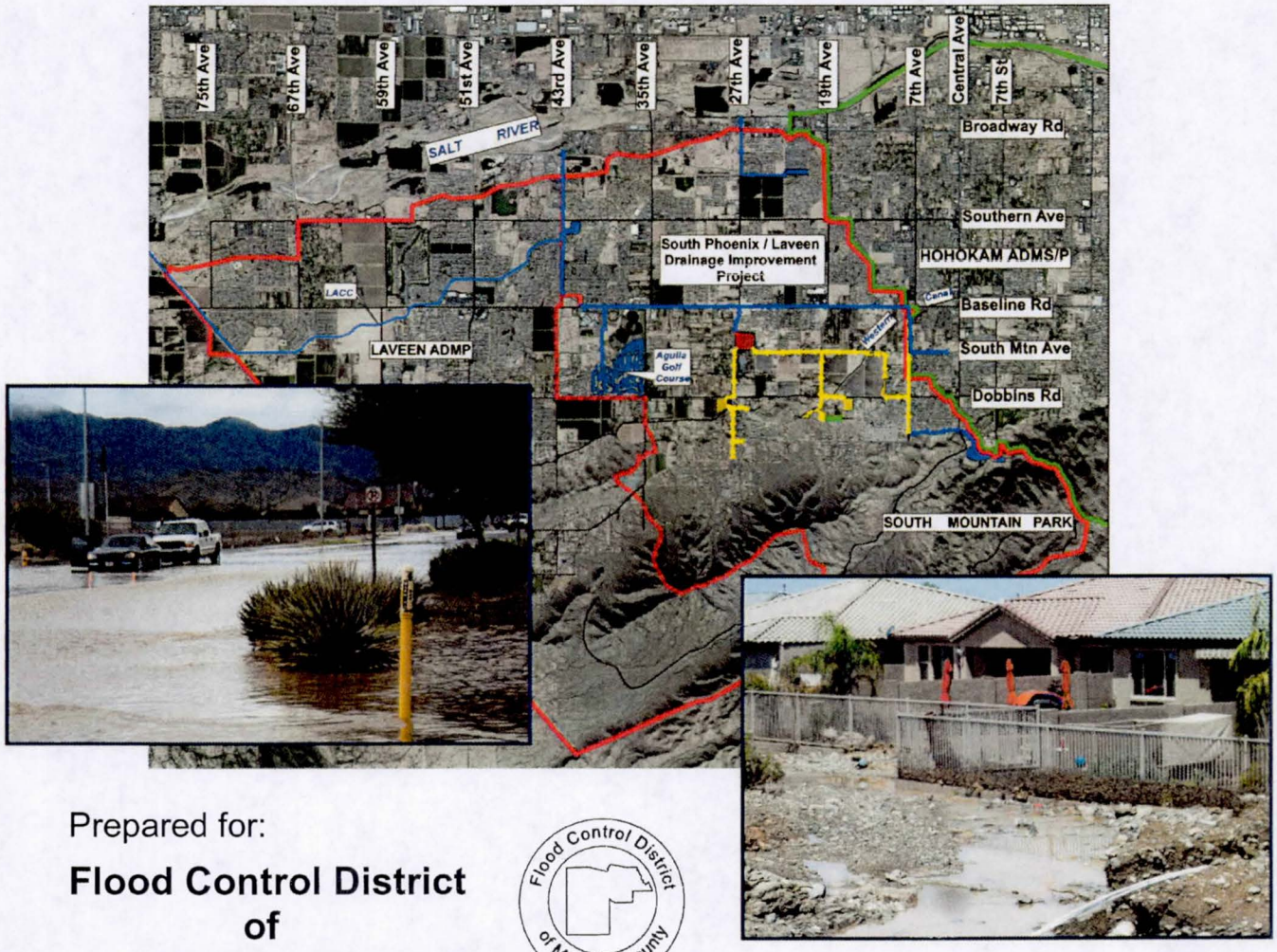
South Phoenix / Laveen
Drainage Improvement Project Supplement
Hydrology and Hydraulics Report



Prepared for:

Flood Control District of Maricopa County

and project partner: **City of Phoenix**

Prepared by:

Stanley Consultants INC.

Registered Professional Engineer (Civil)
CERTIFICATE NO.
26837
G. SCOTT BUCHANAN
Date Signed 9-28-15
ARIZONA U.S.A.

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APPENDICES (Supporting data and calculations)

Appendix A – Hydrology / Hydraulics (electronic files on disc inside back cover of report)

Expires 3-31-17

OTHER RELATED DOCUMENTS (under separate covers)

- *South Phoenix / Laveen Drainage Improvement Project Concept Plans,* HDR Engineers, June, 1997
- *South Phoenix / Laveen Drainage Improvement Project Addendum*, Stanley Consultants, May 2013
- *South Phoenix Two Basins Project Design Report (including Data Collection Report),* Stanley Consultants, May 2013
- *Laveen ADMP Update Report for Flood Control District of Maricopa*, Stantec, June 2015
- *South Phoenix / Laveen Stormwater Infrastructure Evaluation Report for City of Phoenix,* Entellus, 2015

Expires 3-31-17

1 Introduction

1.1 Project Purpose

The South Phoenix / Laveen Drainage Improvement Project Supplement (SP/LDIP Supplement) will assess specific flooding locations within the study area which were identified subsequent to the monsoon storms of August and September 2014. This study is a supplement to the South Phoenix / Laveen Drainage Improvement Project Addendum (SP/LDIP Addendum) which was concluded in May of 2013 by Stanley Consultants for the Flood Control District of Maricopa County and project partner City of Phoenix. The 2013 Addendum is based on the original South Phoenix / Laveen Drainage Improvement Project prepared by HDR Engineers in 1997.

The SP/LDIP Supplement may then evaluate whether there are viable expansions of the drainage improvements recommended in the 2013 SP/LDIP Addendum that would help mitigate the identified flooding locations. The concept level expansion of drainage infrastructure is generally envisioned as extending into the upper (southern) portion of the SP/LDIP watershed.

1.2 Project Authorization

The SP/LDIP Supplement is a Flood Control District of Maricopa County (District) project. The District is the lead agency and the City of Phoenix is a project partner. The project was authorized by Contract FCD 2014C015 between the District and Stanley Consultants, Inc. (Stanley) with an effective notice-to-proceed date of February 10, 2015.

1.3 Concurrent Studies

There are two other studies being done concurrent with the SP/LDIP Supplement. One study is very similar in scope to the SP/LDIP Supplement. It is being done for the area to the west within the Laveen Area Drainage Master Plan (Laveen ADMP). That concurrent study is called the Laveen ADMP Update and is being done by consultant Stantec for the Flood Control District of Maricopa County and is dated June, 2015. Like the SP/LDIP Supplement, it was prompted by flooding in that area by the monsoon storms of 2014.

