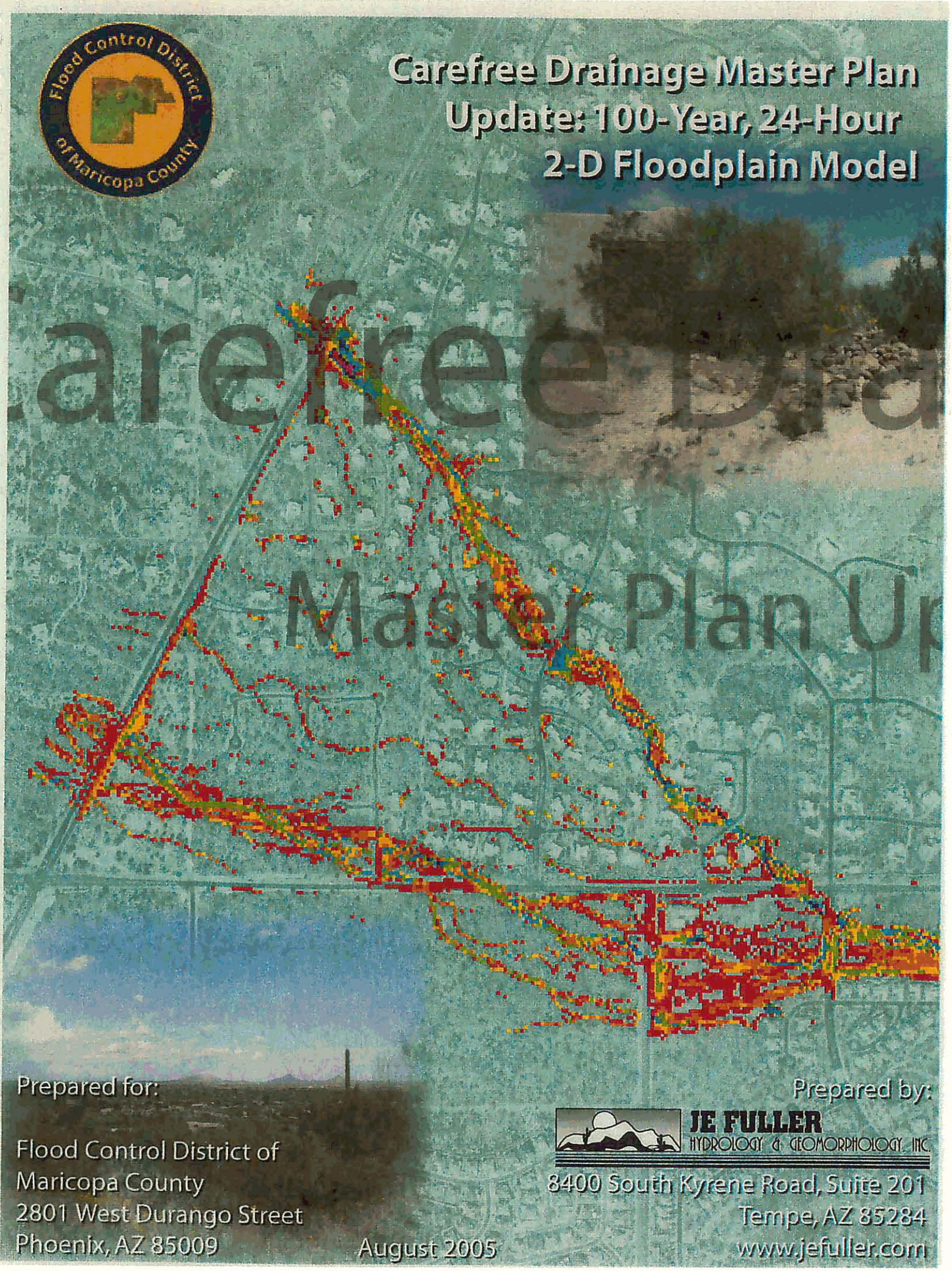
Carefree Drainage Master Plan Update: 100-Year, 24-Hour 2-D Floodplain Model



Prepared for:

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August 2005

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Memorandum JE Fuller/ Hydrology & Geomorphology, Inc.

Carefree Drainage Master Plan Update

DATE: August 2, 2005

TO: Felicia Terry, P.E., FCDMC

FROM: Rob Lyons, P.E.
W. Scott Ogden, P.E.

RE: Carefree DMP Update 100-Year, 24-Hour 2-D Floodplain Model, FCD 2004C025 Work Assignment #2

Registered Professional Engineer (Civil) CERTIFICATE NO. 42752 ROBERT O. LYONS Date Signed 8-02-05 ARIZONA, U.S.A.

Introduction

The Flood Control District of Maricopa County (District) authorized JE Fuller/Hydrology & Geomorphology, Inc. (JEF) to evaluate the 100-Year, 24-Hour Floodplain on the Unnamed Central Tributary to Cave Creek (UCT). The primary objective of the project is to determine the floodplain limits using the 100-year, 24-hour hydrology developed for the Carefree Drainage Master Plan (Carefree DMP) and the FLO-2D hydraulic model previously developed under a separate contract. Flood protection alternatives were also developed and analyzed.

Purpose

The purpose of the project is to determine the 100-year, 24-hour floodplain on the UCT wash. The resulting floodplain limits were then compared with the previous 100-year, 6-hour floodplain and used to identify additional homes or structures within the flood hazard area. The Town of Carefree plans to construct flood control structures to remove homes from the floodplain. Therefore, flood control alternatives were considered and analyzed to develop recommendations for a Capital Improvement Program (CIP) project. This memorandum summarizes the analyses performed, results and recommended alternatives.

Background

The Carefree Drainage Master Plan (Carefree DMP) was a flood control planning study prepared by CH2M HILL for the District. A floodplain delineation study (FDS) was conducted as part of the Carefree DMP, which revealed a complicated, two-dimensional flooding condition on the UCT between Terravita Way and Cave Creek Road. The District authorized JEF to reevaluate the flood hazards on the UCT using a combination of hydrologic, geomorphic, and hydraulic techniques under contract FCD 2002C009.

Under contract FCD 2002C009, JEF developed a 100-year, 6-hour existing condition two-dimensional (2D) hydraulic model of the UCT to evaluate the flooding potential for certain homes identified as within the floodplain in the Carefree DMP FDS. JEF also developed a model to evaluate proposed flood control alternatives to mitigate flood

hazards for structures within the floodplain. Complete documentation for the models are included in the Carefree DMP Update, Work Assignment #7 – Task 5A and 5B: Floodplain Delineation.

Although a floodplain delineation was performed for both contracts using the results from the 2D analysis, the District plans to conduct a formal floodplain delineation study using a conventional hydraulic model for the UCT as part of the upcoming Cave Creek ADMP. The study will be based on updated topography and discharges reported from the 2D analysis.

Location

The UCT is located within the town limits of Carefree and Scottsdale along Carefree Highway between Terravita Way and Cave Creek Road. The UCT wash consists of braided channels with several flow-split locations where flow divides and continues along separate paths. The split location of primary interest to this analysis is located at Terravita Way, and consists of two branches referred to as the North Branch and the South Branch.

Hydrology

The 100-year, 24-hour HEC-1 hydrology model developed for the Carefree DMP was used to extract input hydrographs for use in the FLO-2D model. The DMP HEC-1 model is documented in the CH2M HILL Carefree DMP Data Collection Report[1] and is the model used to establish the 100-year discharges for a recent floodplain delineation submittal to FEMA. Hydrographs at 6 major points of concentration along the FLO-2D modeling perimeter were developed as input parameters. The FLO-2D model itself simulates the rainfall/runoff process within the network grid area. Figure 1 shows the limits of the FLO-2D grid network modeling area, the HEC-1 subbasins, and the six points at which major flows enter the modeling network, as well as cross section and outflow locations discussed later in this memorandum. The results of the HEC-1 modeling for each of the six inflow locations indicated on Figure 1 are summarized in Table 1.

[1] CH2M HILL, Data Collection Report – Carefree Drainage Master Plan, FCD 00-37, November 2002.

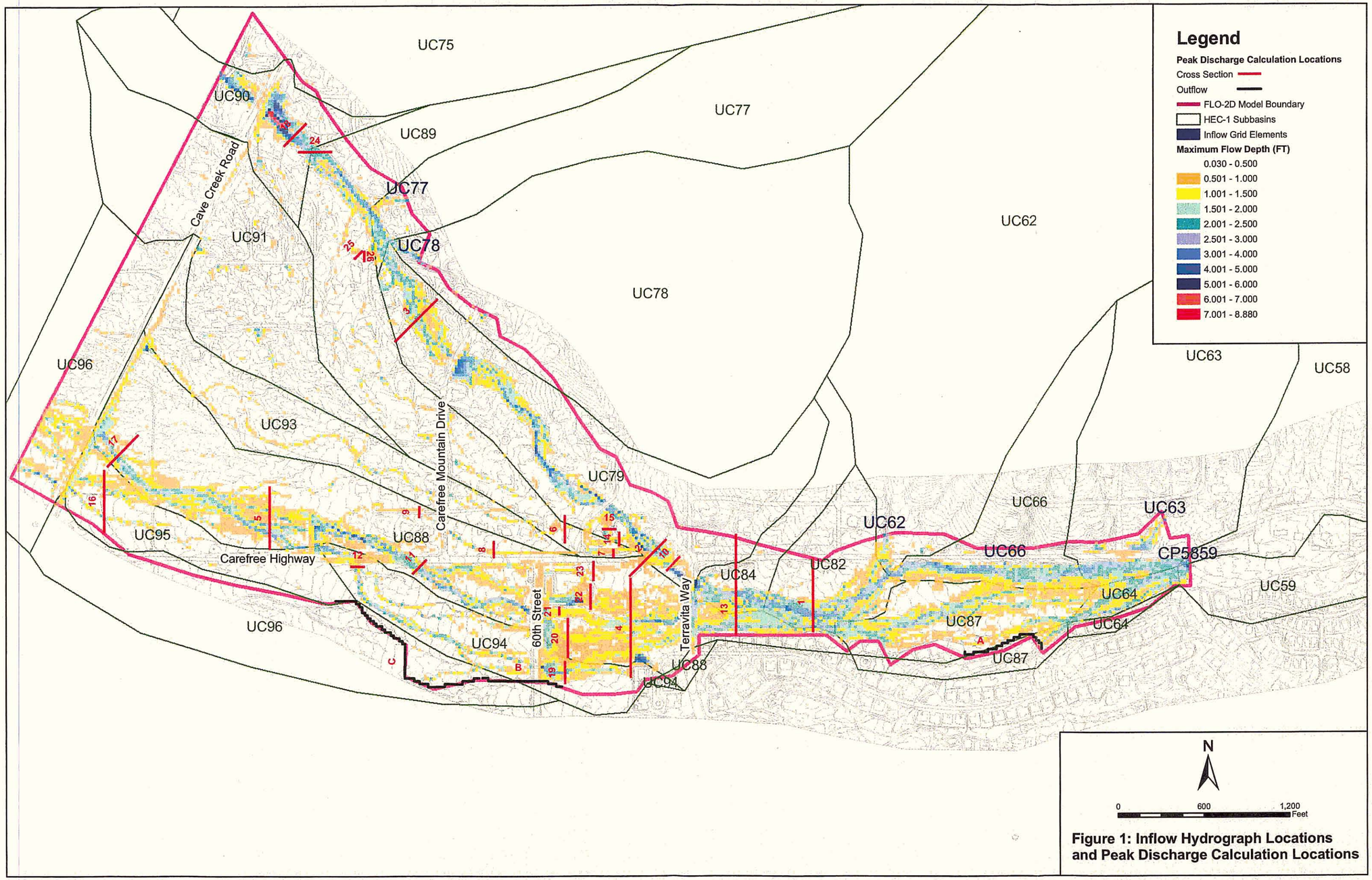

Figure 1: Inflow Hydrograph Locations and Peak Discharge Calculation Locations

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Table 1
Summary of HEC-1 modeling results

FLO-2D Grid Element	HEC-1 Model Operation	Basin Area (sq. mi.)	HEC-1 Peak Discharge (cfs)	Time to Peak (hrs)
34429	CP5859	1.88	2,622	12.20
34297	UC63	0.12	248	12.07
32602	UC66	0.04	79	12.07
30961	UC62	0.36	762	12.10
18898	UC87	0.03	30	12.17
18255	UC77	0.10	225	12.03

The input hydrographs were coded into the FLO-2D model to start at simulation hour 8 to save model run time. Therefore, a complete FLO-2D model run is 16 hours in simulation time. Figure 2 illustrates the modification.

