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**A post-evaluation of rainfall reports associated with
the Pawnee Creek flood of July 29-30, 1997 in
eastern Weld and western Logan counties
in northeast Colorado**

Nolan J. Doesken



Climatology Report No. 98-3

**DEPARTMENT OF ATMOSPHERIC SCIENCE
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO**

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the Pawnee Creek flood of July 29-30, 1997 in
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by

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Executive Summary

An extreme flash flood occurred on Pawnee Creek in northeastern Colorado July 29-30, 1997 following several hours of intense rainfall. A survey of the storm conducted a few days afterwards, and published in draft form in October 1997, revealed that extreme rainfall occurred over a fairly large area of eastern Weld County and western Logan County. Storm totals from this preliminary analysis reached 15 inches at the center of the storm, making this one of only a handful of such extreme events ever documented in Colorado history.

Because of the excessive rainfall totals and extreme flash flooding associated with this storm, the Colorado Climate Center at Colorado State University was enlisted to evaluate and confirm the rainfall reports. This report contains and summarizes the results of many interviews with residents of the area that witnessed and, in some cases, measured the rainfall.

The results of this survey conducted one year after the storm confirmed that an extreme event had indeed occurred and that significant rain had already fallen in the previous days.

- From July 19 to 25, moderate to locally heavy rains (generally one to three inches) fell over eastern Weld County bringing beneficial moisture after several weeks of hot and dry weather.
- A widespread heavy rainfall event took place during the evening of July 28 dropping one to two inches of rain over most of eastern Weld and western Morgan counties, enough to produce runoff in many of the normally-dry creek beds. Locally, as much as three inches of rain fell north of New Raymer.
- On July 29, 1997, heavy rains began in extreme northeastern Weld County during the afternoon. Then around 7:30 PM MDT, very heavy rains began north of Stoneham near the Weld-Logan county line. These heavy rains spread slowly northeastward but also developed and propagated southwestward with the heaviest and most widespread rains falling from approximately 9:00 PM to just after midnight, with lighter rains continuing until 02:00 to 03:00 AM on July 30. No hail was reported with this storm.

The area of the Pawnee Creek watershed is very sparsely populated. However, a remarkably large percentage of the residents of this ranching and dryland farming area were equipped with rain gauges and attempted to measure the rainfall. This evaluation of the original rainfall reports gathered after the storm found that most reports and observations in the areas of heaviest rainfall were estimates as opposed to accurate gauge measurements since most rain gauges overflowed. Some of these estimates were derived from stock tank levels and water depths in 5-gallon buckets. A few rainfall reports near the storm center likely included rain from previous days or from splash from surface water, thus placing in question some of the largest reports. Nevertheless, there was convincing evidence that rainfall totals for the evening of July 29 into the early morning of July 30, 1997 exceeded 12 inches and locally approached 14 inches over an area of perhaps 17 square miles.

The 1998 survey uncovered several more observations that apparently were not obtained for the original analysis. These additional data suggest that the original survey may have underestimated rainfall in some areas, particularly over eastern Weld County. A re-analysis shows that rainfall totals for the evening may have exceeded six inches over an area of approximately 270 square miles. The areas of greatest uncertainty in this analysis include portions of western Logan county just east of the storm's center and a narrow band extending southwestward to just northwest of New Raymer where there are solid indications of extreme rainfall but few confident observations.

In addition to ground measurements of rainfall, the National Weather Service radar data were collected and are available to help estimate storm rainfall for areas without gauge measurements. These radar data proved very helpful in defining storm locations, duration, and areas of maximum rainfall over Morgan and Weld counties, but were less helpful over Logan County which is farther away from the radar transceiver.

In conclusion, despite the low population density of the area, a reasonably confident depiction of storm rainfall has been assembled suitable for hydrologic and engineering applications. The Pawnee Creek storm of July 29-30, 1997 was, indeed, an extreme event in terms of total rainfall depth, area and duration. It will stand out for many years to come as one of just a handful of extreme rainfall events in eastern Colorado's recorded history with rainfall totals exceeding 12 inches in a duration of less than 12 hours.

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Introduction and Background

On the night of July 29-30, 1997 exactly one day after the devastating Fort Collins, Colorado flash flood of July 28, 1997, a similar extreme rainfall event occurred over portions of eastern Weld and western Logan counties in northeast Colorado. The storm developed in an extremely moist air mass which spawned other heavy rain events in other portions of Colorado over a period of several days in late July and early August. The resulting flood on Pawnee Creek miraculously claimed no human lives but destroyed numerous roads, bridges and property before inundating farmland and large portions of the town of Atwood and the city of Sterling, Colorado.

Within a few days of this flood on Pawnee Creek and its tributaries, teams were organized to gather rainfall data from the affected areas of Weld and Logan counties. The purpose of this effort was to determine how much rain had fallen to produce such a large and dramatic flash flood. Team members consisted of officials from the Logan County Cooperative Extension Office in Sterling, Colorado, the U.S. Army Corps of Engineers from Omaha, Nebraska, and the Colorado Water Conservation Board in Denver. A total of at least six individuals participated in this survey. In addition, several other officials concentrated their efforts on documenting flood damage and peak flows. The results of these surveys were assembled into a draft report prepared by Tom Browning of the Colorado Water Conservation Board in October 1997 entitled, "Pawnee Creek, Logan County Colorado -- Flood of July 1997." This preliminary analysis showed that 12 to 15 inches of rain fell within six to eight hours over an area of several square miles near the core of the storm. These excessive rainfall totals, if accurate, make this one of only a handful of extreme storms of this magnitude in the recorded history of Colorado.

Because of the extreme rainfall totals, keen interest in this storm can be expected for many years to come by both hydrologists, meteorologists and engineers. It could potentially influence design criteria for dams and spillways and other critical structures in Colorado. It is very important that this storm be documented thoroughly for scientific, engineering and historical purposes while quantitative data about the storm are still readily available. In June 1998, the Colorado Climate Center was approached by the Colorado Water Conservation Board (Department of Natural Resources) to assist in this documentation effort. Funds were approved in July 1998 through an existing contract with Riverside Technology, Inc. in Fort Collins, Colorado for evaluation of 1997 Colorado flooding.

The basis for this post-evaluation were the tabulations of names of residents, locations and rainfall totals assembled for this sparsely populated grassland area by the original survey teams and printed in the October 1997 draft report. The goal of this effort was to verify rainfall reports for the evening of July 29-30, 1997 and evaluate their accuracy and confidence, seek additional reports and supporting information, produce a map depicting the storm rainfall pattern, and determine how much rain may have fallen in the days immediately preceding the July 29-30, 1997 event.

Data Collection

Field work and analysis were undertaken and completed by the Colorado Climate Center in late July and early August, 1998, one year after the storm. Five days of field work were conducted to obtain as much information as possible about rainfall on July 29, 1997 into the early morning hours of July 30. Many of the residents were contacted and interviewed who had provided rainfall observations or estimates immediately after the storm. Special emphasis was made in this post-evaluation to determine how much rain had already fallen in the hours and days immediately preceding the flood-producing storm.

The post analysis consisted of four categories of data collection:

- 1) Review of WSR-88D radar data and associated rainfall estimates from the National Weather Service radar located east of Denver (graciously provided by Matt Kelsch of NOAA-FSL in Boulder, CO).
- 2) Site visits and personal interviews with residents who had previously been surveyed who witnessed the storm and/or measured the rainfall. These included locating and examining the rain gauge(s) or other receptacles that had been used in July 1997 to determine rainfall amounts. (Note: Site visits were time consuming and were generally limited to those sites in and near the core of maximum rainfall.)
- 3) Phone interviews with residents surrounding the core of heaviest rainfall who had previously been surveyed.
- 4) Phone interviews and personal visits with residents of the area who had witnessed the storm but had not been included in the preliminary surveys.

Field work consisted of: 1) a one-day trip to the New Raymer area on Saturday, July 25, 1998 to gather names, addresses and phone numbers and to set up appointments to meet residents in the area hardest hit by the storm, 2) a half-day trip to Boulder, Colorado Monday, July 27 to meet with Matt Kelsch and examine rainfall estimates from National Weather Service radar, 3) a 3-day trip to the Sterling area July 28-30 to conduct site visits and interviews, and 4) follow-up phone calls made August 3-10, 1998 from Colorado State University to individuals in the affected area that were not previously contacted.

Although a year had elapsed since the storm, the residents of the area were extremely cooperative and went out of their way to provide the information needed to complete this study. While the area where the heaviest rains fell was very sparsely populated (approximately one occupied farm or ranch house per ten square miles for the region north of Colorado Highway 14 up to the Nebraska border), the majority of people in this ranching and farming area were found to be conscientious weather watchers who routinely measure and record rainfall each day throughout the summer. Many individuals maintain

journals or calendars that make it easy for them to look up past storms. One full year after the storm, it was still feasible to gather data.

Results

1) National Weather Service Radar data

A detailed radar analysis of this storm was originally considered beyond the scope of this post-analysis project. However, with the help of the National Oceanic and Atmospheric Administration in Boulder and meteorologist Matt Kelsch, a relatively thorough review was performed. The data for that storm had been captured and saved for local analysis and research almost by accident last year as a part of the archival of data associated with the Fort Collins flash flood of July 28, 1997.

Using NOAA system software, maps of radar-derived estimated precipitation were produced for a variety of time intervals. Some maps were also prepared for two different estimation procedures: 1) the standard radar reflectivity versus rainfall relationship and 2) a special reflectivity versus rainfall relationship for a tropical airmass. The tropical analysis was performed since meteorological analysis had shown that the airmass over the region had many traits of a tropical humid airmass.

Four maps are included in this report to show the general spatial patterns and timing of rainfall as estimated by radar for successive three-hour period. Keep in mind that some heavy rain had already fallen in extreme northeastern Weld County and adjacent areas during the afternoon of the 29th, and this is not included on the maps provided here. Readers should please be aware that radar is an excellent tool for tracking storms, defining storm areas, motions and relative intensities. However, the technology is not always capable of accurately determining the rainfall that reaches the ground. Therefore, the results below need to be interpreted carefully with that limitation in mind.

There are many interesting features of the storms shown by these radar products. For example, a narrow band of very heavy precipitation can be seen extending southwestward from the center of maximum rainfall to a point west of New Raymer. Another feature is the secondary rainfall maximum that appears over extreme northeast Weld County. Heavy rains also fell that night over Morgan County but were not the focus of this study.