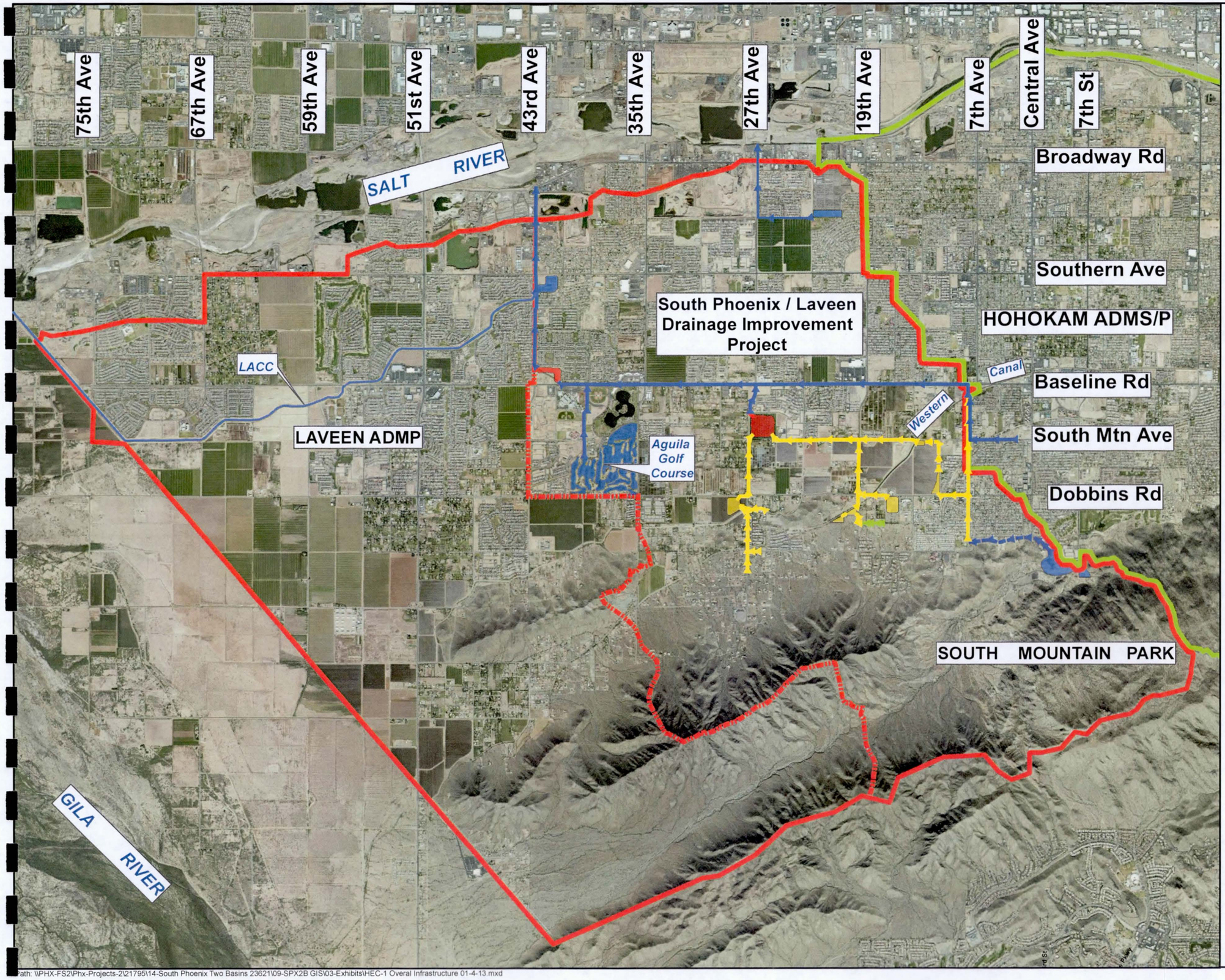
The purpose of the Laveen ADMP Update is to evaluate specific flooding hazards within the Laveen ADMP area and potential future regional infrastructure alternatives to mitigate the flooding. The basis of hydrology, hydraulics and previous recommended future regional drainage infrastructure for the Update is the Laveen ADMP prepared by consultant HDR Engineers for the Flood Control District of Maricopa County in November 2001. The SP/LDIP and Laveen ADMP areas and the SP/LDIP Addendum recommended overall regional drainage system features are illustrated on Figure 1.1 on the next page. Figure 1.1 is Figure 1B from the 2013 SP/LDIP Addendum Report.

The other concurrent study, which is led by City of Phoenix, is being prepared by consultant Entellus (for the City of Phoenix). The Entellus study is titled *"South Phoenix / Laveen Stormwater Infrastructure Evaluation Report"*. This study was initiated in the fall of 2014 subsequent to the monsoon storms. The main objective of the Entellus study is to identify and document areas flooded during the 2014 monsoon storms, focusing primarily on subdivisions with private streets and private open space / drainage tracts. A second objective is to develop recommendations for maintenance and operation of the privately owned drainage facilities within those subdivisions that would help mitigate flooding in the future. The area included in the Entellus study is generally south of Baseline Road from around 36th Street on the east to about 27th Avenue on the west.

South Phoenix / Laveen Drainage Improvement Project Addendum

Recommended Alternative Overall Regional Drainage System Features

Figure 1B



Legend

- Existing Detention Facility
- New Basin
- Future Basin
- Existing Storm Drain
- Future Storm Drain
- Future Storm Drain (Optional)
- Future Channel
- Existing Wash
- Laveen ADMS Boundary
- Hohokam ADMS/P
- Boundary Between SP/LDIP and Laveen ADMP Watersheds

N

N.T.S.

Date: 4/11/2013

Path: \\PHX-FS2\Phx-Projects-2\21795\14-South Phoenix Two Basins 23621\09-SPX2B GIS\03-Exhibits\HEC-1 Overal Infrastructure 01-4-13.mxd

1.4 Regional Hydrology and Hydraulics

Hydrology for the evaluation of specific flooding locations within the SP/LDIP study area is based on the SP/LDIP Addendum Recommended Alternative 6 regional HEC-1 model. This hydrology is documented in the SP/LDIP Addendum Report from May of 2013.

The SP/LDIP Addendum Recommended Alternative 6 regional HEC-1 model was based on a model used by consultant URS in 2000 in support of the design of the Baseline Road improvement project for the Maricopa County Department of Transportation. Baseline Road improvements included a regional storm drain trunk line from 7th Avenue to 43rd Avenue which was a significant feature recommended in the original South Phoenix / Laveen Drainage Improvement Project.

The URS HEC-1 model was updated by Stanley for the SP/LDIP Addendum to reflect improvements and developments that had been constructed in the watershed since 2000. This update was generally limited to the area south of Baseline Road from about 7th Street to about 35th Avenue. The model was then developed and refined to reflect the additional regional drainage infrastructure recommended in Alternative 6 of the SP/LDIP Addendum. The recommended future regional infrastructure is generally in the area south of Baseline Road from 7th Avenue to just west of 27th Avenue.

The 2013 Addendum Alternative 6 HEC-1 model assumes that future completely developed land use conditions exist in the watershed and that future recommended Alternative 6 regional drainage infrastructure has all been completely constructed. The model uses 100-year, 24-hour precipitation based on NOAA 2 rainfall data. No other frequency or duration storm was used for the hydrology.

Per the scope of work for the SP/LDIP Supplement, the hydrologic basis for evaluation of existing flooding hazards and for any potential alternatives is the SP/LDIP Addendum regional HEC-1 model. Improvements are not being evaluated on the basis of any hydrology related to the 2014 monsoon storms.

SWMM hydraulic models were created for most of the existing and future storm drain infrastructure in the SP/LDIP area, concurrent with the regional hydrology update. There is an optional item in the SP/LDIP Supplement scope of work to update the SWMM model(s) if any of the recommended additional drainage infrastructure impacts the regional hydrology.

Figure 1.2 on the following page illustrates sub-basins, flow paths, peak flows and peak times corresponding to SP/LDIP Addendum Recommended Alternative 6. Figure 1.2 is Figure 1C from the SP/LDIP Addendum Report from May of 2013.

Baseline Rd
Western Canal
South Mountain Ave
Dobbins Rd
Elliot Rd
Carver Rd
35th Ave
27th Ave
19th Ave
7th Ave
Central Ave
7th St
br43c
br35cw
br35c1
br27n
br27s
br19c
br35ce
sma15w
sma7w
sma19c
cbde
sma15e
drwc1c
sm5c
dr35ce
dr35cw
dr43c
dr27cn
dr2c
dr
27
cw
dr27cs
dr1c
sm4cw
sm4ce
sm3ce
sm3cw
wc6a
wc7a
wc9a
wc10a
wc2.1a
wc1a
wc2a
wc4a
pm1a
pm2a
wc13b
wc14b
wc12a
wc15a
wc5a
wc8a
drw2c
305 cfs (SD) @12.83 rbr19c
292 cfs (SD) @12.17 rccbde
298 cfs @12.08 ccbde
410 cfs (SD) @12.83 c27n
105 cfs @12.83 br27n
326 cfs @12.67 cbr19c
237 cfs (SD) @12.00 rc15e
280 cfs @12.58 br35cw
342 cfs @12.50 c27s
226 cfs (SD) @12.50 rb27cn
101 cfs @12.67 br19c
180 cfs @12.17 cma19c
71 cfs @12.17 sma15w
NOTE: ALL FLOW FROM EAST OF 7TH AVE IS INTERCEPTED BY FUTURE EXTENDED STORM DRAIN
Hydrographs: c27s c27n r35ce
778 cfs @12.83 c27bas
108 cfs @12.42 cbde
128 cfs (SD) @12.83 r35ce
236 cfs @12.42 cps19c
25 cfs (SD) @14.25 rwc1cs
109 cfs @12.17 rc1cwc
163 cfs @12.08 sma7w
242 cfs @12.00 c15e
182 cfs @13.00 br35c1
116 cfs @12.50 br27s
218 cfs (SD) @12.42 rb27cs
54 cfs @12.75 br35ce
112 cfs (SD) @12.33 rst274
43 cfs @13.25 sma19c
81 cfs @12.33 drwc1c
304 cfs @12.08 cwc1ce
96 cfs @12.00 sma15e
46 cfs @12.17 dr2c
217 cfs @12.33 cpdr2c
148 cfs (SD) @12.08 rcsm5c
234 cfs (SD) @12.17 rd27cn
84 cfs @12.25 dr27cn
Hydrographs: rd27cn st27cw rd35ce wc6a dr35ce
1058 cfs @12.25 cd27.4
223 cfs @12.08 rt5c3
374 cfs @12.08 csm5c
164 cfs @12.08 sm5c
57 cfs @12.00 sm4ce
376 cfs @12.25 cp1a2c
739 cfs @12.25 cdrw2c
154 cfs @12:08 sm4cw
170 cfs (SD) @12.08 rsm3ce
88 cfs @20.58 rdent
288 cfs (SD) @12.33 rd35ce
543 cfs @12.25 csm4cw
79 cfs @12.42 dr35ce
152 cfs @12.25 dr1c
172 cfs @12.08 c3e
168 cfs @12.08 sm3ce
87 cfs @12.00 dr27cw
274 cfs @12.25 wc1a
17 cfs @12.08 wc6a
163 cfs @12.08 dr27cs
5072 cfs @12.33 csm1
S. Mtn. Park det. Basin
48 cfs @12.33 wc2a
70 cfs @12.17 wc2.1a
240 cfs @12.25 sm3cw
401 cfs @12.33 drw2c
4137 cfs @12.42 10
433 cfs @12.17 wc4a
290 cfs @12.25 wc5a
NOTE: ORIGINAL SOUTH PHOENIX/LAVEEN SUB-BASINS SM1C, SM1AC AND SM2C HAVE BEEN REPLACED BY HOHOKAM ADMS/P SUB-BASINS 10 AND 20 REPRESENTING TOTAL INFLOW TO EXST S.MTN. PARK DET BASIN.
SOUTH MOUNTAIN PARK