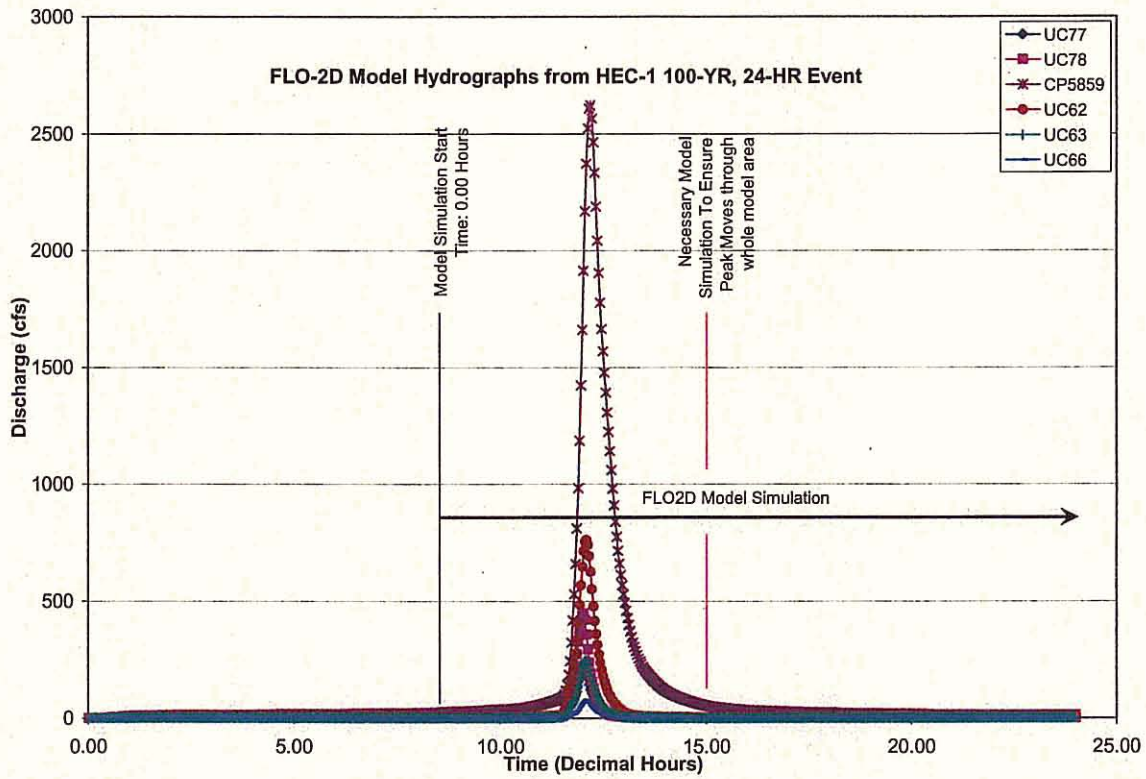

Figure 2: FLO-2D Input Hydrograph Model Simulation

The point rainfall coded into the Carefree DMP HEC-1 100-year, 24-hour model for the UCT watershed is 4.60 inches. At a modeling area of 10.0 square miles, the point rainfall is areally reduced to 4.324 inches. The point rainfall for the FLO-2D model was interpolated based on a 2.80 square mile average watershed area resulting in an areally reduced point rainfall of 4.52 inches.

The total rainfall and rainfall distribution on the grid network area was adjusted to remove the first 8 hours of simulation. After removing the first 8 hours of rainfall accumulation, the remaining areally-reduced point rainfall depth for the 16-hour distribution is 3.98 inches. Table A-1 in the Appendix documents how this was achieved.

FLO-2D Modeling Parameters

The key data input aspects of the FLO-2D model used in this analysis include the floodplain grid network elevations, Manning's n roughness values, culvert rating tables and area and width reduction factors. These model input parameters are documented in the Carefree DMP Update, Work Assignment #7 – Task 5A and 5B: Floodplain Delineation report prepared by JEF.

FLO-2D Version 2004.10 was released in October 2004 and subsequent updates are posted on the FLO-2D website[1] regularly. A significant revision to the FLO-2D model was released on November 14th, 2004. The new model uses a depth variable n-value for floodplain flow depths less than 3 ft. The modeling results reported in this memorandum are based on this model revision and corresponding model executable (modified date 1/24/2005). The revision was outlined in the revisions document[2] and is repeated below:

The model creates an exponentially variable n-value for flows less than 3 ft such that the n-value will be approximately two times the original n-value assignment at (a) depth of 0.2 ft and 1.5 times the original n-value at a depth of 1 ft.

Therefore, the initial floodplain n-values should be assigned in the FPLAIN.DAT input file assuming a depth of 3 ft over the surface. The n-values in the previous Carefree FLO-2D model were not assigned based on this variable n-value adjustment, therefore the n-value assignments had to be revised.

The initial roughness values assigned under contract FCD 2002C009 were used as a starting point. The Manning's n-values were based on guidelines provided in the District's Drainage Manuals[3], field observations, and engineering judgment. Table 2 summarizes the initial Manning's n-values used in the model. A shapefile was created to assign n-values to each grid element in the FLO-2D model. The n-value polygons were intersected with the grid elements and roughness values were assigned to grid elements based on an area weighted average for grid elements spanning more than one n-value

[1] http://www.flo-2d.com/

[2] Revisions, Enhancements and Bug Fixes to the FLO-2D Model and Processor Programs Updated 1/04/05

[3] DISTRICT, Drainage Design Manual for Maricopa County, Volume I – Hydrology, and Volume II – Hydrualics.

polygon. Figure 3 contains the various initial n-value areas, the model grid elements and 2003 orthophotography.

Table 2
Summary of Manning's N-Values Used in the FLO-2D Model

Manning's n-value	Description
0.020	Smooth barren ground and roadway areas.
0.035	Used for sandy channel bottoms
0.050	Used for most wash corridors with light density vegetative lining and light vegetative density floodplain areas.
0.065	Wash corridors and floodplains with medium to heavy vegetative density
0.100	Used for buildings, houses, and perimeter walls and obstructions typical to a single family lot in the area

An initial run was executed and the resulting hydraulic data were reviewed. Numerous grid elements within the wash channel had high velocities ranging from 12 to 20 feet per second (fps) and high calculated Froude numbers ranging from 1.1 to 2.2. High energy floodwater in alluvial systems will usually dissipate energy by mobilizing sediment. It is expected that the system will fluctuate between the sub-critical and supercritical flow regime but will not sustain a strong supercritical flow regime for long reaches and for a long duration. The Manning's n-value associated with grid elements in sandy channel bottoms was increased to 0.045.

This change brought most of the velocities and Froude numbers down within reason however, several grid elements within the channel still had high velocities and Froude numbers. It was necessary to establish criteria for increasing the n-values for these grid elements. Supercritical flow regimes that result in Froude numbers ranging from 1.0 to 1.7 are conducive to undular jumps[1] or standing waves that have been observed in the Town of Carefree and are documented in a previous report[2] by JEF for the Carefree DMP. A Froude number limitation of 1.5 was used to increase the n-value for the remaining high velocity grid elements according to the criteria listed in Table 3. The resultant existing condition n-values are summarized in the *FPLAIN.DAT* file included on the enclosed CD.

[1] Open-Channel Hydraulics, Ven Te Chow, 1959

[2] Carefree Drainage Master Plan Sedimentation Engineering & Geomorphic Evaluation Task 2.1.10 Data Collection, February 2002.

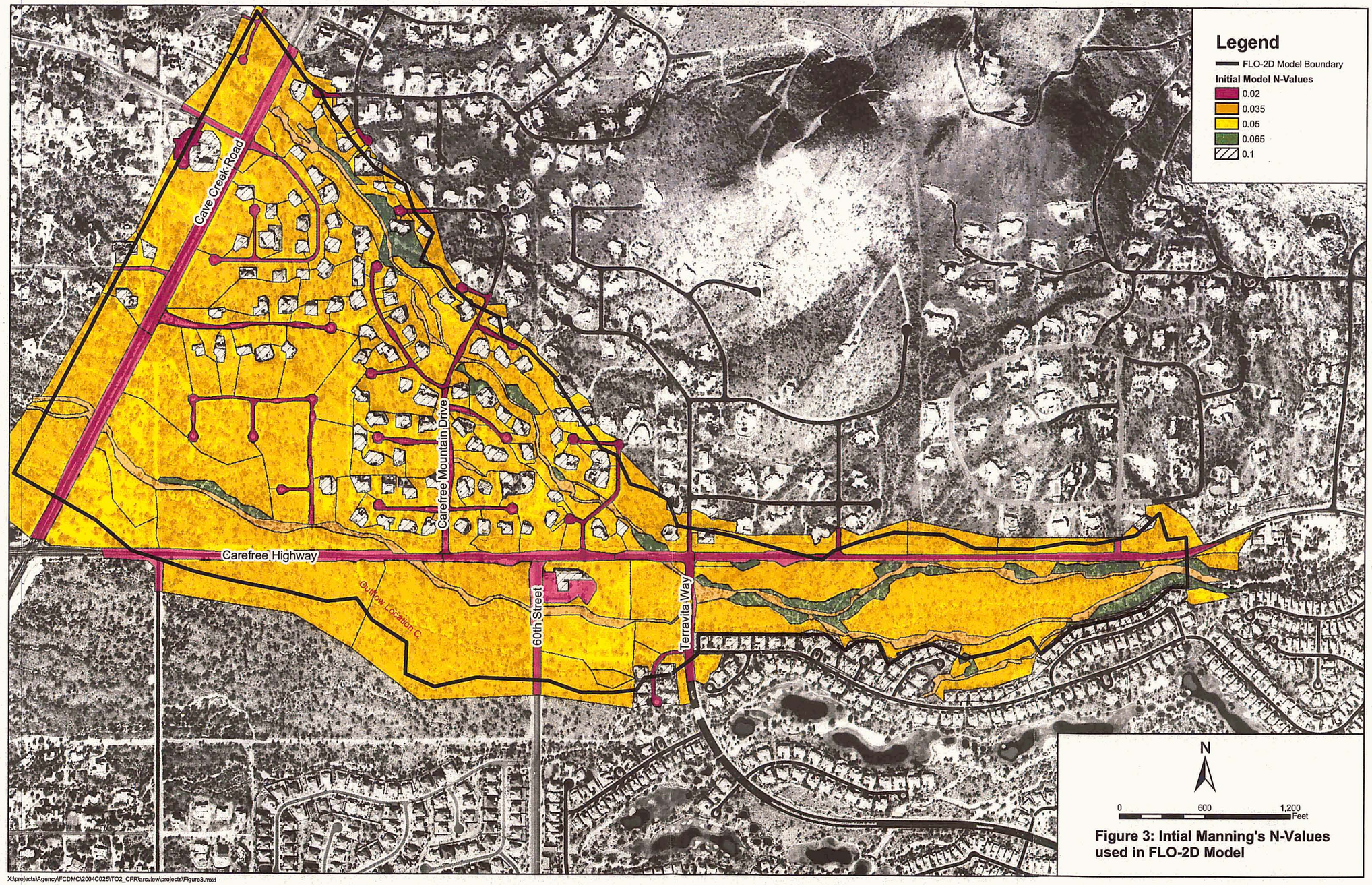

Figure 3: Intial Manning's N-Values used in FLO-2D Model

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Table 3
Manning's N-Value Adjustments for Grid Elements with a Froude Number > 1.50

