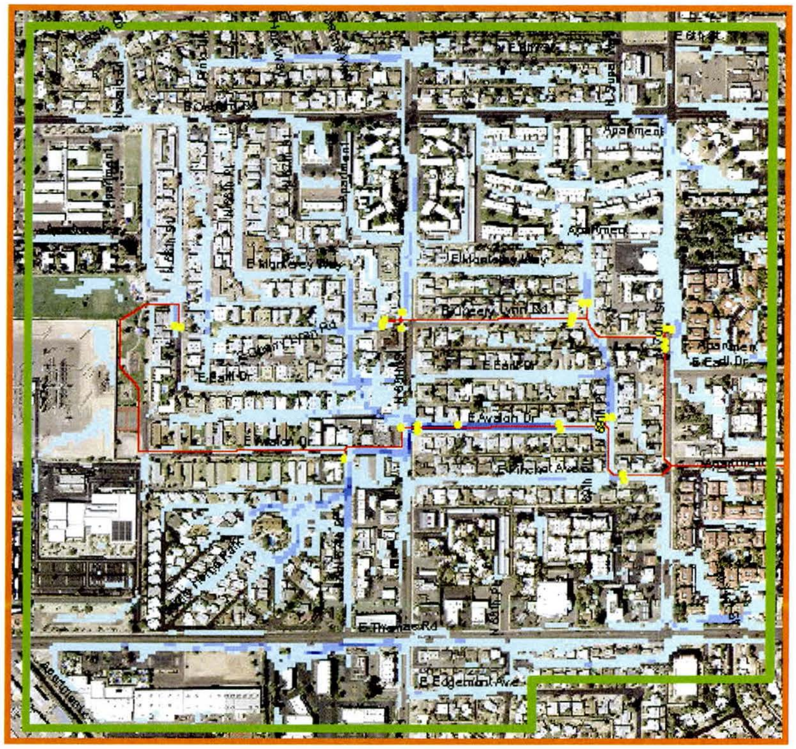
Lower Indian Bend Wash
Area Drainage Master Study/Plan

Contract No. FCD2011C019

Focused Area Study Technical Memorandum



September 14, 2012

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Expires 3/31/2017

Flood Control District of Maricopa County

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LIST OF APPENDICES

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1.0 Introduction

1.1 Purpose

The goals of the Focused Area Study were to evaluate the optimal FLO-2D grid size to use with the EPA SWMM model, evaluate the accuracy of the SWMM model results, define data collection requirements and methods and develop the GIS data standards to allow for large-scale FLO-2D/SWMM model development for the Primary Study.

1.2 Location

The focused area study is located in south Scottsdale, generally bounded by Osborn Road on the north, 70th Street on the east, Thomas Road on the south and Paiute Park on the west. The study area is approximately 0.5 square miles.

2.0 Geodatabase Development for EPA SWMM Model

The EPA SWMM model that is used in the Focused Area Study was created using the inpPINS computer program. The program was found to efficiently populate an EPA SWMM input file using ArcGIS shapefiles that were created from storm drain as-built data (see Section 4.1). For the procedure used to develop the storm drain as-built shapefiles, refer to the "LIBW ADMP/S Data Collection Report."

3.0 FLO-2D Model

3.1 Methodology

The two-dimensional analysis conducted for the focused area study was completed per the District's most current guidance for parameter development and modeling techniques. The current version of the FLO-2D Software (Version 2009.06 Build No: 09-11.07.06) was used for modeling. ArcGIS 10 and Manifold System 8.0, were both utilized to develop the parameters for FLO-2D input files.

3.2 Parameter Estimation

3.2.1 Grid Boundary and Size

The study area encompasses a previous design project completed by Gavan & Barker. Since the area is built out, conditions were assumed to be identical for both current and future conditions. The FLO-2D model was analyzed using three grid sizes (15'x15', 20'x20' and 25'x25') with the intent that a comparison would be made of SWMM storm drain results. A 500' buffer was added to the focused area study to ensure that there was enough context for the model to produce accurate data. Grid geometry data for the FLO-2D model area is contained within the **GRID.shp** file as well as the **FPLAIN.DAT** and **CADPTS.DAT** files. Refer to the electronic files included with this report.

3.2.2 Precipitation and Storm Frequency

Per the FCDMC's Drainage Design Manual, the NOAA Atlas 14 was used to determine point depth rainfall parameters for the FLO-2D model. The 100-year/10-year, 6-hour storms were used to analyze the study area (See Exhibits 1A & 1B, Appendix A). Since the study area was small, little spatial variation in rainfall was observed across the study area. The 6-hour storm distribution, Pattern No. 1 (Drainage Design Manual) was applied for both frequency events regardless of the size of the area. Since it is the most conservative rainfall pattern, it was applied to prevent underestimation of peak flows. All rainfall data for the FLO-2D model is contained within the **RAIN.DAT** file.

3.2.3 Physical Parameters

For the FLO-2D model, the individual physical attributes assigned to each grid element included: elevations, roughness coefficients and infiltration. Elevation and roughness coefficient values are found in the **FPLAIN.DAT** file. Infiltration values are found in the **INFIL.DAT** file.

Elevations

Elevations were assigned to each grid via surface sampling. A TIN was created of the study area. DEM format (ESRI ASCII Grid) was used for sampling the TIN using a grid size of at least 25% of the proposed model grid size. Based on 15'x15', 20'x20' and 25'x25' grid sizes, 3', 4' and 5' DEMs were used as the sampled surfaces, respectively. The DEMs were overlaid with the model grid elements and the points averaged to produce each grid elevation (see Exhibit 2).

Roughness Coefficients

Roughness coefficients were based per land characterization type in the study area. A land characterization shapefile was provided by the District based on the project mapping. Any missing areas were designated as "Urban Low Vegetation". Area-weighted average roughness coefficients were created for each grid element. Refer to the following table for assigned values:

Table 3-1 FLO-2D Roughness Coefficients

Type	Description	n-value
Urban High Vegetation	Trees	0.065
Urban Low Vegetation	Lawns and low shrubs	0.055
Urban Bare Ground	Urban bare ground	0.040
Concrete	Sidewalks, curb, driveways	0.020
Asphalt	Streets and parking lots	0.025
Buildings	Physical structures that are flow obstructions	0.035
Shade Structures	Parking covers, canopies	0.035
Unpaved Roadway	Gravel and dirt roads	0.055

Infiltration

The Green-Ampt method was used to estimate losses associated with infiltration. A limiting infiltration depth of 4 inches was applied to the study area to account for overestimation of infiltration. Data to estimate infiltration losses was obtained from the NRCS soils shapefile for the State of Arizona (April 2010) and the land characterization shapefile. Table 3-2 shows the parameters assigned to the land use types.

Table 3-2 FLO-2D Green & Ampt Loss Parameters

Type	Description	IA	RTIMP	InitSat
Urban High Vegetation	Trees	0.35	0	Normal
Urban Low Vegetation	Lawns and low shrubs	0.25	0	Normal
Urban Bare Ground	Urban bare ground	0.20	0	Dry
Concrete	Sidewalks, curb, driveways	0.05	98	Dry
Asphalt	Streets and parking lots	0.05	95	Dry
Buildings	Flow obstructions	0.05	95	Dry
Shade Structures	Parking covers, canopies	0.05	98	Dry
Unpaved Roadway	Gravel and dirt roads	0.10	50	Dry

*In the model, IA was reduced by 0.05 inches to account for volume already removed by TOL.

FLO-2D required a minimum surface detention value (TOL) for numerical stability during model runs. This value accounts for some of the IA for the model. Because of this, IA in the table above was adjusted to account for TOL. Since TOL cannot be zero, the minimum equivalent IA was 0.05 inches. TOL was then set to 0.0042 (0.05 in) and 0.05 was subtracted from the above IA for each land type.

The grid elements were assigned area-weighted average values for loss parameters with the exception of XKSAT. XKSAT was averaged by the following equation:

$$\overline{XKSAT} = 10^{\left(\frac{\sum A_i \log(XKSAT_i)}{A_{GE}}\right)}$$

Where: $XKSAT_i$ was obtained from the NRCS shapefile
A_i is the subarea within the grid element associated with $XKSAT_i$
A_{GE} is the total grid element area

PSIF and DTHETA were determined based on Figure 4.3 in the District's Hydrology Manual using the composite XKSAT and InitSat values for each grid element. XKSAT was not adjusted for vegetation cover in accordance with District guidance for 2D models.

Area Reduction Factors

Houses or structures preventing flow from occupying grid elements were characterized by Area Reduction Factors (ARF's). Building polygons were used to apply area-weighted ARF's to the grid elements. (See Exhibit 3, Appendix A). ARF values are located in the **ARF.DAT** file.

Levees

Levees were used to characterize walls that blocked shallow or minor flows. These walls were obtained from the project mapping. Linear wall features were imported into the GDS to create levees for all models. The **LEVEE.DAT** file documents the levee constraints. Refer to Exhibit 5 for locations.

3.2.4 Outflow Elements

Outflow elements were applied to the perimeter of the model study area to allow flows to leave the model as well as to eliminate any possible ponding along the boundary within the buffer areas. Outflow elements are identified in the **OUTFLOW.DAT** file.

3.2.5 Parameter Input Documentation

The following exhibits depict the data inputs for the FLO-2D model:

- **Exhibit 1A, 1B: Rainfall Maps**
- **Exhibit 2: Elevations Map**
- **Exhibit 3: Land Characterization Map**
- **Exhibit 4: Soils Map**
- **Exhibit 5: Storm Drain & Levees Map**

3.3 Modeling Controls

The CONT.DAT file established the system and global parameters for each model run specifying what output will be produced. Figure 3-1 shows the settings used for the study.

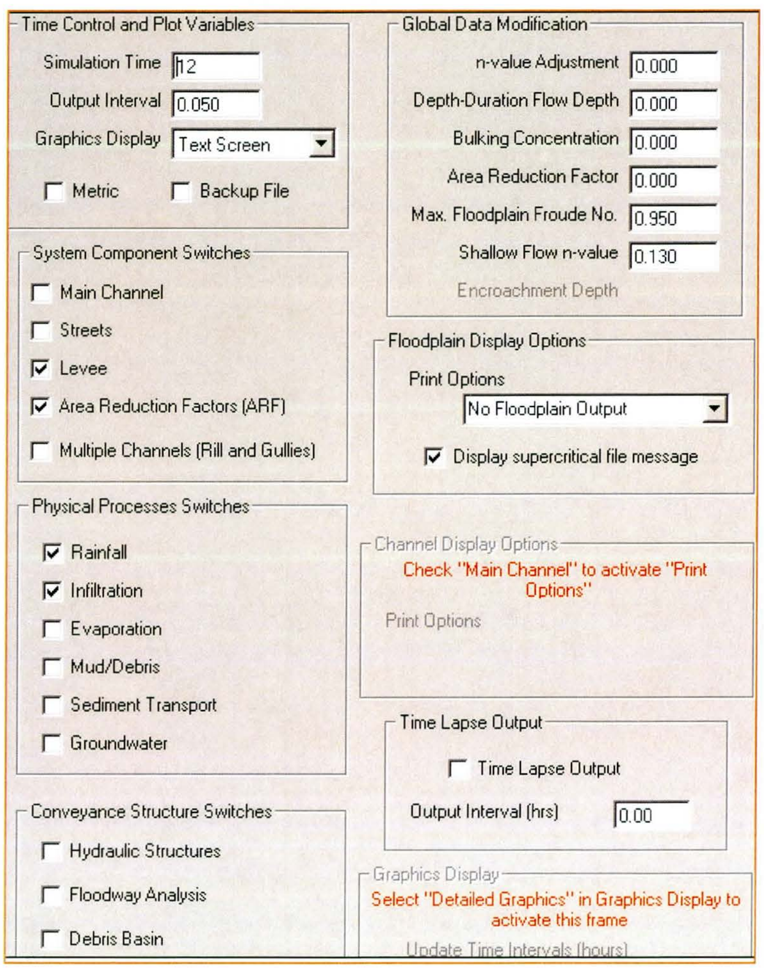


Figure 3-1 - FLO-2D Control Variables (6-hr Storm)

It was important that the swmm.inp file be set with the same simulation time as the CONT.DAT so that the model would run correctly. Table 3-3 shows the global settings used for the model runs.

Table 3-3 Global Data Modification Settings

Variable	Setting	Reason
AMANN	0	Roughness coefficient does not change during model run.
DEPTHDUR	0	Creates file of time duration of inundation for grid elements.
XCONC	0	Assumes model is running with clear water conditions.
XARF	0	Accounts for small obstructions that reduce available volume within grid elements.
FROUDL	0.95	Assumes model is running under subcritical conditions.
SHALLOWN	0.13	N-value for depths less than 0.2 ft.

3.4 Numerical Stability

The TOLER.DAT file established the tolerance values for the numeric calculations of the model which helped maintain stability. The following are the settings used for this study:

Table 3-4 FLO-2D TOLER.DAT Settings

Variable	Setting	Reason
TOL	0.0042	Matches IA for concrete/asphalt. TOL is subtracted from all IA.
DEPTOL	0	Turned off. Defaults to Courant.
WAVEMAX	0	Turned off. Defaults to Courant.
Courant Number	0.6	Recommended setting.

3.5 Problems and Error Messages

No special problems were observed in the FLO-2D models themselves. Some minor adjustments were made to n-values to improve model run times. Errors and warnings for FLO-2D were reported in the **ERROR.CHK** file. All errors have been either eliminated or minimized so as not to significantly affect the model. The following was reported in the error file. Based on the warning, the model appears to be functioning as intended:

WARNING: THE IMPERVIOUS AREA ASSIGNED BY THE RTIMP VARIABLE IS PRESUMED TO INCLUDE THE BUILDING AREA ASSIGNED BY THE ARF VALUE. ONLY THE RTIMP VARIABLE WILL USED IN THE INFILTRATION VOLUME COMPUTATION

3.6 Results

Results of the FLO-2D analysis (with the SWMM function on) are documented in the following exhibits for Maximum Depth, Velocity and Discharge (See Appendix A).

- **Exhibit 6A-C – 100-yr, 6-hr (15' Model)**
- **Exhibit 7A-C – 100-yr, 6-hr (20' Model)**
- **Exhibit 8A-C– 100-yr, 6-hr (25' Model)**
- **Exhibit 9A-C – 10-yr, 6-hr (15' Model)**

- **Exhibit 10A-C – 10-yr, 6-hr (20' Model)**
- **Exhibit 11A-C – 10-yr, 6-hr (25' Model)**

4.0 SWMM Interface

The SWMM function runs simultaneously with FLO-2D and accounts for flows being removed from designated grid elements within the FLO-2D model and input into a SWMM storm drain model. Beta testing was performed on the SWMM model function after some issues were noticed during initial model runs. These issues are discussed in Section 5.0 and summarized in Section 7.1. The need for corrections and for certain modeling and reporting functionality were discussed in several technical meetings with the District. The laundry list of SWMM fixes/additions was developed by the District for further collaboration with the FLO-2D/SWMM model developer/programmer and includes the following items:

- Introduce FHWA HEC-22 inlet equations to the model. Allow user to set limiting values for the flow transition zones (Weir/Orifice), and control over coefficients on equations. Include literature references and equations in the user manual.
- Add hydrograph reporting capability for FLO-2D grids at the storm drain inlets/outlets to show flows going into/from the storm drain system.
- Add EPA SWMM outfall/Outlet flows to return and interact with FLO-2D surface hydraulics. Allow water surface to control hydraulics at the outfall/outlet. Integrate capabilities with SWMMFLO.DAT and document use in the user's manual.
- Fix the EPA SWMM GUI Bug to display the results.
- Add inlet control culvert calculations from the FLO-2D culvert routines as part of the inlet options in the SWMMFLO.DAT. Document use in the user's manual.
- Add manhole one way - flow exchange to the FLO-2D surface, such that SWMM discharges (surcharge) back onto the FLO-2D surface. Do not let water flow back into SWMM through the manhole opening.
- Add the capability of using rating curves or tables for the inlet nodes.

4.1 EPA SWMM Setup

Setting up the SWMM model function in FLO-2D begins by importing a **swmm.inp** file from the GDS (the **swmm.inp** file contains all the storm drain information for the external SWMM model which is set up separately in SWMM). The SWMM function in the GDS then creates the **SWMMFLO.DAT** file. This file is produced (by the SWMM function in GDS) by spatially comparing the nodes in the **swmm.inp** with the grids in the GDS. Each grid element encompassing an inlet in the SWMM model is correctly identified and its number added to the **SWMMFLO.DAT** file. The GDS only operates on SWMM nodes with subcatchments attached. This file also assigns each inlet one of three user selected configurations:

- Curb opening inlet at grade (Type 1)
- Curb opening inlet in sag (Type 2)
- Grate (gutter) inlet (Type 3)

Each configuration type includes both weir and orifice equations to evaluate interception rate for a range of depths at each inlet location. Based on these parameters, FLO-2D calculates inlet interception at each time step and the sum is transferred to the SWMM node at next SWMM time step.

4.2 Modeling Controls

The modeling controls for SWMM are located in the **swmm.inp** 'OPTIONS' category. Table 4-1 shows the settings used for the SWMM model.

