – Placerville – Iowa Hill – Blue Canyon).

Step No. 1: Estimated rainfall amounts listed by segment

11.47 in. Sonora – Placerville (assumed to be equal)
3.6 in. Placerville – Iowa Hill (lift factor)
7.05 in. Iowa Hill – Blue Canyon (adjusted lift factor)
**Total: 22.12 in. Final Blue Canyon estimate for Route "B"**

**Comments and Conclusions**: Considering the size of the area and the variation of the terrain, we think the results are truly amazing! Only **3/100ths** of an inch separates the two Blue Canyon estimates! Even if the difference was **3/10ths** of an inch, the difference between the two estimates would be less than **1 1/2%.** Without a doubt this proves how uniform and proportional the distribution of the precipitation was for these two super storms--throughout the region. This incredible consistency is strong support for our final 3-day estimated rainfall increase of **13.3%** for the January 9-11, 1862 storm at Blue Canyon. *Refer to section "I" of the Main report to review method used to derive our final estimate.*

EXHIBIT "F"

**Introduction:** **Other researchers have claimed that rain shadows have reduced the amount of rain that fell on the American River watershed during the January 9 – 11, 1862 flood producing storm. The following news articles dispute this claim:**

1. Sacramento Union – – January 10, 1862

   a. Websters: 35 miles east of Placerville – – South Fork of American as high as it was at any time this season; still rising.

2. Sacramento Union – – January 14, 1862

   a. Placerville, January 10 at 9 PM– – Editors Union: Rain, Rain, Rain! There seems to be no let up to it; for three days it has poured down upon us and at this writing it seems to be coming down in torrents – – rivulets are turned into rivers which sweeps everything before them.

   b. THE FLOOD IN GEORGETOWN: A correspondent of the Union writing from Georgetown, El Dorado County, January 10 says: the hardest rain ever known in the mountains by any of our old settlers has been falling here for the last three days and nights, and it has been impossible to cross any of the small streams.