Velocity Range (fps)	Adjustment
$0 \leq V < 12$	N + 0.005
$12 \leq V < 15$	N + 0.010
$15 \leq V < 18$	N + 0.015
$18 \leq V$	N + 0.020

The floodplain grid network developed using the digital terrain model from the two-foot mapping and supplemental field survey data as documented in a previous report[1], was used with one exception. Field survey data was obtained for Lot 23 of the Carefree Mountain Estates subdivision (35222 N. Saphora Dr.). Several grid element elevations, n-values, and area reduction factors were adjusted in the model to better represent the actual floodplain characteristics. Table A-2 in the Appendix summarizes the grid element changes from the original model. The ground elevation for each grid element is shown on the Floodplain Delineation Plates in the Appendix.

Estimation of Peak Discharges within and Leaving the Modeling Limits

The FLO-2D model output can be formatted to develop a cross-section comprised of grid elements for the purpose of estimating a composite peak discharge for that cross section. The user specifies the flow direction of interest for each desired cross-section location. This tool was used for determining discharges at several key locations within the model area.

The peak discharges exiting the modeling limits have also been estimated. One of the outflow locations was used to estimate the peak discharge exiting the model area and entering the Terravita subdivision upstream of Terravita Way (Outflow Location A). The locations of cross sections and outflow locations queried are shown in Figure 1. The peak discharges for the existing conditions 100-year, 6-hour and 100-year, 24-hour are presented below in Table 4.

Another 100-year, 24-hour FLO-2D model was ran with the proposed improvements (discussed later in this report) modeled upstream of Los Reales Drive and at the end of Saphora Drive. Peak discharges from the proposed model are also listed in Table 4. All discharges are reported in the corresponding *CROSSMAX.OUT* files provided on the data CD at the back of this report.

[1] Carefree DMP Update, Work Assignment #7 – Task 5A and 5B: Floodplain Delineation, July 2004

Table 4
Summary of Peak Flow Rates at Cross Section and Outflow Locations

Cross Section or Outflow Location	Existing 100-Year, 6-Hr Discharge (cfs)	Existing 100-Year, 24-Hr Discharge (cfs)	Proposed 100-Year, 24-Hr Discharge (cfs)
1	2565	2920	2940
2	875	1241	1250
3	719	1021	1049
4	1396	1668	1666
5	1286	1362	1364
6	33	61	27
7	25	59	64
8	32	68	71
9	43	39	37
10	665	1172	1179
11	768	1135	1133
12	254	277	275
13	N/A	2923	2935
14	N/A	149	10
15	N/A	97	6
16	N/A	413	414
17	N/A	937	934
18	N/A	1192	1231
19	N/A	515	516
20	N/A	489	487
21	N/A	206	206
22	N/A	459	461
23	N/A	116	116
24	N/A	1172	1205
25	N/A	29	19
26	N/A	29	20
A	403	569	571
B	185	248	248
C	36	50	49

While the FLO-2D model used the HEC-1 computed hydrographs as a boundary input to the model, it is noted that the FLO-2D discharges shown in Table 4 are different than the recommended discharges for analogous concentration points for the HEC-1 model. The best comparison is between HEC-1 operation CP82 and FLO-2D Cross Section 1, with reported discharges of 2,849 cfs and 2,920 cfs, respectively (refer to Tables 2 and 4). The difference in HEC-1 and FLO-2D reported peak discharges stems primarily from the following computational differences in the modeling approach and are discussed below:

- Areal Reduction and use of the HEC-1 JD Card
- Diversion into the Terravita Development
- Channel Routing
- Diversion Routine
- Hydrograph Timing

Areal Reduction. A peak discharge discrepancy between the HEC-1 model results and the FLO-2D results was previously identified during the FLO-2D 100-year, 6-hour model development. The HEC-1 model reported a peak discharge at concentration point CP82 that was less than the discharge reported from the FLO-2D Cross Section 1 in the same general location. The 100-year, 6-hour discrepancy was determined to be primarily related to the use of JD records in the HEC-1 model. A complete discussion of this condition can be found in the Carefree DMP Update, Work Assignment #7 Task 5: Addendum. This issue was reviewed for the 100-year, 24-hour model resulting in similar results.

The JD records are used to estimate peak discharges that reflect areally reduced point precipitation values and rainfall distribution patterns that are appropriate for the watershed area tributary to a specific concentration point. The HEC-1 model accomplishes this by calculating transposition hydrographs for set modeling basin area increments, with each transposition hydrograph reflecting the corresponding areally reduced precipitation and area specific distribution. HEC-1 then performs a logarithmic interpolation between transposition hydrographs based on the known tributary area to the concentration point in question for each runoff hydrograph ordinate. The result is a runoff hydrograph that in theory will reflect the correct areal reduction and rainfall distribution for the tributary area. The areal reduction for 6- and 24-hour point precipitation is very similar. However, the 6-hour rainfall distribution changes from Pattern 1 to Pattern 2 for watershed areas of 1.8 square miles and the 24-hour rainfall distribution (SCS Type II) does not change with watershed area.

Table 5 illustrates the concept of using JD records in the 100-year, 24-hour HEC-1 model for the operations CP5859, UC62, UC63, and UC66 and CP82.

Table 5. HEC-1 model results using JD records

HEC-1 Operation	Basin Area, in sq. miles	Peak Discharge by Transposition Hydrograph Area, in cfs		Interpolated Peak Discharge, in cfs
		A = 0.0 sq. miles	A = 10.0 sq. miles	
CP5859	1.88	2774	2573	2622
UC62	0.36	791	736	762
UC63	0.12	254	237	248
UC66	0.04	80	74	79
CP82	2.44	3024	2804	2849

The inflow hydrographs coded into the FLO-2D model were obtained directly from the HEC-1 output, and therefore, reflect the interpolated runoff hydrograph reported by HEC-1 for the particular concentration point (refer to Table 5). This makes comparison of the HEC-1 and FLO-2D model results at CP82 difficult, since the HEC-1 runoff hydrograph at CP82 reflects a runoff hydrograph interpolated for 2.44 square miles. The FLO-2D model is in comparison, a blend of interpolated hydrographs that are being hydraulically routed through the modeling area. In theory, this would make the FLO-2D model results slightly conservative, however, since there is only a very small difference

in the volume of flow represented by the hydrograph reported at the FLO-2D Cross-Section No. 1 versus the hydrograph reported by HEC-1, the impacts downstream in terms of flooding depths are likely to be minimal and certainly within the tolerances of the base mapping.

Diversion into Terravita Development. The FLO-2D model does not explicitly compute a diversion from a single flow path, but instead computes flow at every grid cell into all adjacent grid cells at each time increment of the model. The FLO-2D Outflow Location A was used to estimate the diversion and resulted in 569 cfs leaving the model and flowing into the Terravita development. The DMP HEC-1 estimated the diversion based on a simplified rating table developed from a one-dimensional uniform flow model. The HEC-1 diversion estimate is 580 cfs at operation D64S. This accounts for 19 cfs of the discrepancy at CP82 and Cross Section 1.

Channel Routing. FLO-2D is a true, fully dynamic hydraulic routing model with conservation of volume as a key modeling constraint. HEC-1 uses hydrologic channel routing algorithms based on normal depth techniques along a single, defined channel reach with a generalized 8-point cross section, and are critically tied to the modeling time increment. Differences in the translation of flood peaks are certain to occur.

Diversion Routine. As discussed above, the FLO-2D model does not explicitly compute a diversion from a single flow path. The flow split at Terravita Way was modeled in FLO-2D with a culvert capacity rating table and the flow exchange over each grid element. The DMP HEC-1 modeled the split using a rating table based on a one-dimensional hydraulic analysis and significant engineering judgment.

Hydrograph Timing. The differences in routing techniques also result in differences in hydrograph timing that can cause differences in peak discharge estimates, particularly when compared with the storage that can be simulated in a two-dimensional grid cell network in a broad flood-prone area.

In summary, it is our professional opinion that the FLO-2D model prepared for this study accurately depicts the hydrologic conditions in the study area, and is sufficiently accurate to accomplish the study objectives. Furthermore, differences in HEC-1 and FLO-2D computed peak discharges were not unexpected, and are within reasonable limits.

FLO-2D Model Results

Floodplain Delineation Results

The floodplain water surface elevations predicted for the 100-year, 24-hour model generally are 0.05-0.35 feet higher than the 100-year, 6-hour model. No additional breakouts or bifurcations were identified as a result of the larger peak flow rate. The 100-year, 24-hour floodplain delineation and maximum water surface elevations calculated for each grid element are shown in Plates I-V in the Appendix. Plate VI provides a graphical depiction of the maximum flooding depths for the modeled area. Other FLO-2D model input and output data files are provided on the data CD at the back of this report.

Terravita Way Flow Split

The flow split at Terravita Way was calculated based on the 100-year, 24-hour flow rates reported at FLO-2D Cross Sections 2 and 4. The FLO-2D model resulted in 1241 cfs (43%) entering the North Branch and 1668 cfs (57%) entering the South Branch. The 100-year, 6-hour FLO-2D model resulted in 875 cfs (39%) entering the North Branch and 1396 cfs (61%) entering the South Branch.

Houses in the Floodplain

Fourteen of the 19 structures shown in Figure 4 were previously identified to be in the floodplain by the Carefree Drainage Master Plan (DMP). The 100-year floodplain for the Carefree DMP was determined using the conventional one-dimensional model HEC-RAS and the 100-year, 24-hour duration HEC-1 model hydrology, as described in the Carefree DMP Update. The remaining five structures were identified by JEF for more detailed consideration once the FLO-2D modeling was complete. One of these structures, Structure ID 9 - Scottsdale Health Center, is outside of the Town limits.

Of the 14 homes identified in the Carefree DMP, only three were determined to be in the floodplain delineated based on the 100-year, 6-hour FLO-2D results. The 100-year, 24-hour FLO-2D modeling results in one additional home (House ID G) marginally within the floodplain as a result of the higher peak flow rate and revised modeling methodology.

It should be noted that the break out over Los Reales Drive increased from 33 to 61 cfs (FLO-2D Cross Section 6) and this flow will head due west towards houses 5 and 6. A comparison of water surface elevations to finish floor elevations for the four houses is listed in Table 6.