Table 4-1 SWMM Model Settings

Variable	Setting	Comments
FLOW_ROUTING	DYNWAVE	Required to run with FLO-2D.
START_DATE	04/23/2012	
START_TIME	00:00:00	Should be set to zero.
REPORT_START_DATE	04/23/2012	
REPORT_START_TIME	00:00:00	
END_DATE	04/23/2012	
END_TIME	12:00:00	Needs to match the Simulation Time in FLO-2D.
REPORT_STEP	00:03:00	Should match the Output Interval for FLO-2D.
WET_STEP	00:00:01	A catchment variable that affects FLO-2D/SWMM interaction.
DRY_STEP	00:00:01	
ROUTING_STEP	0.1	Should be set low enough to maintain stability.
ALLOW_PONDING	YES	

4.3 Results

Results of the FLO-2D/SWMM analysis are documented in the following exhibits (see Appendix A):

- **Exhibit 12A – 100-yr, 6-hr (Total SWMM outflow for each grid size)**
- **Exhibit 12B – 10-yr, 6-hr (Total SWMM outflow for each grid size)**
- **Exhibit 13A – 10-yr, 6-hr (Max Discharge comparison)**
- **Exhibit 13B – 100-yr, 6-hr (Max Discharge comparison)**

Exhibits 12A and 12B show a difference in total storm drain outflow (and volume) for the three different grid sizes modeled. However, differences of this magnitude could not necessarily be due to grid size alone. Based on results from beta testing (see Section 5.0), these differences may be due to the effect of the wet-step variable, volume transfer/conservation/time-step issues and possible drawdown effects at inlet grid elements.

Exhibits 13A and 13B are provided for reference. These exhibits (and electronic results files provided with this technical memorandum) indicate that flow is in fact being removed with the SWMM model from the FLO-2D grid. However, the magnitude and accuracy of these results remain in question.

5.0 SWMM Beta Testing

Beta testing was conducted for the SWMM interface in order to try and understand issues with results. These tests are documented here for reference for further beta testing to be conducted by the District with the model developer/programmer.

5.1 Inlet under Rainfall Conditions with High Wet-Step

Initial results showed many oscillations in the interception hydrographs for all inlets. These oscillations are depicted in Figure 5-1, an inlet hydrograph for the 100-year, 6-hour 20'x20' grid model. The oscillations appear to occur if the wet-step (a SWMM catchment hydrologic time-step) is set too high. In Figure 5-1, the Wet-Step was initially set to 3 minutes to match the reporting time-step for FLO-2D.

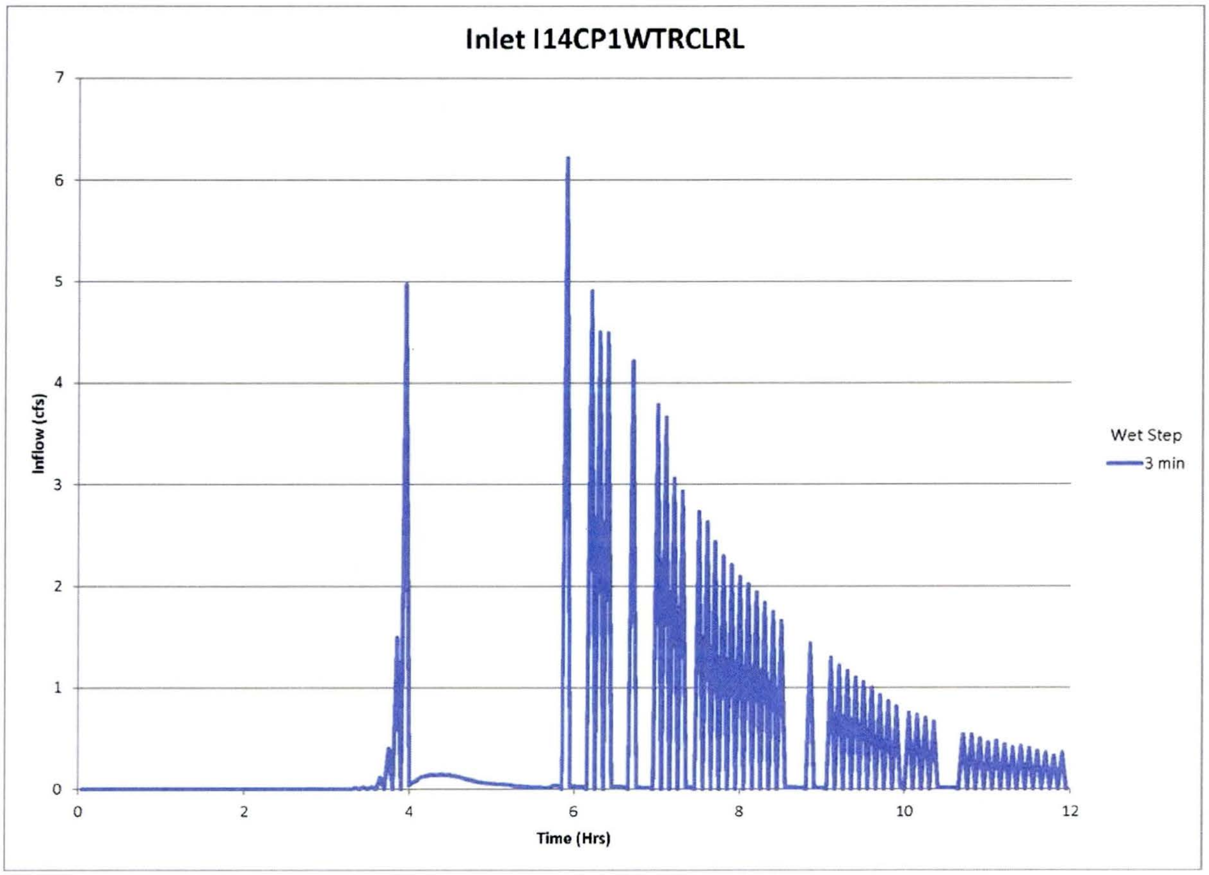


Figure 5-1 – Inlet Hydrograph with 3-min Wet-Step

5.2 Inlet under Rainfall Conditions with Lower Wet-Step

Our current understanding is that the wet-step should have no effect on the SWMM interface because it is a hydrologic catchment parameter in SWMM. However, further testing using a more appropriate wet-step of 1, 2 and 3 seconds produced the following interception hydrograph for the same inlet (see Figure 5-2). The effects of a large wet-step on interception require further investigation.

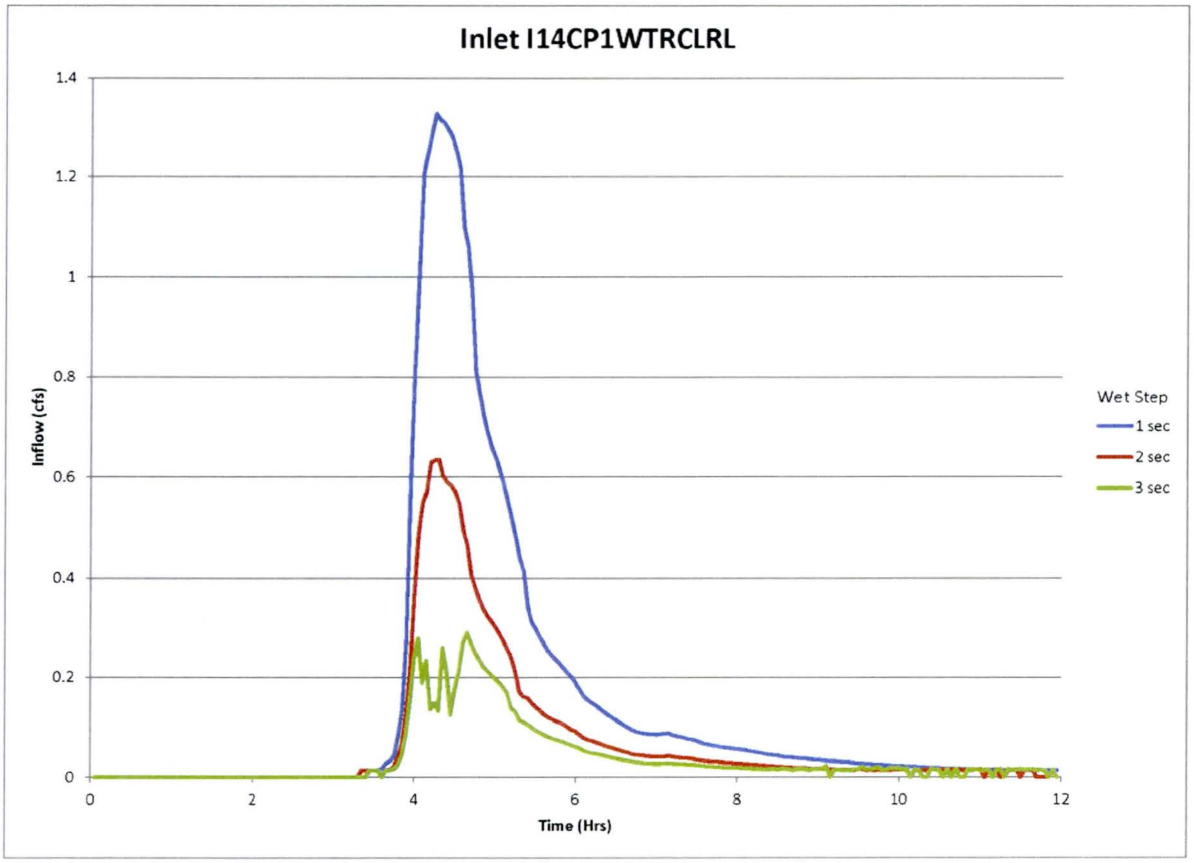


Figure 5-2 – Inlet Hydrograph with small Wet-Step

5.3 Inlet under Constant, Confined Flow Condition

Another test was performed (before the wet-step issue was discovered) to ascertain whether oscillations were caused by drawdown at the inlet grid element, followed by subsequent side flows from adjacent grids, followed by a refilling of the inlet grid. This assessment is only our opinion, but may need to be addressed. Figure 5-3 shows results hydrographs for the same inlet with a 40 cfs baseflow directed over the inlet beginning two grid elements upstream and remaining confined (with levees) for several grid elements downstream. The spike indicates nearly complete interception for a large wet-step and the others, a varying constant interception rates for wet-steps of 1, 2 and 3 seconds. A key thing to note is that there are no oscillations with the confined, constant 40 cfs flow. This may indicate (barring the wet-step variation), that draw-down at the inlet may be an issue and needs to be addressed. The varying constant rates of interception with different wet-steps need further investigation.

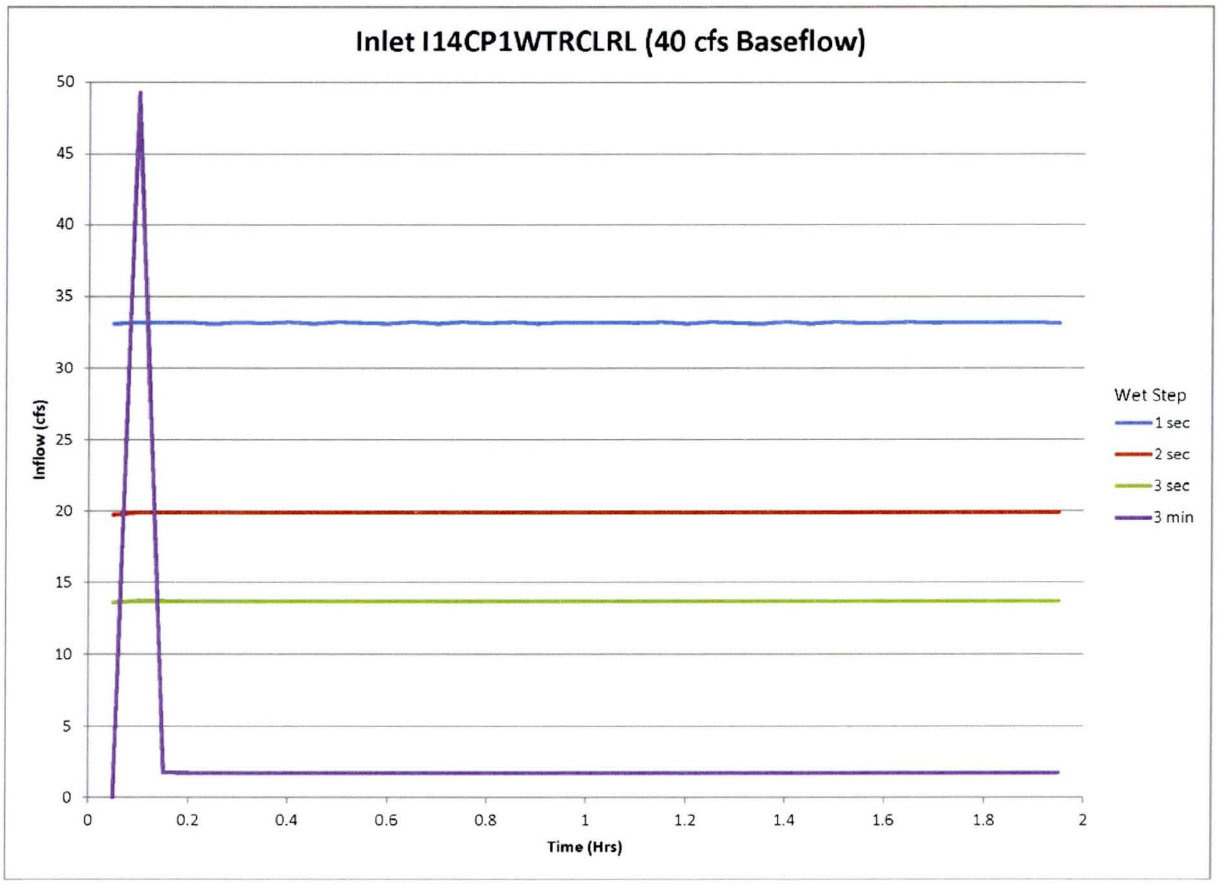


Figure 5-3 – Inlet Hydrograph for Confined, Constant Flow - varied Wet-Steps

5.4 Comparison of FLO-2D/SWMM Outflow Volumes and Timestep

Figure 5-4 shows a plot of the total outflow hydrographs from the SWMM storm drain network for the focused area study for the three different grid size models. Hand notation is added to show the total outflow volumes from the FLO-2D SUMMARY.OUT file compared to the SWMM outflow volume (calculated from hydrographs areas). The average timestep from FLO-2D is listed as well. Model run was for a wet-step of one second. This figure indicates variation due to different grid sizes and for different average FLO-2D timesteps. The effects of the grid-size and timestep relative to the wetstep on volume conservation need further investigation. Volume conservation may be an issue affected by other variables as well. An accurate reporting mechanism needs to be added to accurately check FLO-2D outflow volume (into SWMM) versus outflow volume from SWMM.

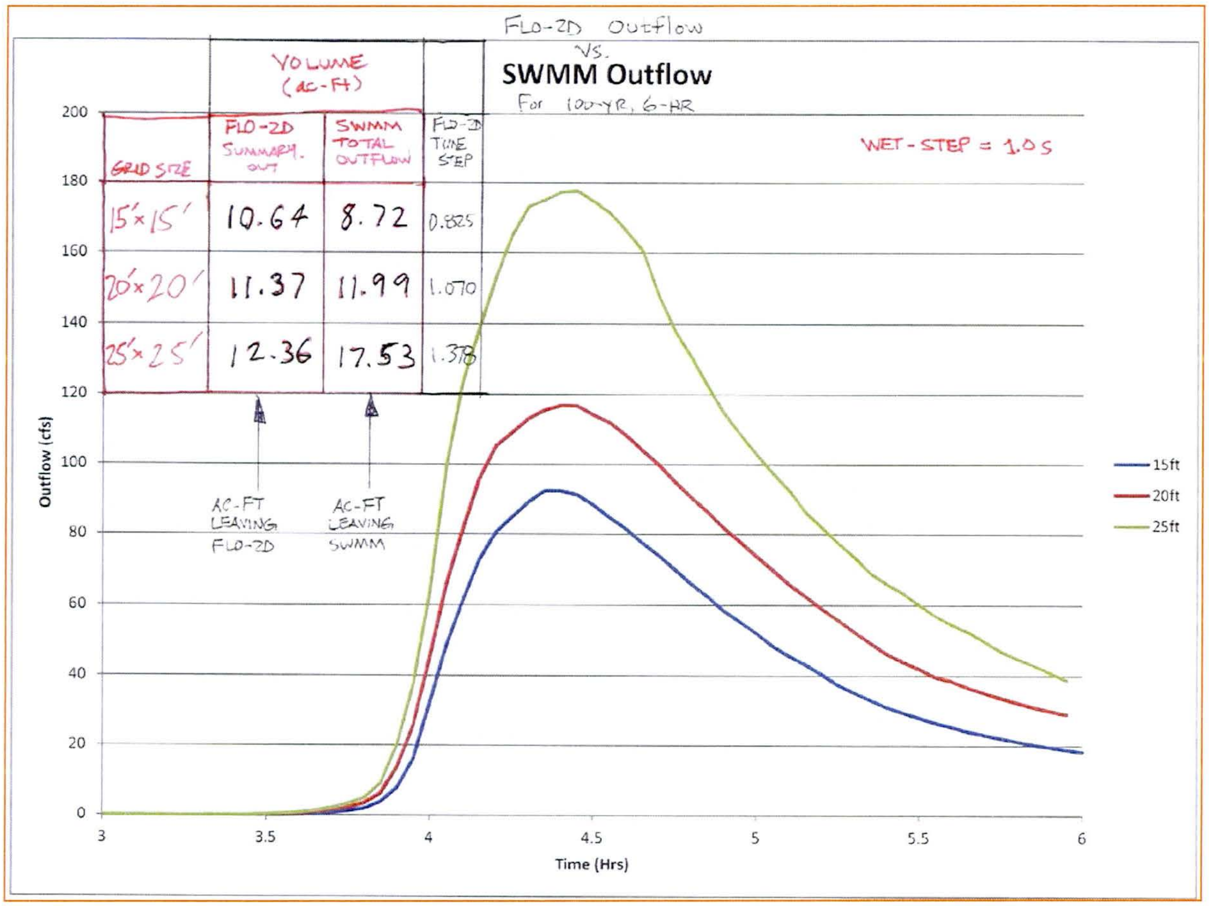


Figure 5-4 – FLO-2D/SWMM Outflow Volume & Timestep Comparison

5.5 Inlet under Constant Depth Conditions

A test was conducted to verify whether the inlet equations (weir and orifice) were causing results issues (see Figure 5-5). An outflow element was coded with specific depths onto a grid element containing an inlet. Hard-coded depth values were based on triggering the key phases of weir, orifice or transition between the two conditions as set by the equations in the SWMM code. The red line is the interception hydrograph for the inlet with the corresponding depth notated (set to change each hour over six hours). The results indicate that the weir and orifice equations (as coded at the time of this test) were functioning as intended.