MODIFIED VERSION of NRC's *Figure 3.1*

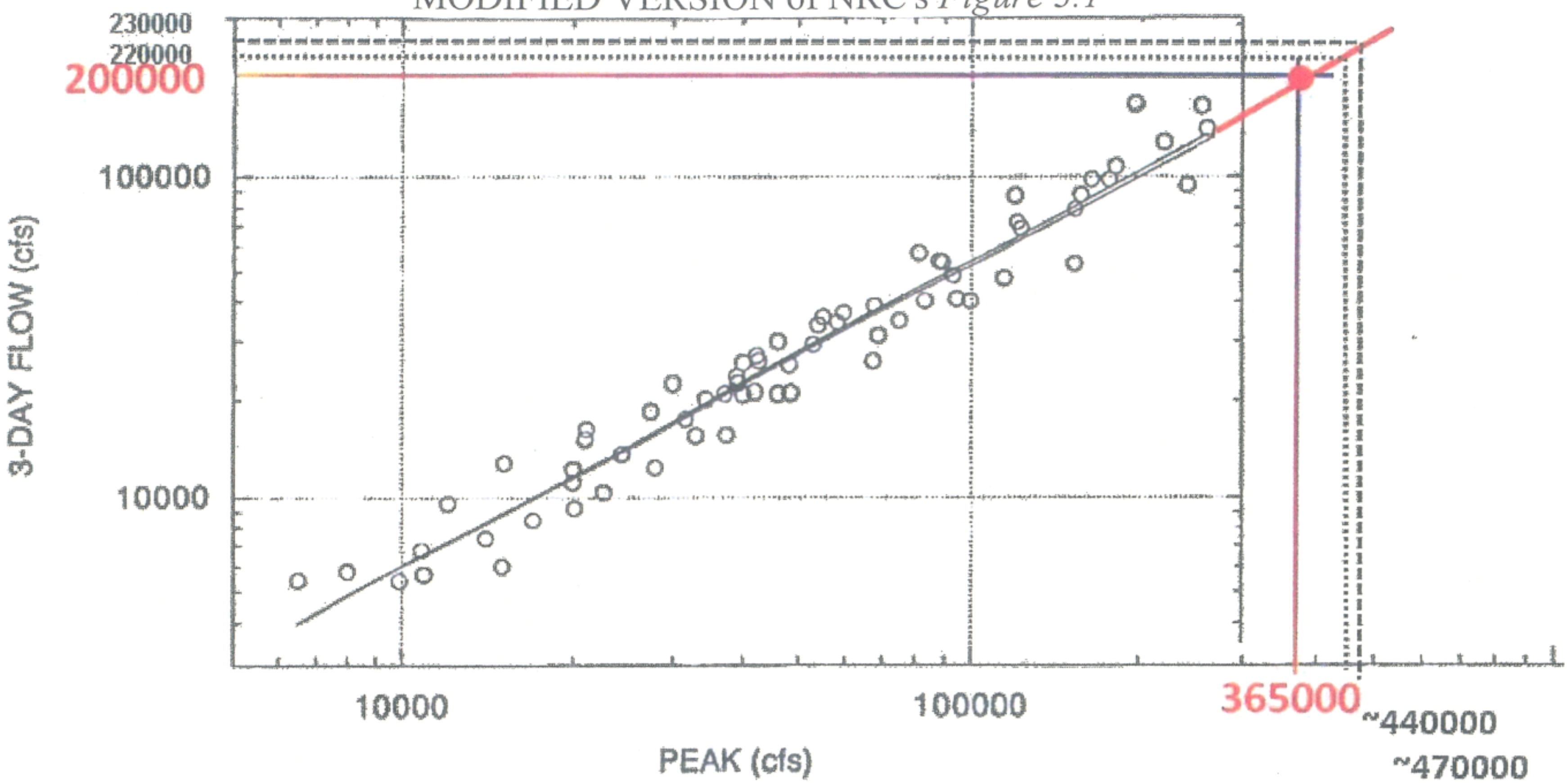
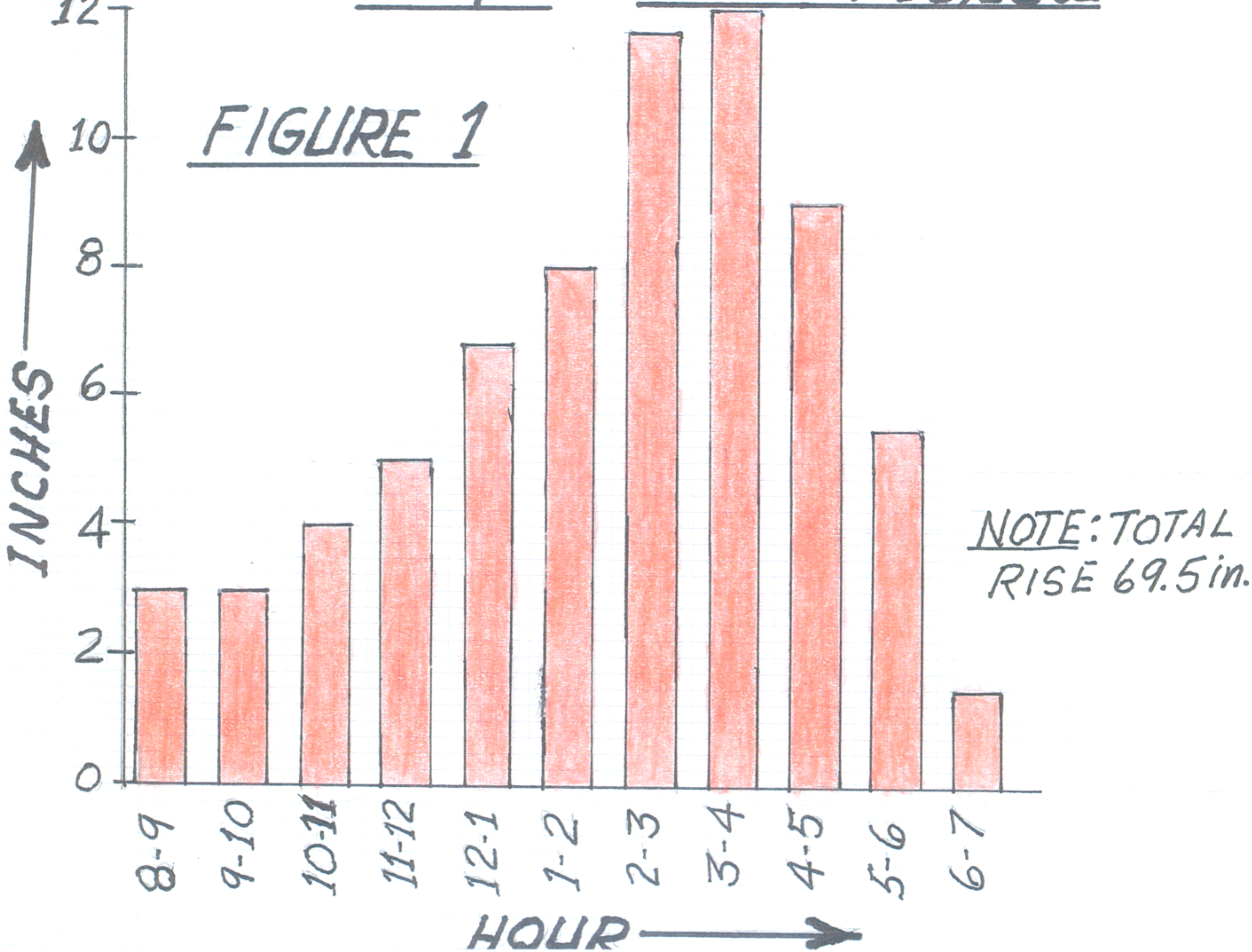