The processed radar data will be archived and available for an unknown period of time in Boulder, Colorado. Additional analyses and maps could be produced, if needed. Original data will be permanently archived at the National Climatic Data Center, but access to that data and re-analysis will be very time consuming and expensive.

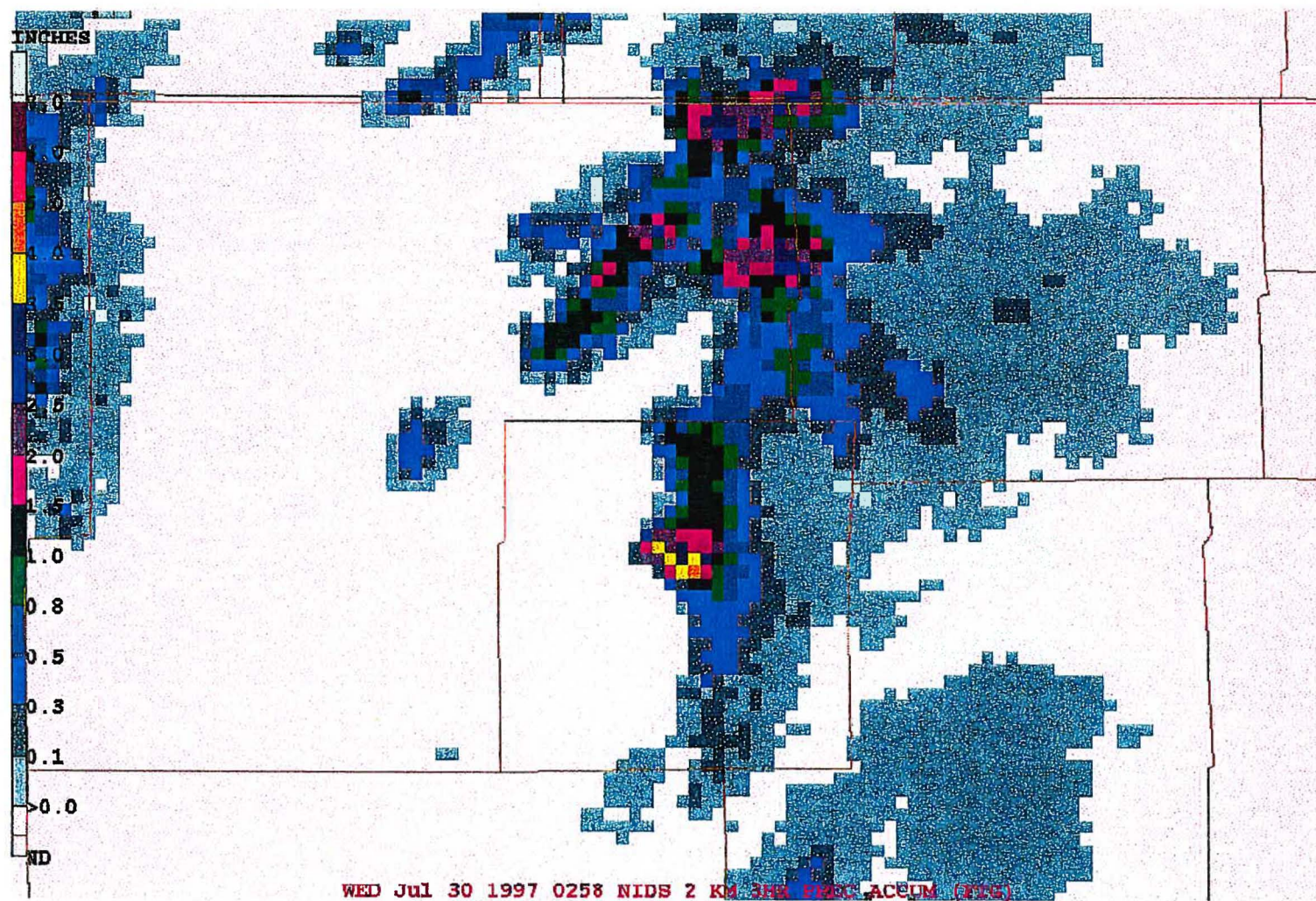


Figure 1. Three-hour estimated rainfall, 0000 - 0300Z on 30 July 1997 (6:00 - 9:00 PM MDT 29 July) using the standard NWS reflectivity-rainfall relationship.

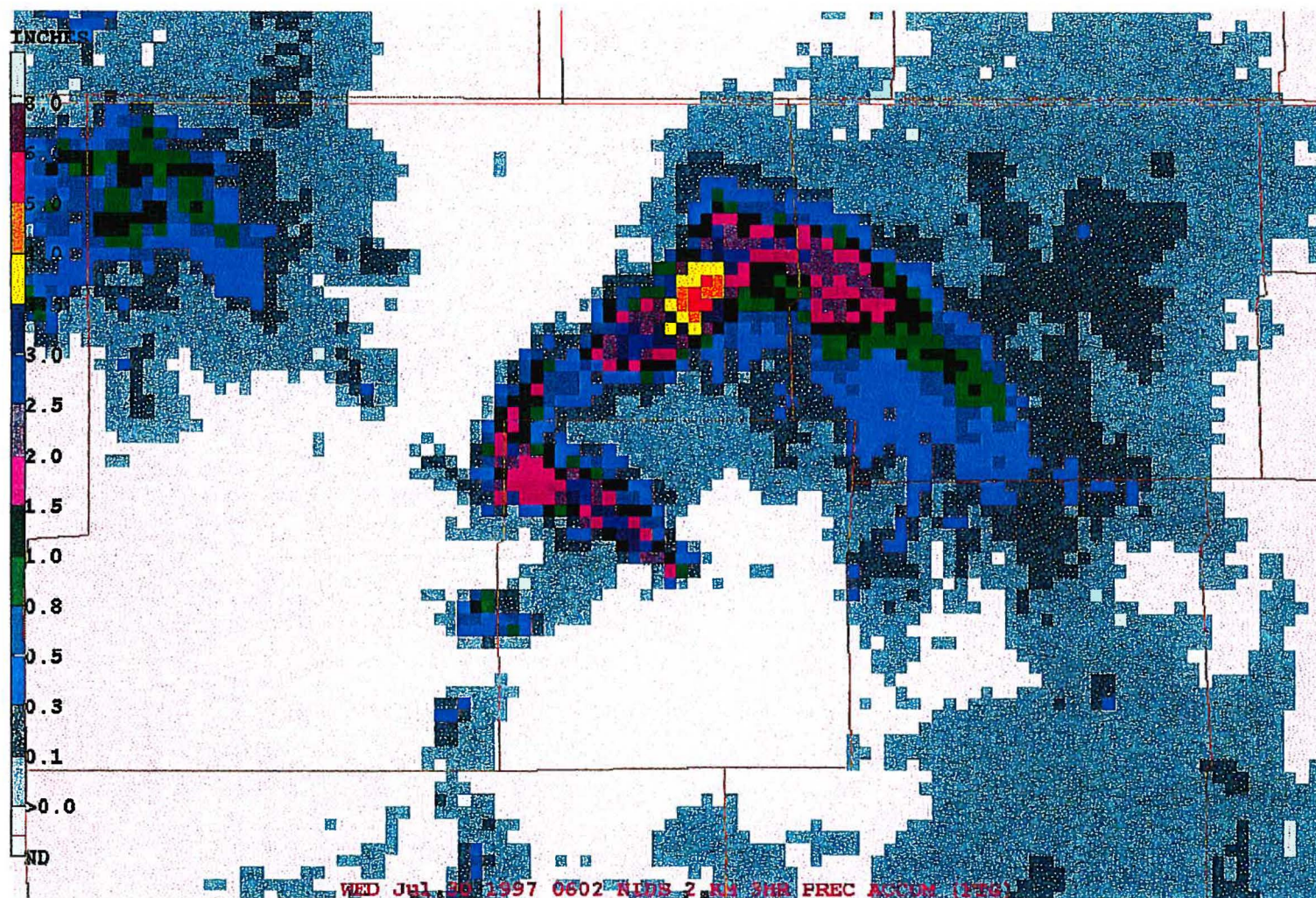


Figure 2. Three-hour estimated rainfall, 0300 - 0600Z on 30 July 1997 (9:00 PM - Midnight MDT 29 July) using the standard NWS reflectivity-rainfall relationship.