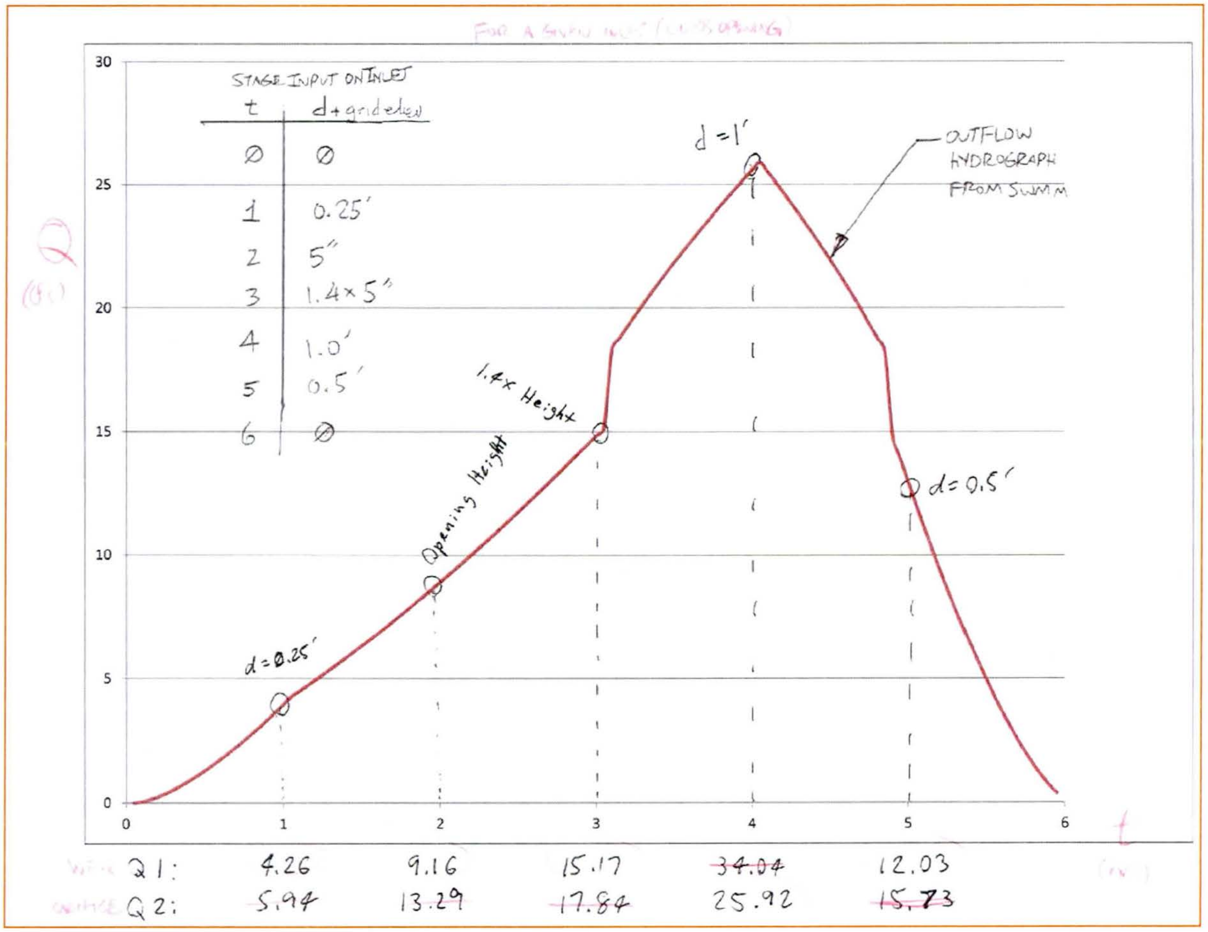


Figure 5-5 – Inlet under Constant Depths

5.6 Further Notes/Comments

A modification to the Figure 5-3 test (confined inlet, levees on both sides of approach grid elements and a base flow of 40 cfs directed over the inlet using an inflow hydrograph) was performed. For a 20-foot long curb-opening inlet, all flow was taken off grid. We then reduced the length of the curb-opening to 3-feet expecting some bypass flow in the confined downstream grid elements. There was no by-pass and all 40 cfs was intercepted in the 3-foot curb opening.

The wet-step for this case was set to 3 minutes. The wet-step appears to affect interception on grid. Further tests using a wet-step of 1 second produced results in which the 3-foot long curb-opening did not intercept all flow and bypass flow was present on grid. The affect of the wet-step on curb opening size requires further investigation.

6.0 Mapping Accuracy

During preparation of the models for the Focused Area Study, review of the mapping data was conducted. After inspection of the level of detail applied to represent topographic features, including arterial and residential streets, it became apparent that a limiting factor in determining modeling grid size may be the mapping product itself. Figure 6-1 depicts one of the major intersections in the mapping area. The yellow lines are breaklines and red dots are mass points. Generally, the arterial streets are well represented with median and gutter/curb breaklines. In some cases, the breaklines are intermittent in arterial streets and either characterizes the bottom or top of curb, but not both. This means the net cross slope may not be consistent.

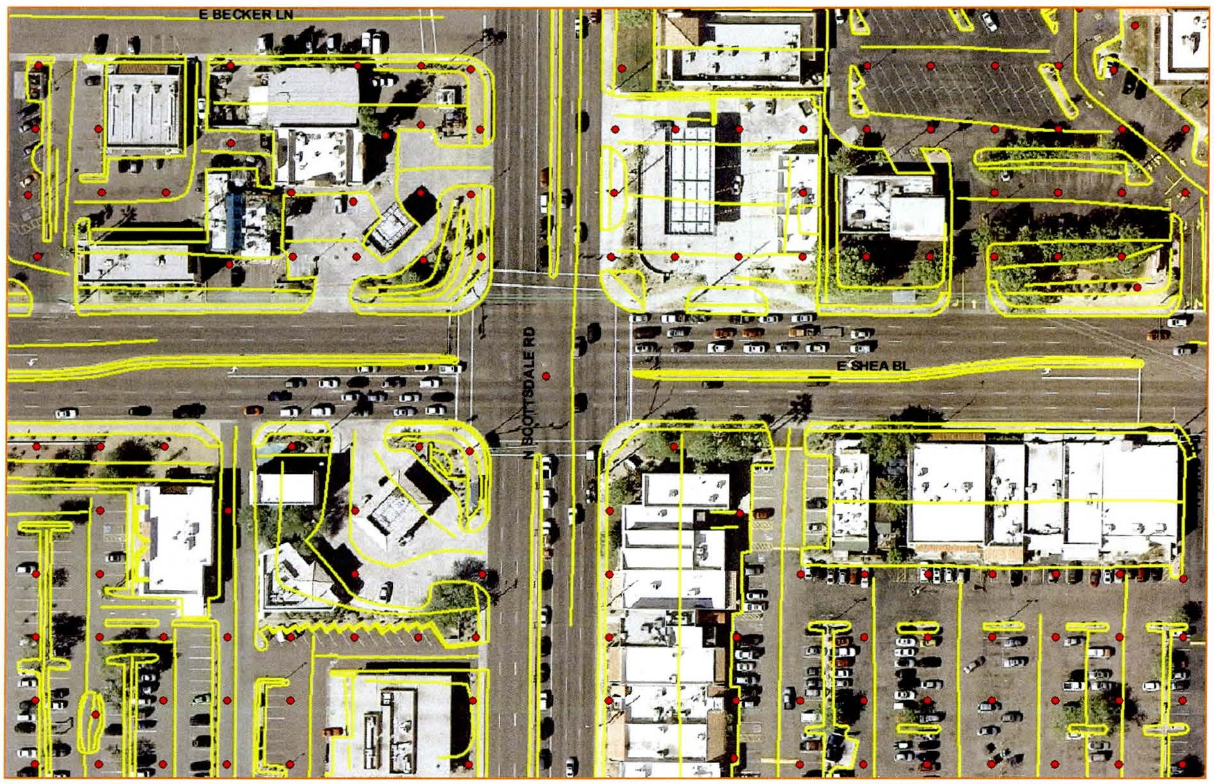


Figure 6-1 – Major Arterial Intersection

Residential streets were reviewed for level of breakline and mass point detail. Figure 6-2 shows the typical detail, which is from edge of pavement / gutter / curb to edge of pavement / pavement / gutter / curb. The characterization of roadway edges is not consistent; therefore residential street cross-slopes may not represent actual cross slopes.

Figure 6-2 – Residential Streets

7.0 Recommendations

7.1 Further SWMM Beta Testing

The FLO-2D/SWMM model interface beta testing provided some indication of where there needs to be further testing and corrections. As mentioned in Section 5, items requiring further investigation include:

1) Figure 5-1: Effects of a large wet-step on interception – Why the oscillations? Investigation may include the programmer attempting to figure out how to decouple the interface from the wet-step.
2) Figure 5-2: Draw-down at inlets needs further investigation – Investigation may include the programmer using depths in adjacent grids to trigger the interception equations (or rating curves).
3) Figure 5-3: Effects of a smaller wet-step on interception – Why the variation in interception for the same flow for the same inlet? Investigation may include the programmer attempting to figure out how to decouple the interface from the wet-step.
4) Figure 5-4: Effects of grid size and timestep on volume conservation
5) Figure 5-5: Interception equations appear to function correctly when provided a constant depth
6) Further notes: Why is interception unaffected when the curb-opening length was changed from 20 feet to 3 feet with a large wet step?

7.2 Recommended Grid Size Based on Mapping Detail

The level of mapping accuracy in large part dictates how fine a grid size can be used for the FLO-2D modeling efforts. Because the residential streets (typically 24 feet wide) are characterized from curb to curb, a grid size much less than 24 feet would generally not provide further level of detail in these conveyance areas. This would apply to the ½ street of arterial roadways as well. For example, a 15 foot grid size would not produce a better resolution and may create unnecessary additional modeling time for the Primary Study Area. For modeling purposes, and in order to define flow patterning within urbanized areas, we recommend a 20 foot grid size for the LIBW FLO-2D modeling.

7.3 Comments on Storm Drain Modeling

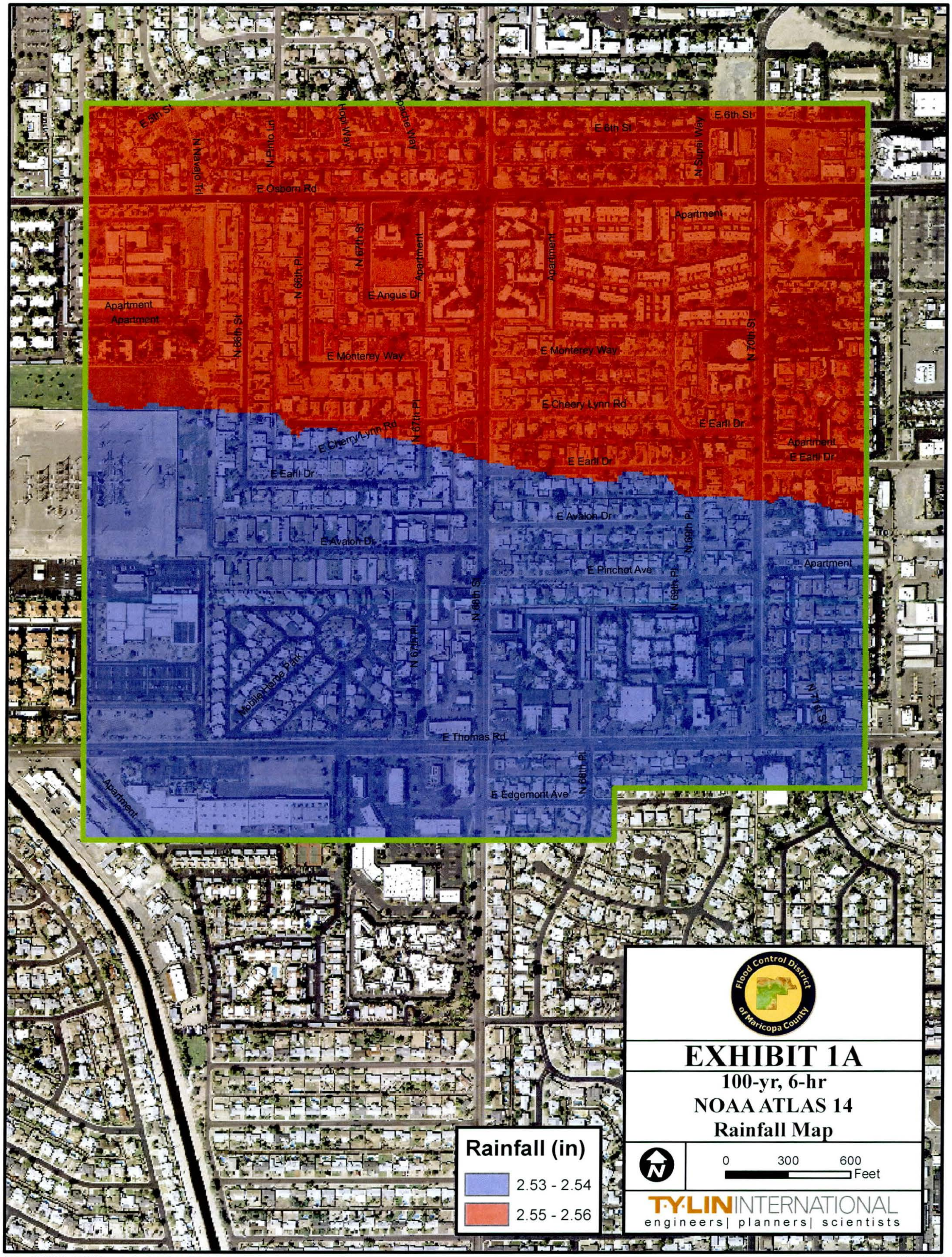
There is a need to brainstorm the level of accuracy to which the storm drain modeling should proceed. The depth results in FLO-2D based on the mapping accuracy may not be detailed enough to yield accurate results at specific inlets. This in turn would affect the evaluation of capacity for smaller systems or the upstream portions of larger systems. If the approach to accounting for a majority of inlets is maintained, the overall removal of flow from grids into the storm drain systems could be accounted for and generally beneficial.

8.0 References

- Bentley Systems, Inc., *CulvertMaster*, Version 3.2, August 2008.
- *Drainage Design Manual for Maricopa County, Arizona, Volume I – Hydrology*, Flood Control District of Maricopa County, November 2009.
- *Drainage Design Manual for Maricopa County, Arizona, Volume II – Hydraulics*, Flood Control District of Maricopa County, January 1996.
- ESRI, *ArcGIS,* Version 10, 2010.
- FLO-2D Software Inc., *FLO-2D*, Version 2009.06, 2009.
- Manifold Software Limited, *Manifold System*, Version 8.0, 2010.
- U.S. Environmental Protection Agency, *EPA SWMM,* Version 5.0 (Build 5.0.022), April 2011
- inpPINS Computer Program, https://sites.google.com/site/inppins/guide

APPENDIX A – Exhibits

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



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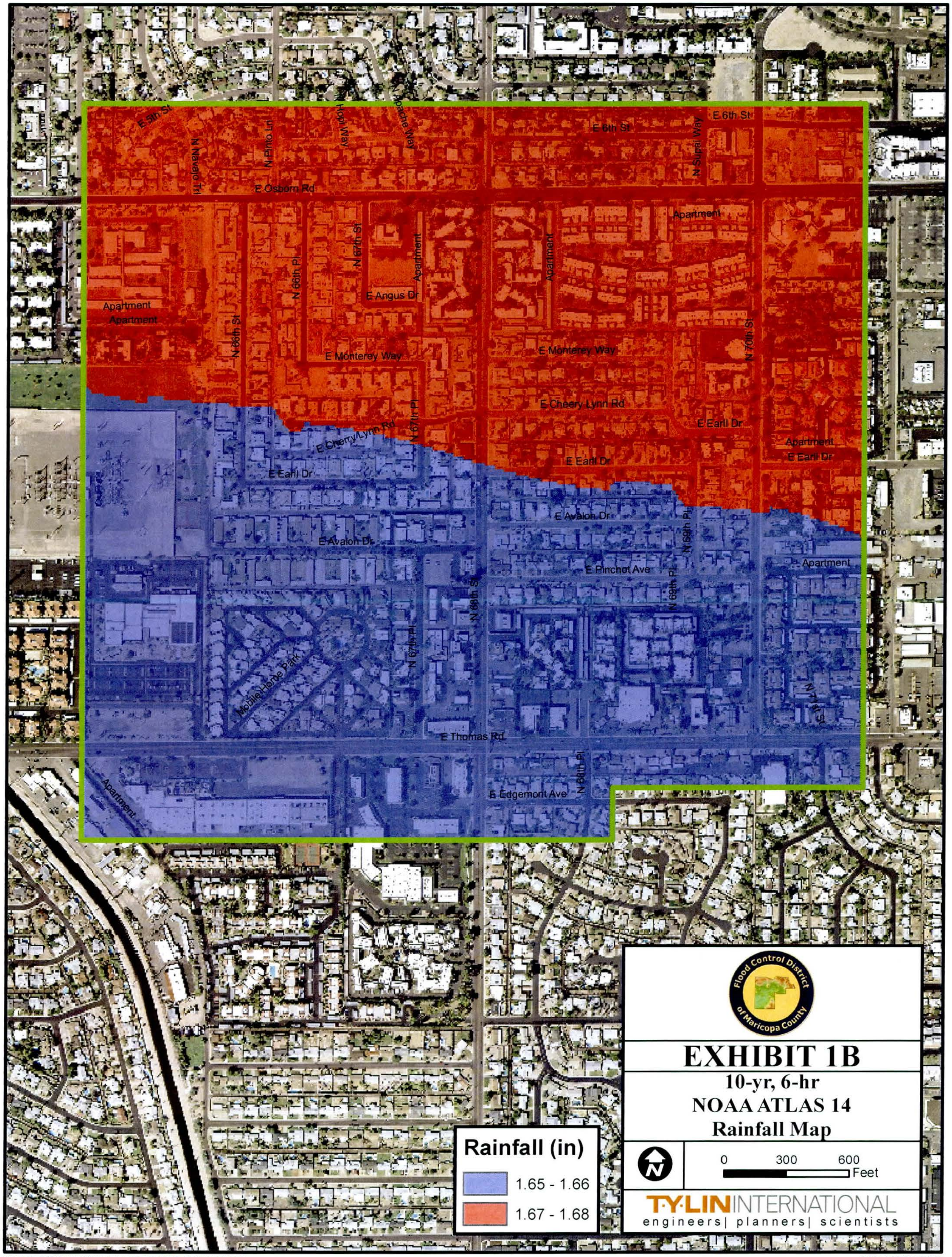
FOCUSED AREA STUDY