South Phoenix / Laveen Drainage Improvement Project Addendum
Figure 1C
Recommended Alternative 6 Including 27th Ave / Dobbins Rd Future Basin Alt 1
Summary of Peak Flows and Times

Date: 1/7/2013

Flood Control District of Maricopa County

Legend

- Sub-Basin Boundary
- wc4a Sub-Basin ID
- HEC-1 Route Flow, Direction
- 146 cfs @17.33 rdent — 100-yr Peak Flow, Peak Time, Hydrograph Name
- (SD) = Storm Drain

HEC-1 File Used for this Exhibit:
SPX2BALT602JAN13.dat: 100-yr 24-hr Storm

N

1 inch = Approx 1,500 feet

2011 Aerial Photography
Contour Flight Date: 07/01/1990
Contour Interval is 2 ft
Vertical Datum NGVD29

Stanley Consultants INC

Path: Q:\21795\14-South Phoenix Two Basins 23621\09-SPX2B GIS\03-Exhibits\HEC-1 Hydrology 9-20-12.mxd

2 Comparison of Regional and 2014 Storm Hydrology

2.1 Introduction

A hydrologic analysis task was requested by the District and City of Phoenix staff to compare the regional HEC-1 flow rates from the South Phoenix / Laveen Drainage Improvement Project (SP/LDIP) Addendum to flow rates estimated using rainfall records from the 2014 monsoon storms that flooded numerous locations within the SP/LDIP project area. The regional SP/LDIP future land use condition / with future regional drainage improvements HEC-1 hydrology was prepared by Stanley Consultants in 2013 for the South Phoenix Two Basins (SPX2B) Project. It served as the hydrologic basis of design for the two regional detention basins project and also as the basis for planning of future regional storm drains and detention basins in the recommended alternative (Alternative 6) of the SP/LDIP Addendum.

Flooding issues involving the 2014 monsoon storms in the SP/LDIP area were mostly located in the area south of Baseline Road. Most, but not all of the structures that were flooded were in the area from around Dobbins Road south to the Phoenix South Mountain Park boundary. Structures flooded included residences, commercial and municipal buildings. The area south of Dobbins Road is in the upper SP/LDIP contributing drainage area and includes medium and low density residential development on the foothills of South Mountain and moderately steep, undeveloped hillslope within the Phoenix South Mountain Park. Figure 1.2 on the previous page illustrates the local contributing HEC-1 sub-basins.

The area south of Dobbins Road between roughly Central Avenue on the east and 43rd Avenue on the west was the primary area considered for this hydrologic comparison. Per team discussion, the target area chosen for the hydrology comparison was the area south of Dobbins Road consisting of the regional HEC-1 sub-basins contributing offsite drainage to the Citrus Mountain, Southern Highlands and Talasera residential subdivisions which were significantly impacted by flooding in both the August and September storms. This area is roughly bounded by about 15th Avenue on the east, 27th Avenue on the west, Dobbins Road on the north and the contributing watershed limit along the north ridgeline of the Phoenix South Mountains on the south.

2.2 Rainfall

The storms of August 12 and September 8, 2014 were both considered for comparison of discharges to the SP/LDIP Addendum Alternative 6 regional HEC-1 hydrology model. There were storm reports prepared by FCDMC staff for both of these storms. There was another significant storm that occurred on August 19 that covered nearly all of the metropolitan Phoenix area to widely varying degrees. The August 19 storm produced large rainfall totals, mainly in the north Phoenix watersheds of New River, Skunk Creek and Cave Creek. The August 19 storm did not impact the South Phoenix / Laveen area nearly as much as the August 12 and September 8 storms. There was a storm report produced by FCDMC staff for the August 19 storm but since it was by far the smallest of the 2014 monsoon storms in the Laveen area, it was not considered in the comparison.

In the South Phoenix / Laveen area, the September 8 storm generally produced a greater rainfall total and produced larger runoff volume than the August 12 storm. In contrast, the August 12 storm had a smaller rainfall total than the September 8 storm but had greater rainfall intensity. The primary storm of interest would be the one that produced the greatest peak flows, but at the onset, it was not known which of the two storms that would be. Gage #6525, 'South Mtn. Park HQ precipitation gage' was the nearest gage in the ALERT system to the area of

interest for the comparison and was therefore used for the comparison. Gage #6525 is located within the SP/LDIP contributing drainage area.

There is another rainfall record from a nearby gage in the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network that is close to the area of interest for the comparison and also within the SP/LDIP contributing watershed. The CoCoRaHS gage is Station No. AZ-MR-326 and is located about seven tenths of a mile north of ALERT gage #6525. The rainfall at CoCoRaHS gage AZ-MR-326 is documented in five minute increments in FCDMC's August 12, 2014 Storm Report. The CoCoRaHS gage is noted herein but has not been used in the comparison with regional HEC-1 hydrology.

The regional design HEC-1 model which was originally developed in the 1990's and partially updated by Stanley in 2013 for the SP/LDIP Addendum uses a 24-hour SCS (NRCS) Type II storm distribution and an aerially reduced 100-year NOAA 2 storm total. In the design HEC-1 model, the SCS Type II storm is input using the PC record option at 30 minute time increments. The 24 hour storm total of 4.20 inches in the design HEC-1 model is aerially reduced by 10% to 3.78 inches. The percent aerial reduction factor corresponds to a 30 square mile contributing area which is the approximate total contributing area in the regional design HEC-1 model at its outfall point to the Salt River.

The storm rainfall for Gage #6525 was extracted from the ALERT data base for both the August 12 and September 8 storms at five minute time increments and tabulated in a spreadsheet for input into HEC-1 models used for the comparison to the regional design hydrology. A dimensionless PC record using a five minute increment was created from the ALERT data. Because the area of interest is much smaller than the overall regional design HEC-1 model, the storm rainfall extracted from ALERT data was used directly with no aerial reduction or other accounting of the spatial or temporal variation in rainfall.

FCDMC's storm reports indicate that rainfall intensities in the South Phoenix / Laveen area for shorter durations, say from about 5 minutes up to the 1 to 2 hour range, are on par with or greater than a 100-year return frequency. Storm totals for durations longer than about 2 hours are significantly greater than 100-year return frequency. The rain gage record from the August 12, 2014 storm includes a 30-minute intensity that is about 30% greater than the most intense 30-minute time step of the SCS Type II rainfall used in the SP/LDIP regional HEC-1 design model. Per Figure 6 in FCDMC's September 8 storm report, the 3 hour and 6 hour storm totals for ALERT Gage #6525 have return periods of 165 years and 1,000 years, respectively.

2.3 Regional HEC-1 Design Model and Comparison of Flows

The SP/LDIP regional HEC-1 model reflects completely developed future land use conditions in the watershed and also the completely constructed future regional storm drain and detention basin infrastructure recommended in Addendum Alternative 6 from 2013. Four specific drainage sub-basins were selected from the regional HEC-1 model comprising the offsite drainage for the three residential subdivisions mentioned previously. These four sub-basins represent a diversity of size, length, slope and land use. There are no future regional drainage infrastructure improvements proposed in the selected sub-basins south of Dobbins Road. Also, these sub-basins are virtually completely developed or will not have significant hydrologic impacts from future land development.

