CONTRA COSTA COUNTY FLOOD CONTROL
AND WATER CONSERVATION DISTRICT
255 GLACIER DRIVE, MARTINEZ, CALIFORNIA

DATE: December 23, 2009

TO: Greg Connaughton, Assistant Public Works Director, Flood Control

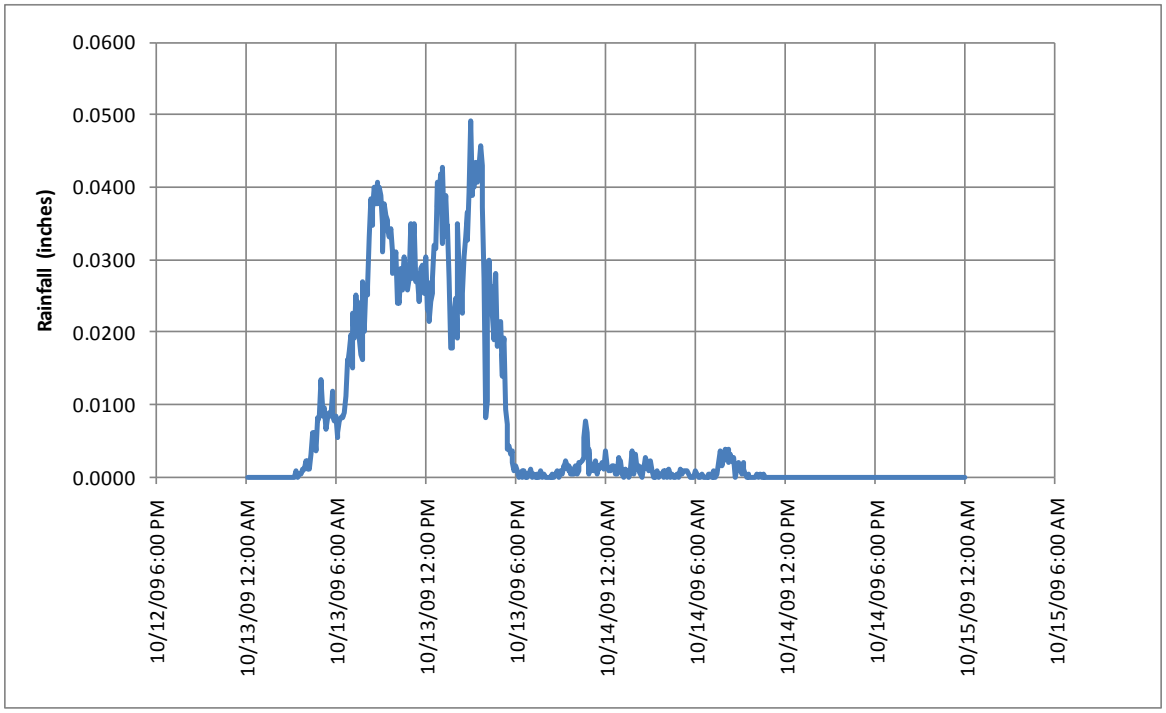
FROM: Mark Boucher, Sr. Hydrologist, Flood Control

COPY: Mitch Avalon, Deputy Public Works Director, Administration

SUBJECT: Report on the October 13, 2009 Storm

On Tuesday, October 13, 2009, a large storm struck the Bay Area. The National Weather Service reported it was the largest October storm to hit the area since 1962[1]. The October 13 storm started around 3:30 AM and ended around 6:00 PM with minor showers continuing till late morning on the 14th. It was widespread with spatially varied intensities. The plot below is an average of the 5-minute rainfall totals for 25 of our 26 gauges during that storm.

Figure 1 Average of 5 minute Data of 25 Gauges



[1] In their study entitled "Walnut Creek Basin, California – Hydrology" dated January 1971 (Revised January 1972), the Corps of Engineers developed a 96-hour design storm based on the October 1962 "Orinda Filters" storm. This rain gauge is operated by the East Bay Municipal Utilities District at their Orinda Filter Plant. We use the 96-hour design storm rainfall distribution curve from that Corps of Engineers study as our 96-hour storm standard.

For all gauges, the 12-hour storm duration resulted in the highest return frequency. A map in the attachments presents the maximum rainfall depth and return period for the 12-hour storm duration. Table 1 below summarizes the data shown on the map. Stations that are shaded had extreme return periods greater than one hundred years (100-yr). The estimated return period we calculated varied from as low as a 7-year storm to over a 1000-year storm[2].The backup calculations for the return periods for this storm are also attached.