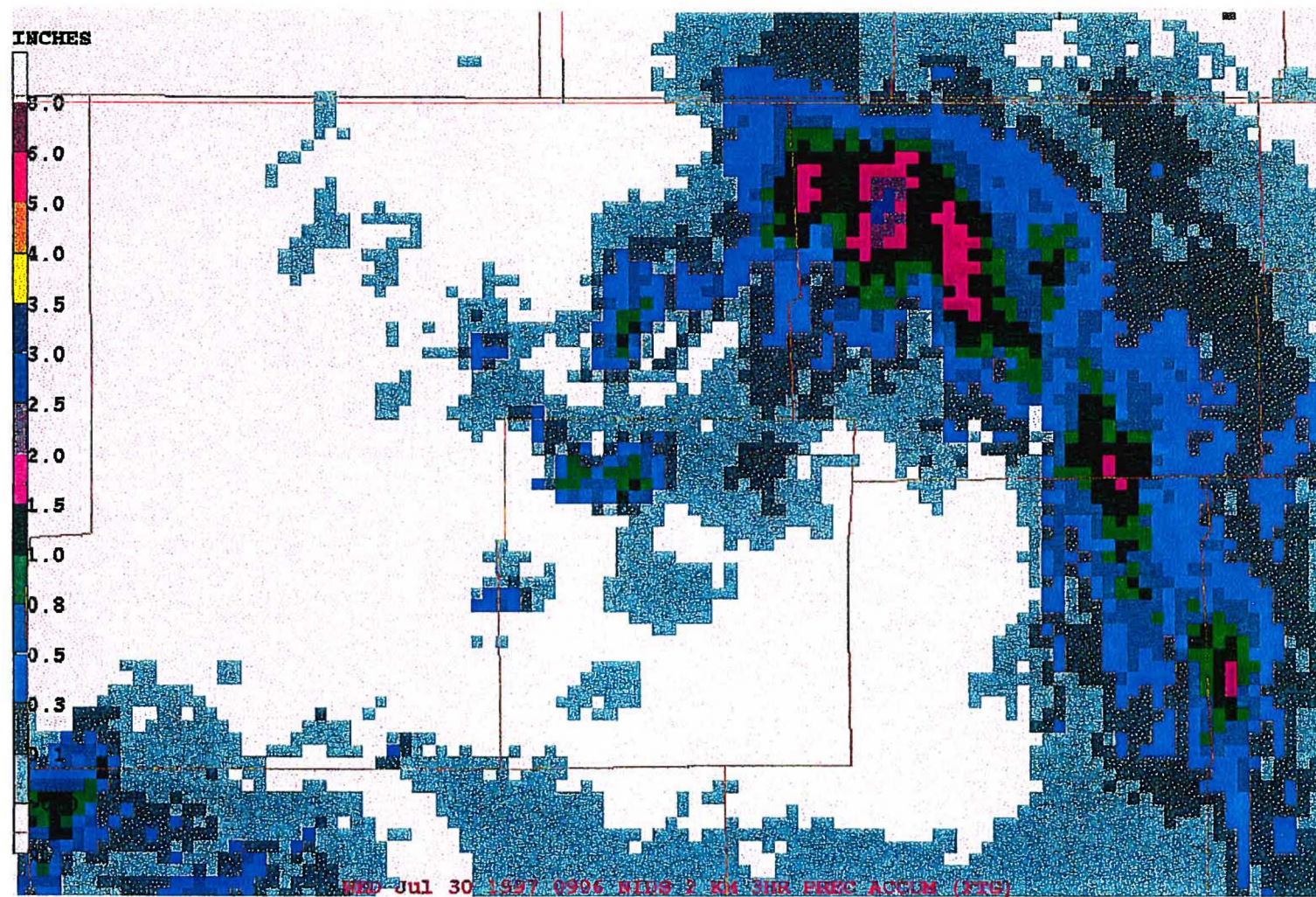


Figure 3. Three-hour estimated rainfall, 0600 - 0900Z on 30 July 1997 (Midnight - 3:00 AM 30 July) using the standard NWS reflectivity-rainfall relationship.

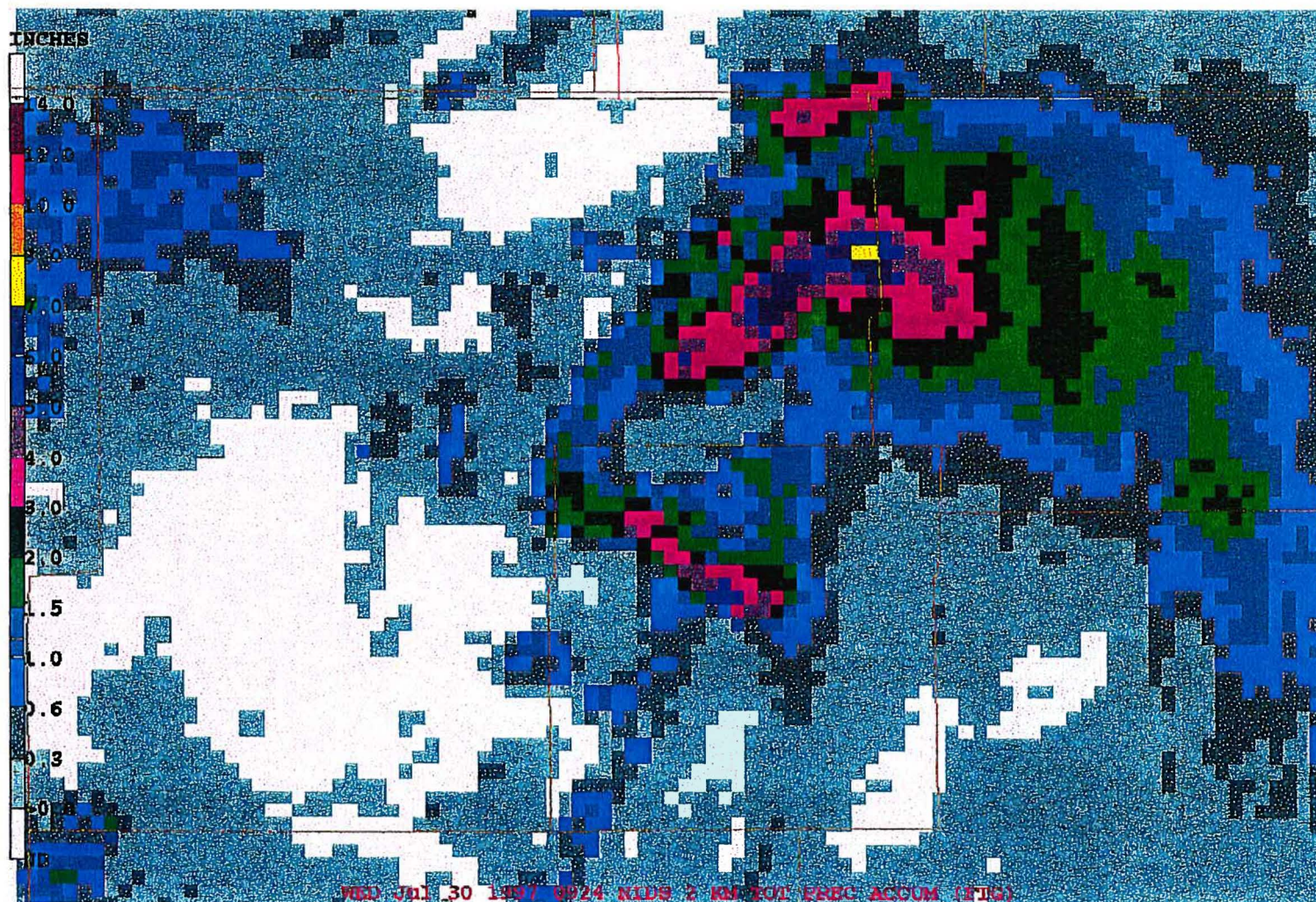


Figure 4. Total precipitation for the period 0000 - 0924Z 30 July 1997.

2) Site visits and interviews with residents near the primary core of the storm.

The 1997 storm survey was conducted as well and as quickly as possible after the Pawnee Creek flood. However, the survey was not conducted by meteorologists or experts on rainfall measurement procedures and gauge exposure. Since the event occurred, many questions have been raised concerning the accuracy and representativeness of rainfall reports. The purpose of these site visits and interviews was to independently evaluate the original rainfall reports and assign levels of confidence to the reports that were assembled after the storm. We feared that this would be quite difficult due to how much time has elapsed since the storm. However, with the cooperation of the local residents, many questions could still be answered.

The following is a rather thorough summary of each site visit and/or phone interview followed by conclusions about data accuracy and confidence. A simple rating system was developed to assign confidence to each observation. "A" represents complete confidence. "B" means reasonable confidence but with some unanswered or unanswerable questions. "C" means the data are uncertain but contain some useful information. "D" represents almost no confidence. In each case, an explanation is given.

Roger and Peggy Blake (and family) 75144 WCR 110, Stoneham	T 9N R 56W Sec. 3 extreme north edge Original rainfall report: 15.1 inches from rain gauge accumulations.
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Evaluation:

This was one of a handful of reports used to define the core of maximum rainfall for the storm. At the time of the 1997 storm survey, this report was given high confidence because it was the only excessive precipitation total (greater than 6 inches) that was based solely on rain gauge accumulation. Family members checked and emptied the small conical gauge (capacity of just over 6 inches) approximately every two hours during the storm and were thus able to report an accumulated storm total.

In interviewing the family, they showed me the 1997 calendar on which a daily rainfall total of 15" had been written. Based on their memories and notes (mother and daughter, Christy, had both helped read the gauge and agreed with each other), rainfall amounts and times of observation were approximately as follows:

7:30 PM MDT 7/29/98	Rain Began	They had just gotten home from Ft. Collins.
10 PM MDT	6"	Gauge nearly but not quite full to the top - still raining hard.
12 midnight	5.5"	Still raining hard.
2 AM MDT 7/30/98	2"	Rain letting up so family went to bed at 2:30 AM
approx 7 AM 7/30/98	<u>1.5"</u>	They weren't quite sure how they had come up
TOTAL	15"	with the 15.1" total reported previously.

They had double checked their readings and were very confident. They normally read and record rainfall totals to the nearest 0.1 inches. They were also sure that the gauge was empty that morning, since they had written down 1.3 inches of rain from the previous evening 7/28/98 and were conscientious about reading, recording and emptying. Their records showed that an additional 2" of rain had fallen 7/19-7/27, so local conditions were fairly moist immediately preceding the big storm. As an independent measure, they had at least two 5-gallon buckets sitting out which were both full to the top after the storm. They were thought to be empty before the storm.

Of meteorological interest, the rain came in with an east wind and actually seemed to move over them from east to west. Ms. Blake recalled that the rain felt warm and that there was no hail with the storm. They recall a lot of lightning but no sharp thunder. They described the lightning as "sheet lightning."

In reviewing this observation, I conclude that the family members were very conscientious, their memories were consistent, and their "Country General" cone-shaped rain gauge was located in a wide-open area of their back yard, well away from any trees or buildings in what would normally be considered an excellent exposure (photographs were taken 7/29/98). Since there was no hail and no strong winds, gauge catch efficiency and accuracy should be good with almost any gauge of reasonable quality.

There was one matter that concerned me that could have adversely affected the reading. The gauge was the type that has a small plastic mount that sticks in the ground. The gauge stands upright in that holder. When installed, the top of the gauge is no more than 10 inches above the ground. This is normally satisfactory, but in this case the gauge was mounted in a small depression that most certainly would have been filled with water during the storm to a depth of at least four inches. Thus, the top of the gauge would have only been about six inches above a water surface. During heavy rain, a great deal of splashing would take place near the water surface. It is likely that some water would splash in a manner that would enhance the gauge catch. It seems unlikely that splash would enhance the gauge catch by more than 10-20%, but a field test would be needed to test this hypothesis.

An additional concern is that several neighbors don't recall any significant precipitation after 2 AM. The 1.6" they measured between 2 AM and the next morning seemed larger than expected. This could be evaluated by comparing to NWS radar data.

Because of this ground-level exposure in a local depression, and the uncertainty about the rainfall after 2 AM, I feel that the quality of this observation must be considered "B." But even if splash was a problem, it seems likely that at least 12-13 inches of rain really did fall -- an exceptional amount for a period of just over seven hours. The 15 inch measurement is still possible if it can be demonstrated that splash was not a problem.