Table 6. Houses in the Floodplain

House ID	WSEL 100-year, 6-Hour	WSEL 100-year, 24-Hour	Finished Floor Elevation
1	2063.47	2063.56	2062.30
4	2124.09	2124.47	2123.03
E	2127.55	2127.76	2127.24
G	2057.07	2057.38	2057.14

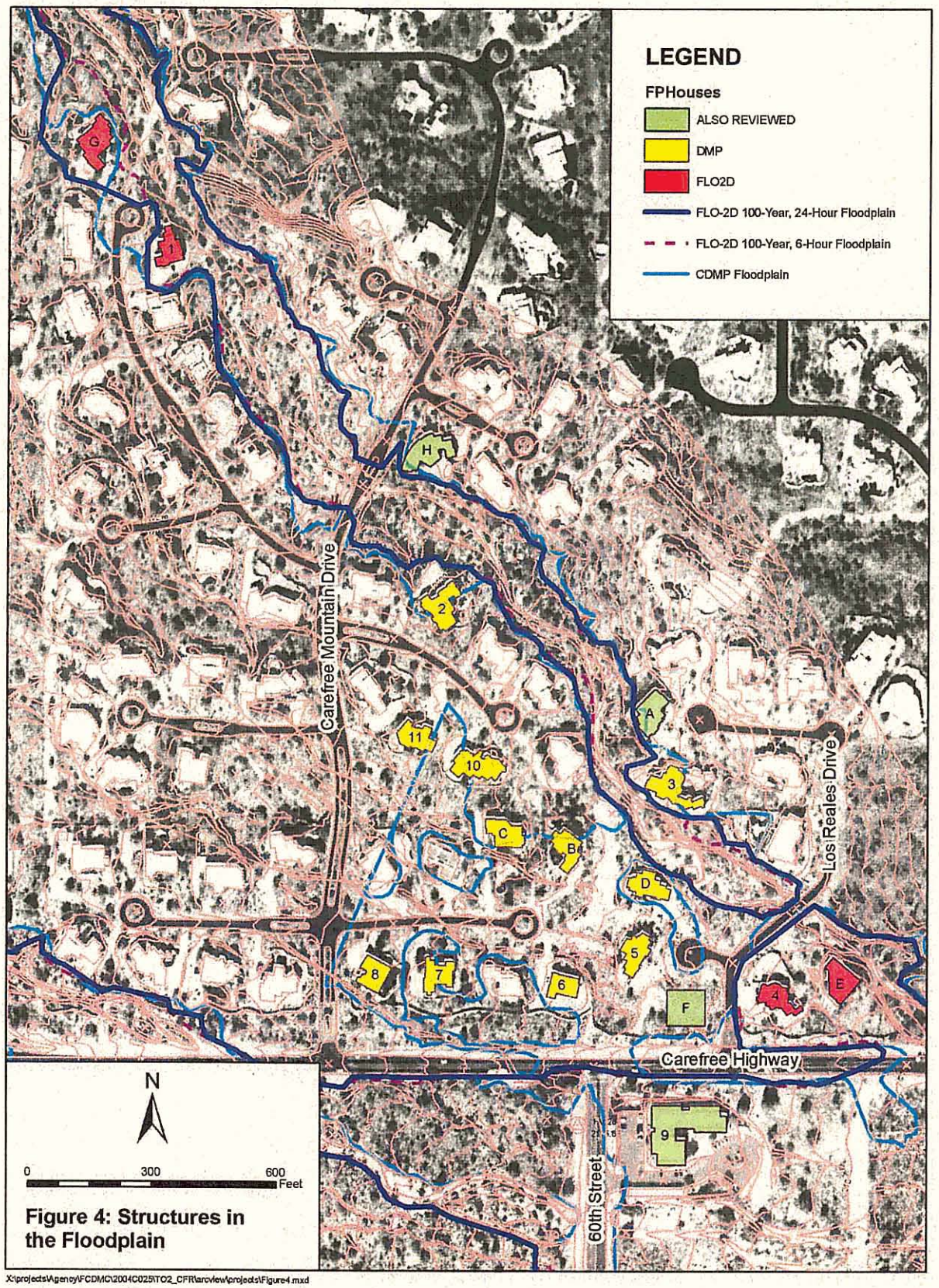

Figure 4: Structures in the Floodplain

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Recommended Improvement Concepts and Modeling

House 1: 35191 N Saphora Drive

House 1 is adjacent to the UCT – North Branch Wash channel approximately 1 to 2 feet higher than the wash bottom. Numerous flood control alternatives were considered to remove the house from the floodplain. The installation of a flood wall was ultimately agreed upon by project stakeholders.

The flood wall will extend from the north side of the existing house along the channel to the existing left bank that confines the wash on the south end of the property. Erosion protection will be required to prevent undermining of the wall and an interior drainage system will be required to dispose of local runoff. Plate VII shows the improvement concept and location, the proposed conditions floodplain, and model grid element water surface elevations.

The flood wall concept was modeled in the 2D hydraulic model with the use of the *ARF.DAT* input file that instructs the model to block available volumetric capacity and flow exchange between specified grid elements. The model results indicate that the upstream water surface elevation would remain unchanged, the water surface elevation adjacent to the floodwall would increase by up to 1.67 feet, and the water surface elevation downstream of the improvements would increase by about 0.03 feet for approximately 150 feet before it returns to the existing conditions water surface elevation. Therefore, it is anticipated that this concept would not have any significant adverse impacts upstream or downstream of the project.

Houses E & 4: 34659 N Los Reales Drive

House E is located adjacent to the UCT – North Branch Wash near the top of the south bank. House 4 is in the same vicinity and is located 150 feet from the top of the south bank. Flooding breaks out onto the south bank and inundates both houses. Most of the breakout floodwater then continues west and re-enters the wash with the remainder overtopping Los Reales Drive at a low point 200 feet southeast of the existing culvert crossing on the road. Two additional houses, 5 and 6, are located along the path of the Los Reales Drive overtopping as shown in Figure 4. Although these two houses are not considered to be in the floodplain, they may experience nuisance drainage through their property that could result in minor flood damage.

Although a few flood control alternatives were considered to remove the houses from the floodplain, elevated fill along the south bank was ultimately agreed upon by project stakeholders. The fill will extend from the southeast side of the existing house along the bank to the existing subdivision wall at the south end of the property. The fill will essentially elevate the entire backyard of House E by approximately 2 feet. Erosion protection will be required to protect the fill and a minor retaining wall and sidewalk will likely be required adjacent to the house. Refer to Plate VII for the location of the improvement.

The elevated fill concept was modeled in the 2D hydraulic model with the use of the *LEVEE.DAT* input file that instructs the model to block flow exchange between specified grid elements up to a certain depth or elevation. The protected fill improvement will reduce the overtopping of Los Reales Drive. The flow rate in the UCT – North Branch would increase by about 35 cfs, and would therefore increase the water surface elevation downstream of the improvement by about 0.01 to 0.06 feet. The increase in water surface elevation does not cause any additional houses to be within the floodplain. There is sufficient capacity at the culvert crossing at Los Reales Drive to convey the increased discharge. Change in erosion potential is anticipated to be negligible.

House G: 35222 N Saphora Drive

House G is adjacent to the UCT – North Branch Wash channel on the lot adjacent to House 1 to the south. The house was not within the floodplain resulting from the 100-year, 6-hour FLO-2D model. However with the increased discharge from the 100-year, 24-hour storm, and the revised modeling methodology, the model predicts a small breakout onto the property as discussed previously. It is estimated that 29 cfs breaks out of the channel and enters the property likely causing marginal inundation of the structure. Details of the flooding problem are discussed in a previous memorandum prepared by JEF on March 28th, 2005 included in the Appendix.

Channelization or a long flood control structure would be required to remove this home from the floodplain. Therefore, the project stakeholders agreed that depending on the results of the floodplain delineation study planned for the Cave Creek ADMS, no action would be taken by the Town or District and the purchase of flood insurance may be recommended to the property owner.

Summary and Conclusions

The floodplain water surface elevations predicted for the 100-year, 24-hour model generally are 0.05-0.35 feet higher than the 100-year, 6-hour model. No additional breakouts or bifurcations were identified. In general, the increased water surface elevations resulted in minor revisions to the floodplain delineation. However, the modeling results in one additional home to be marginally within the floodplain. The project team agreed that no flood control alternatives be analyzed for this home until the FDS planned for the Cave Creek ADMS is underway. Two flood control concepts were developed to remove the other three homes from the floodplain.

Appendix

Table A-1: Rainfall Distribution Adjustment from 24-Hour to 16-Hour

4.52 Aerially Reduced 100-Year, 24-Hour Point Rainfall (Interpolated based on 2.80 average watershed area and interpolated between 4.60 inches for 0.0 sq. mi. and 4.324 for 10.0 sq. mi.)

3.98 Total Rainfall Amount Left after 8 Hours

Time Increments (hours)	24 Hour Distribution (ratio)	24 Hour Incremental Rainfall (inches)	16 Hour Cumulative Rainfall (inches)	16 Hour Percent of Total (ratio)	16 Hour Incremental Rainfall - check (inches)
0.00	0.000	0.0000			
0.25	0.002	0.0090			
0.50	0.005	0.0136			
0.75	0.008	0.0136			
1.00	0.011	0.0136			
1.25	0.014	0.0136			
1.50	0.017	0.0136			
1.75	0.020	0.0136			
2.00	0.023	0.0136			
2.25	0.026	0.0136			
2.50	0.029	0.0136			
2.75	0.032	0.0136			
3.00	0.035	0.0136			
3.25	0.038	0.0136			
3.50	0.041	0.0136			
3.75	0.044	0.0136			
4.00	0.048	0.0181			
4.25	0.052	0.0181			
4.50	0.056	0.0181			
4.75	0.060	0.0181			
5.00	0.064	0.0181			
5.25	0.068	0.0181			
5.50	0.072	0.0181			
5.75	0.076	0.0181			
6.00	0.080	0.0181			
6.25	0.085	0.0226			
6.50	0.090	0.0226			
6.75	0.095	0.0226			
7.00	0.100	0.0226			
7.25	0.105	0.0226			
7.50	0.110	0.0226			
7.75	0.115	0.0226			
8.00	0.120	0.0226	0.0000	0.000	0.0000
8.25	0.126	0.0271	0.0271	0.007	0.0271
8.50	0.133	0.0317	0.0588	0.015	0.0317
8.75	0.140	0.0317	0.0905	0.023	0.0317
9.00	0.147	0.0317	0.1221	0.031	0.0317
9.25	0.155	0.0362	0.1583	0.040	0.0362
9.50	0.163	0.0362	0.1945	0.049	0.0362

Table A-1: Rainfall Distribution Adjustment from 24-Hour to 16-Hour

4.52 Aerially Reduced 100-Year, 24-Hour Point Rainfall (Interpolated based on 2.80 average watershed area and interpolated between 4.60 inches for 0.0 sq. mi. and 4.324 for 10.0 sq. mi.)