Table 1 -- Summary of Approximate Return Periods for October 13, 2009 Storm

Recording Stations	Rainfall Depth for 12-hour Duration	Approx. Max Return Period	Station Description
ADH 37	3.55 in.	19-Yr	ADH - ARROYO DEL HAMBRE FERNDALE ROAD MARTINEZ
BAP 45*	3.63 in.	>1000-Yr	BAP - BYRON AIRPORT
BCO 86	3.69 in.	>1000-Yr	BCO - CC COUNTY CORPORATION YARD BRENTWOOD
BIF 44*	3.42 in.	>1000-Yr	BIF - BETHEL ISLAND FIRE
BIX 14	2.41 in.	47-Yr	BIX - EBMUD PUMP STATION BIXLER
BLD 32	5.00 in.	23-Yr	BLD - EBRPD BALD PEAK TILDEN PARK
CCP 43	2.43 in.	9-Yr	CCP - CONCORD PAVILION
CRK 35	3.07 in.	18-Yr	CRK - CUMMINGS PEAK MICROWAVE STATION CROCKETT
DBF 20	3.58 in.	27-Yr	DBF - DUBLIN FIRE STATION DUBLIN
DBL 22	4.69 in.	40-Yr	DBL - MT DIABLO MICROWAVE STATION
DVB 31	4.39 in.	88-Yr	DVB - DANVILLE LIBRARY
FCD 11	3.41 in.	52-Yr	FCD - CCC FLOOD CONTROL DISTRICT MARTINEZ
HLD 10	4.04 in.	74-Yr	HLD - HIGHLAND PEAK
ISD 39*	3.32 in.	490-Yr	ISD - IRONHOUSE SANITARY DISTRICT
KRG 38	2.65 in.	7-Yr	KGR - KREGOR PEAK MICROWAVE STATION CLAYTON
MCF 16	5.33 in.	>1000-Yr	MCF - MARSH CREEK FIRE STA CLAYTON
MCR 25	2.63 in.	37-Yr	MCR - MARSH CREEK RESERVOIR
MDP 13	4.40 in.	109-Yr	MDP - MT. DIABLO PARK ROCK CITY
MED 19	3.47 in.	577-Yr	MED - LOS MEDANOS CHEVRON PUMP PLANT
ORF 18	4.25 in.	19-Yr	ORF - ORINDA FIRE STATION ORINDA
RIC 21	3.73 in.	33-Yr	RIC - RICHMOND CITY HALL
RKY 34	4.31 in.	22-Yr	RKY - ROCKY RIDGE MICROWAVE STATION
ROF 15	3.12 in.	26-Yr	ROF - RODEO FIRE STATION RODEO
RSS 29	6.02 in.	>1000-Yr	RSS - ROSSMOOR 800 ROCKVIEW DR WALNUT CREEK
SMC 12	5.10 in.	58-Yr	SMC - SAINT MARY'S COLLEGE MORAGA
YGF 33	3.72 in.	123-Yr	YGF - FIRE TRAINING CNTR TREAT BLVD WC/CON

Notes:
*These gauges are some of our most recently installed gauges. The BAP, BIF, and ISD gauges are in the east county where we have little long-term data.

[2] Please keep in mind the calculation of a return period is not precise and the values should be rounded off. The non-rounded numbers are shown here simply to provide the detail reflected in the data.

Initial Data Review and Corrections

This storm produced the highest return periods I have ever calculated. Some return period values were so extreme, and inconsistently distributed spatially, that I immediately doubted that all of the gauges were collecting data correctly.

Our review of the data took some time, resulting in the delay of this report. We reviewed the data and discussed it with our vendor (HydroLynx Systems, Inc.[3]) until we were satisfied with their explanations and able to correct the data.

Our rain gauges are all tipping bucket rain gauges (see example image to the right). We expect to record only one tip (0.01 inches of rainfall) for each time record in the data.

In the past, when we had mercury switches in the gauges, we would occasionally get "double tips" in the data. Then, when we saw double tips in the data, we suspected that the mercury in the switch was bouncing around and falsely shorting the contacts. This occurrence was rare and we did not routinely comb through the data to correct the double tips.

We replaced all of the mercury switches with reed switches years ago. Each switch now has a reed in it that closes as a magnet on the tipping bucket passes the switch. We expected that the changeover to reed switches would eliminate the double tips. However, we saw many double tips and several instances of more than two tips per recorded time in the October 13th raw data. We had incidences of 3 to 21 tips per recorded time show up in the data on several gauges.

After discussions with HydroLynx, we are convinced that double tips can occur due to how the two processors in the data collection units (DCU's) communicate with each other. The explanation of this is somewhat complicated. I have copied their explanation in an attachment for the record.

We went through the data and where there were more than two unexplainable tips, we changed them to one tip. We decided this was the best process to make the data as accurate as possible.

Potential Changes in Equipment and Practices

The Rossmoor gauge had the most tips in a single time step; it had 21 tips for one recorded time record. We suspect that the wind shook the gauge causing multiple tips. We have moved that gauge from the top of a 2" metal pole down to the top of the box containing our DCU. This location is lower and should not suffer from shaking due to wind.

We have further researched the multi-tip issue on a website dedicated to weather related topics[4]. Some comments from that website indicate that older reed switches can "chatter" and produce more than one signal per tip. From discussions through this website, we developed a circuit that could eliminate the possibility of "chatter" in the reed switch. We have tested this circuit and found it is not reliable. We

[3] http://www.hydrolynx.com/hydrolynx.htm
[4] http://www2.buoy.com/pipermail/weather/ (See October 2009 threads on "Rain Gauge Contact Bounce)

have tried to contact the reed switch and gauge manufacturers to understand how long the switches normally last. We have also developed and are trying out a simple test for the old reed switches to see if they give false readings. These two efforts and others like them may lead us to adopt a practice of routine reed switch replacement and/or a change in switch type.

We are also looking at Hall Effect switches. These are solid state and will not chatter, but they require a small continuous voltage that could be a drain on our solar charged batteries. Scott McQuarrie has fabricated the necessary circuitry and is testing one of these switches.