Clinton and Sharon Tappy
70758 WCR 104, Stoneham

T 9N R 57W Sec 14 NW
Original rain report: 13 3/4" from feed barrel

Evaluation:

It appears that this family was interviewed by one of the initial survey teams, but their 13 3/4" rainfall total was not included in the CWCB tabulation. A 13.5" value was written on one of the working maps provided by Tom Browning.

Clinton is an avid weather watcher and is equipped with a 4-inch diameter clear plastic high capacity rain gauge. For several years he provided daily reports to Mountain States Weather Services in Fort Collins, and now serves as a severe weather spotter for the Denver National Weather Service Office. Unfortunately, he was not at home for the storm having been at work in Fort Morgan working the evening shift. He recalls that rain began that afternoon sometime after he left for work at 3 PM. Based on his wife's recollections, Cottonwood Creek was rising rapidly around 10 PM. Water coming down the hillside from the north began coming into their house around 10 PM. Sharon recalled frequent lightning illuminating the rising water, but she recalled no hail at all. Sometime later, the water went down quickly. That must have been when Highway 71 just east of them washed out.

The next day when he got home his high-capacity rain gauge was completely full (holding at least 10 inches). It had been empty, since he had measured and emptied 2.0 inches the previous day. Nearby was a 20-gallon plastic barrel which had held cattle feed. It was straight sided and stood about two feet high. He was sure it had been empty, in spite of the rain the previous day. Based on a stick measurement in the barrel, he estimated a 24-hour rainfall total from the storm of 13 3/4 inches. Using this value in combination with daily readings from his 4-inch diameter gauge, he recorded a total of 20.75 inches of rain for the month of July, the most he had ever measured. An additional 3.63" fell in August.

In summary, this was a very credible and motivated weather observer doing a careful job estimating rainfall. I was unable to see and measure a comparable 20-gallon receptacle to verify its size and shape. Likewise, it is impossible to be sure that it was empty before the storm. **However, it is a certainty that at least ten inches of rain fell after 3 PM on the 29th, so the 13 3/4" estimate is reasonable with "B" confidence.**

Jake and Jewell Artzer
49905 WCR 137.5, New Raymer

T 9N R 57W Sec 28
Original rainfall report: 14" from stock tank

Evaluation:

This elderly couple had lived here for many years along the normally dry creek bed of Pawnee Creek but had never seen flooding so severe, even in June 1965. Most of their small dams that provide water for their cattle were washed out, and they cannot afford to replace them. Their house and outbuildings are all near Pawnee Creek, and they were surrounded by rushing water. They recall the rain coming in from the NE with the heaviest rain beginning before dark and quickly becoming very intense. They were

without electricity, and Mrs. Artzer was immobile at the time, due to a very recent hip replacement. However, they recall watching the rising flood waters illuminated by frequent lightning. They have two rain gauges near their house that they read regularly. Mr. Artzer considered going out to check them during the storm, but the water was too high. When he checked the next day, they were both full to a depth of about six inches and overflowing. The Artzers have a long history of reading and recording daily rainfall and were disappointed to have missed that measurement. The following day, as he recalled (July 31), he went up to a stock tank on the hill about one mile north of their house. It had been empty, but was full to a depth of 14" when he measured it. He credited all that rain to the storm, but he also noted that about 1 1/2" had fallen the previous evening (July 28).

The location of the stock tank was T 9N R 57W in the extreme SE corner of Sec. 16. As I visited and photographed the stock tank, I found it totally open and exposed on the top of the hill overlooking the Pawnee Creek valley to the south -- beautiful remote setting. It had just rained 1/2" before I arrived July 29, 1998 (based on Mr. Artzer's gauges) so I tried to measure it in the tank. I noted a very uneven concrete bottom with depth measurements varying from 0 to more than 2 inches depending on the location in the tank.

In summary, there is considerable evidence of extreme rainfall near the Artzer's home during the evening of July 29th. Mr. Artzer's estimate of 14" was not unreasonable but could have varied depending on exactly where in the uneven-bottomed tank he took his measurement. Also, the rain from the previous evening and, in fact, from other rains in late July, were likely included to some extent in the measurement. **In my estimation, taking the stock tank's unevenness into account and the rain that had fallen the previous night, plus any evaporation that may have occurred, an estimate of 12" would have been more reasonable with "B" confidence.**

Guy Whitlock

T 10N R 56W Sec. 20 SW

Original rain report: 12" in 5-gallon bucket

He and his wife were not at home for the storm. They had left on the 28th for Wyoming. No measurements were taken at their home on Highway 71. However, when they returned soon after the storm, they found 12 inches of water in what he described as a straight-sided 5-gallon bucket on their land approximately two miles east of their house (see location above).

There was no easy way to evaluate this measurement, as the bucket was no longer there and no one lives at the site. Without a doubt, very heavy rain fell at this location along Spring Creek. However, there are two concerns that must be considered with this report. First, it appeared from the timing of the Whitlock's trip to Wyoming, that the bucket was probably placed there before the rain began on the evening of the 28th. Based on nearby reports one-half mile away (Virgil Johnson), 1.5 inches fell late on the 28th and would have still been in the bucket along with the later rain. Secondly, there is the question of whether the bucket was truly straight sided. For the most common shapes of 5-gallon

buckets, the top opening is larger than the bottom, leading to rainfall magnification of 10 to 20 percent, where the error decreases as the water depth in the bucket increases.

Therefore, the confidence in this report can only be considered "C," and if the above assumptions are correct, the rainfall July 29-30th at this location may have been closer to nine inches.

Virgil Johnson	T10 N R56 W Sec 29 SE
54900 WCR 149, Stoneham	T10 N R56 W Sec 33 NW ??
	Original rainfall report: 11" in stock tank.
	9.2" or 9.5" also reported for same area

Two brothers and their 100 year-old father live very close to each other at the corner of WCR 112 and WCR 149. In the original survey, there were two rainfall reports from this area in the data table: an 11" total from section 33 (no name given), and a 9.2" total in Section 29 credited to "Johnsons." This contradicted slightly with the 9.5" total written on a rough-draft rainfall map. I only talked to one of the Johnsons -- Virgil, but based on this conversation and the site visit, it appears that his one stock tank reading may have been the source for both of the reports above. Based on heavy rain falling at the time of my visit, I was unable to see and locate the tank exactly.

Mr. Johnson had several clear memories of the day. He recalled no afternoon rain, but remembers the rain beginning hard during the early evening before dark. He recalled no hail with this storm compared to huge accumulations of hail during the storm that caused the last huge flood in the area -- June 1965. The rain came down very hard until it let up a bit around 10-10:30 PM. The rain hit the east side of his house, but the winds weren't strong. It came on real hard again, so he got back up and waited out the storm until it began to let up again. He fell asleep sometime after midnight and did not know when the rain stopped. After the storm, he measured a total depth of 11 inches of water in a stock tank a few hundred feet from his home. He had measured and recorded 1.5 inches of rain the evening of the 28th which he thought should be subtracted from the 11-inch total to give a rainfall total for the Tuesday night storm of 9.5 inches. He was very careful with his measurements and believed they were representative.

Based on this review, I believe that the best estimate for storm rainfall at this location was 9.5 inches with a confidence of "B." Without additional information, it appears that the 11-inch measurement from that location was a two-day total.

Cervi Ranch	T 10N R 56W Sec. 28
75905 WCR 124, Padroni	T 11N R 56W Sec. 35
	Apparently the identical report
	for two different locations 6"

I was unable to reach Mike Cervi, but spoke to Susie Martinez, the wife of Tino (sp??) Martinez, the ranch manager. Memories were no longer clear, but she recalled that the gauge at their house (and probably the other gauge down by the Johnson's) were both full to the top. Based on nearby reports, it appears extremely likely that rainfall greatly exceeded 6" at the southern location. This is useful information with good confidence, but is not an actual rain report since the gauges spilled.

Jaeger Farms (Dan or Nathan)
52249 WCR 149, Stoneham

T 9N R 56W Sec. 8 SE
Original rain report: 15" source unknown

I found and spoke with Dan Jaeger and his new bride Christy (daughter of the Blakes). They were both very familiar with the storm, and Christy had helped her mother take the rain gauge readings at the Blake farm two miles to the northeast. Dan was very helpful, but simply remembers that their small six-inch capacity cone-shaped rain gauge had totally filled and spilled so that no reading was taken at their farm. He recalls no buckets or tanks that may have been out and empty for measuring the rain. His brother was out in the field and not available to talk to. His assumption was that the 15 inch report credited to their location may have been the reading taken at the Blakes. The storm appeared to hit both places about equally, and he had driven to the Blakes in his truck during the storm to bring them a shop-vac to try to sweep up water from their basement. He found the road nearly impassable at that time, but I failed to note what time that was. He suggested not including the 15 inch report in the storm tabulation, so confidence assigned "D."

John Dunning
75473 WCR 100, Stoneham

T 9N R 56 W Sec 27
Original report: 4.0" in table,
4.5" on map from gauge

John was driving home that night from Fort Morgan and did not get home until flood waters receded. He was confident that 4.5 inches had fallen, but he had not written it down. He had no record of what had fallen the previous day. Upon visual inspection, the rain gauge appeared to be in good shape with a capacity of nearly six inches, but the 4.5 inch total seemed too low with respect to neighboring reports. But with no other information, I have no grounds for rejecting this report. Confidence "B."

C. J. Frank
26667 CR 7, Merino (Logan County)

T 10N R 55W Sec 21
Original report: 5.5" from gauge

His gauge only held four inches and was full to the top. Therefore, the daily total should have been reported as 4". The 5.5" report given to the survey team included the 1.5 inches that fell the previous evening (July 28). As we talked, his memory changed and he said that 2.5" late on the 28th for a storm total of 6.5". He did not consult any written records when talking to me. Although the gauge was full on the morning of the 30th, he believed that very little had spilled based on the amount of flooding on his hay fields and roads, which he described as "minimal." By comparison, the flood of 1965 following 9

inches of rain in his area was much higher and right up to the house (they did not live there yet, but that is what the previous residents told them.)

In talking to neighbors, they believed that the rainfall was greater than 4 inches. Since this was a spilled gauge, and some of the memories of the storm were no longer consistent, the confidence in this reading must be judged as low (C).