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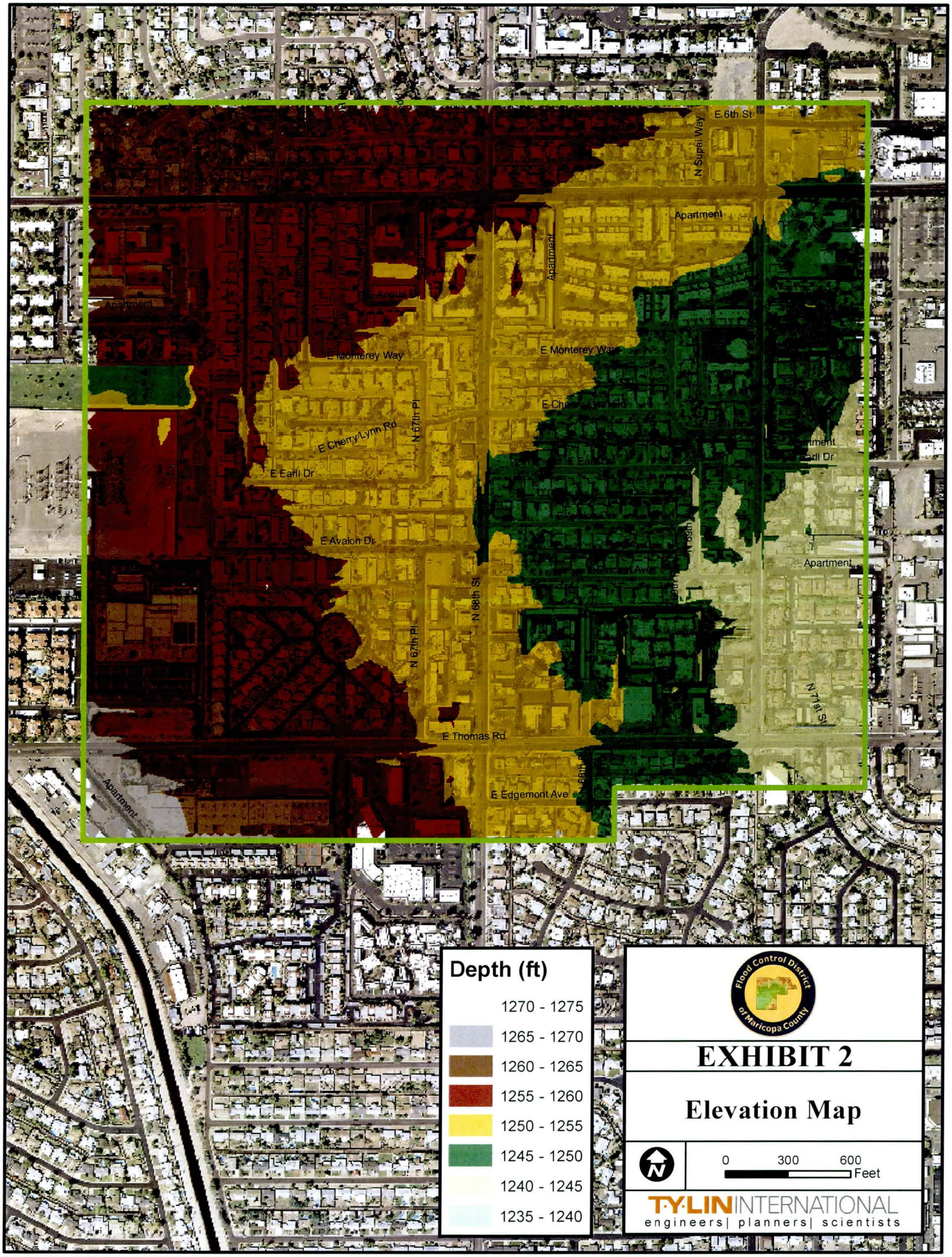
LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 2 - Elevation Map.mxd

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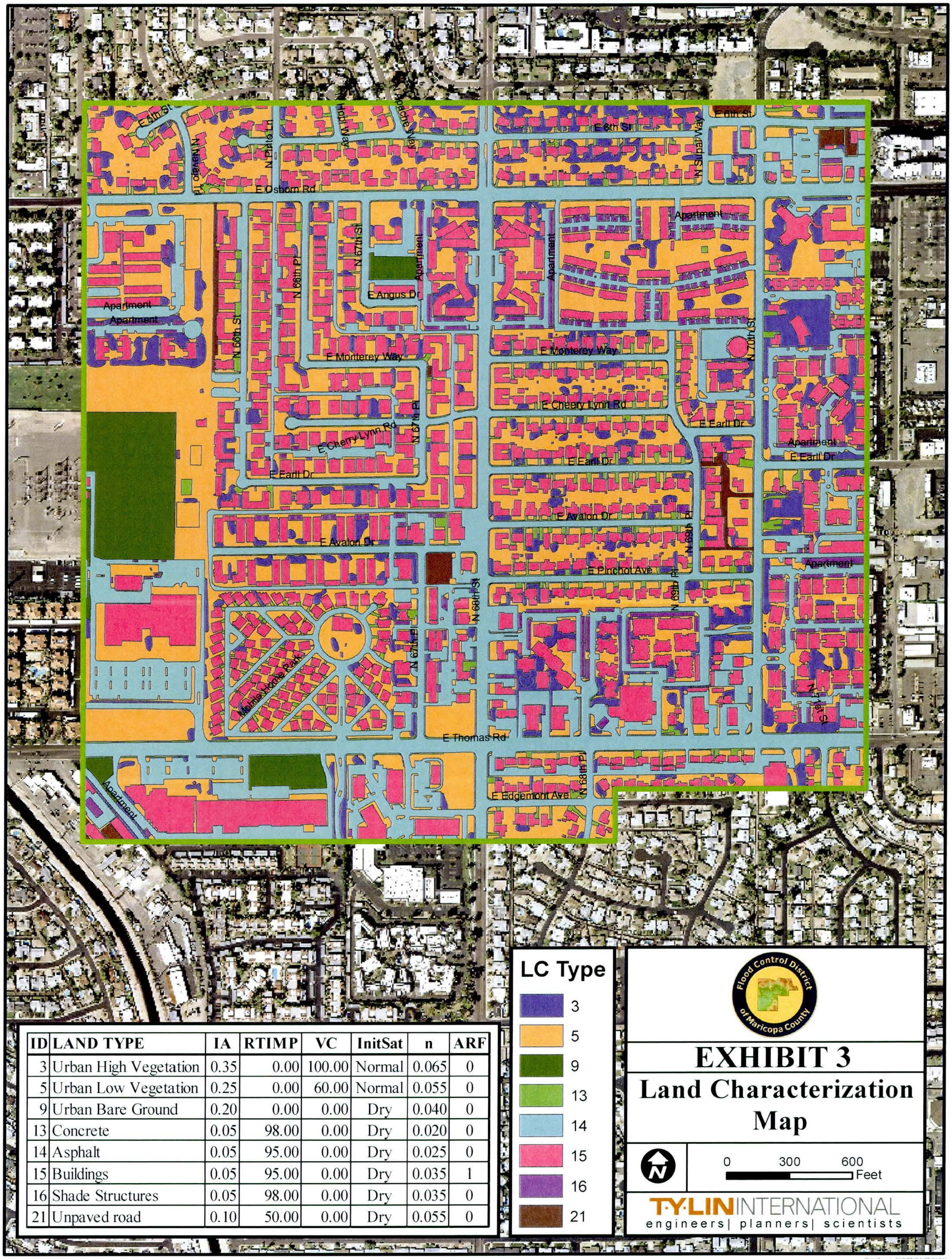
LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



ID	LAND TYPE	IA	RTIMP	VC	InitSat	n	ARF
3	Urban High Vegetation	0.35	0.00	100.00	Normal	0.065	0
5	Urban Low Vegetation	0.25	0.00	60.00	Normal	0.055	0
9	Urban Bare Ground	0.20	0.00	0.00	Dry	0.040	0
13	Concrete	0.05	98.00	0.00	Dry	0.020	0
14	Asphalt	0.05	95.00	0.00	Dry	0.025	0
15	Buildings	0.05	95.00	0.00	Dry	0.035	1
16	Shade Structures	0.05	98.00	0.00	Dry	0.035	0
21	Unpaved road	0.10	50.00	0.00	Dry	0.055	0

EXHIBIT 3
Land Characterization Map

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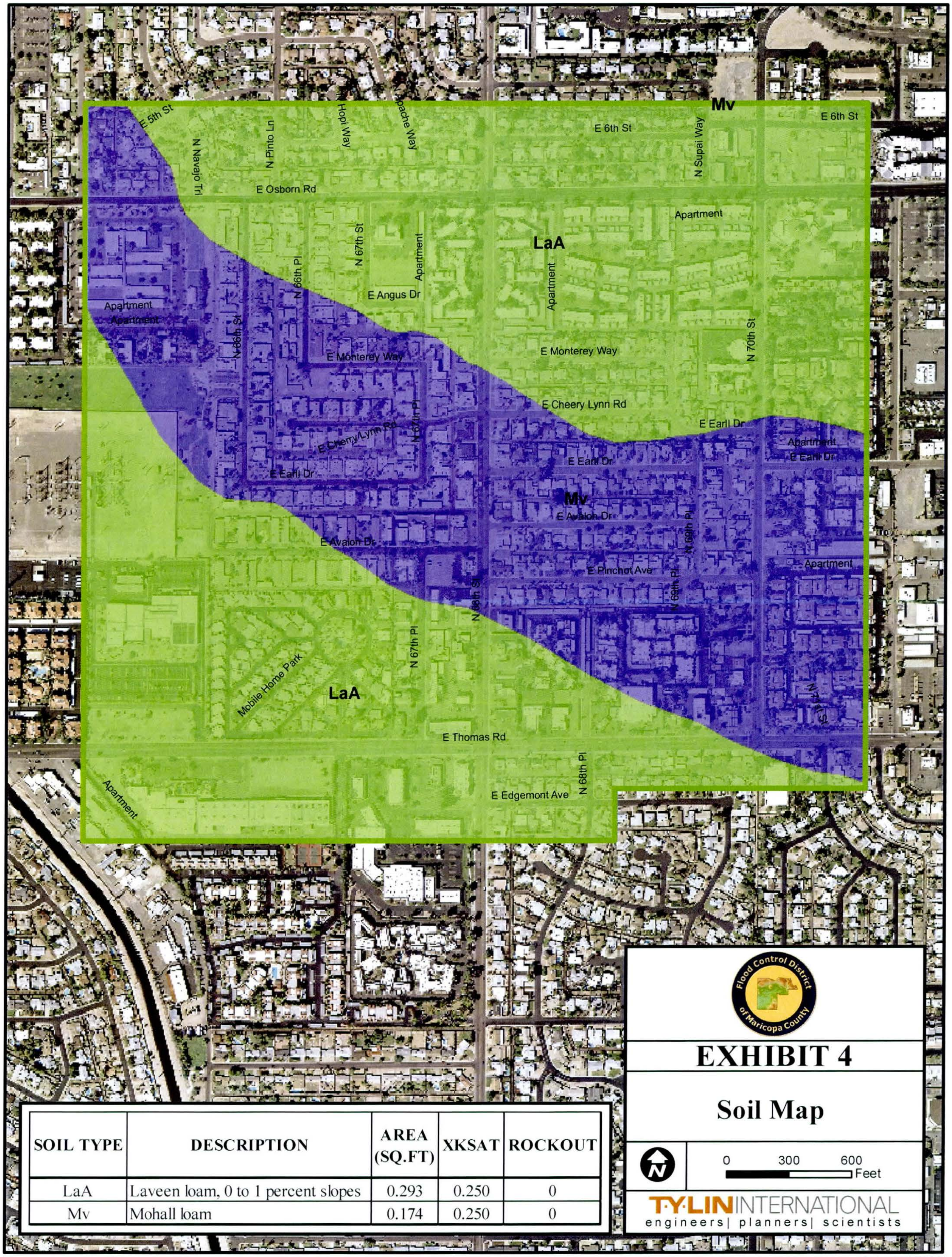
Path Name: Q:\1221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 3 - Land Characterization Map.mxd

Date Saved: 7/18/2012 5:26:34 PM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



SOIL TYPE	DESCRIPTION	AREA (SQ.FT)	XKSAT	ROCKOUT
LaA	Laveen loam, 0 to 1 percent slopes	0.293	0.250	0
Mv	Mohall loam	0.174	0.250	0

Flood Control District of Maricopa County

EXHIBIT 4

Soil Map

N

0 300 600 Feet

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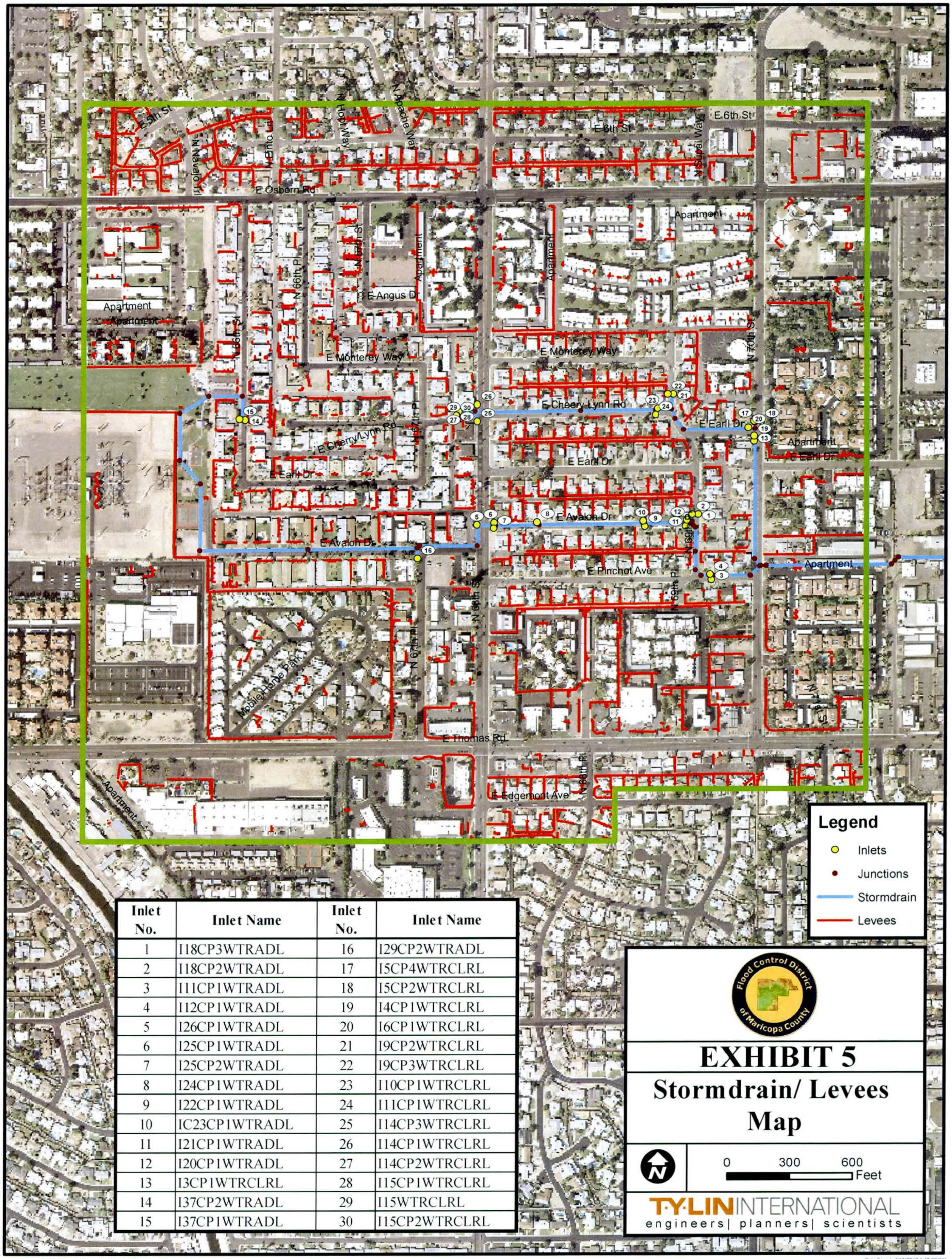
Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 4 - Soil Map.mxd

Date Saved: 7/18/2012 5:26:54 PM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