Data Discussion

The rain depth and return period data was added to a rain gauge GIS layer to provide spatial representation of the results for easier analysis. Figure 2, Figure 3, and Figure 4 show simplified maps of the county with the 12-hour rainfall depth, the total storm rainfall depth, and the calculated return period, respectively. Figure 2 shows reasonable 12-hour rainfall depths if we ignore the return periods. That is, the high rainfall amounts are not much higher than those around them. The figures show a "hypothetical storm center path5". This path "connects the dots" of the rain gauges that had the highest depths compared to those around them. The high values in the east county are a little scattered north and south of the path axis, but the rain depths are not so far out of the ordinary that they are implausible. The extreme return periods shown in Figure 4 clearly coincide with the "hypothetical storm path" and the difference in magnitude of the return periods is very pronounced.

Other's Data

We collected data from rain gauges maintained by others and, with a couple of exceptions, have not found any significant difference between their rainfall depths and ours. Figure 5 shows the relative depth of rainfall for all of the gauges including ours. There is one gauge operated by others on Mt. Diablo that has significantly less rain than ours and a couple of others that are circled. We suspect the other's Mt. Diablo gauge was not operating correctly.

Extreme Return Periods

We created Figure 6 to assess the incremental depth of rainfall required to change the return period to an extreme value. Figure 6 presents the return period-depth curve for the 10-, 20-, and 30-inch Mean Seasonal Precipitation (MSP) isohyets. These depths generally represent the range of isohyets in Contra Costa County. From this we can see that it takes less incremental rain depth to change the return period from 100-years to 1000-years than it does to change it from the 5-year to the 100-year. In addition, the slope on the 10-inch MSP isohyets curve is flatter than the other curves in the higher return periods. This indicates that in areas of lower MSP, it is easier to attain a high return period. The east county area has the lowest MSP in the county. This may explain the extreme return periods there.

Keeping in mind that our estimates of the return periods are based 30 to 40 years of data with some correlation to a few distant gauges that have near 100-years of data, we are hard pressed to state the exact return period for storms that calculate out to have return periods over 100-years. **Therefore, I would say that overall, in the hardest hit locations, this storm had a rainfall return period in the order of 40- to 100-years with some gauges recording depths so high that we cannot estimate an accurate return period.**

[5] We have not reviewed the National Weather Service Doppler images to determine if there was a storm center path in this location.