Rob Roberts
21280 CR 7, Merino

T 9N R55 W Sec. 10
Original report: 7.5 inches as shown on map
provided by Logan County Extension, but
his data was not included in the table in
October 1997 report

He had written down "7 inches" on his calendar (not the 7.5 inch value shown on the Logan County map. He had forgotten most details about the storm. They had no flooding on their place, but they are on high ground. There was significant flooding south of them. He remembered that most of the rain came at night, and with no hail and not that much lightning. I asked him how much rain his gauge could hold. He said only 5-6 inches. He then started to wonder how he came up with 7 or 7.5 inches last year. He couldn't remember. He gave me names and numbers for other neighbors in the area (there aren't many). I found one neighbor 2 miles north of him (Dave and Charlene Lowen) who remembered their 6-inch rain gauge full to the top with "flooding in all directions." Their notes showed that two inches had fallen the previous evening (July 28). That was all the confirmation I could find. While the confidence in his observation was low, the reported value may be realistic or conceivably too low. Confidence, "B-C."

Paul and Teresa Beintema
17843 CR 3.5 (Logan County)

T 8N R 55W Sec. 5
Original report: 5 inches from gauge

Their low-cost cone-shaped "advertisement rain gauge" was full to the top and could have overflowed. They recall the heaviest rain at their location between 10:30 and 11:00 PM MDT with the rain finally letting up before 3 AM. The river crested at 3 AM. Based on rainfall reports from neighbors, they seemed to be near the southern end of the heaviest rain area in Logan County. While their rainfall may have exceeded 5", it probably did not exceed it by much. However, it does lend support for extending the 6" rainfall isohyet farther south over western Logan County. While an accurate rainfall report for this site is unknown, there is good confidence (B) that more than 5 inches of rain fell at or near their location, as all reporting gauges from their location northward were full to the top.

Toedtli Ranch (John and Barbara)
69664 WCR 120, Stoneham

T 10N R 57W Sec. 10 NE
Original report: 5.5 inches from rain gauge

They have a large ranch covering many miles. She believed that about one inch had fallen the previous evening and had been emptied from their gauge. She did not have a written

record, however. She could not remember much rain on the afternoon of the 29th, and thought most of the 5.5 inches fell that evening. She recalled steady rain after dark with lots of lightning but not "vicious" like many of their summer thunderstorms. Their gauge was cone shaped with a capacity of around six inches. She believed it had not overflowed. However, several other gauges they read on grazing lands south of their house all overflowed. Those gauges are not emptied every day, so they may have included rainfall from the previous day.

The water moving down Spring Creek near their house made enough noise that they could hear it running, but the various small dams on their ranch all held.

My confidence in this report is "B" since there was some chance that the gauge could have overflowed. However, we suggest using the 5.5 inch report without modification. It is likely accurate.

Ken McEndaffer
61331 State Hiway 71 N, Stoneham

T 11N R 57W Sec. 25 southeast
Original report: 2.5" from gauge
(point plotted on working map, but
was not included on data table)

Mr. McEndaffer could neither confirm or deny the 2.5" report that had been credited to his house. He thought it had likely been more than that, since some of his fences along Two Mile Creek had been washed out. He suggested low confidence in the report, so I will call it "C."

Gary and Penny Naill
70008 WCR 132, New Raymer

T 11N R 57W Sec. 15 SW
Original report: 14 inches (source unknown)

I spoke to them by phone and did not visit their site. They provided enthusiastic but conflicting information. They did not have a rain gauge and had not written down any rainfall amounts. She recalled heavy rain on the afternoon of the 29th and again that evening. They recalled a survey team visiting them, but had no idea where the 14 inch rainfall total may have been based on. She believed they had exceptionally heavy rain, but Gary thought it was "no big deal -- maybe 2 1/2 inches." After some friendly arguing, they decided that they had likely had 8-9 inches of rain, and that some significant rainfall had occurred in the day(s) preceding the storm. However, they had no proof other than they had quite a bit of fence washed out by flooding. Without additional information from the original survey team, I would have to judge the 14 inch report as extremely suspect (C or D). There is insufficient information for this site to offer a better estimate.

Dan Clyncke
71033 WCR 132, New Raymer

T 11N R 57W Sec 2
Original report: 9.5 inches (shown on map
but not included in data tabulation)

He recalled the storm and had written down brief notes indicating that it had rained the evening of the 28th (I failed to record the amount). He then read and emptied his gauge on the evening of the 29th before with a total of 2.5 inches. The next morning an additional 4.5 inches was in his gauge for a **total of 7 inches with "B" confidence**. He did not know how the survey team had come up with 9.5 inches for his site unless it included rain from the previous day or from some source other than his measurements.

Dennis Bringleon (name misspelled in CWCB report)	T 9N R 58 W Sec 33
48904 WCR 127, New Raymer	Original Report: 3.7 inches (gauge)

They recall that they were not hard hit by the storm and only remember a little over 2 inches. However, they did not write it down, so assume 3.7 inches is correct. They do remember that the storm was mostly at night and just east of them. However, they do recall that their road was washed both north and especially south of them so there might have been heavier rains to the south. Confidence of report: **B**

Elk Echo Ranch (Craig and Noreen McConnell)	T 8N R 56 W Sec. 12
	Original report: 5.5"

Visited site but only talked to the children. Called back later and talked to Noreen. They had been in Fort Collins that day and drove back on highway 14, arriving home in heavy rain about 11 PM. Around 3 AM they heard a roar like a strong wind, but it was actually the sound of Pawnee Creek about 1/2 mile away roaring through the valley. They sustained nearly \$90,000 in damages. A barn on their ranch close to the river that survived the 1965 flood was destroyed in 1997. She recalled about five inches of rain but referred me to their ranch manager, Mark Anderson, for more information.

Terry and Nancy Kugler (and son Steve)	T 8N R 57W Sec. 10
45000 WCR 141, New Raymer	Original Report: 4.5"

I first visited with son, Steve, who had good memories of the storm since he drove home from Sterling 9:30-10:30 PM MDT with rain the whole way. The rain was not really bad, but got increasingly heavy as he got close to home. The creek was rising as he got home. By 11:30 PM it was way out of its banks and reached its peak 12:30-12:45 AM. He recalls that they read and emptied their gauge twice and that the total was much greater than 4.5 inches, but he preferred that I speak to his mother.

I later spoke with Nancy who had written down a lot about the storm. In fact, as an English teacher at the local high school, she had organized a literature project that included stories written by several individuals in the area that had been affected by the flood. She was delighted to learn that we considered that storm to be among the set of most extreme rain storms in Colorado's recorded history. That made her feel that her community literature project may have had more significance than she first realized.

As for the storm, she recalled that the rain started near or a little after 8 PM. In addition, she had written down that 1.95 inches of rain had fallen the previous evening (July 28th) and was enough to get the South Fork of Pawnee Creek (which is only about 100 yards north of their house) flowing. The rains fell all evening quite steadily. She did not remember the rainfall rate as unusually heavy, but it just kept coming down. She did not recall on her own that the storm backed in from the east, but when I mentioned it she agreed whole-heartedly. Near or before midnight, they went out to check their rain gauge (Taylor amber-colored wedge shaped gauge with markings up to five inches but a capacity for perhaps six inches total). They are confident that they had NOT emptied the gauge from the previous evening, but were still very surprised to find the gauge totally filled to the top. They conservatively estimated that it rained just over four inches up to that time (assuming a gauge capacity of six inches and that very little had spilled). When they checked their gauge the next morning, they found an additional 3.65 inches. Thus, they estimated that the total at their place was about eight inches.

Nancy recalled that the river peaked about 1:30 AM on the 30th only about 20 feet from their house and by 3:30 AM was beginning to recede. At that time, the rain had stopped, and she believed the rain let up or had nearly stopped not long after 2 AM.

In addition to the rain reports, she also had several comments about flooding and damage. Their ranch is 6000 acres, much of it not far from the South Pawnee Creek. They had two spreader dams badly damaged, many corrals destroyed, 200 giant round hay bales swept away and 32 fence crossings wiped out. Ben Walker from New Raymer told them that this was worse than the 1965 flood. It was definitely far worse than anything the Kuglers have experienced since they moved their in 1969. As an aside, after the flood, Pawnee Creek has been clear, sand-bottomed and very attractive through their property with several deep holes. Prior to the flood it was a muddy and occasionally scummy intermittent stream.

In summary, it appears that at least 7.5 inches of rain fell at their location on top of 1.95 inches the previous evening. Confidence in this lower limit is quite high (B), as they read and recorded their rain measurements and maintain their gauge faithfully during the summer. However, the reading is obviously not precise since the gauge spilled. There is also the question of why the original survey team reported 4.5 inches for this station. It appears that they did not include the 3.65" that fell after they emptied the gauge the first time. While there are some uncertainties, the magnitude of the flooding they reported definitely support extreme rain amounts at their location and also upstream. This had not previously been shown in the preliminary analysis.

3) Interviews with residents not previously surveyed

While conducting this field survey, I encountered a number of people who either had not been interviewed soon after the storm or whose reports were considered inconsequential for storm documentation. Some additional data were uncovered, predominately from areas surrounding but outside of the region of maximum rainfall.

The following is a summary of supplemental reports that I obtained.

Harold Weisbrook

T 11N R 58W Sec 16 NE

Harold is an official National Weather Service Cooperative Observer. He had a great view of the storm, but only received 0.05 inches on the 29th. For the preceding day ending at 7:00 AM on the 29th, he measured 0.96. He particularly remembered an intense storm just a few miles east of him during the late afternoon. He drove north and then east and found water flowing over the road on WCR 132 already soon after 4:00 PM on the 29th. Then, during the evening he was amazed to watch the storm clouds build rapidly back toward southeast until sunset. Originally, the storm clouds were east and southeast of his farm, but eventually they extend around to the southwest of his location down beyond the Pawnee Buttes. Confidence rating = A

Gary Sheffler

T 11N R 57 W Sec 6 SE

65295 WCR 135, New Raymer

He was very thorough and detailed and remembered the day well. He remembered the storm building just east of him during the afternoon along the ridge north of WCR 132. It eventually backed right over his place. The heaviest rains fell 3-4 PM, but more rain fell during the evening. He recalled a lot of lightning but no hail. He remembered 3" of rain at his place, but his wife's notes said 5" (which is also what Harold Weisbrook had said). Their notes indicated that 1.4" of rain had fallen the previous evening (28th).

He also had several gauges on range land several miles east of his house.

Location	Daily rainfall ending 29th AM	30th AM
T 12N R 56W Sec 22	1.5"	6"+
T 12N R 56W Sec 23	1.8"	6"+
T 12N R 56W Sec 36	1.7"	3.5"

These locations were given to me quickly over the phone, so they should be verified before being used in formal documents. Overall confidence in these reports "A" if verified with observer's personal notes.