A new HEC-1 model was created that contains only the notes, model control, rainfall record and the hydrograph input record for the four selected sub-basins. In the new HEC-1 model, there are no other sub-basins or hydrograph routing or combination steps as in the regional model. The rainfall record from the SP/LDIP design HEC-1 model was replaced by the ALERT Gage #6525 records, as described in the previous rainfall section, from the August and September storms.

In the comparative model, the basin area (BA), Green and Ampt loss rate (LG), and time-area (UA) record for each of the four selected sub-basins is identical to the SP/LDIP regional HEC-1 design model. Initially, no changes were made to the Clark unit hydrograph (UC) records. However, Maricopa County's hydrology manual relates the time of concentration, TC, and indirectly, the storage coefficient, R, on the LG record to the intensity of runoff and therefore, to the intensity of rainfall. A correct comparison should therefore consider a revision of TC and R to properly reflect the change in rainfall / runoff intensity using the actual storm data. The four sub-basin comparative HEC-1 model was first run with TC and R identical to the regional HEC-1 design model for both the August 12 and the September 8 storms. The resulting peak discharges in the comparative model were very similar to the peak discharges in the SP/LDIP regional HEC-1 design model.

A version of the comparative model was then made with revised TC and R to reflect the actual storm rainfall. First, estimates of the sub-basin flow path length, high and low elevation and basin roughness coefficient, Kb, were made. There was no adjustment made for basin slope, although slopes in two of the four sub-basins have very steep slopes from a hydrologic standpoint. The above variables are used in the Maricopa County Hydrology Manual TC equation. The other variable is runoff intensity. The TC equation is then solved iteratively. This is normally done internal to Maricopa County's DDMSW program with storm input based on NOAA 2 or NOAA 14 statistical rainfall data. But since actual rainfall is being used in the comparative model instead of NOAA rainfall, the iterative process was done manually with the aid of a spreadsheet using rainfall intensity-duration-frequency values from the August and September storm records. Using rainfall intensity instead of runoff intensity should result in a slightly shorter TC than using runoff intensity.

As expected, the revised times of concentration for the comparative HEC-1 model were shorter than those in the SP/LDIP regional HEC-1 design model. And also as expected, the resulting peak discharges were greater. This was an intuitively expected result since the storm rainfall was generally of greater intensity and depth compared to the SCS Type II / NOAA 2 rainfall. The comparative model using the August 12 rainfall data yielded higher peak discharges than the model with the September 8 rainfall. Subsequently, based on that result, only comparative models with the August 12 storm rainfall were run.

2.4 Hydrology and Hydraulics for the 15th Avenue Channel

A comparison was made based on the August 12 storm between the flow rate from an existing condition HEC-1 model and the hydraulic estimate for the corresponding flow rate in the existing channel along the west side of 15th Avenue south of Dobbins Road that protects the Arizona Humane Society to see what order of agreement there might be between the two. The existing condition HEC-1 model is one that Stanley Consultants had created in 2012 as part of the South Phoenix Two Basins (SPX2B) design. One design element of the (future) regional basin at 27th Avenue and South Mountain Avenue required an estimate of the existing condition flow rate at the basin's southeast corner.

The 2012 partial existing condition HEC-1 model was based on a portion of the SP/LDIP regional HEC-1 design model consisting only of those sub-basins tributary to the southeast corner of the 27th Avenue and South Mountain Avenue regional basin. In the 2012 model, the future SP/LDIP regional infrastructure was removed and the input for two mostly un-developed drainage sub-basin was modified to reflect their existing land use, thus making it an existing condition model for part of the regional drainage area. The model included a concentration point corresponding to the channel along 15th Avenue. Stanley's 2012 existing condition partial HEC-1 model was revised for the current hydrology comparison to reflect the August 12 ALERT Gage #6525 rainfall. The times of concentration and storage coefficients for each sub-basin in the partial existing condition HEC-1 model were adjusted based the approach and assumptions described in the 'Regional HEC-1 Design Model and Comparison of Flows' section above.

The flow rate in the updated existing condition partial HEC-1 model at the concentration point associated with the 15th Avenue channel is about 550 cfs. The discharge at this same concentration point corresponding to the SP/LDIP Addendum regional design HEC-1 model is about 440 cfs. But again, that model reflects future completely developed land use and future recommended regional drainage infrastructure.

The 15th Avenue drainage channel was constructed in 2012 by the City of Phoenix and FCDMC as part of the Small Project Assistance Program (SPAP) to protect the Arizona Humane Society facility at the southwest corner of Dobbins Road and 15th Avenue which was flooded by offsite drainage sometime after it was developed. The 15th Avenue channel receives flow from an earth channel along the south side of the facility and discharges it to a channel along the south side of Dobbins Road. All three channels were constructed at the same time as part of the SPAP project.

Photo 1 – Earth channel on south side of Humane Society facility looking west (upstream) from 15th Avenue

Photo 2 - 15th Avenue Channel, upstream reach, looking south (upstream)

The upstream reach of the 15th Avenue channel, approximately 300 feet in length, is trapezoidal in section and lined with riprap on its sides and bottom. The downstream reach of the 15th Avenue channel, about 900 feet in length, is lined with riprap on its bottom and east side slope along 15th Avenue but is side-boarded along its west side by a vertical CMU retaining wall / flood wall approximately 4 to 4.5 feet in height above the channel bottom. The channel is relatively straight and has a relatively uniform section, slope and roughness. The upper portion of the 15th Avenue channel CMU retaining wall / flood wall reach does not appear to be impacted by downstream backwater from the reach along the south side of Dobbins Road.

There are expansion joints in the retaining wall / flood wall along the 15th Avenue channel at a more or less uniform spacing of around 20 feet and those joints still have small floating debris from the 2014 storms which became lodged in them when flow in the channel leaked out at each of the joints. The highest point of the floating debris in each of these joints is still visible. If connected together, these points would provide an excellent high water line profile. The retaining wall / flood wall was not overtopped in the monsoon flows of 2014. It is not absolutely certain whether the high water marks in the joints of the flood wall / retaining wall were from the August 12 or the September 8 storm. Based on the rainfall and HEC-1 results, it has been assumed that the larger peak discharge of the two storms at this location was the August 12 storm and therefore, the high water marks would be associated with that storm.

A normal depth capacity estimate was done for the channel. The hydraulic slope was estimated based on 2-ft contour topography from the original 1990 regional drainage plan. The bottom width and east side slope channel section geometry were estimated based on photographs. The depth used was 3 feet, although the depth observed from high water marks was consistently around 3.3 feet. A range of roughness coefficient was used with a low of 0.025 and a high of 0.035. The flow capacity of the 15th Avenue roadway section which parallels the

channel was disregarded, although the roadway would likely have been flowing curb deep with a flow of perhaps around 25 cfs. Based on the above hydraulic configuration, the channel carried a flow of between about 750 – 1,000 cfs.

Photo 3 - 15th Avenue Channel flood wall / retaining wall typical expansion joint with debris high water mark

2.5 Conclusions and Considerations

The 15th Avenue channel is one of the best locations known within the area of interest where a reliable hydraulic estimate can be made for a flow rate from the 2014 monsoon storms. The flow rate for the 15th Avenue channel based on hydraulic analysis indicates that the flow rate from HEC-1 modeling may be underestimated. A better analysis of the 15th Avenue channel hydraulic capacity could be made if the civil drawings for the project from which it was constructed were available or if a simple survey were done for a few typical channel hydraulic sections.

Other considerations which might improve the comparison of design hydrology to storm hydrology involving calibration against the hydraulics for the 15th Avenue channel are described as follows:

1) The time of concentration calculated for each sub-basin is a significant variable in the comparison of HEC-1 hydrology. A more refined estimate could be considered for the hydrologic variables associated with the time of concentration to better relate them to the

SP/LDIP Addendum regional HEC-1 design model and more correctly follow the Maricopa County Hydrology Manual. The HEC-1 model estimate could potentially be better calibrated to the 15th Avenue channel hydraulics through a more appropriate adjustment of the time of concentration.

2) The rainfall record from Community Collaborative Rain, Hail and Snow (CoCoRaHS) gage AZ-MR-326 has the highest intensity of any gage known in the focus area and it is located very near the centroid of the main contributing area to the 15th Avenue channel. If calibration of HEC-1 to the 15th Avenue channel hydraulics were considered, another HEC-1 model using the CoCoRaHS gage AZ-MR-326 rainfall record might also be worth considering.