3.98 Total Rainfall Amount Left after 8 Hours

Time Increments (hours)	24 Hour Distribution (ratio)	24 Hour Incremental Rainfall (inches)	16 Hour Cumulative Rainfall (inches)	16 Hour Percent of Total (ratio)	16 Hour Incremental Rainfall - check (inches)
9.75	0.172	0.0407	0.2352	0.059	0.0407
10.00	0.181	0.0407	0.2759	0.069	0.0407
10.25	0.191	0.0452	0.3211	0.081	0.0452
10.50	0.203	0.0543	0.3754	0.094	0.0543
10.75	0.218	0.0678	0.4433	0.111	0.0678
11.00	0.236	0.0814	0.5247	0.132	0.0814
11.25	0.257	0.0950	0.6197	0.156	0.0950
11.50	0.283	0.1176	0.7372	0.185	0.1176
11.75	0.387	0.4704	1.2076	0.303	0.4704
12.00	0.663	1.2483	2.4560	0.617	1.2483
12.25	0.707	0.1990	2.6550	0.667	0.1990
12.50	0.735	0.1266	2.7816	0.699	0.1266
12.75	0.758	0.1040	2.8857	0.725	0.1040
13.00	0.776	0.0814	2.9671	0.745	0.0814
13.25	0.791	0.0678	3.0349	0.763	0.0678
13.50	0.804	0.0588	3.0937	0.777	0.0588
13.75	0.815	0.0498	3.1435	0.790	0.0498
14.00	0.825	0.0452	3.1887	0.801	0.0452
14.25	0.834	0.0407	3.2294	0.811	0.0407
14.50	0.842	0.0362	3.2656	0.820	0.0362
14.75	0.849	0.0317	3.2973	0.828	0.0317
15.00	0.856	0.0317	3.3289	0.836	0.0317
15.25	0.863	0.0317	3.3606	0.844	0.0317
15.50	0.869	0.0271	3.3877	0.851	0.0271
15.75	0.875	0.0271	3.4149	0.858	0.0271
16.00	0.881	0.0271	3.4420	0.865	0.0271
16.25	0.887	0.0271	3.4691	0.872	0.0271
16.50	0.893	0.0271	3.4963	0.878	0.0271
16.75	0.898	0.0226	3.5189	0.884	0.0226
17.00	0.903	0.0226	3.5415	0.890	0.0226
17.25	0.908	0.0226	3.5641	0.895	0.0226
17.50	0.913	0.0226	3.5867	0.901	0.0226
17.75	0.918	0.0226	3.6094	0.907	0.0226
18.00	0.922	0.0181	3.6274	0.911	0.0181
18.25	0.926	0.0181	3.6455	0.916	0.0181
18.50	0.930	0.0181	3.6636	0.920	0.0181
18.75	0.934	0.0181	3.6817	0.925	0.0181
19.00	0.938	0.0181	3.6998	0.930	0.0181
19.25	0.942	0.0181	3.7179	0.934	0.0181

Table A-1: Rainfall Distribution Adjustment from 24-Hour to 16-Hour

4.52 Aerially Reduced 100-Year, 24-Hour Point Rainfall (Interpolated based on 2.80 average watershed area and interpolated between 4.60 inches for 0.0 sq. mi. and 4.324 for 10.0 sq. mi.)

3.98 Total Rainfall Amount Left after 8 Hours

Time Increments (hours)	24 Hour Distribution (ratio)	24 Hour Incremental Rainfall (inches)	16 Hour Cumulative Rainfall (inches)	16 Hour Percent of Total (ratio)	16 Hour Incremental Rainfall - check (inches)
19.50	0.946	0.0181	3.7360	0.939	0.0181
19.75	0.950	0.0181	3.7541	0.943	0.0181
20.00	0.953	0.0136	3.7677	0.947	0.0136
20.25	0.956	0.0136	3.7812	0.950	0.0136
20.50	0.959	0.0136	3.7948	0.953	0.0136
20.75	0.962	0.0136	3.8084	0.957	0.0136
21.00	0.965	0.0136	3.8219	0.960	0.0136
21.25	0.968	0.0136	3.8355	0.964	0.0136
21.50	0.971	0.0136	3.8491	0.967	0.0136
21.75	0.974	0.0136	3.8626	0.970	0.0136
22.00	0.977	0.0136	3.8762	0.974	0.0136
22.25	0.980	0.0136	3.8898	0.977	0.0136
22.50	0.983	0.0136	3.9033	0.981	0.0136
22.75	0.986	0.0136	3.9169	0.984	0.0136
23.00	0.989	0.0136	3.9305	0.988	0.0136
23.25	0.992	0.0136	3.9441	0.991	0.0136
23.50	0.995	0.0136	3.9576	0.994	0.0136
23.75	0.998	0.0136	3.9712	0.998	0.0136
24.00	1.000	0.0090	**3.9802**	1.000	0.0090

Table A-2: Grid Element Model Input Revisions

GE ID	Base Elevation	Revised Elevation	Base N-Value	Revised N-Value	Description
15148	2056.41		0.068	0.040	Revised to reflect actual floodplain characteristics
15149	2056.10		0.091	0.050	Revised to reflect actual floodplain characteristics
15150	2056.26	2055.90	0.088	0.050	Revised to reflect actual floodplain characteristics
15151	2056.44	2055.70	0.083		Revised to reflect actual floodplain characteristics
15311	2056.49		0.100	0.020	Revised to reflect actual floodplain characteristics
15312	2056.61	2056.20	0.100	0.020	Revised to reflect actual floodplain characteristics
15472	2056.95		0.068	0.020	Revised to reflect actual floodplain characteristics
15473	2055.99	2056.40	0.100	0.020	Revised to reflect actual floodplain characteristics
15474	2056.61	2056.80	0.100	0.020	Revised to reflect actual floodplain characteristics
15633	2057.94		0.050	0.040	Revised to reflect actual floodplain characteristics
15634	2057.35	2057.00	0.050	0.020	Revised to reflect actual floodplain characteristics
15635	2056.47		0.073	0.030	Revised to reflect actual floodplain characteristics
15795	2057.66		0.050	0.020	Revised to reflect actual floodplain characteristics
15796	2057.26		0.050	0.020	Revised to reflect actual floodplain characteristics
15799	2056.97		0.080		Blocked Grid Element in ARF.DAT to reflect enclosed front patio
15956	2057.92		0.050	0.030	Revised to reflect actual floodplain characteristics
15957	2057.60		0.050	0.040	Revised to reflect actual floodplain characteristics
15960	2057.99		0.054		Blocked Grid Element in ARF.DAT to reflect enclosed front patio
15961	2057.53		0.050		Blocked Grid Element in ARF.DAT to reflect enclosed front patio
15962	2056.72		0.057		Blocked Grid Element in ARF.DAT to reflect enclosed front patio

JE Fuller/ Hydrology & Geomorphology, Inc.

Jon Fuller, PE, RG, PH, MS, CFM
Brian Iserman, P.E.
John Wallace, P.E.
Ted Lehman, P.E.
W. Scott Ogden, P.E.
Pat Deschamps, P.E., R.L.S.
Jeff Despain, P.E.

Mike Kellogg, M.S., G.I.T.
Cory Helton, M.S.
Rob Lyons, E.I.T.
Brooks Dillard, E.I.T.
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March 28, 2005

Erich Korsten, P.E.
Town of Carefree
PO Box 17915
Fountain Hills, AZ
85269

RE: Town of Carefree Drainage Concerns at 35222 N. Saphora Dr.

Dear Erich:

Per our meeting with you and the District on February 9, 2005 and a subsequent meeting with the District on March 15, 2005, JE Fuller/Hydrology & Geomorphology, Inc. (JEF) is providing you with the results of our floodplain modeling analysis for the Dubberly property at 35222 N. Saphora Drive on parcel 211-28-256.

The District conducted a field survey of the subject property to determine the finish floor elevation and several adjacent ground elevations. The lowest finish floor elevation surveyed was 2057.14 relative to the NGVD 29 datum. JEF conducted a site visit on March 2, 2005 to verify the drainage conditions on the lot. Exhibit 1 contains a sketch of the drainage and structural features observed in the field overlain on the FLO-2D floodplain model grid. An eight inch corrugated metal pipe (CMP) was identified underneath the driveway that appears to drain local offsite runoff. A rip rap drainage ditch was discovered on the west side of the driveway that drains to a 12 inch CMP underneath the privacy wall for the backyard. The driveway is graded to drain to the rip rap ditch adjacent to the garage as shown on Exhibit 1. The ground elevation on the south side of the garage and front patio is higher than the finished floor elevation of the house.

Based on field observations and ground survey elevations provided by the District, JEF made minor revisions to the existing conditions 100-year, 24-hour FLO-2D floodplain model input parameters to better depict actual drainage conditions on the site. The existing culverts were not modeled considering the small diameter and likelihood of sedimentation and debris blockage during a large flooding event.

The existing conditions model predicts a small breakout from the wash (Unnamed Central Tributary to Cave Creek North Branch) of 29 cfs onto the Dubberly's property between the cul-de-sac and the house, refer to Exhibit 2. The driveway conveyance capacity is not sufficient to convey the breakout flow at an elevation below the finished

floor. The model results indicate a potential for minor flooding in the garage and the house with a water surface elevation of approximately 2057.4.

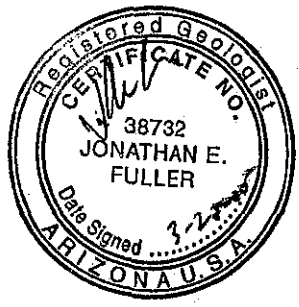
JEF analyzed alternatives to mitigate the flooding potential, including a concept that would prevent the breakout of the wash and better drain local offsite runoff down the driveway as shown on Exhibit 3. The concept would require the installation of a floodwall or berm from the Dubberly's front patio onto the adjacent lot 211-28-255 (Casedei's) approximately 130 feet in length. The concept also includes grading a ditch to an offsite drainage channel on the west edge of the lot that would augment the 12" CMP under the backyard privacy wall.

It is likely that this house would not be considered within the floodplain during the future floodplain delineation study using HEC-RAS. Considering the relatively small breakout discharge of 29 cfs, short duration of the breakout at the crest of the hydrograph, and the small probability of occurrence, it may be more practical to leave the site as is and recommend that the home owners purchase flood insurance.

If you should require further information or have any questions, please do not hesitate to contact me at (480) 752-2124 ext. 210 or by email at jon@jefuller.com.

Sincerely,

JE Fuller Hydrology & Geomorphology, Inc.