Inlet No.	Inlet Name	Inlet No.	Inlet Name
1	I18CP3WTRADL	16	I29CP2WTRADL
2	I18CP2WTRADL	17	I5CP4WTRCLRL
3	I11CP1WTRADL	18	I5CP2WTRCLRL
4	I12CP1WTRADL	19	I4CP1WTRCLRL
5	I26CP1WTRADL	20	I6CP1WTRCLRL
6	I25CP1WTRADL	21	I9CP2WTRCLRL
7	I25CP2WTRADL	22	I9CP3WTRCLRL
8	I24CP1WTRADL	23	I10CP1WTRCLRL
9	I22CP1WTRADL	24	I11CP1WTRCLRL
10	IC23CP1WTRADL	25	I14CP3WTRCLRL
11	I21CP1WTRADL	26	I14CP1WTRCLRL
12	I20CP1WTRADL	27	I14CP2WTRCLRL
13	I3CP1WTRCLRL	28	I15CP1WTRCLRL
14	I37CP2WTRADL	29	I15WTRCLRL
15	I37CP1WTRADL	30	I15CP2WTRCLRL

Flood Control District of Maricopa County

EXHIBIT 5
Stormdrain/ Levees Map

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Path Name: Q:\221765.00 - LIBWADMS\Focused Area Study\Exhibits\Ex 5 - Stormdrain Map.mxd

Date Saved: 7/18/2012 4:18:22 PM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY

Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 6a - 100-yr 6-hr Max Depth 15ft model.mxd

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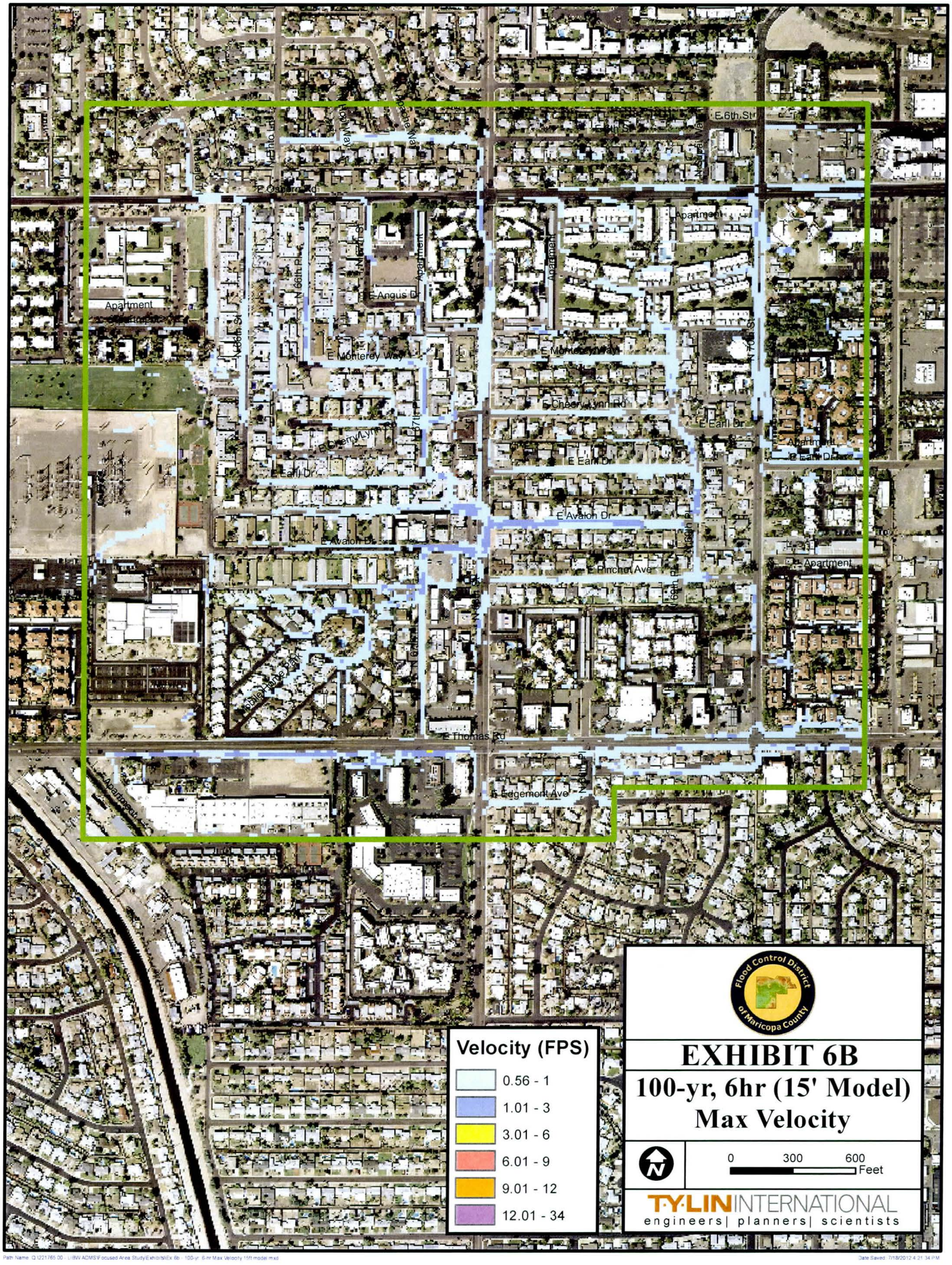
LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



Velocity (FPS)

- 0.56 - 1
- 1.01 - 3
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 34

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EXHIBIT 6B
100-yr, 6hr (15' Model) Max Velocity

0 300 600 Feet

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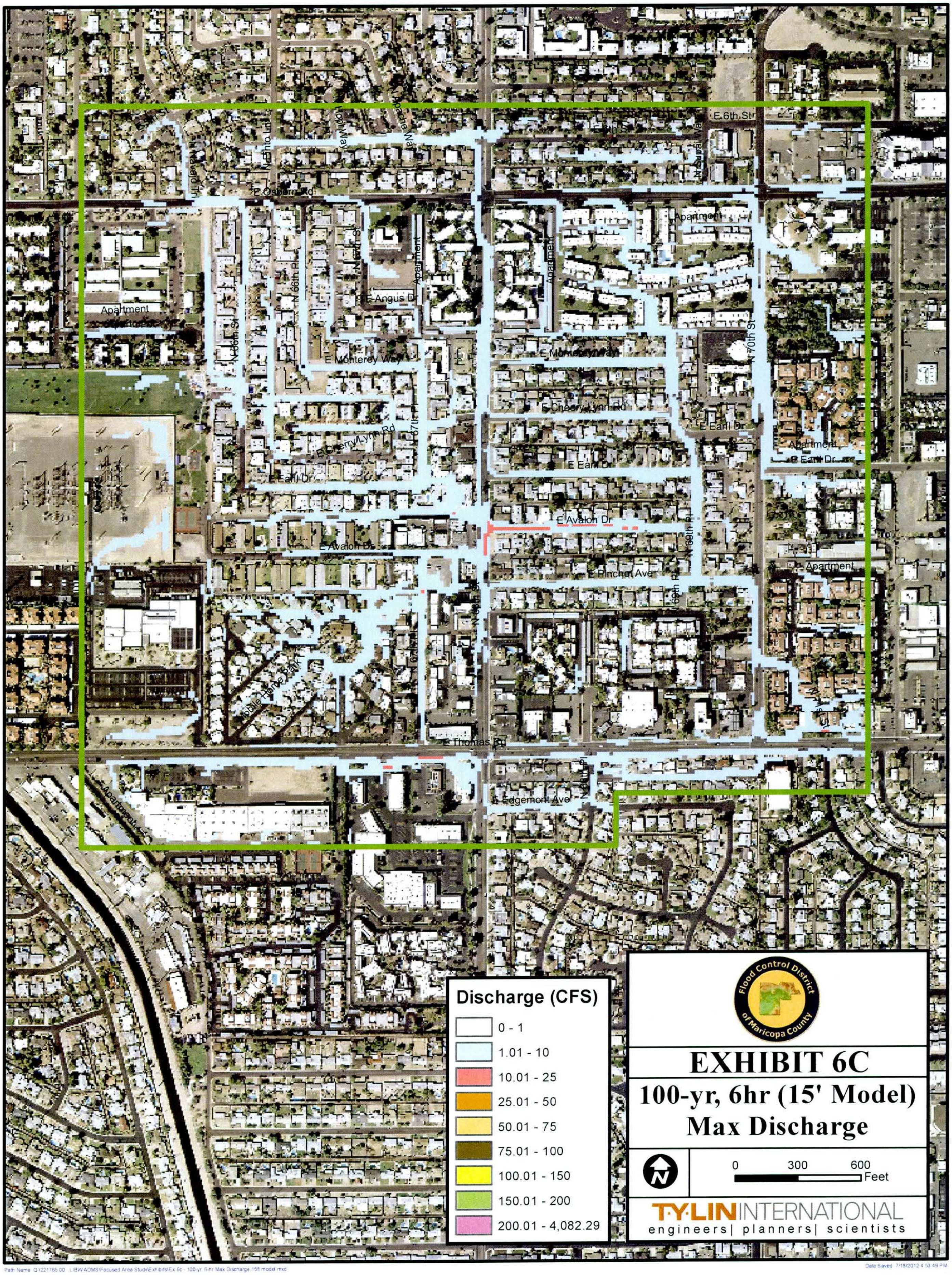
LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



Path Name: Q:\221765.00 LIBW ADMS\Focused Area Study\Exhibits\Ex 6c - 100-yr, 6-hr Max Discharge 15ft model.mxd

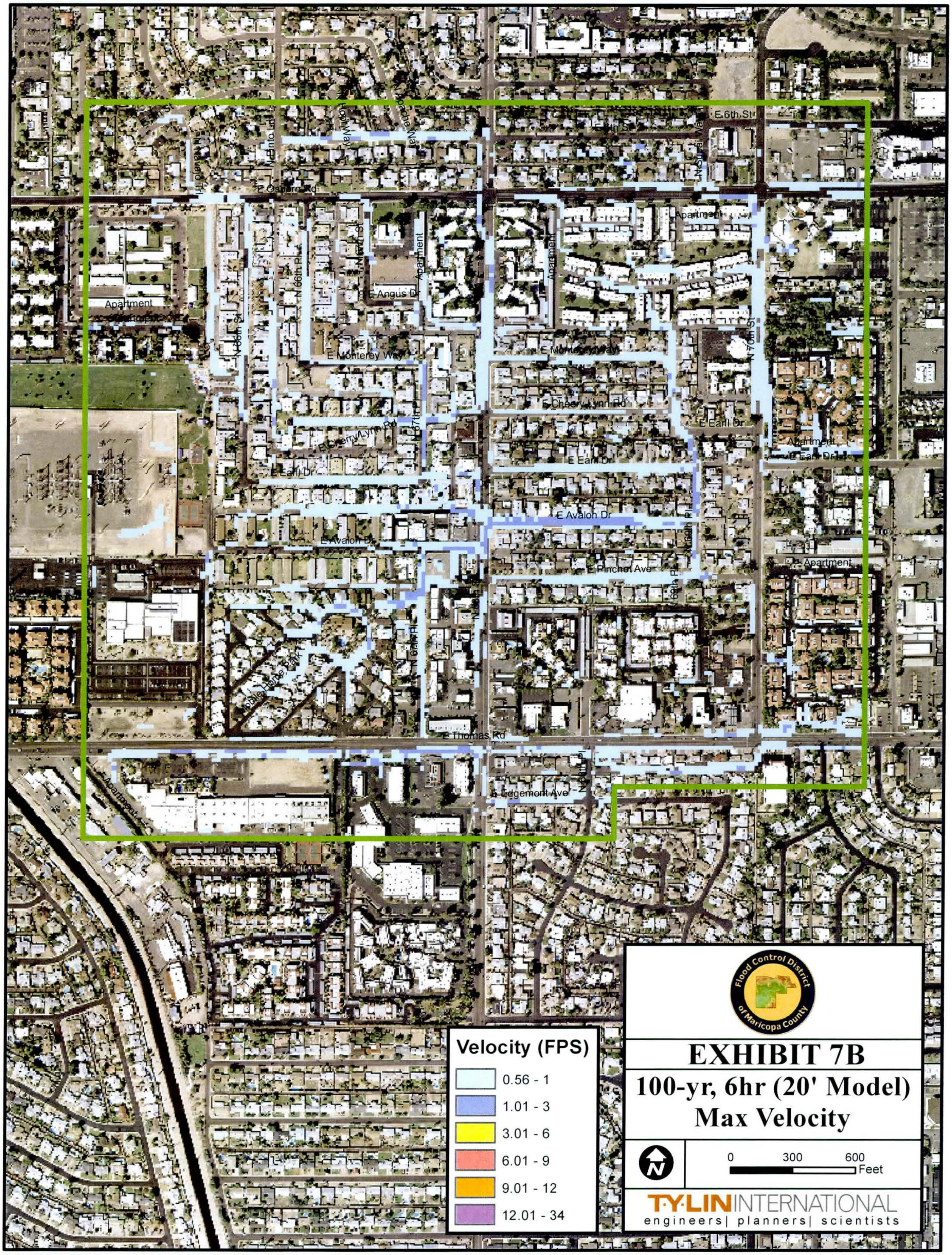
Date Saved: 7/18/2012 4:53:49 PM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY

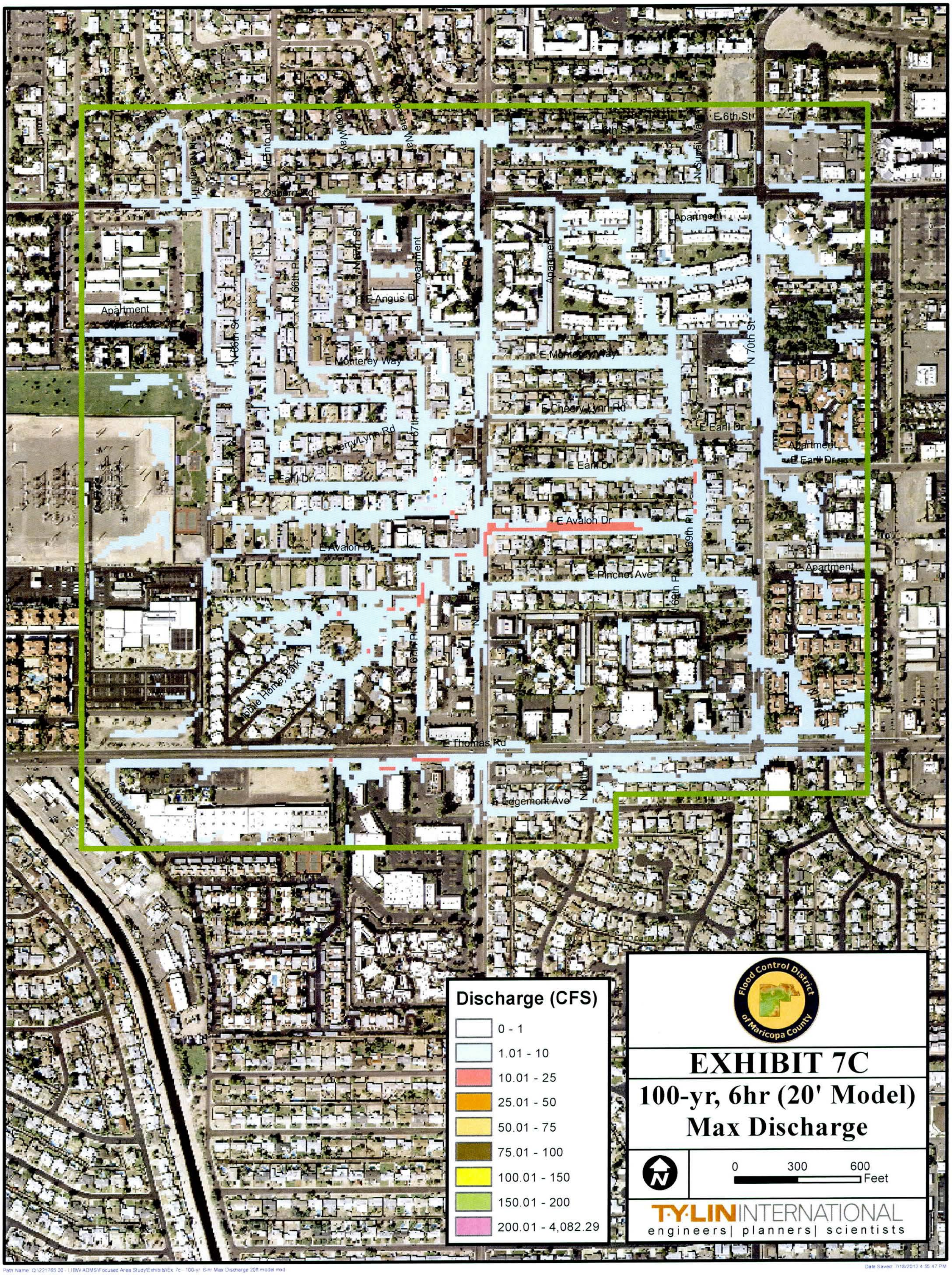
Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 7a - 100-yr 6-hr Max Depth 20ft model.mxd

Date Saved: 7/18/2012 4:55:03 PM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



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LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY

Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 8a - 100-yr 6-hr Max Depth 25ft model.mxd

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LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY

Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 8b - 100-yr 6-hr Max Velocity 25ft model.mxd