Figure 2 October 13, 2009 12-hour Maximum Rainfall Depths

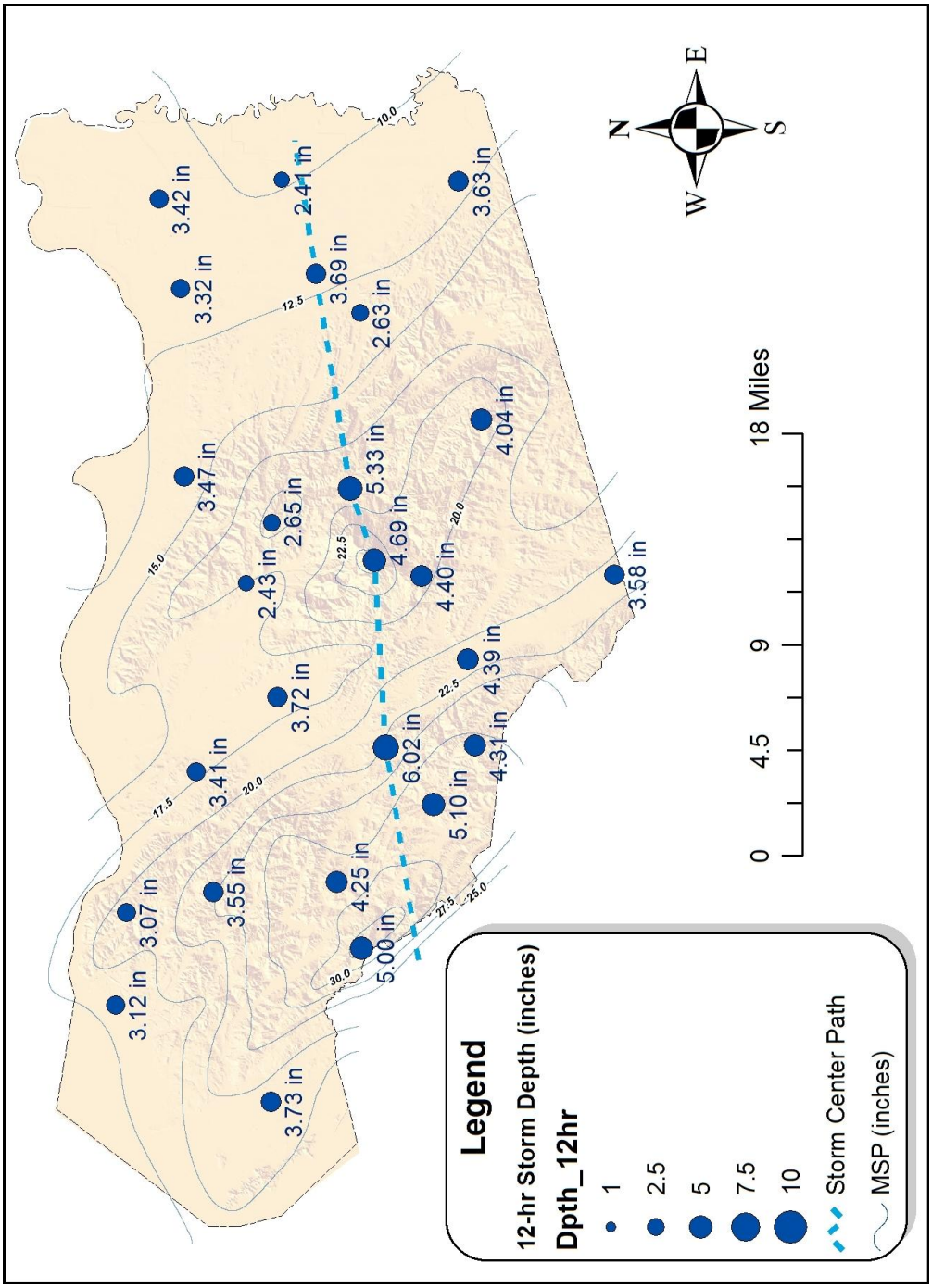


Figure 3 October 13-14, 2009 Total Rainfall Depths with "Storm Path"

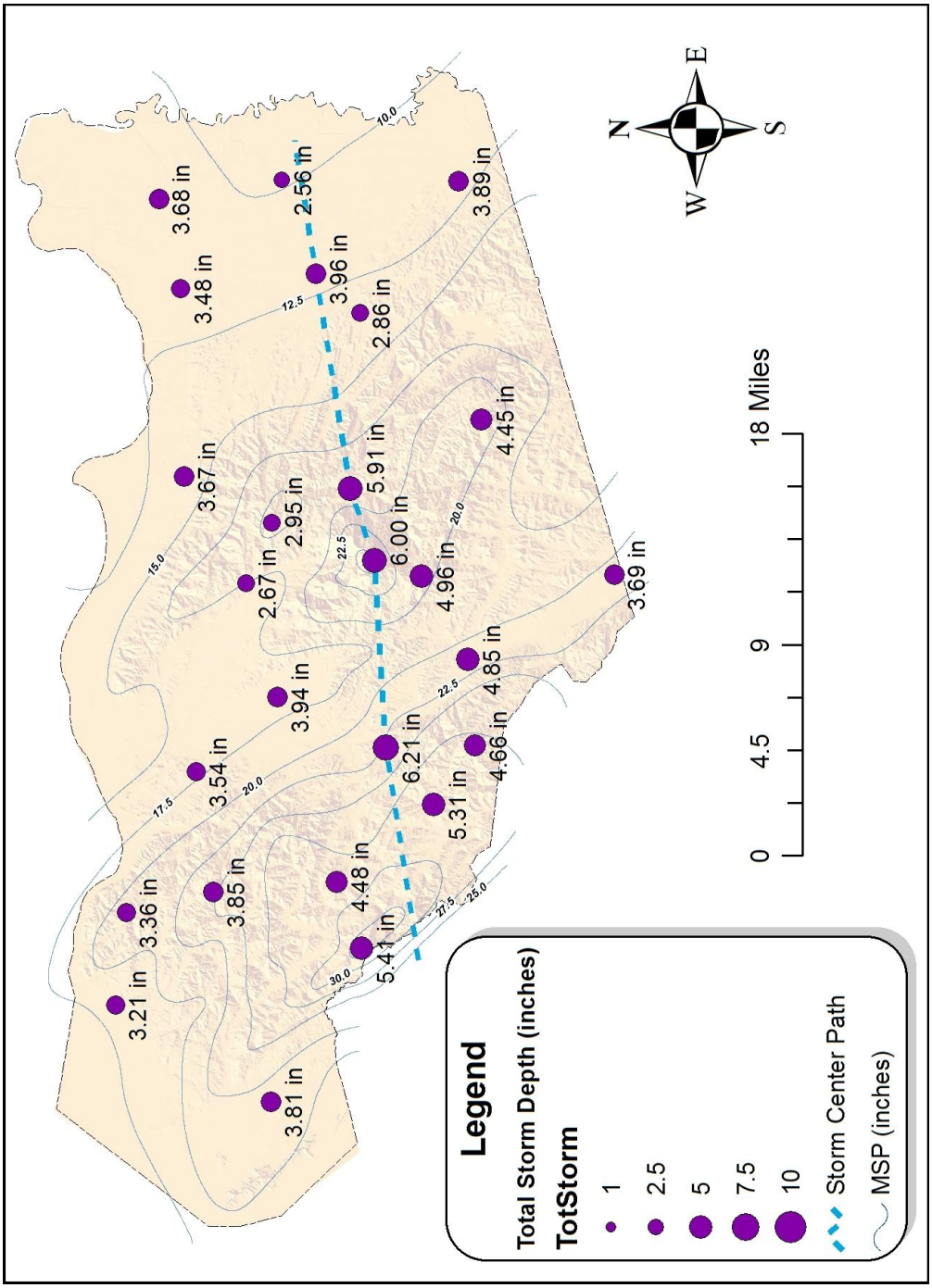


Figure 4 Total Rainfall Return Periods with "Storm Path"