Jonathan Fuller, PE, PH, RG, CFM
Principal

Enclosures
cc: Felicia Terry, P.E. Flood Control District of Maricopa County

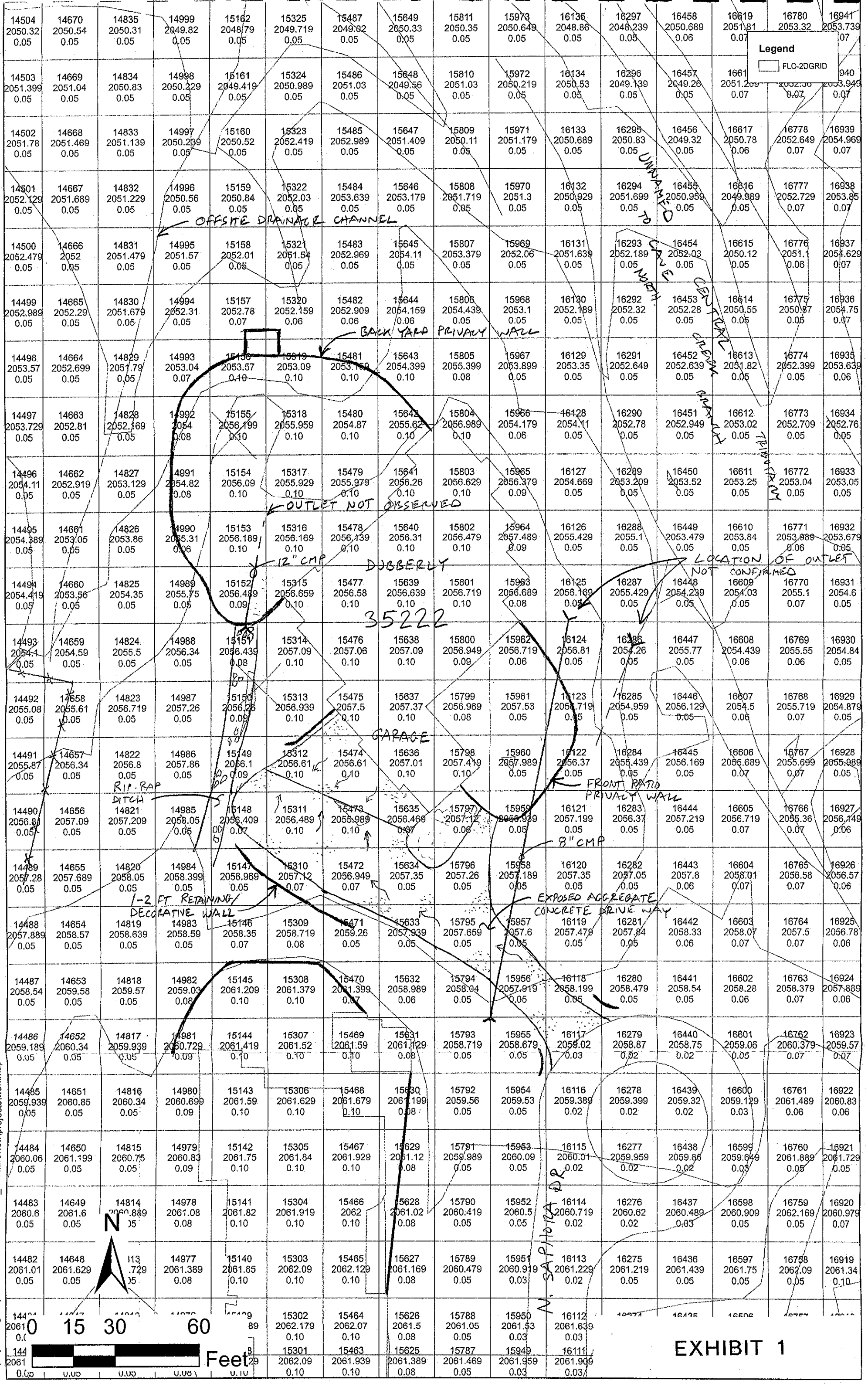

Legend
FLO-2DGRID
OFFSITE DRAINAGE CHANNEL
UNNAMED TO CAVE NORTH
CENTRAL CREEK BRANCH
TRIBUTARY
BACK YARD PRIVACY WALL
OUTLET NOT OBSERVED
12" CMP
DUBBERLY
LOCATION OF OUTLET NOT CONFIRMED
35222
GARAGE
RIP-RAP DITCH
FRONT RATIO PRIVACY WALL
8" CMP
1-2 FT RETAINING/ DECORATIVE WALL
EXPOSED AGGREGATE CONCRETE DRIVE WAY
N. SAPIBIRA DR
N
0 15 30 60
Feet
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EXHIBIT 1

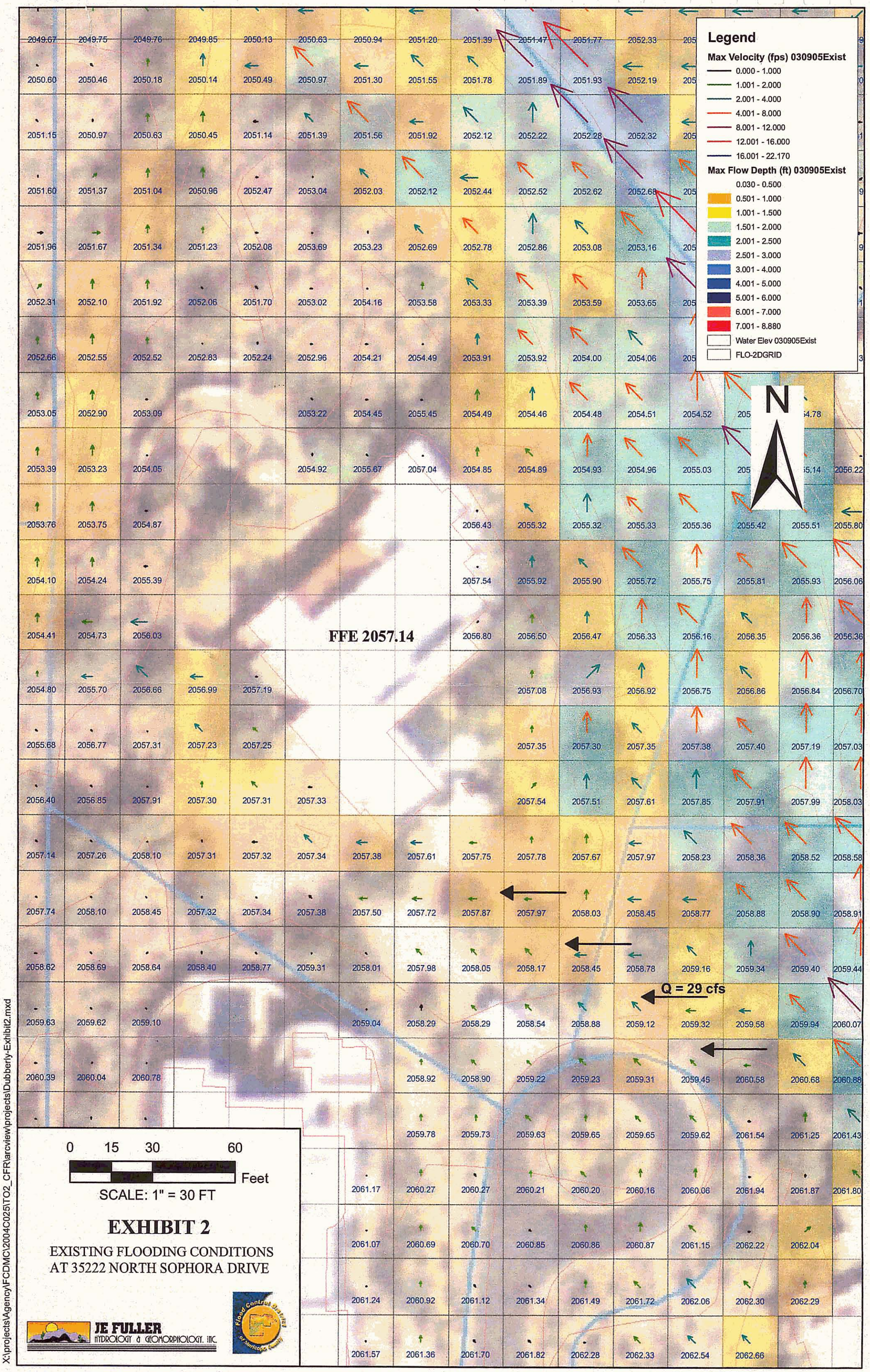

EXHIBIT 2

EXISTING FLOODING CONDITIONS
AT 35222 NORTH SOPHORA DRIVE

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

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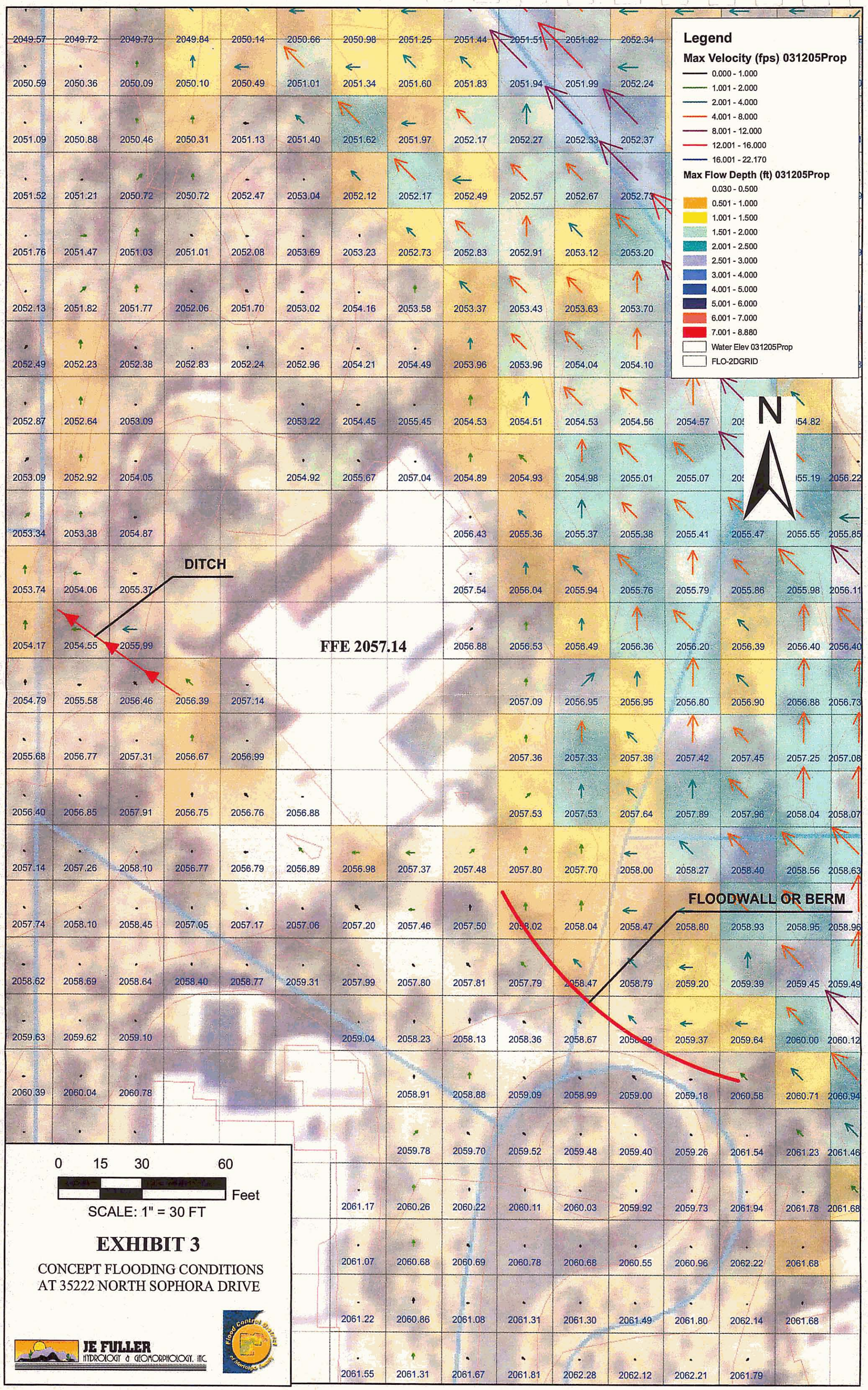

EXHIBIT 3

CONCEPT FLOODING CONDITIONS
AT 35222 NORTH SOPHORA DRIVE

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Flood Control District of Maricopa County