Dewain Shapley
70589 WCR 112, Stoneham

T 10N R 56 W Sec 25 SE ??
(near corner of Highway 71 and WCR 112)

His gauge overflowed so no firm estimate available. He recalls a lot of thunder and lightning, but no hail. He described lightning as "sheet lightning." It was still raining at his location when he went to bed around midnight. He guessed the rain was over between 1:00 and 2:00 AM on the 30th.

Les and Virginia O'Hare
60480 WCR 135, New Raymer

T 11N R 57 W Sec 32 NW

I spoke with Virginia. She recalls never having seen so much rain. On the evening of the 28th, she recalled about an inch of rain. Then on the 29th she remembers the heaviest rains falling after dark with lots of lightning, especially south and southeast of them. Their cone-shaped gauge had 6" when they measured it the next morning. That is about all that it holds, but it was not full to the top, so she thought that was their total. Confidence = B

Steve O'Hare
63743 WCR 131, New Raymer

T 11N R 58 W Sec 13

Only 3.5" fell at Les and Virginia's son's house approx 4 miles northwest of them.
Confidence = B

Jim and Deb Walker
56432 WCR 135, New Raymer

T 8N R 57W Sec 18

Their ranch is located directly west of the Kuglers in an area for which apparently no rain reports were obtained by the original survey teams. However, based on flooding on the South Pawnee Creek near and downstream from their ranch, there definitely appeared to have been very heavy rains. Deb and daughter were not at home that night, and Jim was there alone. He provided fairly detailed information. He recorded 3 inches of rain the previous evening (28th) which was enough to get the creek flowing. He was confident he had emptied the gauge. He remembers the rain began on the 29th around 9:30 PM while he was on the phone with his wife and daughter who were in Toronto, Canada for a special basketball competition. The rain was heavy from the very beginning and did not let up. There was absolutely no hail and almost no wind that he could remember. The lightning was frequent and with loud thunder. It was still raining hard at 1:30 AM (he couldn't get to sleep because of the sound -- and concern for flooding). He went out to their rain gauge at that time and found it full to the top with 6 inches. He emptied it, and then checked it again in the morning and found another 3 inches. As lightning illuminated the valley, he could see the Creek running at least one-quarter mile wide.

His personal estimate from the rain gauge and local flood damage was that at least 10 inches of rain had fallen at his place. He also guessed that the rain was heaviest just south

of him on the hogback between New Raymer and the S. Pawnee Creek. It appeared from damage and erosion on his ranch, that rainfall decreased to the north and decreased rapidly to the west.

I did not visit this site and did not see the exposure of the rain gauge. The approximate (nearest inch) rainfall readings and the large 3-inch report for the evening of the 28th raised some uncertainty. However, the observer was diligent and enthusiastic and trusted his own readings very much, suggesting a confidence of "B." I have no information with which to dispute his 9"+ reading, but it would be nice to know the gauge location and exposure, since this reading at this location definitely modifies the rainfall pattern from what was presented in the preliminary CWCB analysis. Also, the apparent heavier rain to the south could have simply been a result that type and steepness of the terrain were more conducive to erosion. But no matter how you look at it, this observation along with that of the Kuglers, indicates that a narrow band of very heavy rain extended as far west as New Raymer.

Jack and Shirley Fiscus
66410 WCR 120, New Raymer

T 10N R 57W Sec 7 or close

They noted between 3-4 inches, but had no special recollections or additional information. Confidence not evaluated.

Keith and Shirley Ashbaugh
39434 WCR 115, New Raymer

T 7N R 59W Sec unknown

Evidence of heavy rains west of New Raymer from radar data caused me to seek out information for the area near Buckingham. Their place is 8 miles west and 2 miles south of New Raymer. They reported 2 inches of rain late on the 28th, but only 0.5 inches on the evening of the 29th. While the storm was not far away to the north and northeast, they were not hard hit. Their only special memory of the event was the 15-hour power outage they experienced. Confidence = B

Kenneth Thompson
New Raymer, in town

T 7N R 58W Sec 3

Ken is the official National Weather Service cooperative observer in the town of New Raymer. He operates both a large capacity 8-inch diameter manual rain gauge and also a NWS Fischer-Porter recording rain gauge that records rainfall at 15-minute intervals. There in New Raymer, 2.38 inches of rainfall was recorded for the period ending at 7:00 AM on the 29th giving proof of a very significant storm in the area during the evening of the 28th. In fact, 2 inches of rain fell in less than two hours in New Raymer from 9:00 to 11:00 PM on the 28th. The rain began again in New Raymer after 8:00 PM on the 29th and ended before 1:00 AM on the 30th. A total of 3.60 inches was measured in five hours. Of this total, 3.2 inches fell in just 2 hours for the period ending at 10:45 PM

MDT. The 3.6 inch storm total was more rain than had been reported to the initial survey team by another local New Raymer resident. Since this was confirmed by two independent NWS gauges, this report should supersede the 2.5" report contained in the CWCB report. Confidence = A

Charles Craig
47822 Hwy 71 N, Stoneham

T 8N R 56 W Sec. 6

Charles actually had an 8-inch diameter high capacity rain gauge that he was given 25 years ago when he was a volunteer for the National Hail Research Experiment. He reported between 4 and 4.5" from the storm on the 29th. He could not recall the rainfall total from the previous evening. He recalled that the heaviest rains fell west and north of him just a few miles away. His comments included, "When it rained, it came down hard. There was lightning, but not all that intense. The rain seemed warm, and there was no hail." As did many others, he compared this storm to the 1965 storm. That time, the rains were heaviest to the SW, he recalled, and there was tons of hail and much more lightning. The rainfall intensity, however, seemed similar. Confidence in observation = B

Mark Pauling
69295 WCR 106, Stoneham

T 9N R 57 W Sec. 10
No gauges but he "guessed" 11"

He recalled the rain starting sometime between 7:00 and 7:30 PM MDT on the 29th. Unfortunately, he had no gauges or other collectors. He never had seen such a rain before. It mostly fell straight down, as he recalled, and the clouds hung very close to the ground. It would rain very hard, then let up a bit, then lightning activity (very close) would increase again followed shortly by even heavier rain. As he remembered, the rain was letting up at their location by a little before midnight. Good information, but since no actual measurement taken, the confidence can only be assigned a "C."

Colby VanCleave
50985 WCR 135, New Raymer

T 9N R 57W Sec. 18, ext SE corner

He lives right on Pawnee Creek, but was not home during the storm. He had been in Fort Collins all day helping clean out his mother's flooded basement. (By coincidence, she happens to live right across the street from my house in northwest Fort Collins.) He did have a relatively high capacity rain gauge, and he recalled having already had a big rain on the 28th -- close to 3.5 inches. When he got home, he found his house flooded, and his rain gauge full to the top at 8.5 inches. He is reasonably sure that the gauge had been emptied, but he rushed off quickly early on the 29th (around 5 AM) when his mother called for help, so he couldn't be absolutely sure. He definitely experienced severe local flooding. Since it appeared that rainfall decreased rapidly west of his location, it appears likely that extremely heavy rains in excess of 8.5 inches likely did fall at his location. Confidence = B / C

Joe and Karen Kimmel
47853 WCR 153, Stoneham

T 9N R 56W Sec 34 south edge

Their place was right on the creek and experienced severe flooding. However, it appeared that they were south and east of the heaviest rains. They remembered that the creek was already running that day following the rains Monday night. Rain began before dark, but got heavier after dark. There was modest amounts of lightning -- which she described as "sheet lightning." There were big rain drops, but no hail, and the air temperature didn't seem to drop during the storm. Lightning and thunder didn't quit until after about 2 AM. By then, they had evacuated to higher ground at their neighbors, the Dunnings. She also showed me peak water levels, and described the timing of the flooding. They recall the peak occurred not long after midnight after rising very rapidly from 11:00 PM to midnight. Their rain gauge (which was tilted a bit towards the east), had a capacity of 6.5 inches. She had written down that 5 inches fell that night, and she was confident the gauge had not overflowed. Confidence = **B**

Gary Dollerschell
46001 WCR 153, Stoneham

T 8N R 56 W Sec 14

Rain gauge report for 24 hours ending morning of 7/29 1 3/4 inch
Rain gauge report for 24 hours ending morning of 7/30 2.6"
Confidence "A." He just thought it was a good steady rain. No flooding.

Richard and Elaine Raffelson
0382 Logan CR 64

T 11N R 55 W Sec 30

Vivid recollections about driving over an area where bridge was washed out. Memories of rainfall, however, were not clear other than recalling that their gauge (which held 5-6 inches of rain) had been filled to the top. Data confidence rating probably "C."

Jim Nelson
Logan County

T 12N R55 W Sec. 34
3.59" from Weather Wizard III tipping
bucket gauge -- not locally calibrated

They were very interested, but unfortunately were not home at the time of the storm. They recently purchased an automatic weather station which records total rainfall but not the time or intensity. They were confident of the reading based on previous experiences with their weather station, but have not tested and compared it to traditional rain gauges. I suggested they get a regular manual rain gauge and compare them for a time.
Confidence = **B**

Summary and Conclusions

It was an extremely interesting experience to conduct a storm analysis a full year after the event. Overall, I felt that I was successful in assembling very good information suitable for improving upon the original rainfall analysis for the storm. However, very few of the observations were so confident as to earn an "A" rating. While it was possible to make reasonably confident estimates of the storm rainfall pattern, uncertainty still exists regarding exactly where, when and how much rain fell. There were still a few residents of the area that could have been surveyed, but there was not enough time in this study for further field work. Also, the farther away from the storm center, the poorer were the memories of the storm.

The results of the rainfall analysis and review are contained in Table 1. This survey strongly suggests that locally very heavy rains fell farther south and west of the storm center than was indicated in the preliminary analysis. At the same time, this survey failed to uncover information to better define rainfall patterns just east of the storm center in western Logan county. Considerably uncertainty remains as to the limits of the heaviest rains in excess of six to eight inches in Logan County. Observations and interviews from residents of that area provided only marginal verification of actual rainfall patterns.

Table 1. List of locations and rainfall amounts for the storm of July 29-30, 1997.