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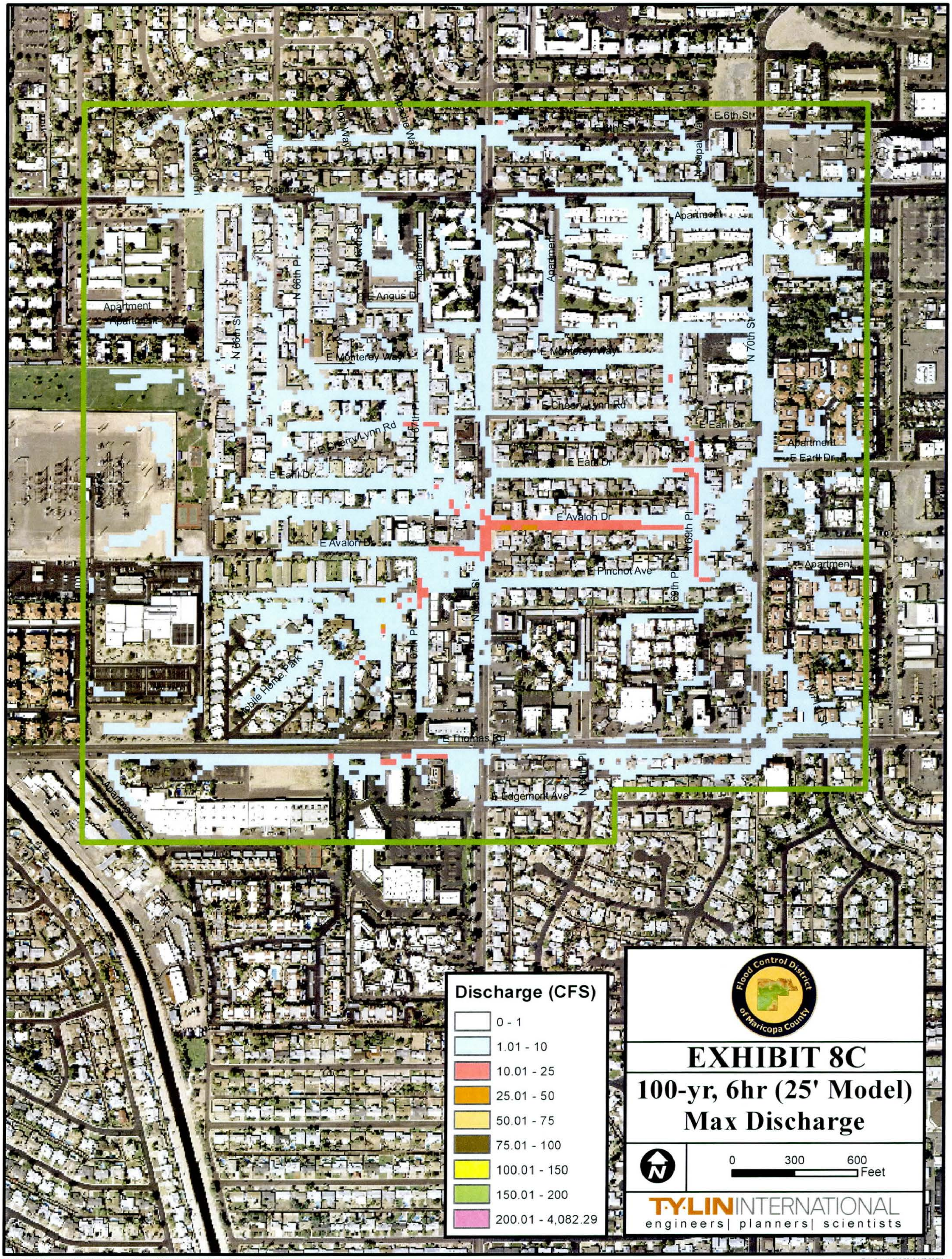

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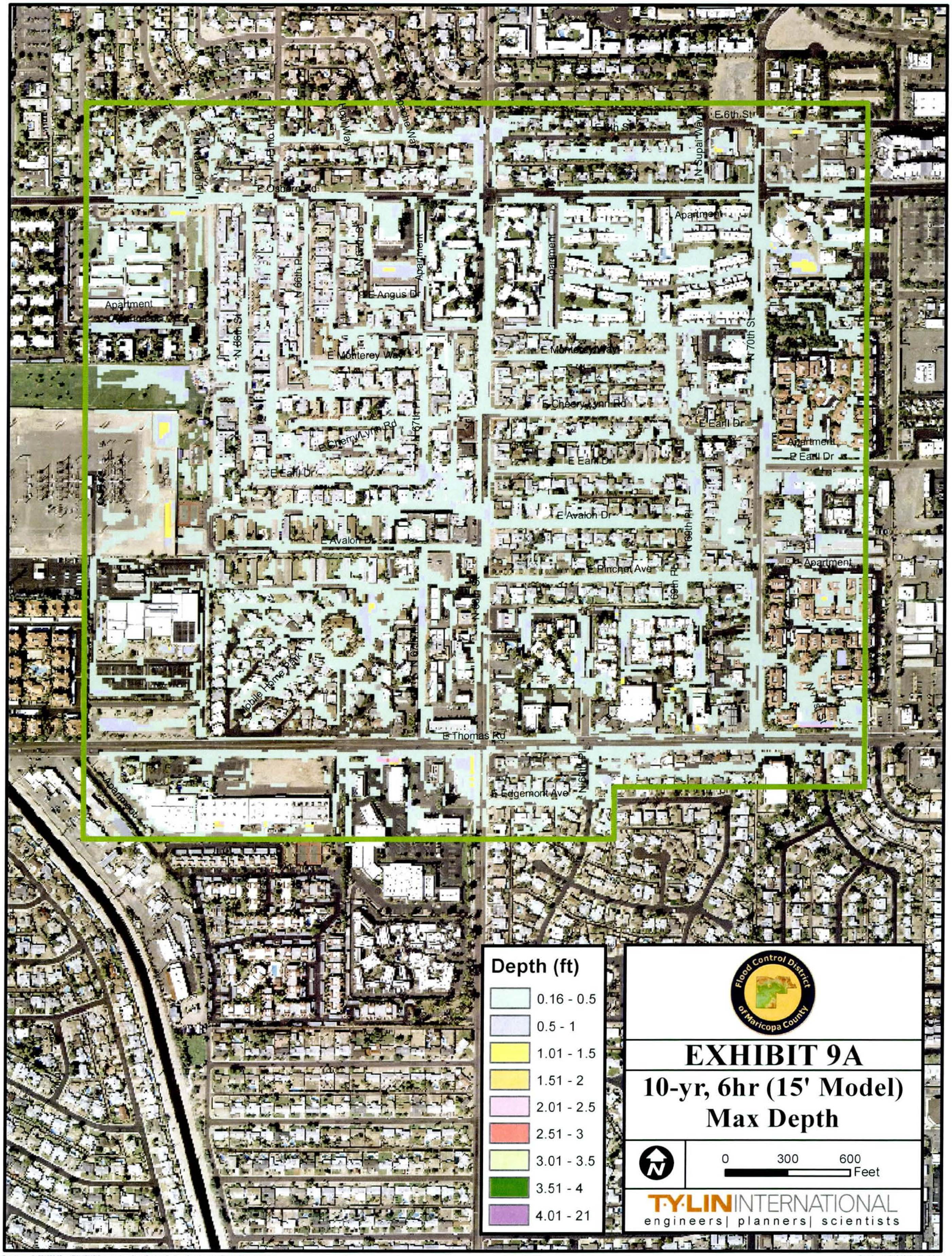
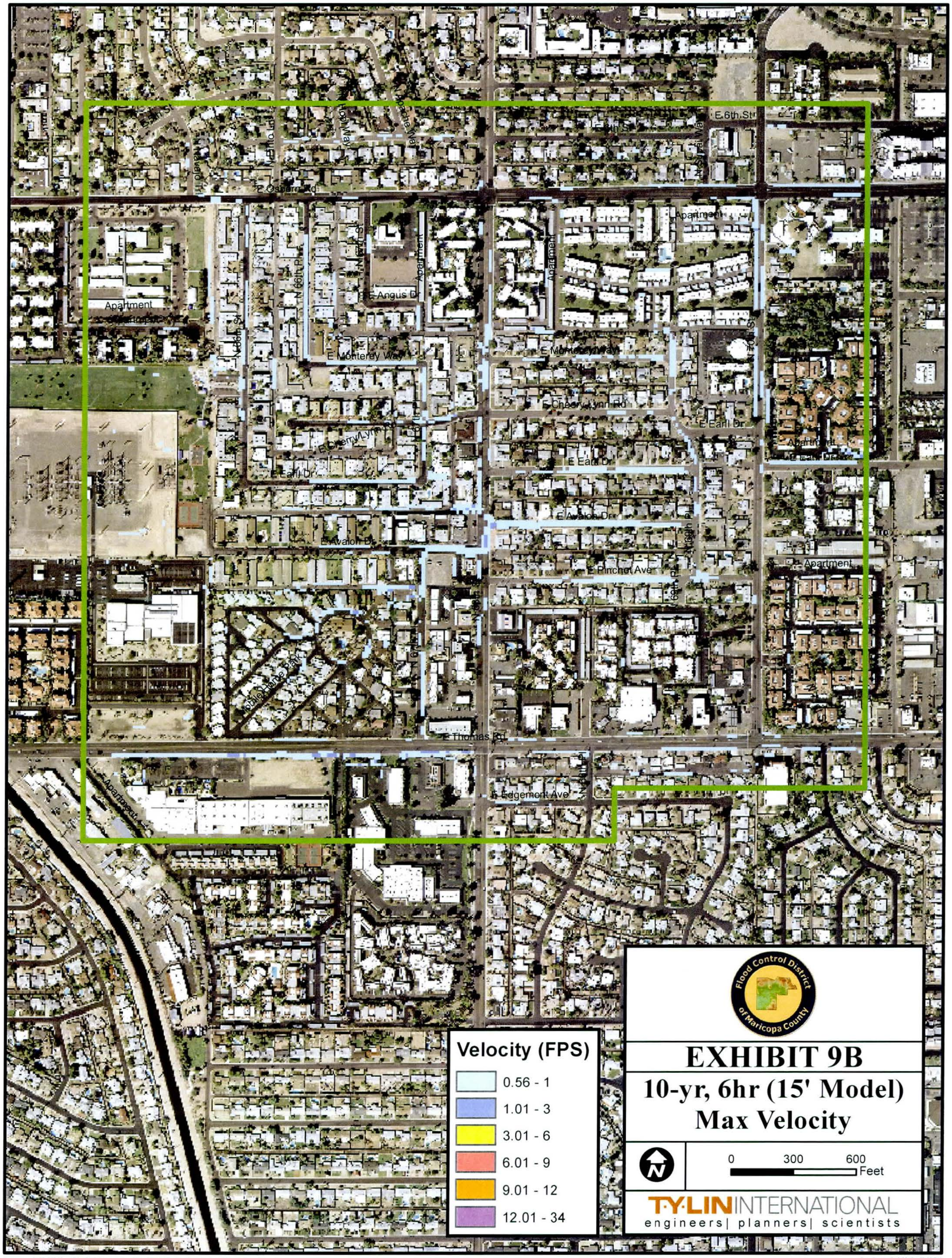


LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



LOWER INDIAN BEND WASH ADMS/P
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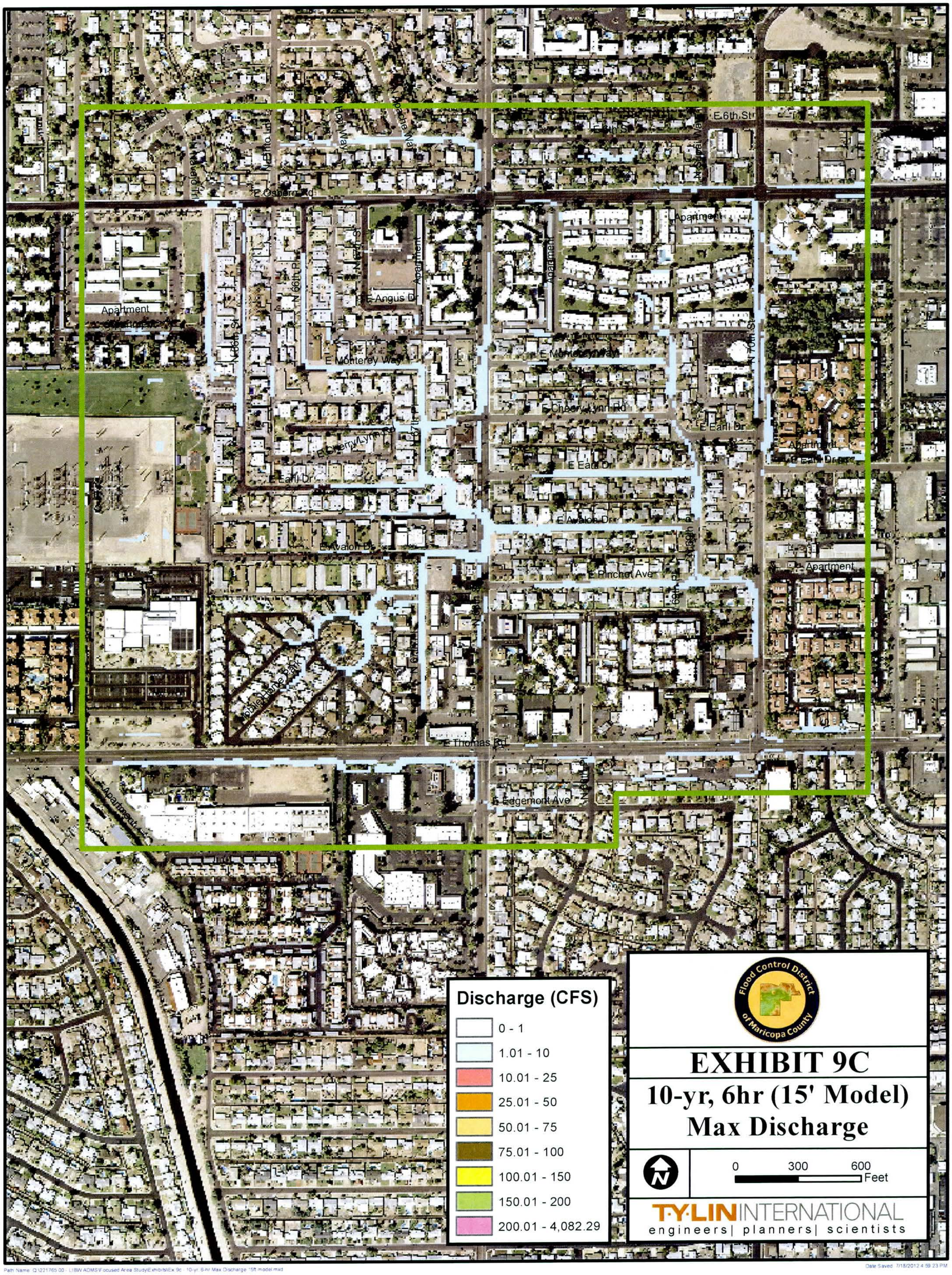

Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 9c - 10-yr 6-hr Max Discharge 15ft model.mxd