3) One potentially significant variable in the HEC-1 model for the drainage contributing to the 15th Avenue channel is the amount of drainage area and flow that would be intercepted by the earth channel along the south side of the Humane Society facility. This earth channel was constructed at the same time as the riprap channel along 15th Avenue. The flow intercepted by the earth channel is directed east to the 15th Ave riprap channel. The proportion of flow from regional HEC-1 sub-basin DRW2C intercepted by the earth channel was approximated by a 50 - 50 flow split step introduced into the regional model as part of the South Phoenix Two Basins / SP/LDIP Addendum hydrology update in 2012. The 50 – 50 flow split was approximated based on field judgement. There was no rigorous analysis involved. A closer examination of this could affect the hydrologic estimate of the flow contributing to the 15th Avenue channel. If this were going to be considered, it would want to be done in conjunction with any hydrologic / hydraulic calibration suggested in the preceding paragraphs.

4) An expanded version of the existing condition model could be considered for the area south of Dobbins Road or for the area south of Baseline Road (which would include the area south of Dobbins Road). An expanded existing condition model with Baseline Road as its north limit could be used to compare hydrologic flows to hydraulic flows estimated along Baseline Road and its regional storm drain which is known to have surcharged during the monsoon storms of 2014. According to the current SP/LDIPS Addendum regional hydrology, the Baseline Road storm drain is designed to essentially not surcharge.

5) Some form of aerial reduction should probably be considered for application to the model if the total assembled area of sub-basins was significant. Also, an exhibit could be created to show the comparison of design flows to storm flows.

3 Evaluation of Flooding at Specific Locations

3.1 City of Phoenix Aguila Golf Course

3.1.1 Description

Portions of text in the following subsection were excerpted from: South Phoenix / Laveen Drainage Improvement Project (SP/LDIP) Addendum Report; May 2013; Section 2.3 – Aguila Golf Course Regional Detention Basin.

The Aguila Golf Course is an existing City of Phoenix municipal golf course located northwest of the intersection of 35th Avenue and Dobbins Road. It occupies roughly the southeast quarter of Section 3, Township 1 South, Range 2 East. To the north is the existing City of Phoenix Cesar Chavez Park and to the west are residential subdivisions. The golf course was designed in 1998, apparently based on concepts developed from the South Phoenix / Laveen Drainage Improvement Project (SP/LDIP), which at the time, was a current, active study project.

Because the golf course was a municipal facility, it presented an opportunity to incorporate regional stormwater storage in its grading design which would help achieve the regional drainage improvement project objectives. The basic concept was to collect regional flows from the southeast and direct them into the golf course where the flow would be attenuated by storage basins, then discharged via storm drain at a much reduced flow rate to the north. This would control a significant portion of the regional drainage and reduce the flows contributing to the (then future) Baseline Road storm drain.

Construction drawings and a stormwater pollution prevention plan for the golf course from 1998 were on file at the Flood Control District of Maricopa County and provided to Stanley Consultants in the form of .pdf scan files in January of 2012 during the pre-design phase of the South Phoenix Two Basins Project. These plans were included in the data collection report for the South Phoenix Two Basins Project. They are also included in the data collection report and deliverables for this project, the South Phoenix / Laveen Drainage Improvement Project Supplement (SP/LDIPS).

The golf course was designed as a system of individual detention basins that would operate in series. Flow would enter from the southeast, pass through the basins from one to another and outfall to a final basin which discharges to a 36" diameter outfall storm drain. The inlet of the 36" storm drain is near the 39th Avenue alignment southwest of the golf course club house.

The individual grading sheets of the golf course construction plans were assembled into one large composite plan so that the extent and inter-relation of the basins could be better understood. This composite plan is a large image and large file size. It is included in electronic format on the CD in the back pocket of this report. According to the 1998 golf course construction plans, there are seven (7) individual detention basins within the golf course that make up the total storage. They are inter-connected by low-level 18" diameter drain pipes in combination with high level overflow spillways of various size and configuration.

The 36" diameter storm drain outfall from the Aguila Golf Course detention to Baseline Road was part of the 1998 golf course plans. The Baseline Road storm drain plans, later prepared by the consultant for the Baseline Road improvements circa 2000, included a 36" diameter storm drain lateral connection at 39th Avenue south to the terminal manhole of the storm drain from the golf course which, at that time, was already in place.

Although the 36" outfall storm drain for the golf course was operational as soon as the Baseline Road improvements were completed, the temporary plug that had been installed at its inlet during the original construction remained in place through early 2013 when it was noted during a field reconnaissance associated with the South Phoenix Two Basins Project. It was removed sometime subsequent to that. Until it was removed, onsite runoff within the golf course and whatever offsite flow may have made its way into the golf course simply percolated or evaporated.

A field reconnaissance of the golf course indicates that it appears to have the basic multi-basin storage represented on the grading plan. The golf course plan does not include a formal inlet for the regional flows from the Dobbins Road / 35th Avenue intersection or from Dobbins Road or from 35th Avenue. A formal inlet for regional drainage from the south may have been envisioned as a future separate project.

There was no drainage report found for the Aguila Golf Course or any documentation for its hydrologic design, other than what is incorporated among the various drain pipe and spillway design elements called out on the 1998 construction plans or what can be inferred from the regional HEC-1 model. Presumably, some hydrologic / hydraulic analysis was done in support of the golf course design to document the storage volume and routing through the basin system, to size the overflow spillways, or to evaluate any dynamics between the individual detention basins or between the detention and outfall pipe.

No design volumes are documented on the grading plan for any of the detention storage in the golf course, either for individual basins, or as a whole. The stormwater pollution prevention plan from 1998 notes a 'volume provided' of 135 acft, which is assumed to be the overall collective volume of all the individual detention basins up to their high level spillway overflow elevations.

Some form of collection system is implied by the regional HEC-1 model for flow from the contributing sub-basins south of Dobbins Road, east of 35th Avenue. As part of this collection system, some form of future storm drain in Dobbins Road or open channel conveyance along the south side of Dobbins Road from 27th Avenue to 35th Avenue would have been anticipated based on the regional sub-basin boundaries and based on the structure of the regional HEC-1 model.

There is no indication from the 1998 golf course construction plans, or from any other documentation that's been found, how offsite regional flows were anticipated to enter the golf course detention system. It is generally thought that the concept would have involved somehow collecting all of the design inflow per the regional HEC-1 model and conveying it into the golf course at a single location at the northwest quadrant of the Dobbins Road / 35th Avenue intersection. However, that concept cannot be confirmed.

Based on the golf course layout and grading design, it is possible that all the regional inflow could have been anticipated at a single location near the intersection. But it also looks possible that the golf course grading was arranged to receive inflow at multiple locations along the adjoining Dobbins Road and the adjoining 35th Avenue roadways. A third possibility is that inflow could have been anticipated as a combination arrangement with the bulk of it entering near the intersection and the rest of the flow entering at multiple locations along Dobbins Road and along 35th Avenue.

Dobbins Place Subdivision Improvements -

There is an existing regional sized open channel along the south and west perimeter of the 'Dobbins Place' residential subdivision at the southeast corner of 35th Avenue and Dobbins Road. This channel was constructed sometime around 2006 / 2007 which would have been perhaps 7 years or so after the Aguila Golf Course was constructed. The channel is substantial in size and appears to have been designed as a portion of a regional collection / conveyance system. The channel has a dead end outfall at the southeast quadrant of the intersection at 35th Avenue and Dobbins Road where the channel flow line is about 4 – 5 feet lower than the intersection.

Photo 4 – Dobbins Place offsite drainage channel along the east side of 35th Avenue looking south (upstream) from Dobbins Road

City of Phoenix staff searched for and found the grading and drainage plan and the drainage report for the Dobbins Place subdivision. These were provided to Stanley as .pdf scan files. The grading and drainage plan and drainage report are included in Stanley's data collection report and deliverables. Stanley reviewed the plan and report to see what, if any, relation there might be to the regional hydrology or how it might have been envisioned that regional flows were to enter the Aguila Golf Course.

The drainage report did not mention any regional culvert or storm drain or any infrastructure that would convey flow from the Dobbins Place perimeter offsite channel to the Aguila Golf Course. The drainage report includes printout and cross sections from a HEC-RAS model for the offsite perimeter channel. Hydraulics for the downstream end of the channel simply represented the flow as spreading out and returning to pre-subdivision sheet flow conditions. The grading and drainage plan included plan and cross sections for the offsite perimeter channel but there were no notes or references to any culvert or storm drain, ether 'future' or 'separate by others', that would convey flow from the channel to the Aguila Golf Course. There was no reference at all to

the Aguila Golf Course. So these documents did not shed any light on any such elements of the regional plan.