<u>Location</u>			<u>Storm Rainfall (inches)</u>		<u>Confidence</u>	<u>Reason for change</u>	<u>July 28</u>
T	R	Sec	original	verified			Rainfall
9	56	3	15.1	12-14 est.	B	Possible gage splash	1.3
9	57	14NW	13.5	13.75	B	Checked his notes	DNA
9	57	16SE	14	12	B	Subtracted previous day's rain	1.5
10	56	20SW	12	9 est.	C	Subtracted previous rain and corrected for shape of bucket	1.5
10	56	29SE	11	9.5	B	Subtracted previous day's rain	1.5
10	56	28	6	6+	C	Gauge overflowed	DNA
11	56	35	6	6+	C	Gauge overflowed	DNA
9	56	8SE	15	----	D	No observation found	NA
9	56	27	4 or 4.5	4.5	B	Observer's memory	NA

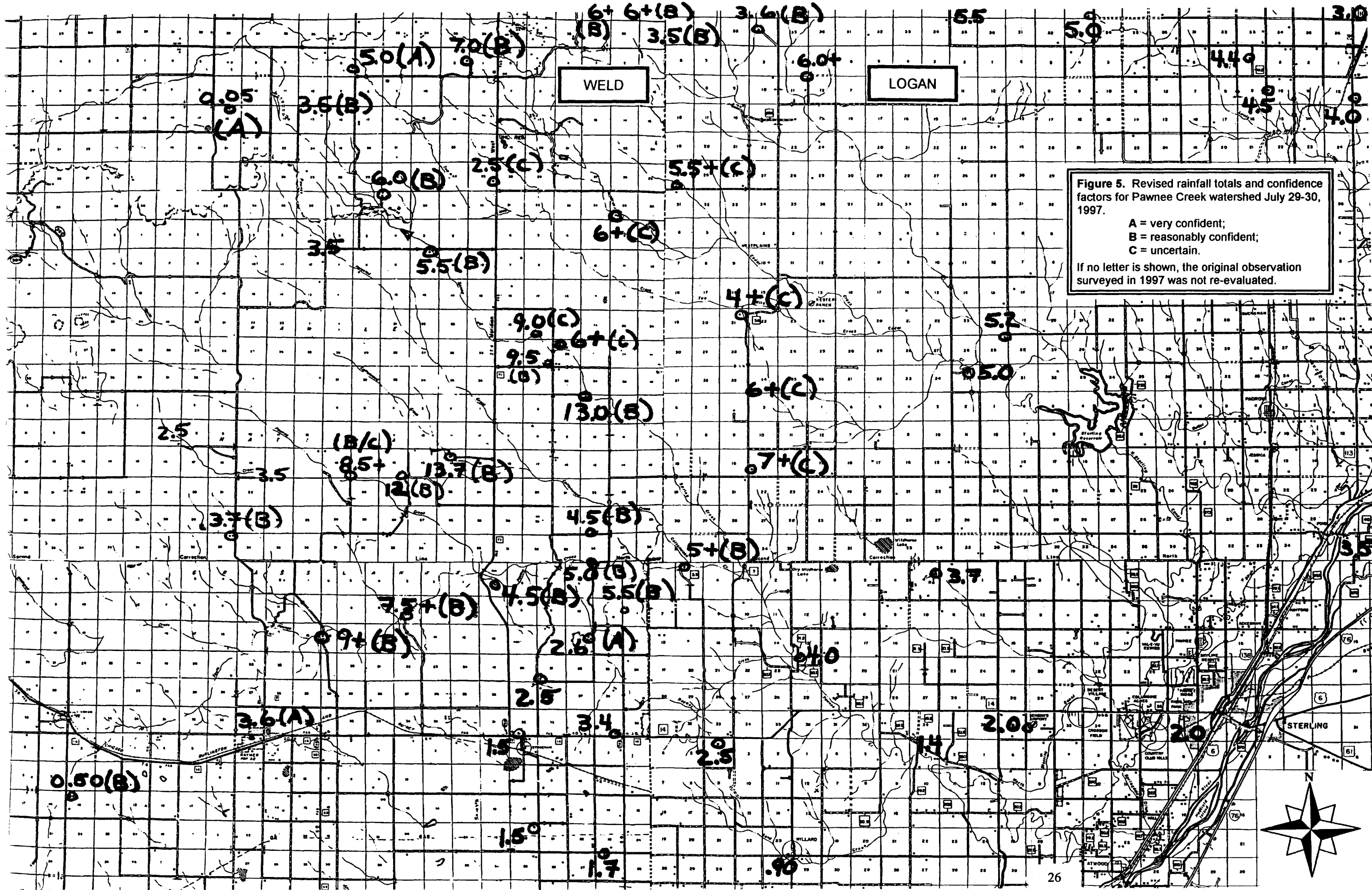
<u>Location</u>			<u>Storm Rainfall (inches)</u>		Confidence	Reason for change	July 28
T	R	Sec	original	verified			Rainfall
10	55	21	5.5	??	C	Subtracted previous day's rain - but gauge overflowed	1.5
9	55	10	7.5	7"(??)	C	Observer's notes, but gauge overflowed	NA
10	55	34 (??)	NA	6+	C	Gauge overflowed	2.0
8	55	5	5	5-6+	B	Gauge overflowed	NA
10	57	10NE	5.5	5.5	B		1.0
11	57	25SE	2.5	2.5 (??)	C	Observer thought his report was too low last year, but had no proof	NA
11	57	15SW	14	8-9 (??)	C-D	No data available but they were sure 14" was false	NA
11	57	2	9.5	7	B	Observer's notes -- maybe subtracted previous day's rain ??	NR
9	58	33	3.7	3.7	B	Confirmed by notes	NA
8	56	12	5.5	5.5	B	No other information	NA
8	57	10	4.5	7.5+	B	Don't know where the 4.5" report came from	1.95
11	58	16NE	--	0.05	A	Additional data	0.96
11	57	6SE	--	5	A	Additional data	1.4
12	56	22	--	6+	B	Gauge spilled	1.5
12	56	23	--	6+	B	Gauge spilled	1.8
12	56	36	--	3.5	B	Additional data	1.7
10	56	25SE (??)	--	6+	C	Gauge overflowed	NA
11	57	32NW	--	6	B	Almost to top	1.0
11	58	13	--	3.5	B		NA
8	57	18	--	9+	B	Additional data -- gauge maybe spilled	3"

<u>Location</u>			<u>Storm Rainfall</u> (inches)		Confidence	Reason for change	July 28
T	R	Sec	original	verified			Rainfall
10	57	7 (??)	--	3-4	NA		
7	59	(??)	--	0.5	B	Additional data	2"
7	58	3	--	3.6	A	Additional data	2.38
8	56	6	--	4 - 4.5	B	Additional data	NA
9	57	10	--	11	C/D	Just a guess	NA
9	57	18SE	--	8.5+	B/C	Gauge spilled	3.5
9	56	34	--	5	B	Additional data	NA
8	56	14	--	2.6	A	Additional data	1.75
11	55	30	--	5-6+	C	Additional data	NA
12	55	34	--	3.59	B	Additional data	NA

Based on this rainfall survey and post-evaluation for the Pawnee Creek flood event of July 29-30, 1997, it was confirmed that near the core of heaviest precipitation, rain began about 7:30 PM and lasted until after midnight. The total storm duration was as much as 8 hours, but the great majority of precipitation fell in six hours or less. Southwest of the storm center, the rains began a bit later -- perhaps 8:30 PM or even later -- as new cells developed on the southwest flank of the storm. Farther to the north over extreme northeastern Weld County, a significant amount of precipitation also fell in the late afternoon, before the main event developed farther to the south.

Reports suggest that there were no incredible rainfall rates (in excess of three to four inches per hour) but rather heavy rainfall that persisted much longer than in more typical intense Colorado thunderstorms. There was little or no hail reported with the storm, and many observers independently reported the lightning as frequent but not extraordinary and more like sheet lightning.

A map of point rainfall reports was produced (Figure 5). Keep in mind that only those reports in Weld County and extreme western Logan County were reviewed during this survey. By comparing this to the results of the original storm survey and draft document of October 1997, some differences in rainfall values are apparent. For example, a few inconsistencies were found in reported rainfall amounts between the data tabulation prepared by the CWCB in 1997 and the rainfall totals plotted on preliminary rainfall maps. We are choosing in favor of the values reported to us this year, if different from what was noted last year and if evidence suggests that the entries made last year were inaccurate. There were also a few inaccuracies in station location, and some rainfall reports gathered last year that could not be confirmed in this post evaluation. Most changes, however, are



due to additional or more complete data from this later survey, in combination with our interpretation of observational uncertainties.

A revised analysis of storm rainfall isohyets is shown in Figure 6. It is with a high degree of confidence that we can say that there was an area of several square miles that received in excess of 10 to 12 inches of rain in a period of 6-8 hours, with the majority of that rainfall occurring in the period from 7:30 PM to Midnight. The maximum rainfall of 15 inches as originally reported is possible and was read and recorded diligently by the local residents. However, there is a good chance that the observation was somewhat exaggerated by ground splash. As a result of this change, we lowered this value to 13 inches, although this is only an estimate, the area exceeding 14 inches shown in the preliminary analysis cannot be confidently confirmed from the available rainfall reports. The largest value is now believed to be somewhat less than 14 inches. While this revised analysis shows less rainfall at the storm center, there is strong evidence that the rainfall maximum extended farther to the west and south than originally thought with very heavy rains extending southwestward to just north of the town of New Raymer. The analysis of two separate areas in excess of twelve inches is somewhat arbitrary but is also suggested from NWS radar analysis.

A secondary smaller maximum over northeast Weld County was confirmed but not to the magnitude originally shown (14 inches). Quantitative data only support an estimated maximum at this secondary center of less than ten inches. From interviews with local residents, it appears that this secondary maximum was a result of heavy rain earlier in the afternoon of the 29th that may have begun as early as 3:00 PM MDT far before rain began farther to the south. The rains later in the evening were substantial in that area, but much less than what was observed farther south.

While our re-analysis of the area and magnitude of heaviest rainfall resulted in a reduction of the areas and the magnitude of the most extreme (12 inches and greater) values, the inclusion of additional reports, plus the follow-up with many of the people surveyed last year whose rain gauges may have been full to the top after the storm, suggests that the areas that received more than six inches of rain from the storm may, in fact, be more extensive than originally thought over portions of Weld County and western Logan county. From this analysis, the area receiving at least six inches of rainfall encompassed approximately 270 square miles. This is a very large storm of this magnitude for Colorado.