FIGURE 3.1 Log-log relationships of three-day flow on peak flow, American River. Both regressions are based on data from the unregulated period of record (1905-1955); the regression line with the larger slope is also based on flow estimates for the period 1956-1997.

(modified with 1862 flood data)

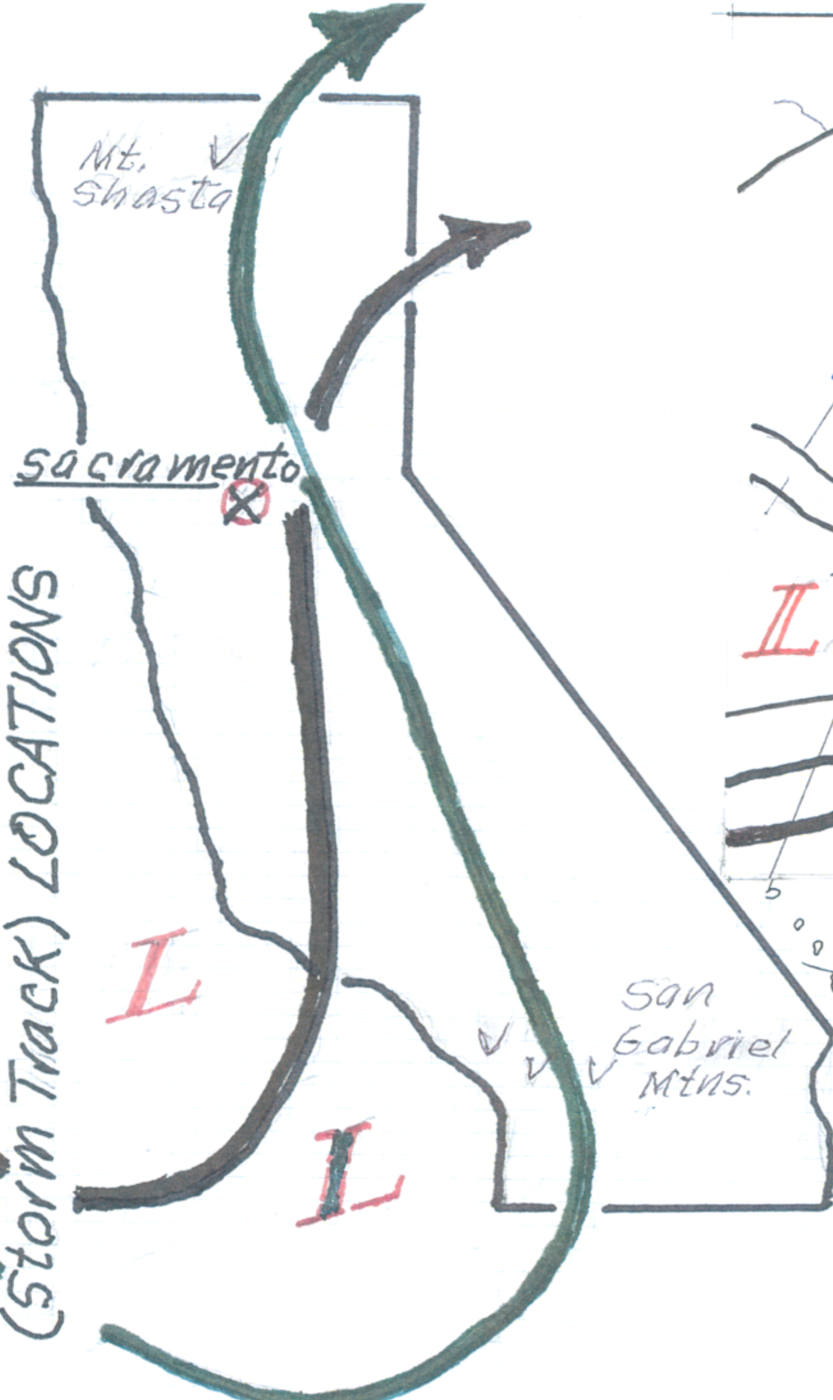
A 10% increase of the 3-DAY FLOW (220,000 cfs)
results in a 20.5% increase in the PEAK (~440,000 cfs)
A 15% increase of the 3-DAY FLOW (230,000 cfs)
results in a 28.7% increase in the PEAK (~470,000 cfs)