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LOWER INDIAN BEND WASH ADMS/P
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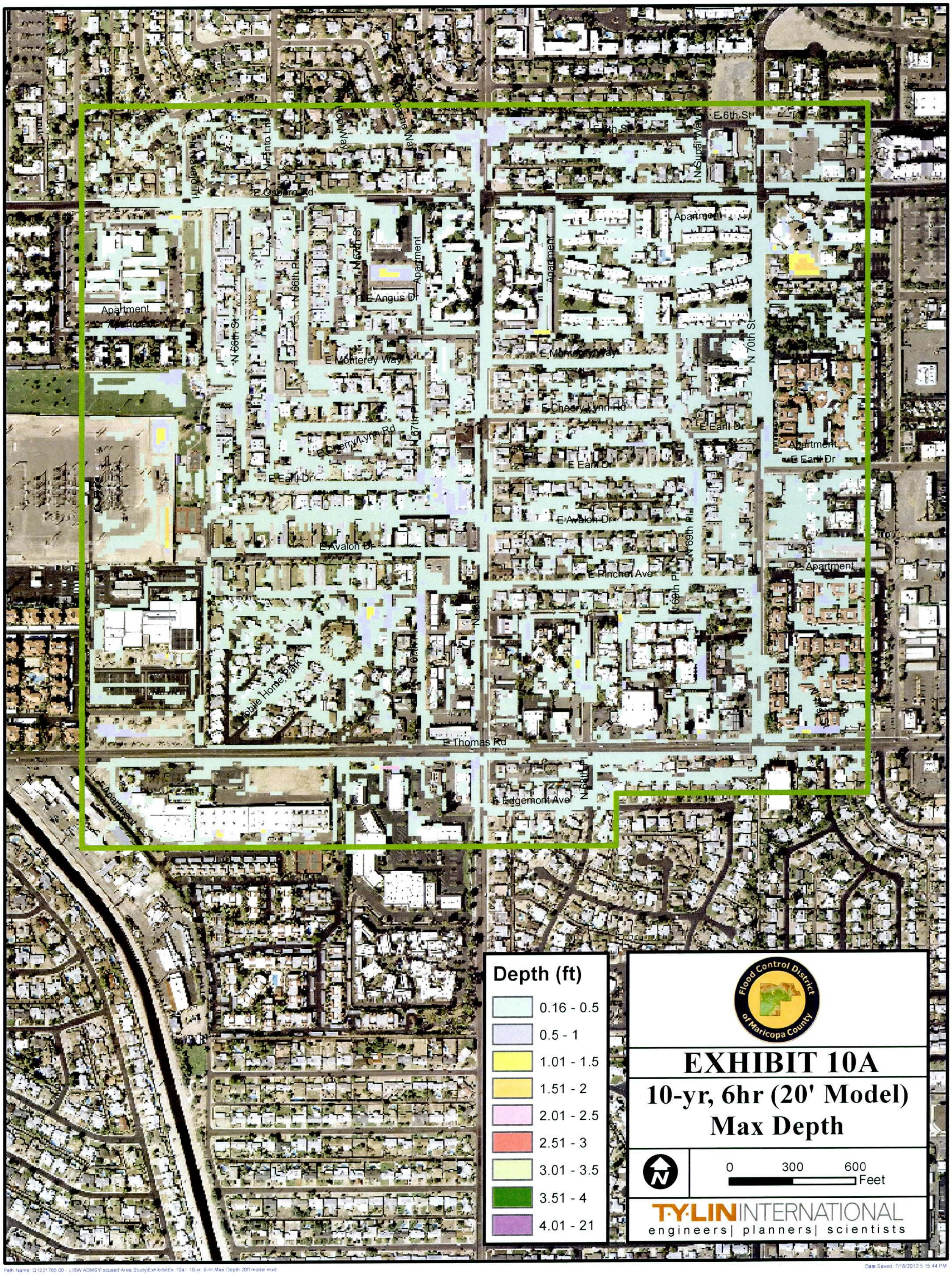
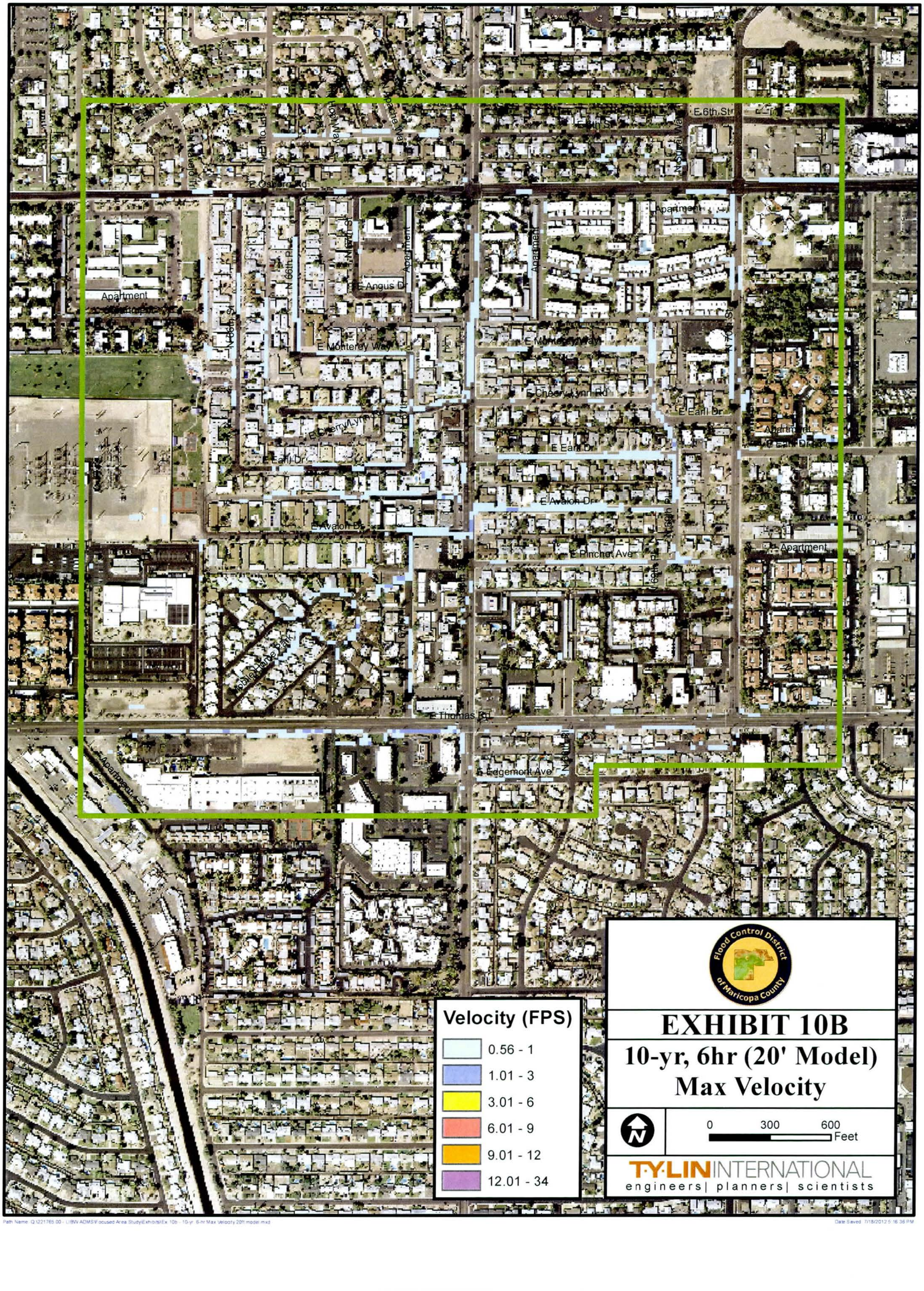


LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



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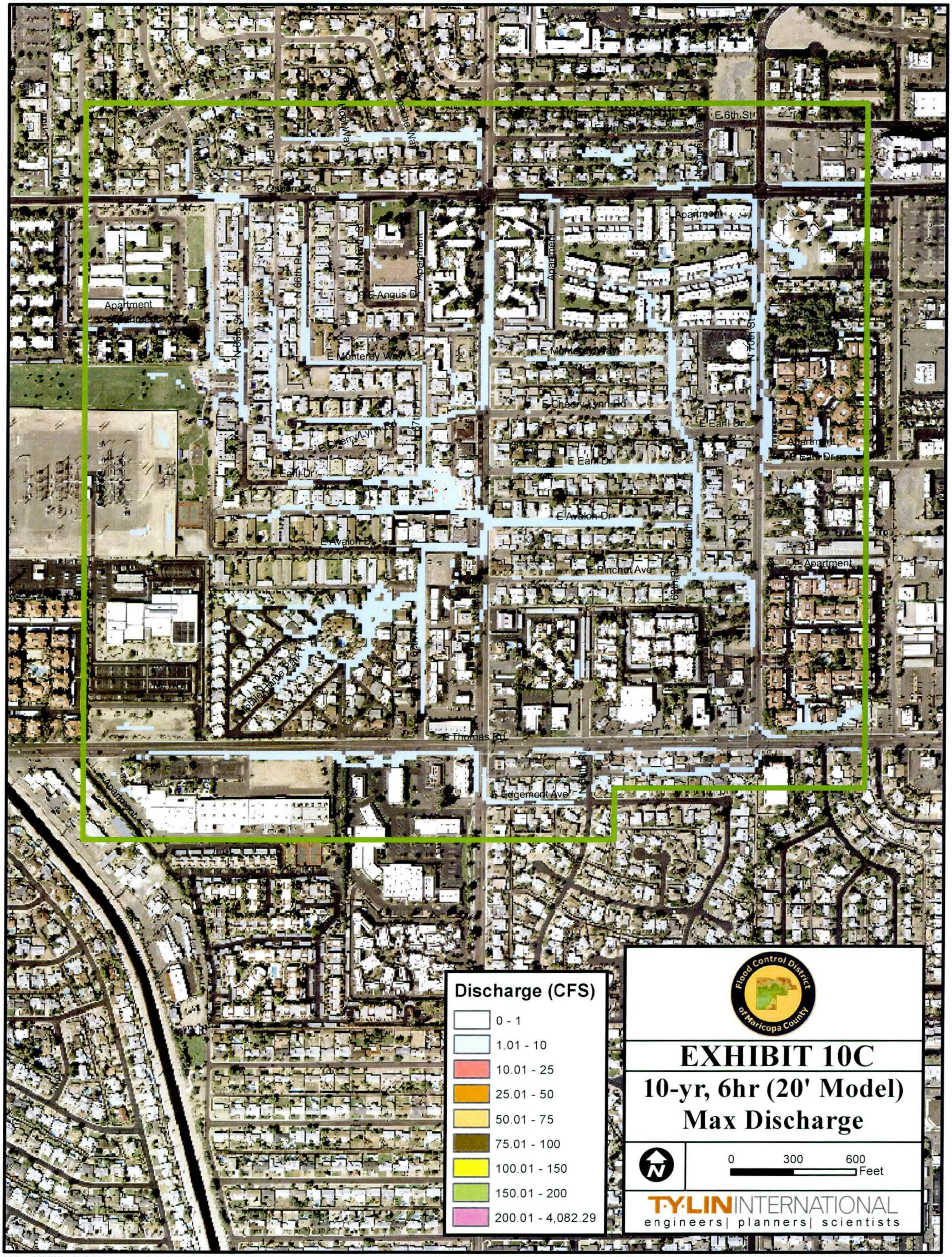

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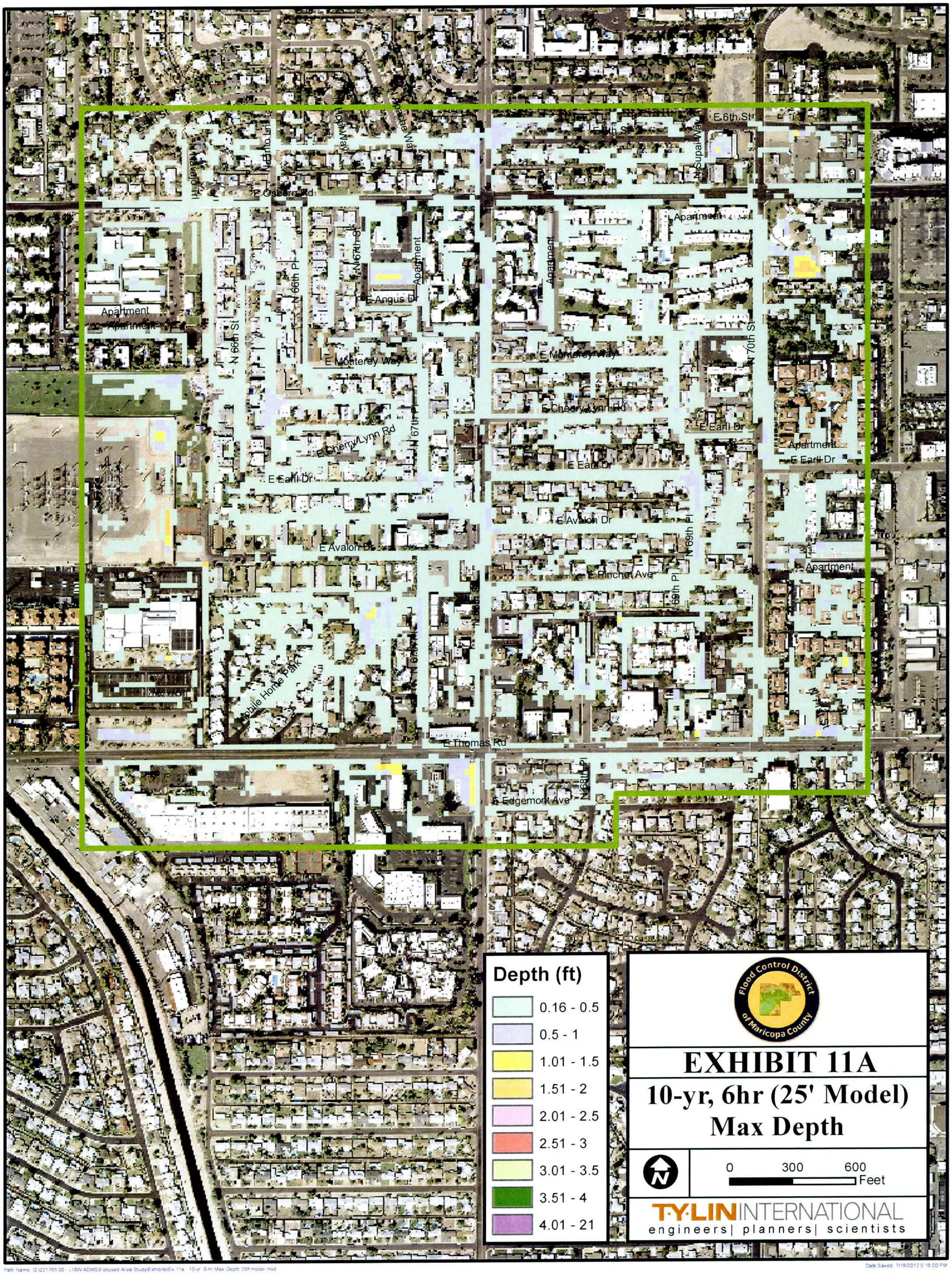

Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 11a - 10-yr 6-hr Max Depth 25ft model.mxd

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LOWER INDIAN BEND WASH ADMS/P
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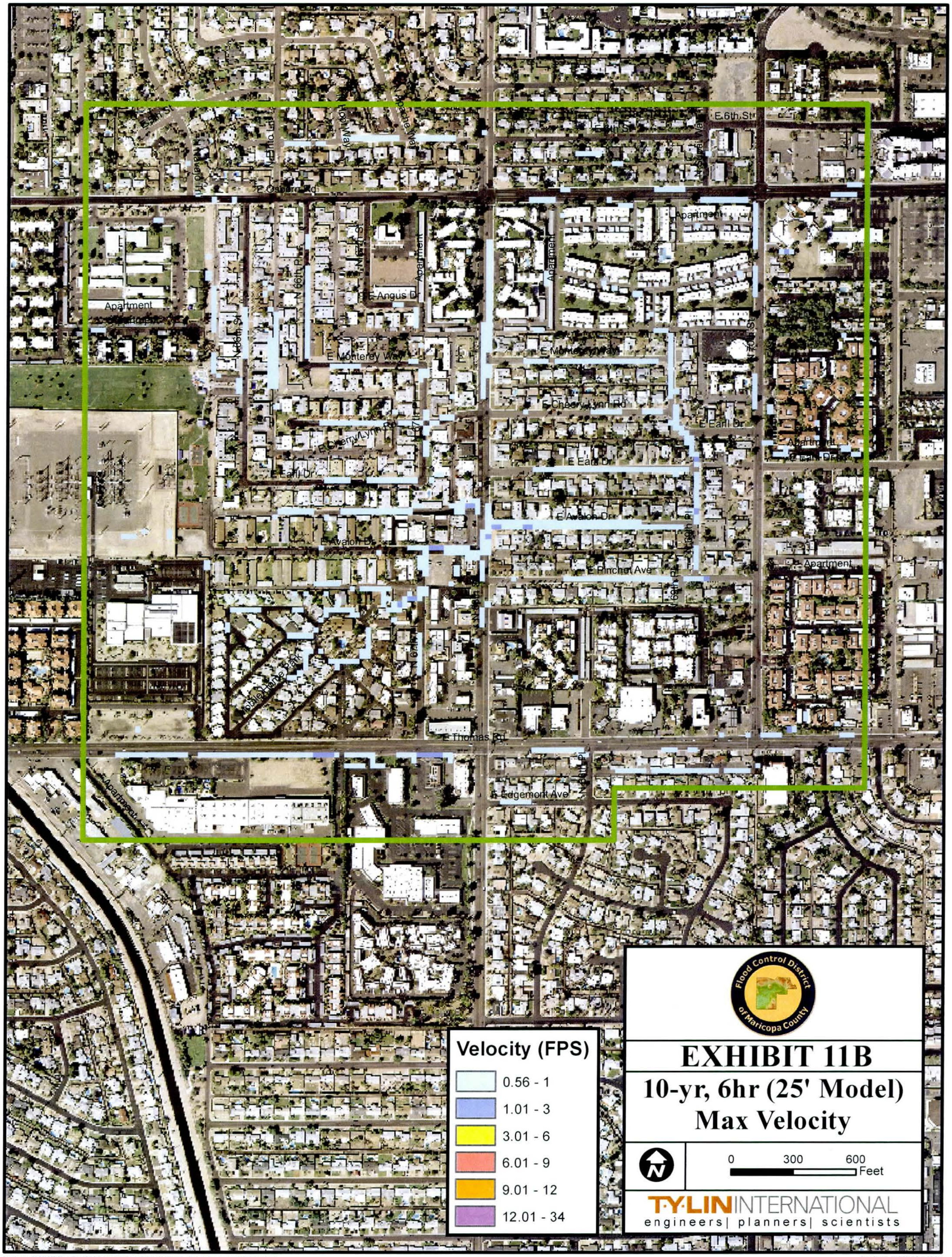