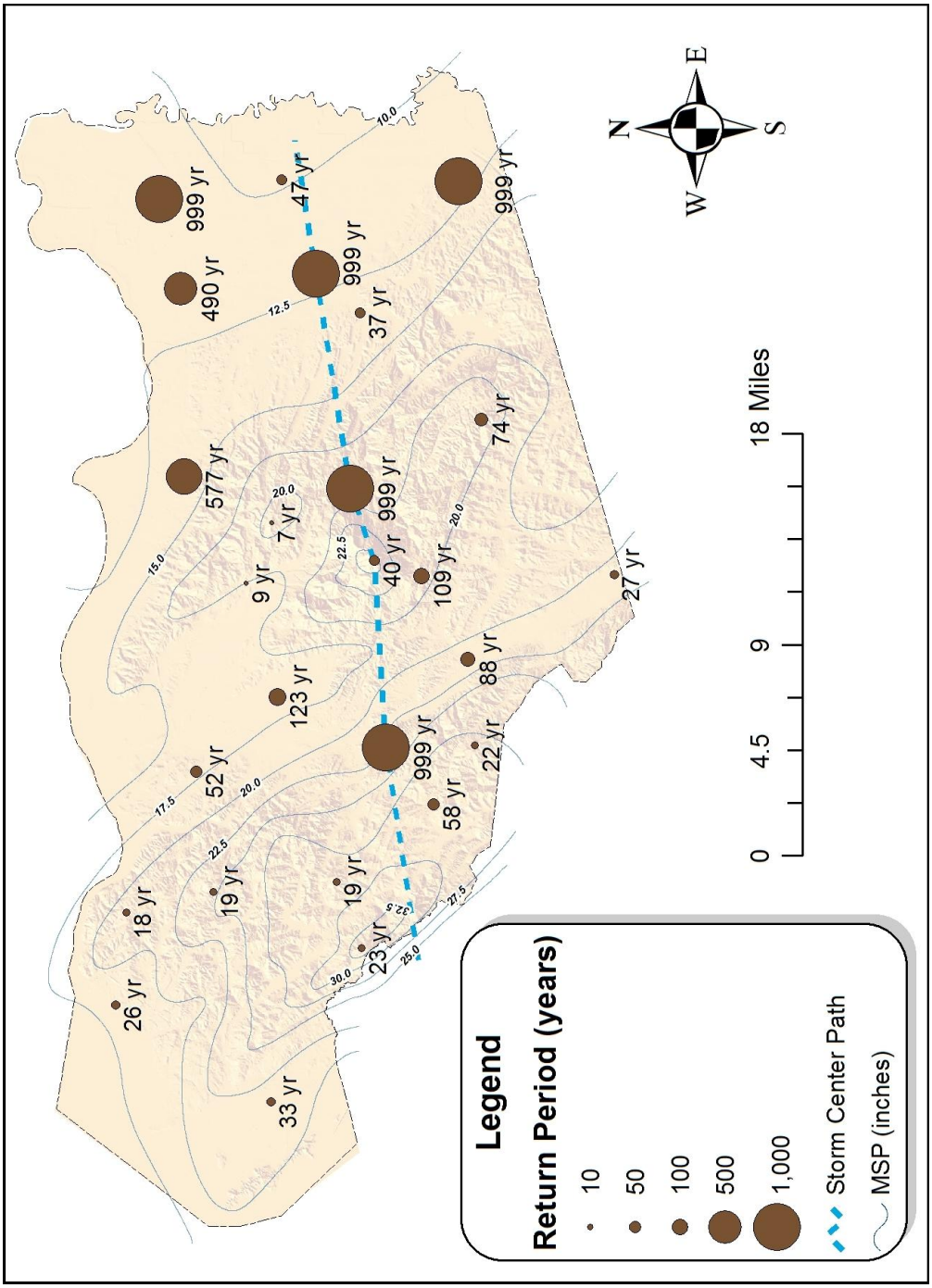


Figure 5 Comparison with Other's Rain Gauges

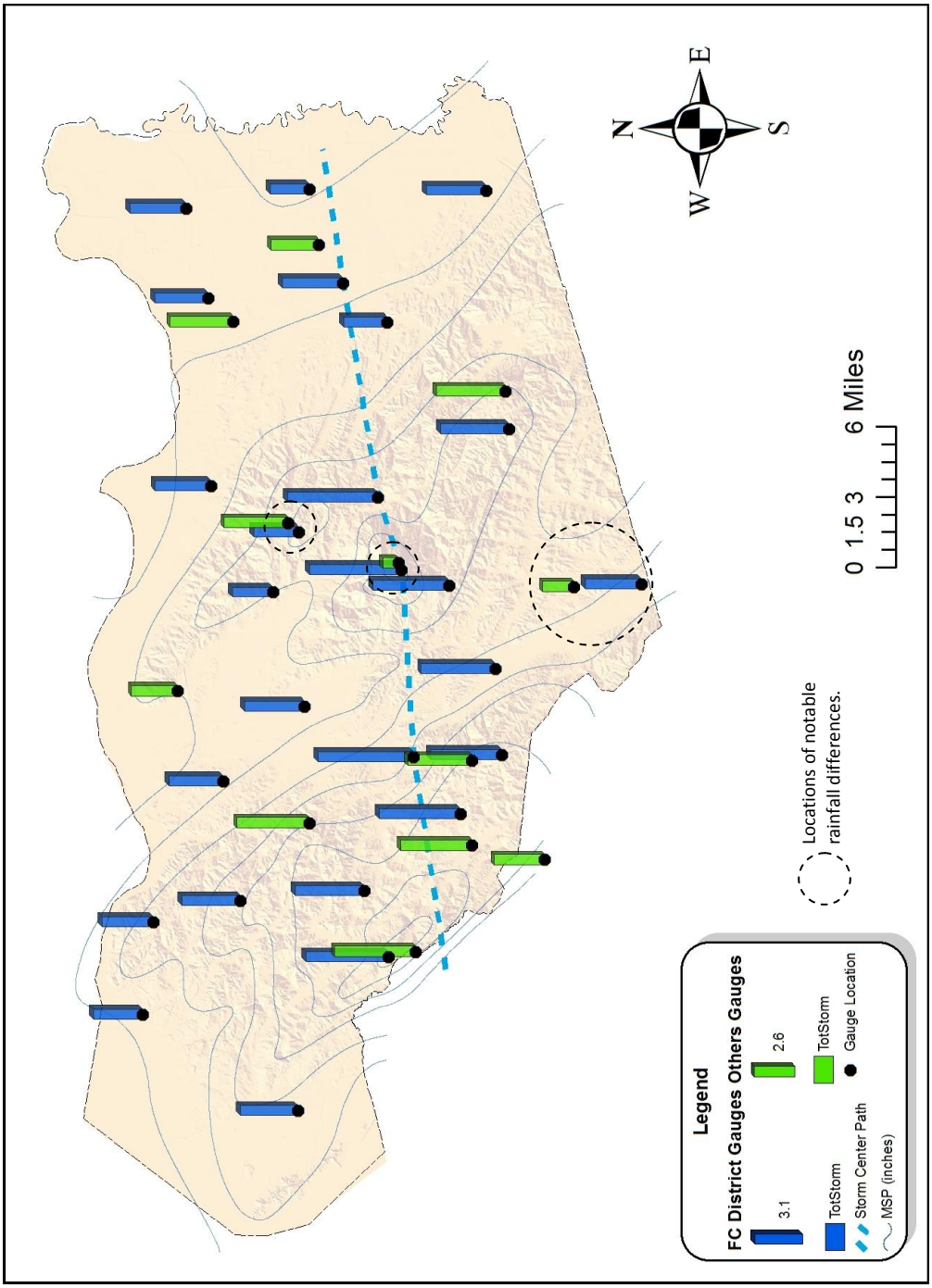
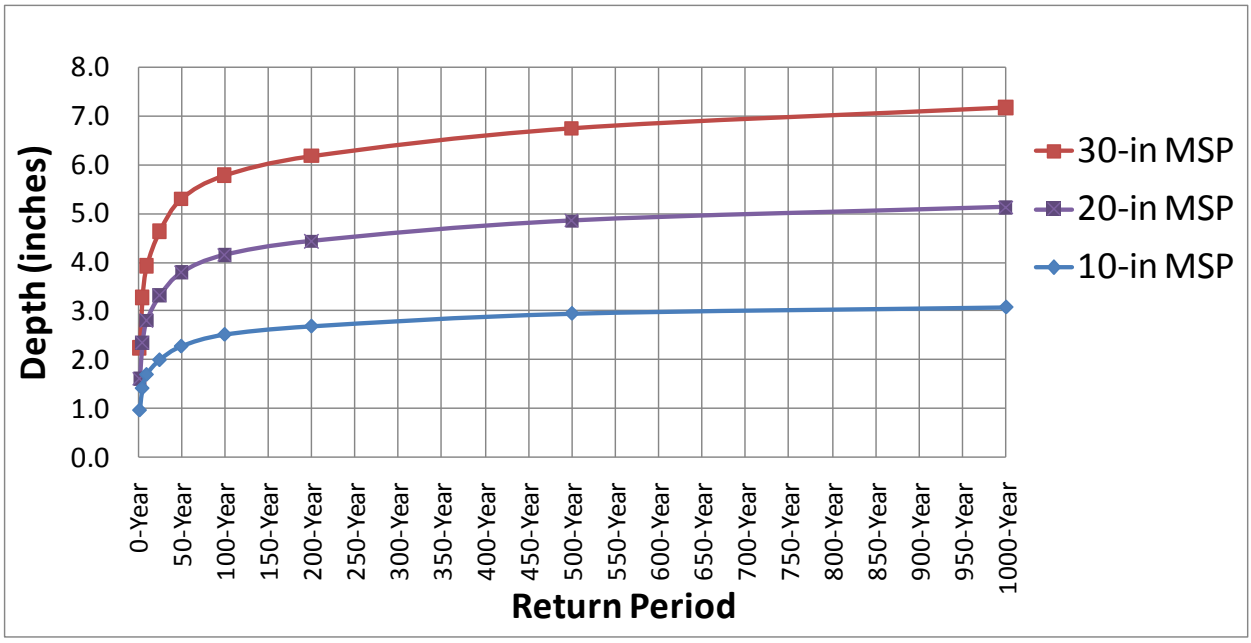


Figure 6 Return Periods vs. Depth Curves



Reports of Flooding

As of the date of this memo, the number of flooding reports was sparse. The following are those reports that are noteworthy.