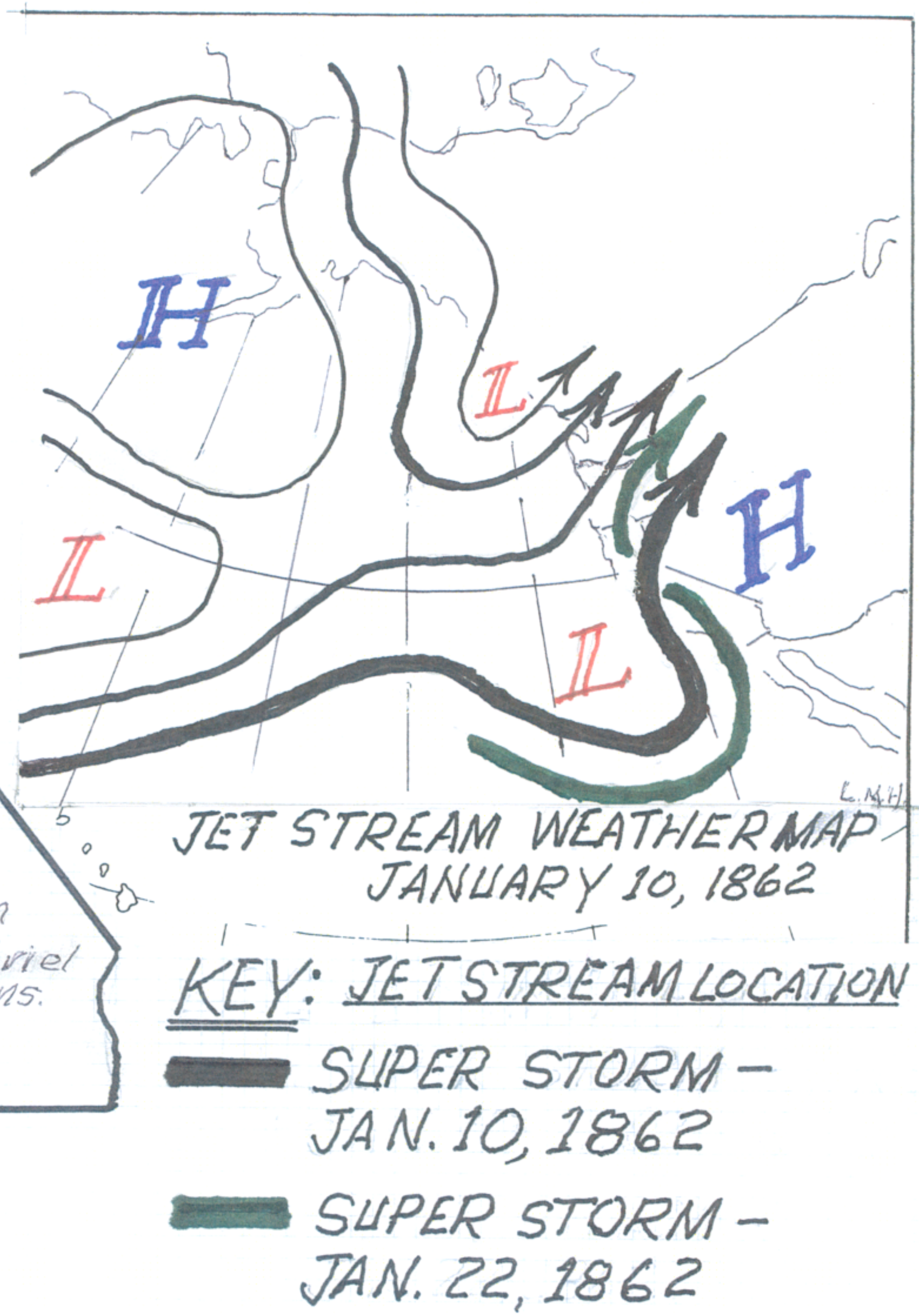
# HOURLY RATE of INCREASE in WATER LEVEL @ 7th & P on JANUARY 10, 1862