The present general assumption is that the inflow concept to the Aguila Golf Course would have involved a single major storm drain or culvert structure conveying flow from the Dobbins Place channel diagonally under the intersection into the golf course. That would seem to be the conventional means and location. However, there is no way to confirm that. There is existing underground irrigation and existing underground electric utility just north of Dobbins Road at its intersection with 35th Avenue which would impact how flow might be conveyed from the existing Dobbins Place perimeter channel into the Aguila Golf Course regional detention if that were to be accomplished via large culvert or storm drain.

Offsite flow from the southeast entered the Aguila Golf Course during at least one of the 2014 monsoon storms. Flow entered at the northwest quadrant of the Dobbins Road / 35th Avenue intersection and also at multiple locations along the north side of Dobbins Road west of 35th Avenue. Flow may have also entered the golf course along the west side of 35th Avenue.

Photo 5 – Aguila Golf Course just north of Dobbins Road (looking north) about 1,700 feet west of 35th Avenue. Slope erosion is from offsite flow that entered the golf course from Dobbins Road during 2014 monsoon storms.

3.1.2 Hydrology

The regional HEC-1 hydrograph step that represents the Aguila Golf Course was initially reviewed in late 2011 / early 2012 during the pre-design phase of the South Phoenix Two Basins project when the regional hydrology was being updated. The amount of storage that actually existed in the golf course was not exactly known other than the volume represented in the regional HEC-1 model and the 135 acft noted on the 1998 stormwater pollution prevention plan. The 135 acft volume was on par with the volume of the inflow hydrograph to the golf course in the regional HEC-1 model.

The golf course hydrograph step in the regional HEC-1 model pre-dates the actual golf course design. In the base regional HEC-1 model which is from the late 1990's, the golf course detention basin routing is hydrograph step 'STG' with KM note "dummy basin to simulate future golf course". As mentioned previously, there may have been a more detailed hydrologic analysis done in support of the golf course design. If there was, however, it had not been reflected in the base regional HEC-1 model.

As it stood, the golf course routing in the regional HEC-1 model is a Modified Puls routing step with volumes of 0, 100 and 5,000 acft on the 'SV' data line and corresponding outflows of 0, 50 and 50 cfs on the 'SQ' data line, hence limiting the outflow to 50 cfs. There is no elevation data incorporated in this detention basin routing step. The outfall from the golf course to Baseline Road in the HEC-1 model is hydrograph step 'RSTG39' representing 7,920 feet of storm drain pipe at a slope of 0.004 ft/ft and a Manning's roughness of 0.014. The pipe diameter in the HEC-1 routing step is 5' as opposed to the 36" pipe which was actually designed and constructed.

In the initial South Phoenix Two Basins pre-design review, the general conclusion was that the golf course hydrograph step was perhaps not the most robust accounting of the actual multi-basin performance, but it seemed to reasonably reflect the overall function of the golf course detention. It was considered an appropriate approximation for the purpose of evaluating the regional system downstream, including design of the 43rd Avenue and Baseline Road regional detention basin.

The regional HEC-1 golf course routing step was re-examined in the final stages of design for the 43rd Avenue regional basin in the fall of 2012. A StormCAD model was prepared by Stanley Consultants for the 36" outlet storm drain from the Aguila Golf Course to Baseline Road to better represent the outfall from the golf course than what was in the regional HEC-1 model. The StormCAD model output was coupled with an elevation –vs- storage relation that Stanley created for the overall collective golf course detention. This was done by uniformly pro-rating 135 acft over the actual range of head associated with the 36" storm drain pipe inlet based on the golf course construction plans.

The resulting HEC-1 output indicated that the 50 cfs maximum outfall was a reasonable approximation, at least as far as the sensitivity of the downstream system was concerned. The Aguila Golf Course hydrograph step in the regional HEC-1 model was therefore left as it was.

In the Dobbins Place drainage report, the design flow for the offsite perimeter channel for that subdivision is 1,502 cfs. The report mentions that the flow rate was determined using HEC-1, presumably in reference to the SP/LDIP regional hydrology model from the late 1990's. But there is no specific reference in the report to SP/LDIP or to its HEC-1 and there is no HEC-1 input / output printout in the report. However, it seems likely that the 1,502 cfs came from some version of the regional hydrology.

The SP/LDIP Addendum base HEC-1 model Stanley re-constructed in 2011 has a discharge of 1,551 cfs at the intersection of 35th Avenue and Dobbins Road. The recommended Alternative 6 HEC-1 model Stanley developed as part of the SP/LDIP Addendum has a flow rate of 1,374 cfs at this same location. The flow rate is a little lower in the Alternative 6 HEC-1 model because of revisions that were made in the model upstream from that point to reflect the future recommended regional drainage system. The existing condition offsite flow rate at this location is probably a little greater than what is estimated in the regional HEC-1 model.

3.2 Citrus Mountain Estates Subdivision

3.2.1 Description

Citrus Mountain Estates is a medium density gated residential subdivision located on the east side of 27th Avenue about 700 feet south of Dobbins Road within the City of Phoenix' incorporated limit. The subdivision has 89 total lots on just over 32 acres. The location, vicinity and layout of the subdivision, including street names, is illustrated on Figure 3.2.1 on the following page.

Citrus Mountain Estates was platted in 2002. There are two large hillside lots in the east central part of the subdivision that are vacant but all other lots in the subdivision have homes constructed on them. A complete 5-sheet as-built grading plan for the subdivision dated 2003 was provided by City of Phoenix consultant Entellus, Inc. This as-built is included in the data collection report and deliverables for this project. There was no drainage report provided for the subdivision, nor was there any paving plan to go along with the as-built grading plan.

Citrus Mountain is bounded on the west by 27th Avenue, on the north by the Salt River Project's (SRP) Western Canal, on the east by the Southern Highlands subdivision and on the south by SRP's Telegraph Pass Canal. 27th Avenue adjacent to the subdivision is a two-lane paved road with east half curb, gutter and sidewalk improvements.

Citrus Mountain is a gated community with private interior streets and tracts containing drainage channel and retention basin improvements. There is no public right-of-way and there are no public roadway improvements within the subdivision. All the interior drainage improvements are private as well. Therefore, maintenance and repairs of internal roadway and drainage improvements in Citrus Mountain is the primary responsibility of the subdivision's property owners association. 27th Avenue adjacent to the subdivision is, however, public right-of-way.

SRP's Western Canal to the north and Telegraph Pass Canal to the south are both open conveyances. The underlying property ownership for both the Western Canal and the Telegraph Pass Canal in this area appears to be private, not SRP property. SRP has an easement of varying width for each canal. It is assumed that the easements cover the canals themselves and any access roads needed for SRP to maintain them and that the easements also cover gates, control structures, turnouts and drainage facilities incidental to SRP operations.

The dominant land slope and drainage direction in this area is generally from south to north. Offsite drainage to the subdivision comes from the south-southeast. The offsite drainage area extends south to the prominent north ridge of the Phoenix South Mountains. The offsite drainage area as a whole is characterized as upland desert with moderate slopes in the lower areas and steep slopes within the Phoenix South Mountain Park. The area between Citrus Mountain Estates and South Mountain Park consists primarily of low to very low density residential land use on mostly large lot split parcels. The area within the park is undeveloped. The offsite area is all situated within incorporated City of Phoenix limits.

Citrus Mountain has been designed to accept offsite drainage from the southeast. Most of the offsite flow is from the area corresponding to SP/LDIP Addendum regional HEC-1 sub-basin WC4A. The onsite flow plus the drainage from the adjacent half of 27th Avenue is directed to a single large retention basin at the north end of the subdivision. This basin is on line with the offsite drainage conveyed through the subdivision.

Figure 3.2.1 – Citrus Mountain Estates Subdivision aerial view

As mentioned in previous sections, the regional hydrology sub-basins are illustrated on Figure 1.2 of this report. The peak flow for sub-basin WC4a is 433 cfs. Offsite drainage for Citrus Mountain that is also offsite to the Southern Highlands subdivision to the east is covered in more detail in Section 3.3 for Southern Highlands which follows this section.