- Mark Trump who works out of the County's Brentwood Corporation Yard provided a photo (Figure 7) showing flooding of Walnut Avenue near Kellogg Creek, south of Brentwood. He says, "The field was saturated so fast that drainage could not keep up." He said, the water came from "the fields" and "Kellogg Creek did not breach." This would support the concept of a very heavy rain on dry watersheds. You would not expect the creeks to flood, but you could expect the local drainage systems to be taxed more than usual.

Figure 7 - Flooding on Walnut Ave. near Kellogg Creek

- Paul Eldridge from the City of Brentwood responded to our inquiry saying, "We definitely had a significant rain event but other than [a] few catch basins plugging due to leaves we did not really experience any localized flooding as far as I know."

- There was a report of flooding from West Antioch Creek near 10th street, a known flood prone location.

- Tom Williams from the Ironhouse Sanitary District reported that their access road that dips under the railroad tracks was flooded. The sump pump could not keep up with the runoff, and the infiltration pond they pump to filled and overflowed.

- There were two reports of swimming pools filling to the brim with rainwater from the storm. One was in Antioch and the other in Walnut Creek.

- Allison Knapp (County Maintenance) stated that she did not know of any extraordinary drainage problems during that storm other that problems caused by illegally dumped trash in drainage ditches.

- We have several calls/emails out, including one to the National Weather Service, and may receive more reports on flooding from the storm.

Summary

There are a few options available in responding to the October 13, 2009 storm:

1. The data is correct and the return periods are accurate. This was an extreme countywide rainfall event with a major storm cell that traveled west to east down a narrow path through the heart of the county. A big cell could have moved across the county center then spread out in the east.

2. The data is correct, but the isohyets on our Mean Seasonal Isohyet map are too low in some places and incorrectly result in high return periods. This could be true for the east county area where we have had little data in the past.

   (A key component of estimating the return period is the MSP of the rain gauge location. If this value is estimated too low, the return period will be estimated too high. As shown by the curve slopes in Figure 6, the lower the MSP, the easier it is to reach an extreme return period.)

3. As much as we have tried to correct the data, it is still inaccurate and we cannot rely on it for several gauges in this storm.

Conclusion

At this time, my opinion is that the rain gauge data is correct and the return periods are accurate with the exception of the Rossmoor gauge (RSS 29). We know there were issues with the data from this gauge. It also has a much more extreme return period than most gauges around it.

Restating from the section on Extreme Return Periods, **in the hardest hit locations, this storm had a rainfall return period in the order of 40- to 100-years with some gauges recording depths so high that we cannot estimate an accurate return period.** I may reverse my opinion on this as I collect reports from people who live in that area and check the data against other agencies gauges.

Please let me know if you have any questions.

Attachments

MB:
G:\FldCtl\Hydrology\Rainfall\StormEvents\2009 October13\October 13 2009 Storm Report Final.doc

Attachments

The hourly storm data and storm frequency analysis attachments can be found at http://www.cccounty.us/index.aspx?NID=1456.