There had been concern prior to this evaluation, that many of the rainfall reports gathered last year and shown as July 29-30 evening storm totals may have also included rain from the evening of July 28 and morning of the 29th. This was found to be much less of a problem than expected, as nearly everyone queried had indeed observed and reported a significant rainfall (generally 1 to 2 inches over the area and locally as much as 3" north of New Raymer) from the storm on the evening of the 28th. In most cases, gauges were read and emptied prior to the July 29th evening storm, so that the storm reports gathered by the original survey teams were not exaggerated by additional precipitation from previous

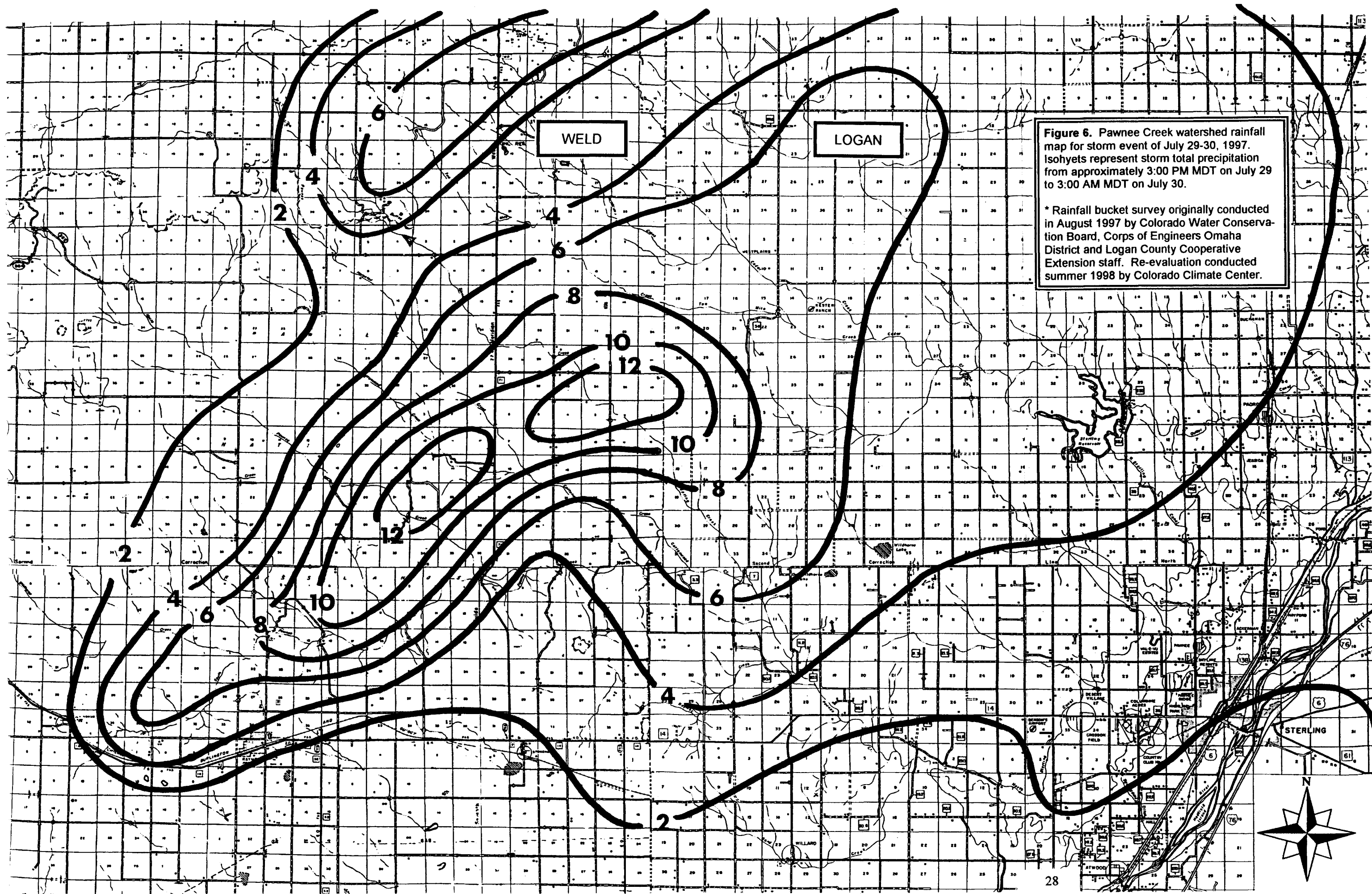


Figure 6. Pawnee Creek watershed rainfall map for storm event of July 29-30, 1997. Isohyets represent storm total precipitation from approximately 3:00 PM MDT on July 29 to 3:00 AM MDT on July 30.

* Rainfall bucket survey originally conducted in August 1997 by Colorado Water Conservation Board, Corps of Engineers Omaha District and Logan County Cooperative Extension staff. Re-evaluation conducted summer 1998 by Colorado Climate Center.

storms. Near the center of heaviest rainfall, accumulation of water from earlier rains was more of a problem since bucket and stock tank depths were used where rain gauges had overflowed. Correcting for rains the previous evening did result in lower storm totals at a few sites.

Overall, considering the very low population density of the area, it was possible to gather surprising amounts of reasonably confident observations. The people of these counties have a long history of weather watching and are used to measuring and recording rainfall on a daily basis. Had more observers had higher capacity rain gauges, it would have been possible to document this complex storm with surprising detail.

Acknowledgments

The author would like to thank the many people of Weld and Logan counties who took time to talk and willingly answer my many questions. It was a real treat to get to talk to so many sincere and experienced weather watchers who have informally studied the weather over these open, wind-swept grasslands for so many decades. It was indeed an honor for me to make their acquaintance. My thanks to Markus Ritsch of Riverside Technology Inc. and the Colorado Water Conservation Board for financial support for this project. Finally, special thanks to Tom Browning of the Colorado Water Conservation Board for his great concern over proper historic documentation of this remarkable storm.

Appendix

List of individuals/families in the vicinity of the 1997 Pawnee Creek flood interviewed by Nolan Doesken in July 1998 while evaluating storm rainfall reports.

Roger and Peggy Blake (and family) 75144 WCR 110, Stoneham 735-2536	T 9N R 56W Sec. 3 extreme north edge
Clinton and Sharon Tappy 70758 WCR 104, Stoneham 735-2561	T 9N R 57W Sec 14 NW
Jake and Jewell Artzer 49905 WCR 137.5, New Raymer 437-5423	T 9N R 57W Sec 28
Guy Whitlock 56601 Hwy 71 N., Stoneham 735-2888	T 10N R 56W Sec. 20 SW (not at his home)
Virgil Johnson 54900 WCR 149, Stoneham 735-2546	T10 N R56 W Sec 29 SE
Cervi Ranch 75905 WCR 124, Padroni 735-2511	T 10N R 56W Sec. 28
Jaeger Farms (Dan or Nathan) 52249 WCR 149, Stoneham 735-2551	T 9N R 56W Sec. 8 SE
John Dunning 75473 WCR 100, Stoneham 735-2571	T 9N R56 W Sec 27
C. J. Frank 26667 CR 7, Merino (Logan County) 437-5421	T 10N R 55W Sec 21
Rob Roberts 21280 CR 7, Merino (Logan County) 228-4176	T 9N R 55W Sec. 10

Dave and Charlene Lowen
22947 CR 7, Merino (Logan County)
228-4171

T 10N R 55W Sec. 34 (???)

Paul and Teresa Beintema
17843 CR 3.5 (Logan County)
228-4106

T 8N R 55W Sec. 5

Toedtli Ranch (John and Barbara)
69664 WCR 120, Stoneham
437-5416

T 10N R 57W Sec. 10 NE

Ken McEndaffer
61331 State Hiway 71 N, Stoneham
437-5448

T 11N R 57W Sec. 25 southeast

Gary and Penny Nail
70008 WCR 132, New Raymer
437-5345

T 11N R 57W Sec. 15 SW

Dan Clyncke
71033 WCR 132, New Raymer
437-5375

T 11N R 57W Sec 2

Dennis Bringleson
48904 WCR 127, New Raymer
437-5413

T 9N R 58 W Sec 33

Elk Echo Ranch
(Craig and Noreen McConnell)
47490 WCR 155, Stoneham
735-2426

T 8N R 56 W Sec. 12

Terry and Nancy Kugler (and son Steve)
45000 WCR 141, New Raymer
437-5464

T 8N R 57W Sec. 10

Harold Weisbrook
62618 WCR 130, New Raymer
437-5434

T 11N R 58W Sec 16 NE

Gary Sheffler
65295 WCR 135, New Raymer
437-5369

T 11N R 57 W Sec 6 SE

Additional rangeland sites
observed by Mr. Sheffler

T 12N R 56W Sec 22
T 12N R 56W Sec 23
T 12N R 56W Sec 36

Dewain Shapley
70589 WCR 112, Stoneham
735-2271

T 10N R 56 W Sec 25 SE ??

Les and Virginia O'Hare
60480 WCR 135, New Raymer
437-5438

T 11N R 57 W Sec 32 NW

Steve O'Hare
63743 WCR 131, New Raymer
437-5316

T 11N R 58 W Sec 13

Jim and Deb Walker
56432 WCR 135, New Raymer
437-5422

T 8N R 57W Sec 18

Jack and Shirley Fiscus
66410 WCR 120, New Raymer
437-5432

T 10N R 57W Sec 7 or close

Keith and Shirley Ashbaugh
39434 WCR 115, New Raymer
437-5331

T 7N R 59W Sec unknown

Kenneth Thompson
235 Centre Avenue, New Raymer, in town
437-5338

T 7N R 58W Sec 3.

Charles Craig
47822 Hwy 71 N, Stoneham
735-2416

T 8N R 56 W Sec. 6

Mark Pauling
69295 WCR 106, Stoneham
735-2700

T 9N R 57 W Sec. 10

Colby VanCleave
50985 WCR 135, New Raymer
437-5426

T 9N R 57W Sec. 18, ext SE corner

Joe and Karen Kimmel
47853 WCR 153, Stoneham
735-2611

T 9N R 56W Sec 34 south edge

Gary Dollerschell
46001 WCR 153, Stoneham
735-2616

T 8N R 56 W Sec 14

Richard and Elaine Raffelson
0382 Logan CR 64
437-5417

T 11N R 55 W Sec 30

Jim Nelson
Logan County
522-8314

T 12N R55 W Sec. 34

Interviews were conducted with a few individuals that did not result in quantitative data. Names and addresses are not shown for these individuals, although some had interesting stories.

There were several others near the storm that I would have liked to interview, had time permitted. Names and numbers for these additional individuals are available, on request.