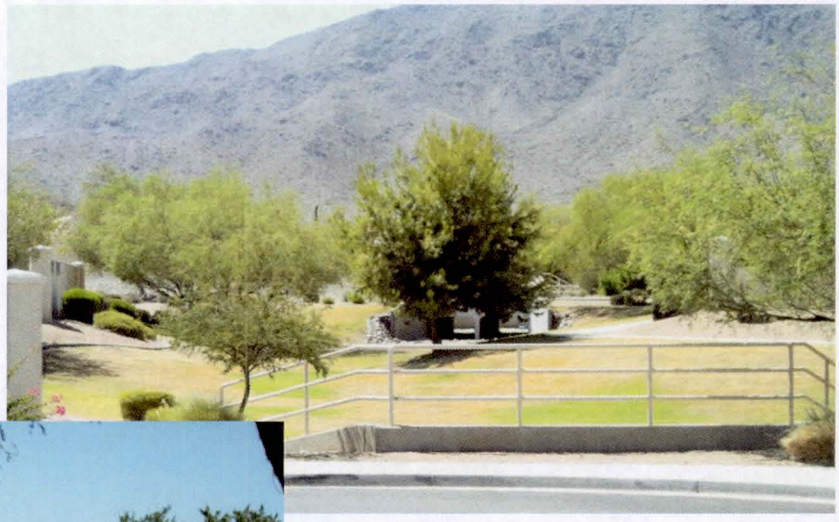
During the monsoon storms of 2014, a portion of the flow from offsite regional sub-basin WC4A entered Citrus Mountain from the drainage easement running along the west edge of Southern Highlands which outfalls to Citrus Mountain about a thousand feet north of Olney Drive. And a portion of the flow from sub-basin WC4A broke out of the Southern Highlands drainage channel on the north side of Olney Drive when it backed up at the inlet to a triple – 36" diameter culvert which conveys flow under the Telegraph Pass Canal. The breakout flow traveled overland to the northwest, knocking down a wire fence, crossing the Telegraph Pass Canal and reaching the south boundary of Citrus Mountain. This flow entered Citrus Mountain through a 6 foot high steel picket perimeter fence section at the south end of 25th Lane, collapsing the fence. The flow then ran north in 25th Lane and joined the flow from the Southern Highlands offsite channel outfall near Buist Avenue.

The combined flow is conveyed via open channel to the single large retention basin, mentioned above, at the north end of the subdivision. There are double barrel box culverts for the channel flow where it passes under Piedmont Road and under Monte Way just south (upstream) of the onsite retention basin at the north end of the subdivision. When the retention basin fills, it simply spills over to the north, passing through the subdivision's 6 foot high steel picket perimeter fence, then over the Western Canal. The steel picked fence on the north side of Citrus Mountain was bent over by flow discharging from the retention basin during the August 12, 2014 monsoon storm. The extent of flooding within the Citrus Mountain Subdivision during the 2014 monsoon storms is depicted in the Entellus study titled *"South Phoenix / Laveen Stormwater Infrastructure Evaluation Report"* mentioned in Section 1.3 of this report.

Photos 6 and 7 – Looking north just north of Olney Drive near the boundary between Citrus Mountain Estates and the Southern Highlands subdivisions. The partially clogged inlet grate of the Southern Highlands triple 36" culvert under the Telegraph Pass Canal can be seen at right – center of lower left photo, and also in upper right photo.

Photos 8 and 9 – Telegraph Pass Canal looking west just south of Citrus Mountain subdivision (main photo left) and section of subdivision 6 foot high steel picket fence that collapsed where flow entered at 25th Lane (inset photo lower right).

Photo 10 - Outfall of Southern Highlands drainage easement at Citrus Mountain subdivision about 1,000 feet north of Olney Drive, looking west, August 12, 2014.



Photos 11 and 12 – Top right photo looking southeast (upstream) from Monte Way at offsite channel box culvert with culvert under Piedmont Road in background. Lower left photo looking northwest (downstream) from same location at retention basin at north end of subdivision.

3.2.2 Hydrology

Discharges and volumes for Citrus Mountain from the SP/LDIP Addendum regional HEC-1 model have been referenced in various parts of this section. There was no additional breakdown of regional sub-basins or additional concentration points or any attempt to evaluate flow splits or other hydrologic / hydraulic phenomenon that happened during the monsoon storms of 2014.

The regional hydrology HEC-1 sub-basin that includes Citrus Mountain had been updated in 2013 for the SP/LDIP Addendum to reflect development that had occurred since around 2000. For the 2013 update, Citrus Mountain was included in (then new) HEC-1 sub-basin DR27CW. In most cases, the volume of onsite retention for the 2013 update was estimated using 80% of the total volume required by City of Phoenix development standards based on land use and runoff coefficients. Then, the estimated volume was simply subtracted from the hydrograph for the sub-basin in which the volume is located using a volume-divert step. That approach was, and still is, the standard practice for regional HEC-1 hydrology modeling.

In the case of Citrus Mountain, however, new 2' contour topography had been acquired in 2011 for the area around 27th Avenue and Dobbins Road. This was to evaluate the future regional 27th Avenue and Dobbins Road Basin as part of the SP/LDIP Addendum. This new topography included the north portion of Citrus Mountain which enabled the addition of a level pool routing step to the HEC-1 model representing the single large retention basin at the north end of the subdivision near the Western Canal. Elevation-storage-discharge data were developed from the 2011 topography. The level pool routing step was placed in the HEC-1 model immediately after the addition of the onsite hydrograph for sub-basin DR27CW and the offsite hydrograph for sub-basin WC4A.

For the 2013 HEC-1 update, the volume of the single large retention basin in Citrus Mountain to its overflow crest was estimated at about 3 acre-feet. The volume corresponding to 1.5 feet above the overflow crest was about 4 acre-feet. The total volume of all onsite and offsite runoff for Citrus Mountain (sub-basins WC4A + DR27CW) is around 43 acre-feet. The peak flow for the combined offsite (WC4A) and onsite (DR27CW) drainage area per the SP/LDIP regional hydrology is 482 cfs. The partial grading plan as-built for Citrus Mountain notes a 100-year discharge of 369 cfs for the drainage channel between Buist Avenue and Piedmont Road which is very near that corresponding regional hydrologic concentration point.

Photos 13 and 14 – Upper right photo looking southeast at Citrus Mountain retention basin from north limit of subdivision and lower left photo looking east at Western Canal just east of 27th Avenue.

3.3 Southern Highlands Subdivision

3.3.1 Description

Southern Highlands is a medium density gated residential subdivision located northwest of 23rd Avenue and Olney Drive within the City of Phoenix' incorporated limit. The subdivision has 204 total lots on around 70 acres. There are significant open space tracts within the subdivision which incorporate hillside areas and which correspond to drainage easements where there are channel and retention basin improvements. The location, vicinity and layout of the subdivision, including street names, is illustrated on Figure 3.3.1 on the following page.

The subdivision was platted in 2007 as "Southern Highlands Amended". There is an undeveloped future phase in the north portion of the subdivision where there are 24 platted lots but no homes built or roadway improvements completed. All other parts of the subdivision are developed. A partial as-built grading and drainage plan set dated 2009 for the subdivision was provided by City of Phoenix consultant Entellus, Inc. This as-built plan is included in the data collection report and deliverables for this project. There was no drainage report provided for the subdivision, nor any paving plan or any other plan to go along with the partial as-built grading and drainage plan.

Southern Highlands is bounded on the south by Olney Drive, on the west by the Citrus Mountain Estates Subdivision, on the north by the Salt River Project's (SRP) Western Canal and the east (partly) by 23rd Avenue. Olney Drive adjacent to the subdivision is a two-lane paved road with north half curb, gutter and sidewalk improvements. 23rd Avenue is improved with west half curb, gutter, sidewalk and pavement to a point about 600 feet north of Olney Drive where the road dead-ends. Land to the east of the subdivision consists of large, low density residential parcels, many of which are undeveloped.

Southern Highlands is a gated community with private interior streets and private drainage tracts. Hence, there is no public right-of-way and there are no public roadway improvements within the subdivision. Therefore, maintenance and repairs of internal roadway and drainage improvements in Southern Highlands is the primary responsibility of the subdivision's property owners association. Olney Drive and 23rd Avenue adjacent to the subdivision are, however, public rights-of-way and City of Phoenix street improvements.

The Salt River Project's Western Canal is an open conveyance within an easement adjacent to the north limit of the plat. SRP's Telegraph Pass Canal, which splits off of the Western Canal just east of 19th Avenue, passes through the southern portion of the subdivision. The Telegraph Pass Canal was undergrounded within the plat limits when the subdivision was developed and water is now carried in that reach by a single 42" diameter pipe in a 25' wide SRP easement. To the east and west of Southern Highlands, the Telegraph Pass Canal remains an open conveyance. There is a trash and debris grate across the canal at the inlet to the 42" pipe near the subdivision's eastern limit.

The underlying property ownership for both the Western Canal and the Telegraph Pass Canal in this area appears to be private, not SRP property. SRP has an easement of varying width for each canal. It is assumed that the easements cover the canals themselves and any access roads needed for SRP to maintain them and that the easements also cover gates, control structures, turnouts and drainage facilities incidental to SRP operations.