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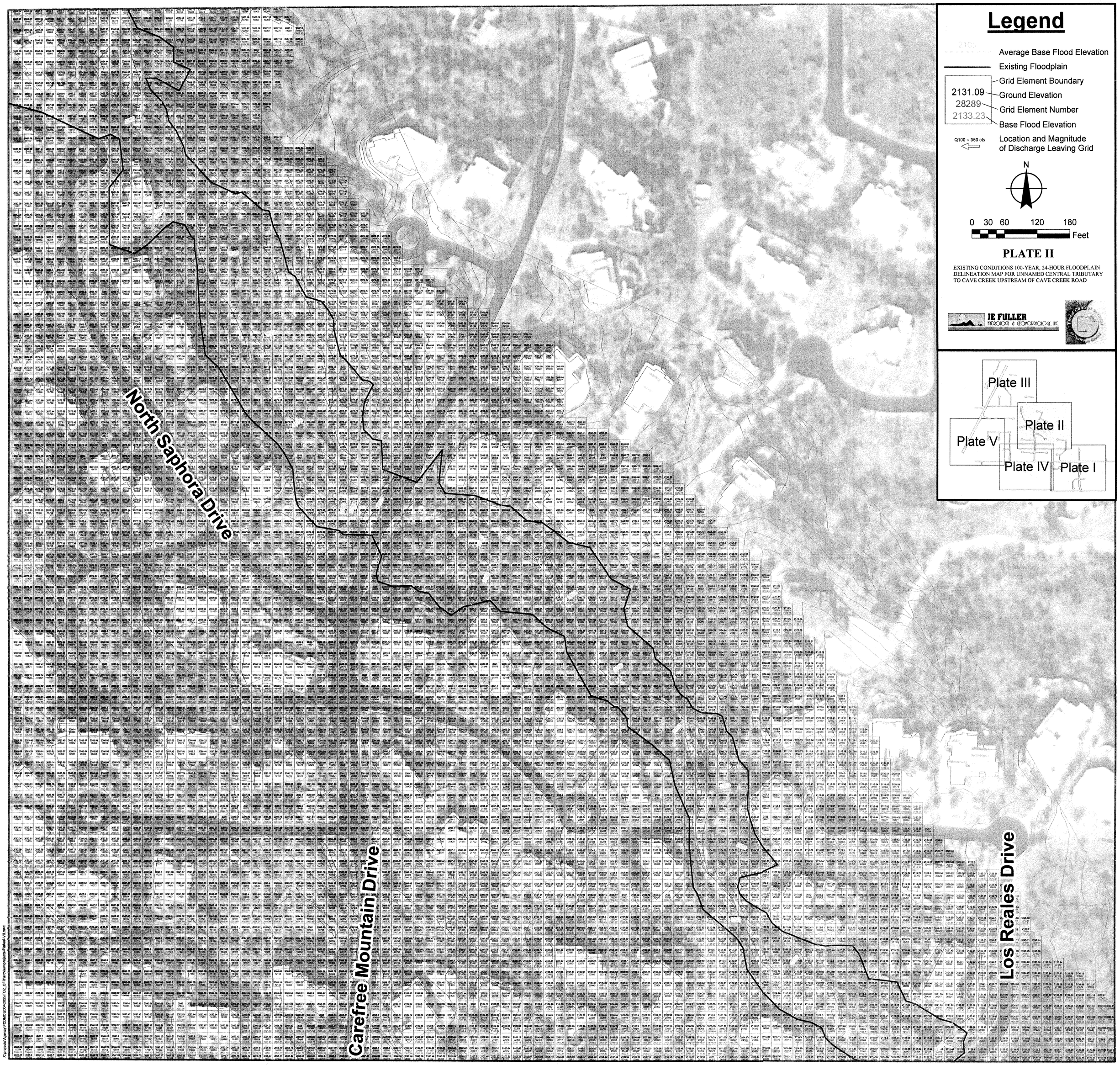

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Legend

2165 — Average Base Flood Elevation

Existing Floodplain

2131.09 — Grid Element Boundary
28289 — Ground Elevation
2133.23 — Grid Element Number
Base Flood Elevation

Q100 = 350 cfs — Location and Magnitude of Discharge Leaving Grid

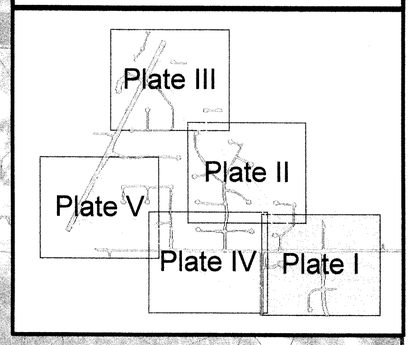
N

0 30 60 120 180 Feet

PLATE I

EXISTING CONDITIONS 100-YEAR, 24-HOUR FLOODPLAIN DELINEATION MAP FOR UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.



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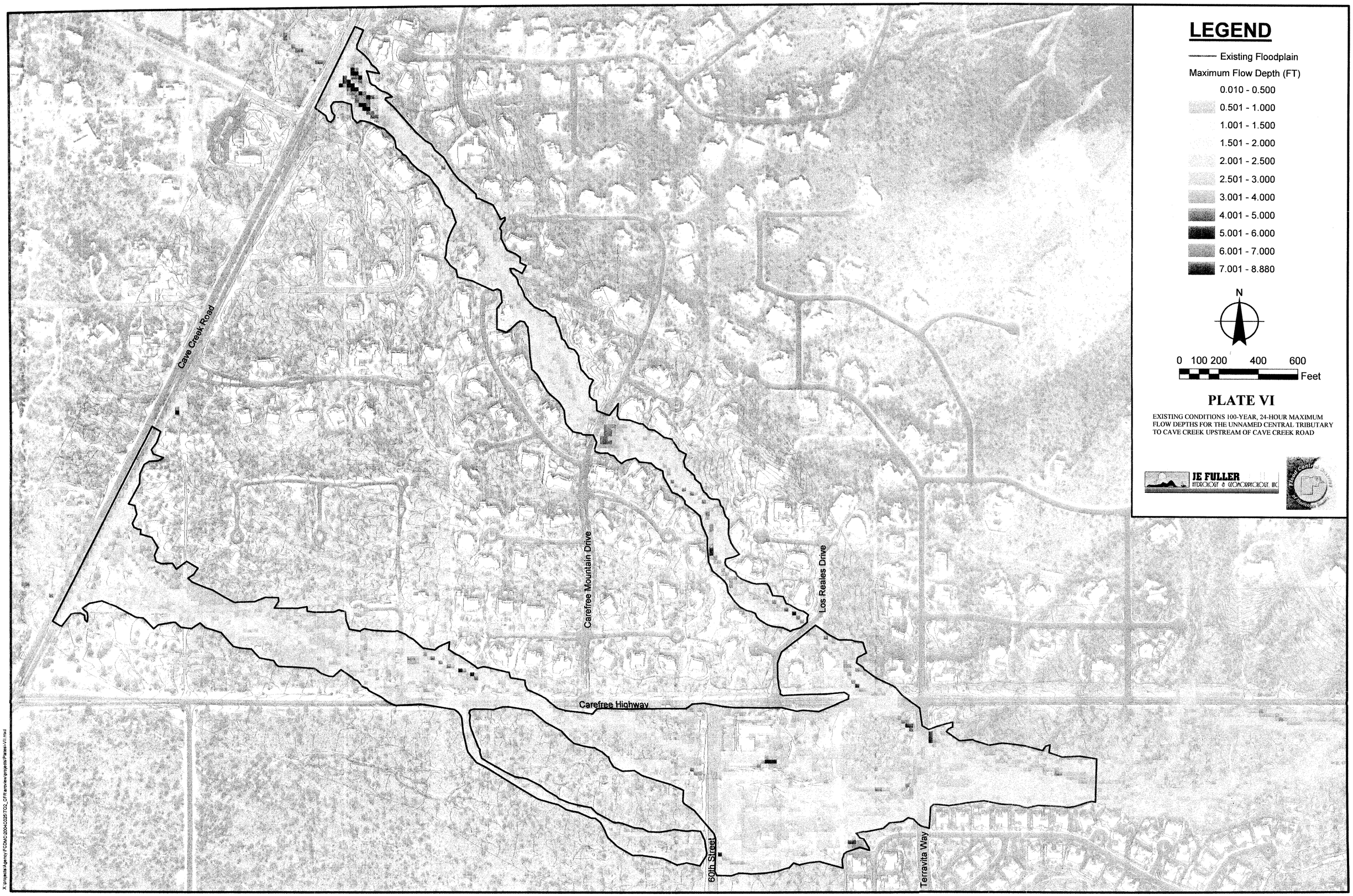

LEGEND

Existing Floodplain

Maximum Flow Depth (FT)

- 0.010 - 0.500
- 0.501 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- 2.001 - 2.500
- 2.501 - 3.000
- 3.001 - 4.000
- 4.001 - 5.000
- 5.001 - 6.000
- 6.001 - 7.000
- 7.001 - 8.880

N

0 100 200 400 600 Feet

PLATE VI

EXISTING CONDITIONS 100-YEAR, 24-HOUR MAXIMUM FLOW DEPTHS FOR THE UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Flood Control of Maricopa County

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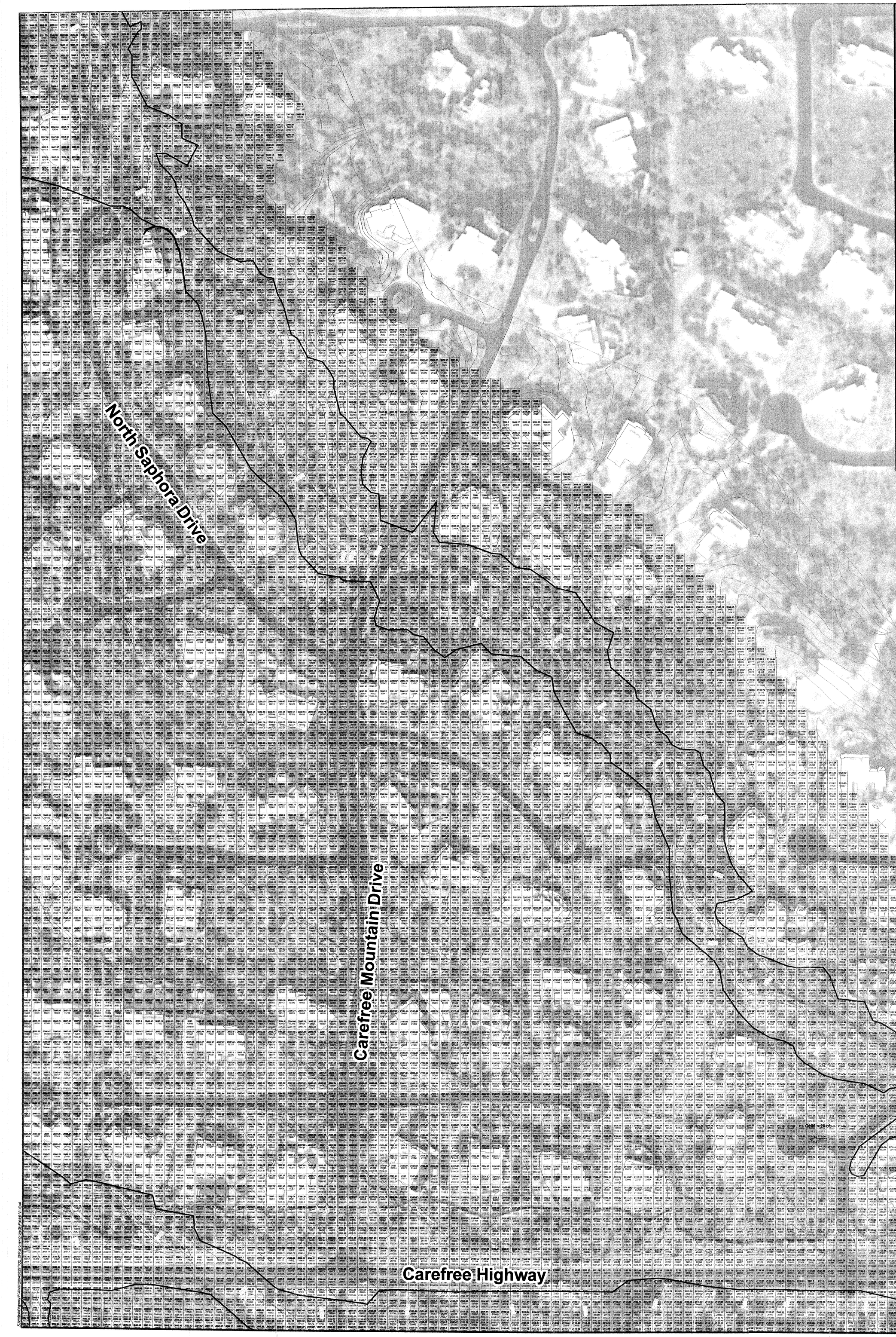


Legend

2105 — Average Base Flood Elevation

Proposed Floodplain

2131.09 — Grid Element Boundary

28289 — Ground Elevation

2133.23 — Grid Element Number

Base Flood Elevation

Q100 = 350 cfs — Location and Magnitude of Discharge Leaving Grid

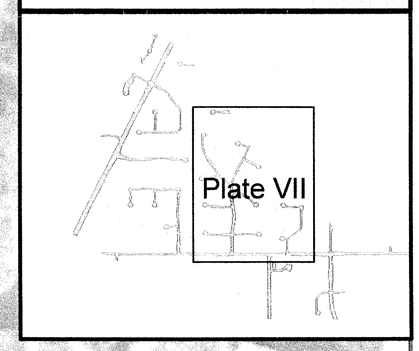
N

0 30 60 120 180 Feet

PLATE VII

PROPOSED CONDITIONS 100-YEAR, 24-HOUR FLOODPLAIN DELINEATION MAP FOR UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.