Explanation of Double Tip Data

From a HydroLynx e-mail on Thursday, October 22, 2009 8:43 AM

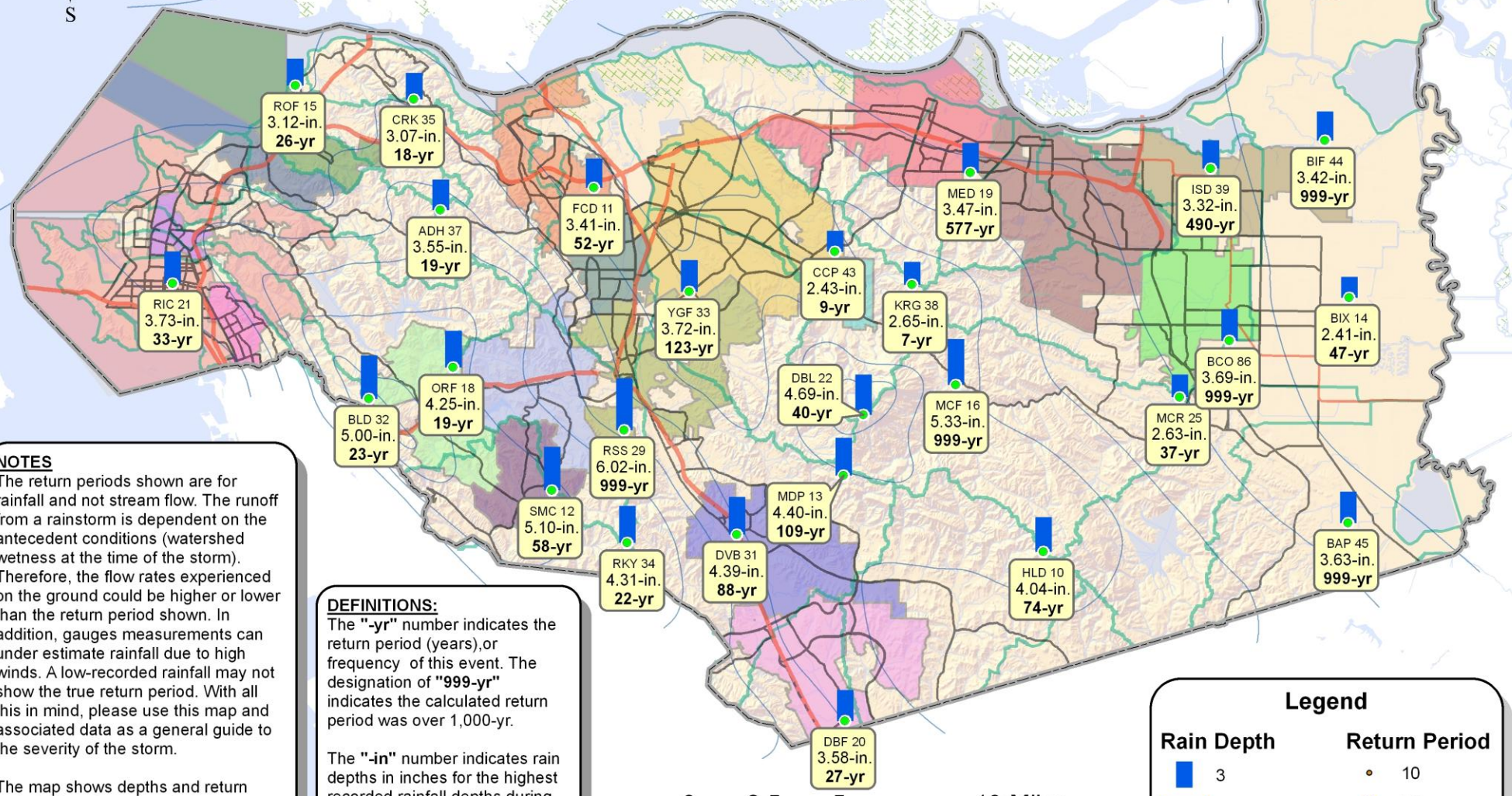
"The 50386 has two processors: the 386 processor on the PCOS, and the IO PIC on the ScadaLynx motherboard. The IO PIC detects the rain gauge tips, increments an internal counter, and wakes up the 386 processor with an interrupt line. When the 386 processor wakes up, it detects the IO PIC interrupt, reads the rain gauge counter from the IO PIC, and processes the information. The 386 will transmit the rain gauge data report and/or log the data to flash. In your stations, the data is logged only, not transmitted. If there is nothing else to do, the 386 processor powers down and waits for the next wakeup event. There is a very short time interval after the 386 decides to power down when it cannot receive any interrupts. If the rain gauge tip occurs at this time, the 386 will not receive the wake up interrupt. It will wait for the next rain gauge tip to wake it up. At this wakeup, the 386 reads the two tip increment from the IO PIC and logs the data. The good news is that the total rainfall count is correct. The bad news is that we do not know the exact time of the rain gauge tip whose interrupt was missed.

There are other events that wake up the 386 processor: timed events to read sensors, radio carrier detect, and a 15 second watch dog timer.
When the 386 powers down after these events, it has the same chance of missing an IO PIC interrupt.

We have been aware of this very short time interval where the IO PIC wake up event could be missed. Our code has been optimized and tested to reduce this possibility to the very shortest possible time. The last thing the 386 does before powering down is check for IO PICS events.

Still we could not eliminate the possibility of missed wakeups and still use the power down feature of the 50386 to conserve battery power on solar sites. To compensate for this possibility, we made the IO PIC code remember the total rain gauge count so the 386 processor would not lose track of the total rainfall events."

Storm Report for FCD Rain Gauges
October 13, 2009 Storm - 12 hour Duration



NOTES

The return periods shown are for rainfall and not stream flow. The runoff from a rainstorm is dependent on the antecedent conditions (watershed wetness at the time of the storm). Therefore, the flow rates experienced on the ground could be higher or lower than the return period shown. In addition, gauges measurements can under estimate rainfall due to high winds. A low-recorded rainfall may not show the true return period. With all this in mind, please use this map and associated data as a general guide to the severity of the storm.

The map shows depths and return periods for rain gauges that we are relatively confident provided good data. Gauges marked as not used have suspicious rainfall amounts and we suspect poor rainfall data due to equipment errors. As we continue to review the data, we may revise this map.

DEFINITIONS:

The **"-yr"** number indicates the return period (years),or frequency of this event. The designation of **"999-yr"** indicates the calculated return period was over 1,000-yr.

The **"-in"** number indicates rain depths in inches for the highest recorded rainfall depths during this storm and over the duration period. See map title for duration this map represents. The start and end times of the duration are not the same for every gauge but the length of the duration is the same for all

All values are **preliminary and subject to revision.** Question regarding this exhibit should be directed to the FC District Hydrologist at 313-2000.

Legend

Rain Depth	Return Period
3	10
Dpth_12hr	50
MSP (inches)	100
Gauge Location	Watersheds
	Creeks

MSP = Mean Seasonal Preciptiation isohyets

Contra Costa County Flood Control and Water Conservation District
Rain Gauge Locations

PREPARED BY:
CONTRA COSTA COUNTY
PUBLIC WORKS DEPARTMENT
COMPUTER SERVICES - MAPPING SCIENCES SECTION
255 GLACIER DRIVE
MARTINEZ, CALIFORNIA 94553

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DATE: November 17, 2009 FILENAME: Rain Gages 10-13-09 12-hour.mxd BY: M. Boucher