LOWER INDIAN BEND WASH ADMS/P
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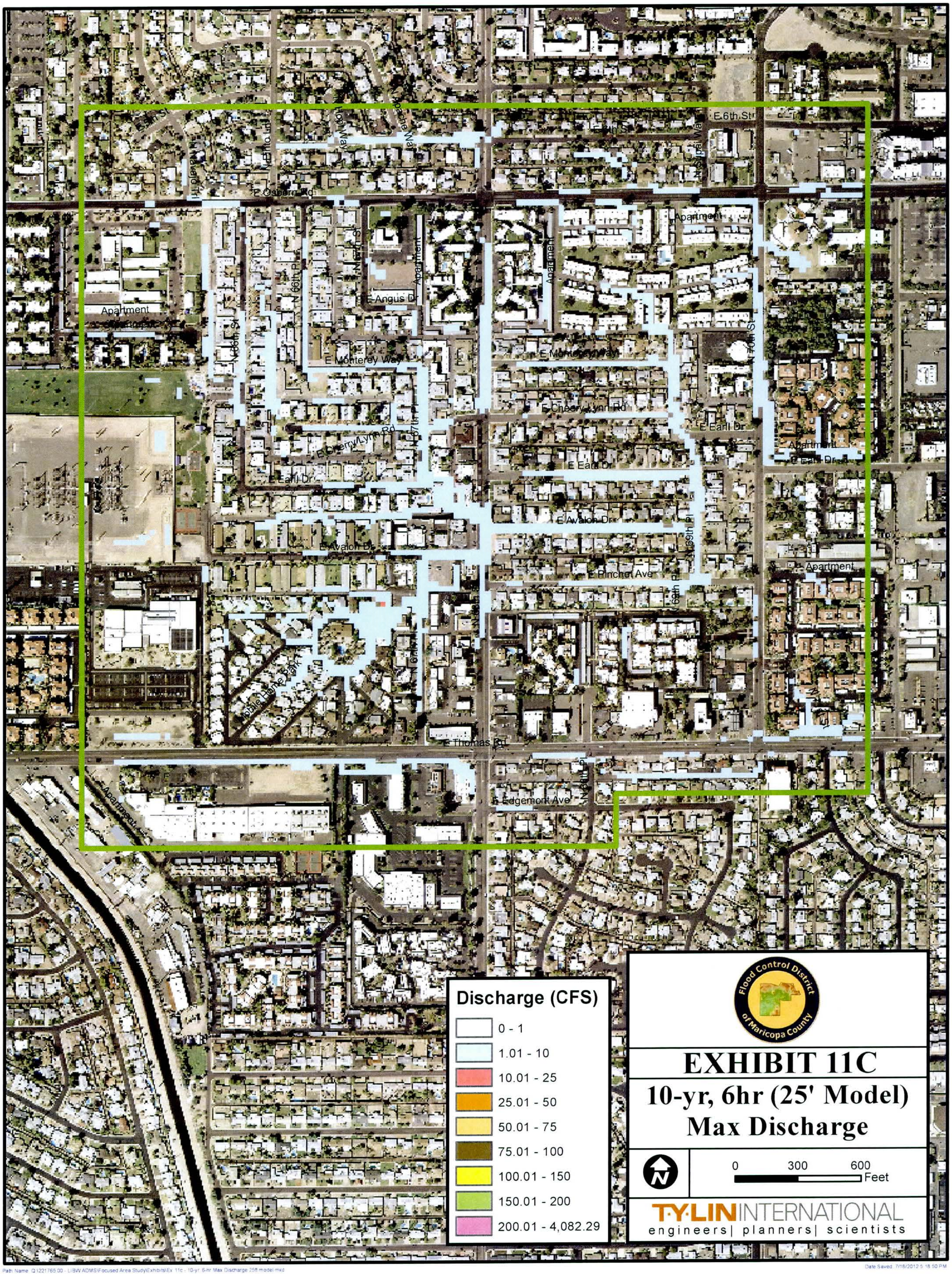

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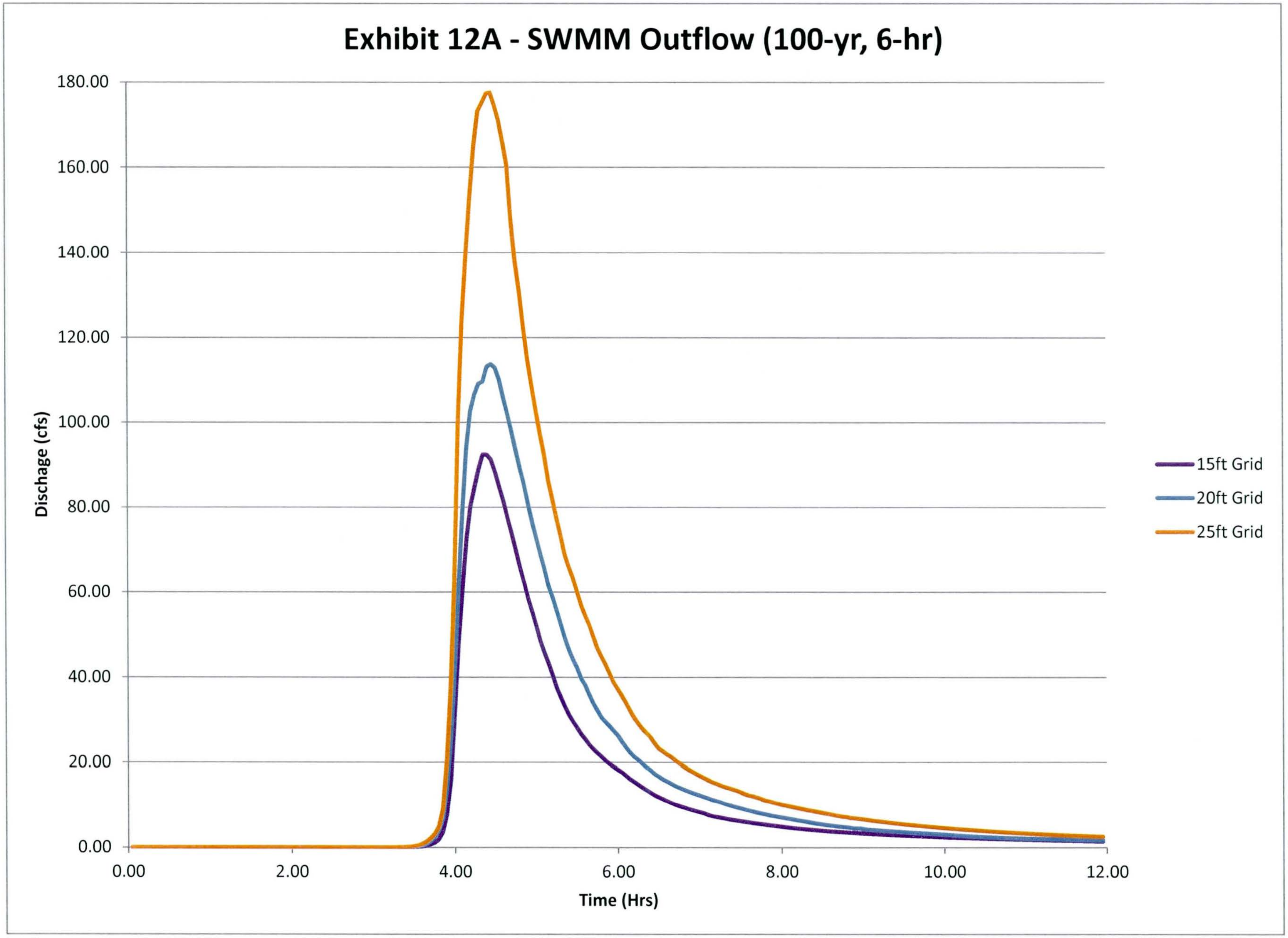


Exhibit 12A - SWMM Outflow (100-yr, 6-hr)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Dischage (cfs)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Time (Hrs)
15ft Grid
20ft Grid
25ft Grid

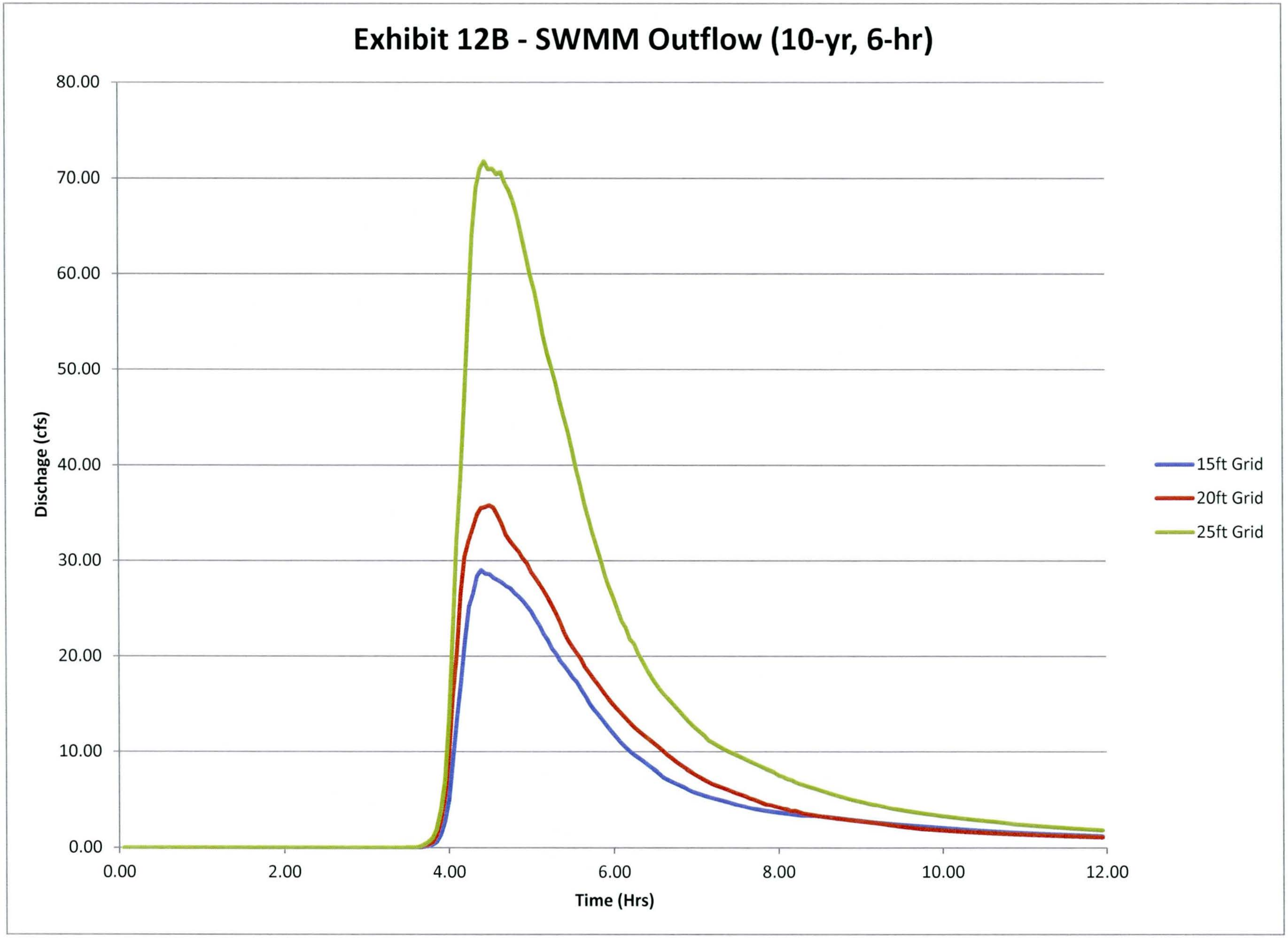
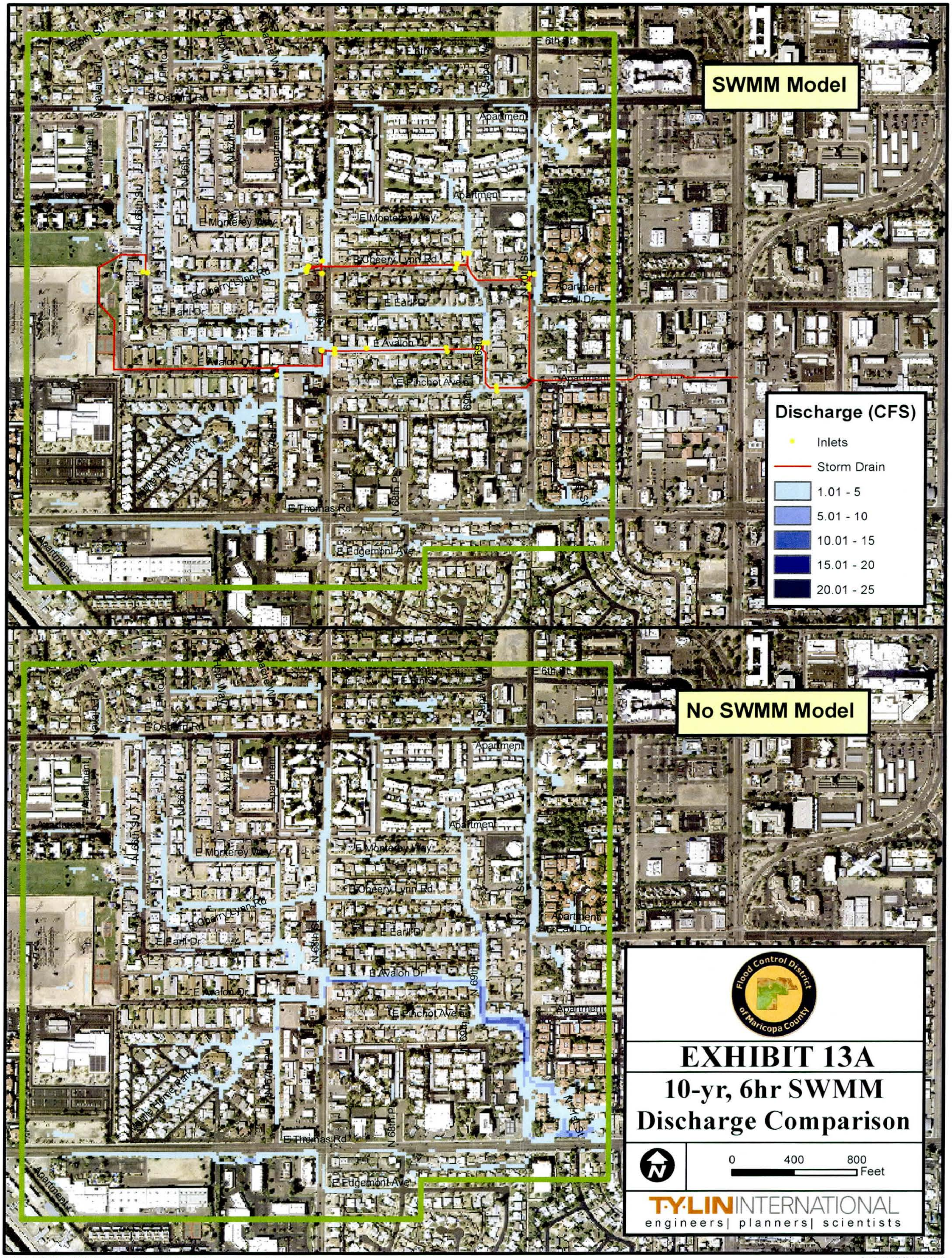


Exhibit 12B - SWMM Outflow (10-yr, 6-hr)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Dischage (cfs)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Time (Hrs)
15ft Grid
20ft Grid
25ft Grid

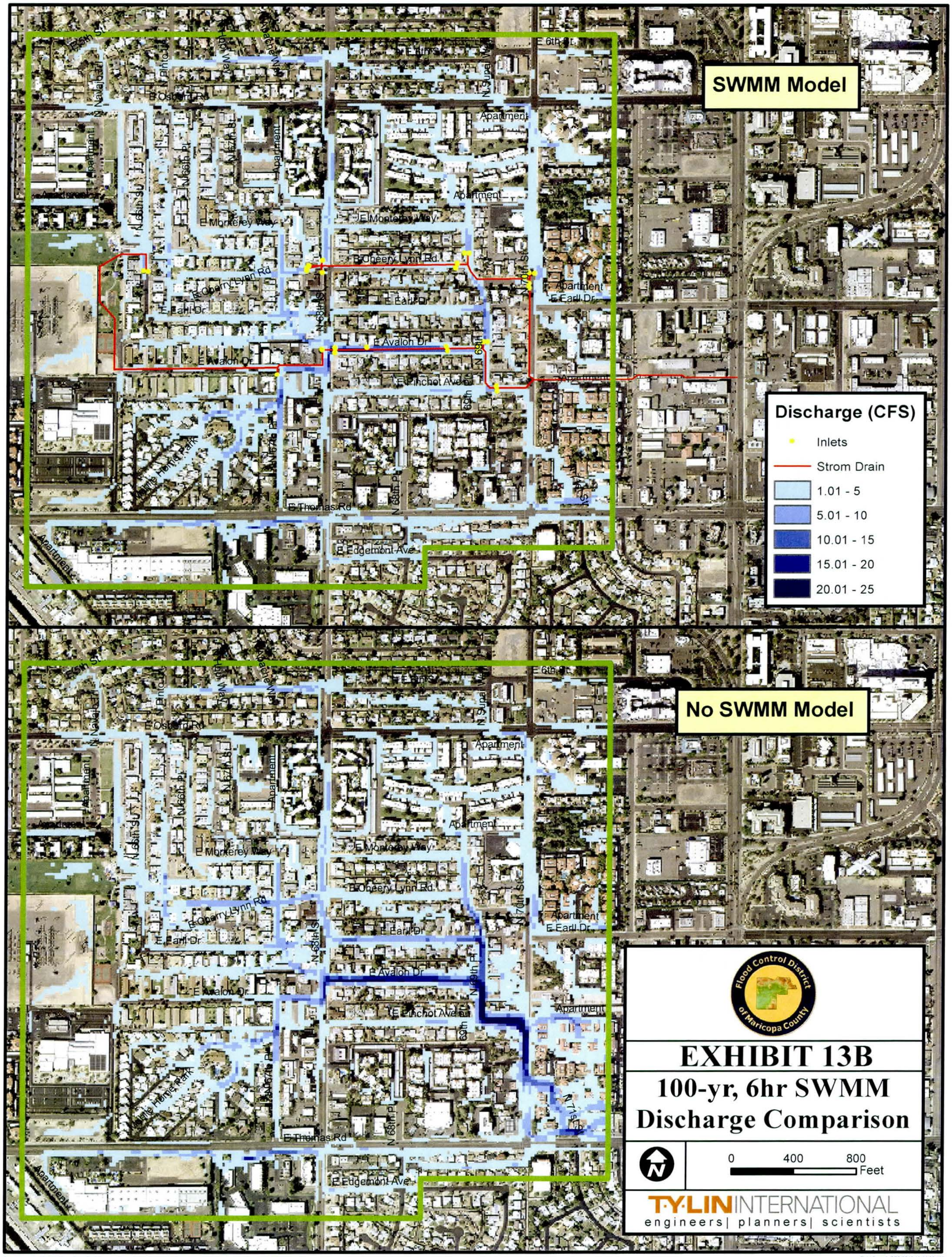
LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



Path Name: Q:\221765.00 - LIBW ADMS\Focused Area Study\Exhibits\Ex 13a - 10-yr 6-hr no swmm comparison 20ft model.mxd

Date Saved: 7/26/2012 11:41:04 AM

LOWER INDIAN BEND WASH ADMS/P
FOCUSED AREA STUDY



APPENDIX B – Electronic Files