Legend

Average Base Flood Elevation

Existing Floodplain

2131.09 — Grid Element Boundary
28289 — Ground Elevation
2133.23 — Grid Element Number
Base Flood Elevation

Q100 = 350 cfs — Location and Magnitude of Discharge Leaving Grid

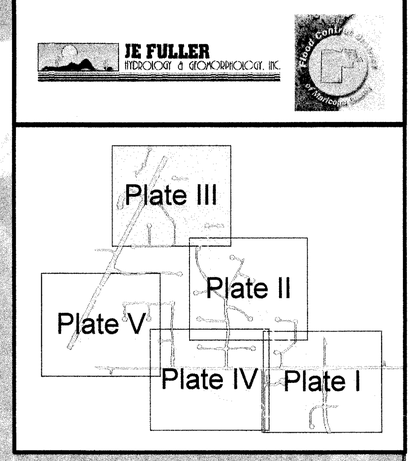
N

0 30 60 120 180 Feet

PLATE III

EXISTING CONDITIONS 100-YEAR, 24-HOUR FLOODPLAIN DELINEATION MAP FOR UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.



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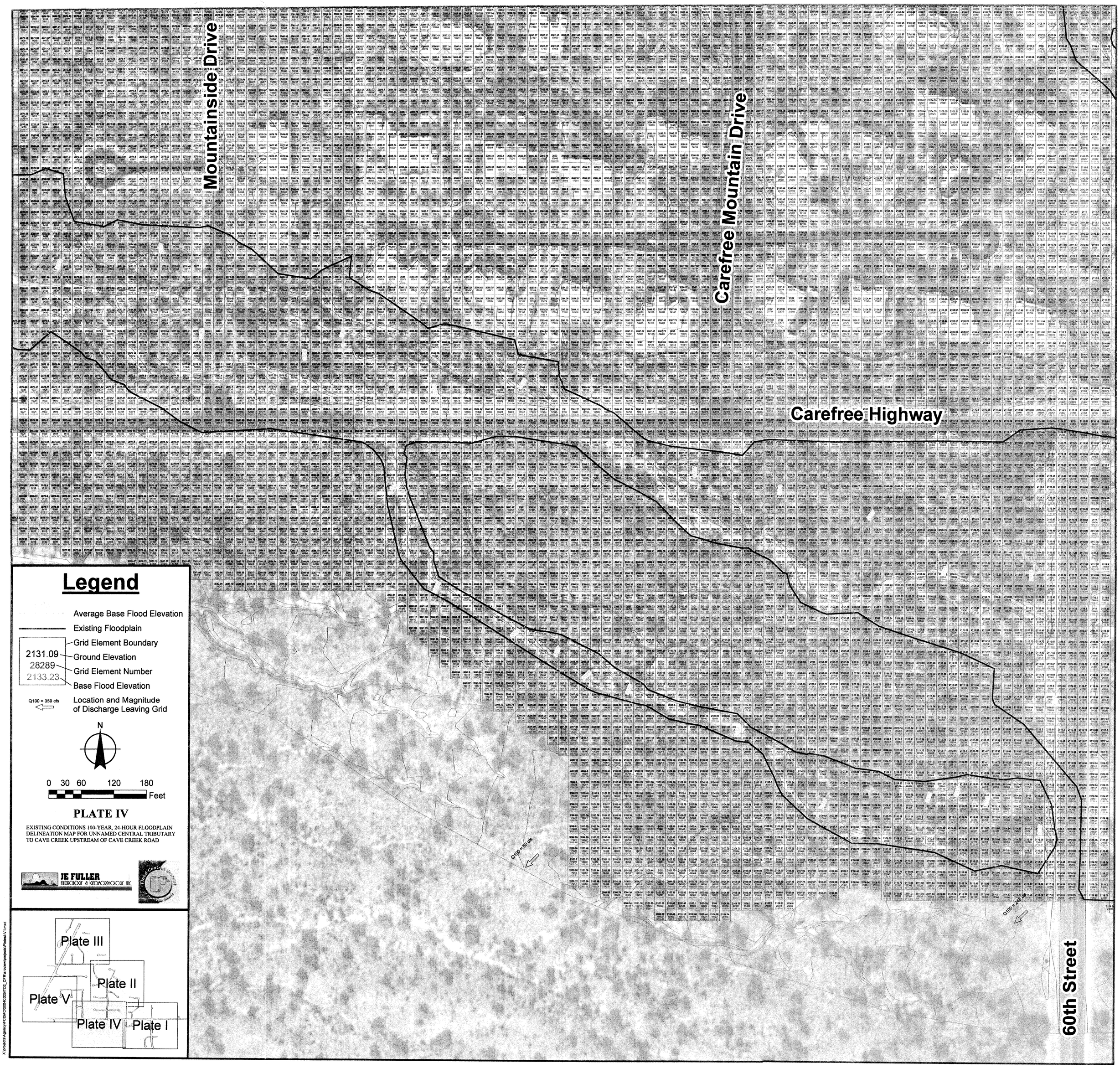

Legend

Average Base Flood Elevation

Existing Floodplain

Grid Element Boundary

2131.09 — Ground Elevation

28289 — Grid Element Number

2133.23 — Base Flood Elevation

Q100 = 350 cfs — Location and Magnitude of Discharge Leaving Grid

N

0 30 60 120 180 Feet

PLATE IV

EXISTING CONDITIONS 100-YEAR, 24-HOUR FLOODPLAIN DELINEATION MAP FOR UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Flood Control District of Maricopa County

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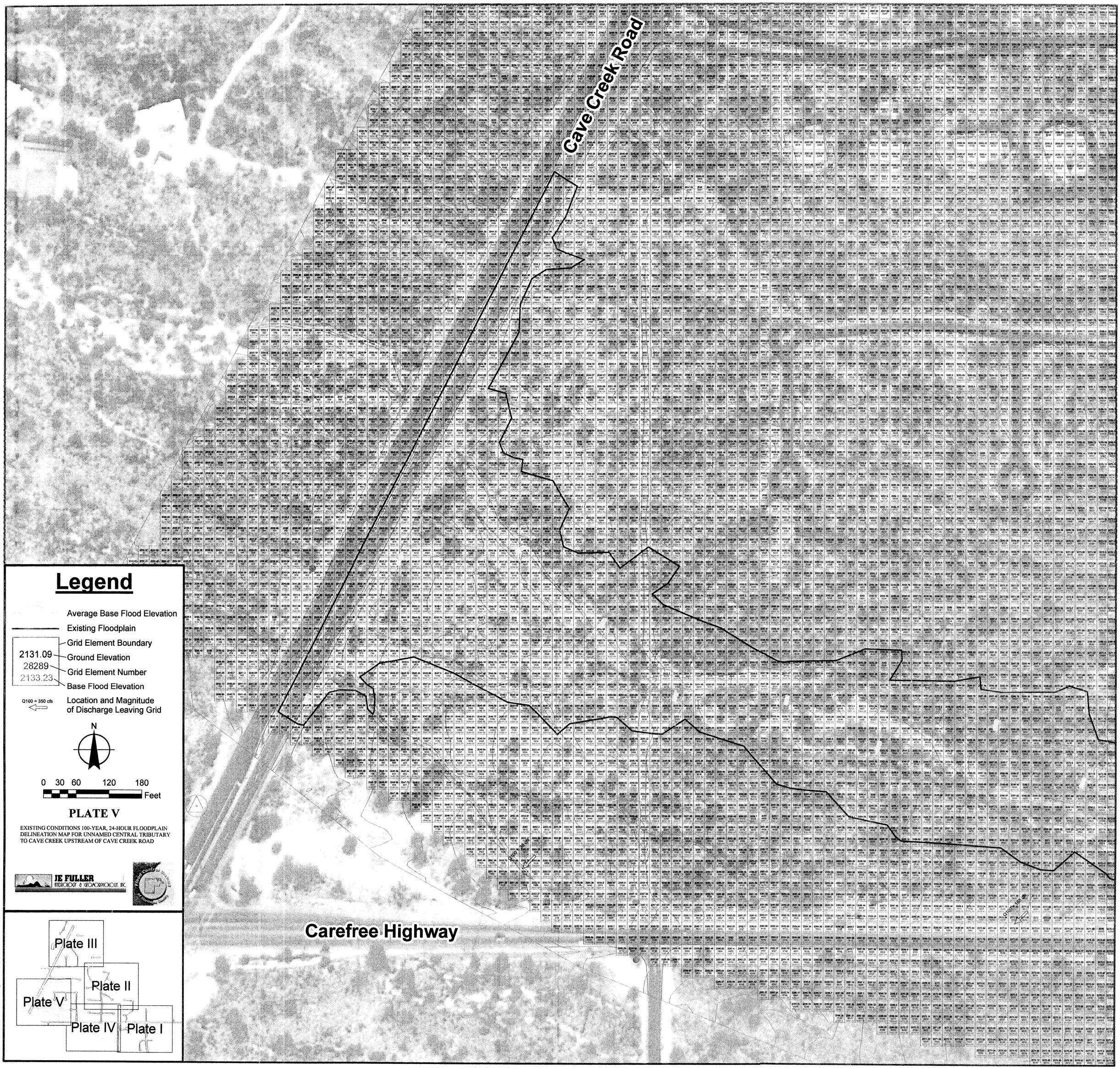

Legend

Average Base Flood Elevation

Existing Floodplain

Grid Element Boundary

2131.09 — Ground Elevation

28289 — Grid Element Number

2133.23 — Base Flood Elevation

Q100 = 350 cfs — Location and Magnitude of Discharge Leaving Grid

N

0 30 60 120 180 Feet

PLATE V

EXISTING CONDITIONS 100-YEAR, 24-HOUR FLOODPLAIN DELINEATION MAP FOR UNNAMED CENTRAL TRIBUTARY TO CAVE CREEK UPSTREAM OF CAVE CREEK ROAD

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Flood Control District of Maricopa County

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