# FIGURE 2

ESTIMATED JAN. 1862 JET STREAM (Storm Track) LOCATIONS



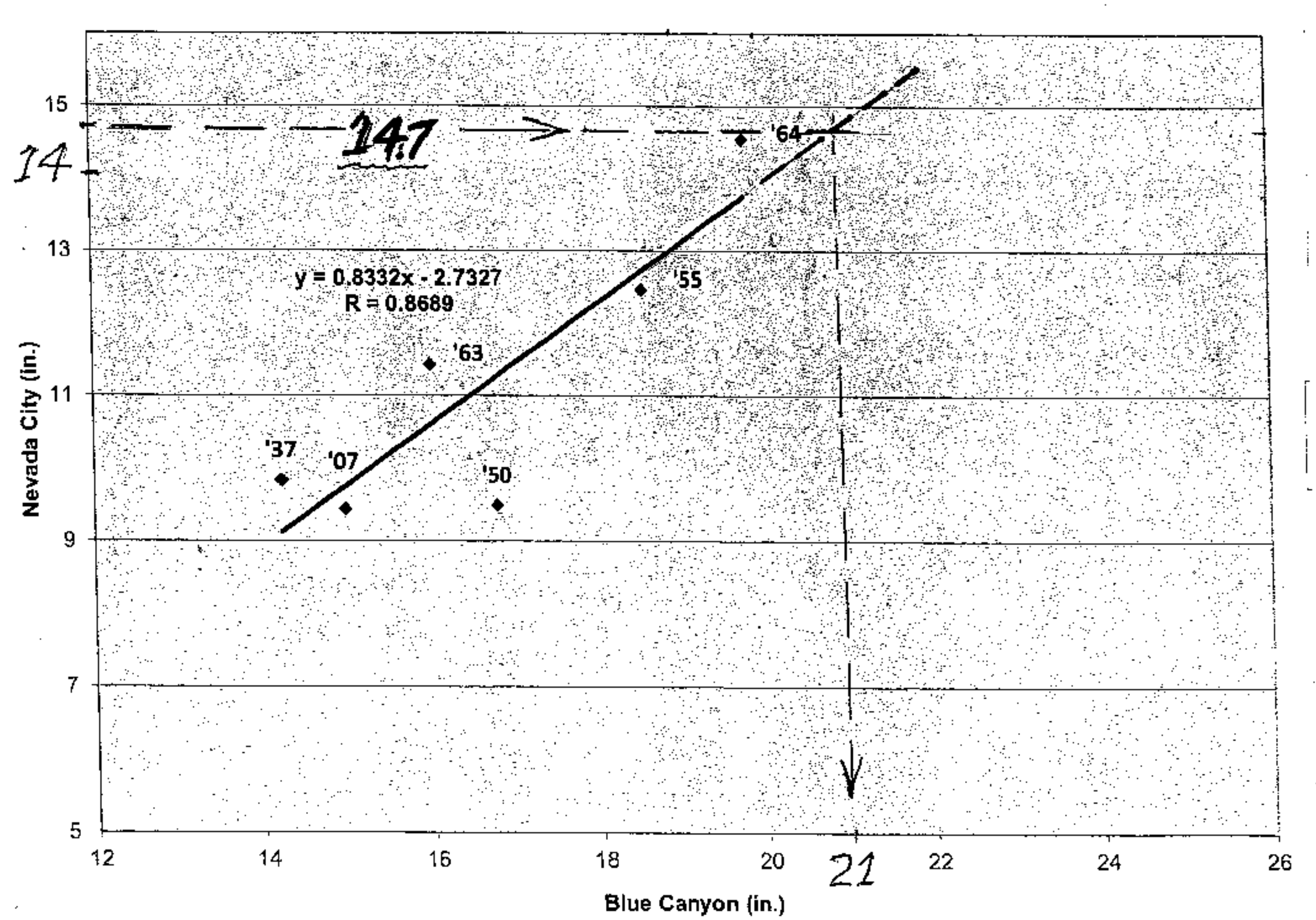
## FIGURE 3

**Using 20th century Grass Valley – Nevada City area rainfall data to estimate the heaviest 3-day January 1862 rainfall at Blue Canyon.** In an effort to have a more compatible sample we selected only those heavy 3-day warm storms that produced between 3 and 4 inches of rain in Sacramento. We chose this range of values because both heavy 3-day warm storms of January 1862 recorded a little over 3 inches in Sacramento.

If we extend the regression line and use the *14.7 inch DWR January 1862 3-day rainfall estimate for Nevada City, we get a 3-day estimate for Blue Canyon of ~ 21 inches. The Grass Valley vs. Blue Canyon graph also yields a 3-day Blue Canyon estimate of ~ 21 inches.

**Note: This estimate can be found in the February 23, 1999 DWR report: Analysis of 1862 Precipitation and Runoff.*

**Nevada City vs. Blue Canyon**



## Grass Valley vs. Blue Canyon