Figure 3.3.1 – Southern Highlands Subdivision aerial view
Note: Figure depicts both the Southern Highlands subdivision (23rd Avenue to 25th Avenue) and the Citrus Mountain subdivision (25th Lane to 27th Avenue)

In the Telegraph Pass Canal reach from 19th Avenue to the east limit of Southern Highlands, (23rd Avenue alignment) there is a 36" diameter inverted sump drainage culvert under the canal about 400 feet east of the subdivision and there is a drainage overchute structure, about 60 feet wide, spanning the canal about 750 feet west of 19th Avenue. These facilities pass drainage under / over the canal from south to north.

Photos 15, 16 and 17 – Telegraph Pass Canal overchute west of 19th Avenue looking east (top photo); 36" inverted siphon culvert east of Southern Highlands (middle); and inlet to 42" pipe at east side of subdivision (bottom photo)

The dominant land slope and drainage direction in this area is generally from south to north. Offsite drainage to the subdivision comes from the south-southeast. The offsite drainage area extends south to the prominent north ridge of the Phoenix South Mountains. The offsite drainage area as a whole is characterized as upland desert with moderate slopes in the lower areas and steep slopes within the Phoenix South Mountain Park. The area between Southern Highlands and South Mountain Park consists primarily of low to very low density residential land use on mostly large lot split parcels. The area within the park is undeveloped. The offsite area is all situated within incorporated City of Phoenix limits.

Southern Highlands has been designed to accept offsite drainage from the east and from the south. At the same time, onsite drainage within the subdivision has been provided for with that flow being directed to one of 11 retention basins incorporated in the subdivision layout. Offsite drainage from the south is collected in a drainage channel on the north side of Olney Drive and directed to the west, then north to a triple 36" diameter storm drain that passes the flow under the 42" diameter Telegraph Pass Canal pipe. The 3 – 36" storm drain outfalls to an open channel along the west edge of the subdivision, which in turn, outfalls to the Citrus Mountain Subdivision about a thousand feet north of Olney Drive. This offsite drainage from the south skirts the south and west edge of Southern Highlands, passing through the subdivision but staying separate from Southern Highland's onsite drainage.

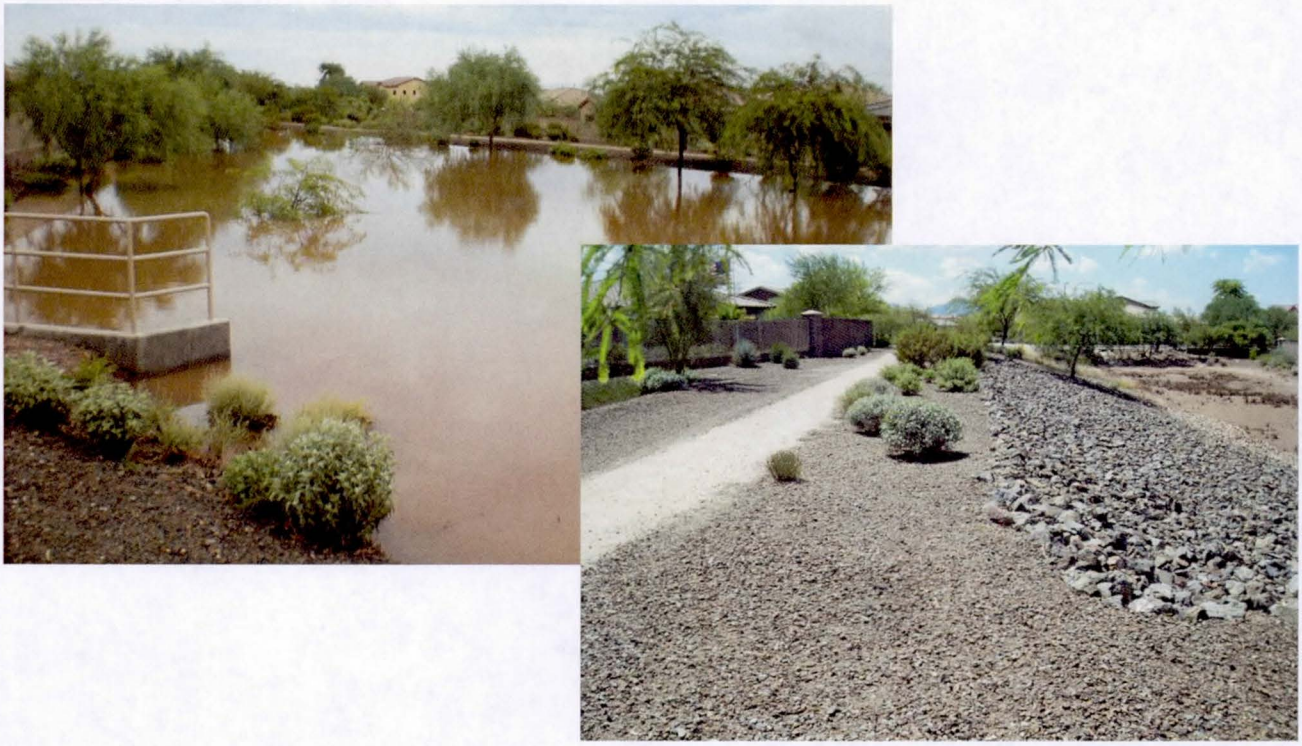
In contrast, offsite drainage from the east enters the subdivision and passes through onsite retention basins en route to its ultimate outfall along the Western Canal at the north edge of the subdivision. The offsite flow intercepted by the storm drain inlets at the north end of 23rd Avenue is conveyed by a pair of 30" storm drain pipes west to a triangular shaped retention basin located just inside the subdivision on the south side of the Telegraph Pass Canal 25' SRP easement. However, both inlets at 23rd Avenue were heavily clogged by debris so they intercepted only a portion of the offsite flow.

Photos 18, 19 and 20 – North end of 23rd Ave (top photo) and the two storm drain inlets that were clogged with debris (middle and bottom photos). Someone apparently cleared debris from the curb opening inlet during or shortly after September 8, 2014 storm when photo was taken.

The two 30" storm drain pipes cross a private parcel adjacent to the subdivision west of 23rd Avenue. There is a 10' wide drainage easement for the storm drain pipes on the private parcel. The maintenance responsibility for the two 30" storm drain pipes is unknown where they cross the private parcel. The private parcel is about ¾ of an acre in size and is presently vacant.

The outfall retention basin in the subdivision that receives the flow from the 2-30" storm drain pipes does not appear to have filled all the way with water in either the August 12 or the September 8, 2014 storms. There is a shallow spillway dip in the 25' SRP Telegraph Pass Canal easement along the north side of the outfall basin and a riprap lined spillway chute about 125' wide that would take overflow from that basin down an embankment, to another triangular shaped retention basin just north of the SRP easement.

The two storm drain inlets at the north end of 23rd Avenue take flow primarily from an offsite wash that comes in from the southeast but also take drainage from the roadway itself. This location corresponds to the concentration point for SP/LDIPS Addendum HEC-1 sub-basin WC2A. As mentioned previously, the regional hydrology sub-basins are illustrated on Figure 1.2 of this report. The 100-year, 24-hour peak flow for sub-basin WC2A is 48 cfs and the volume is around 4 acre-feet.



Photos 21 and 22 – Upper retention basin on south side of SRP canal easement after receiving offsite flow from the 23rd Avenue storm drain on September 8, 2014 (left photo). SRP canal easement looking west with riprap spillway from upper basin in left photo to lower basin north of easement (right side of right photo).

The design flows for the 23rd Avenue storm drain inlets, the two 30" storm drain outfall pipes, the retention basin(s) and the spillway that would take overflow from the upper basin to the lower basin are not known. In both the August and the September monsoon storms of 2014, the bypass flow not intercepted by the 23rd Avenue storm drain inlets went north through the private parcel mentioned earlier and joined the offsite flow that approaches the east limit of Southern Highlands in the area from the Telegraph Pass Canal northward.

Photos 23 and 24 – High water mark on east side of subdivision perimeter wall adjacent to private parcel at north end of 23rd Avenue (upper left photo) and offsite runoff ponded in onsite retention basin at southeast corner of Corral Road / 23rd Drive (lower right photo). Both photos taken September 8, 2014.

The combined offsite flow approaching Southern Highlands in the area north of the Telegraph Pass Canal is primarily from the area corresponding to SP/LDIP Addendum HEC-1 sub-basin WC2.1A. However, it would also include that portion of the flow from sub-basin DR27CS east of the subdivision plus any bypass flow from the 23rd Avenue storm drain inlets mentioned previously. The 100-year, 24-hour flow from sub-basin WC2.1A by itself is 70 cfs with a volume of 4 acre-feet per the SPLDIP Addendum regional hydrology. Combined flow from the three sources mentioned above entered the subdivision by various means in the area north of the Telegraph Pass Canal.

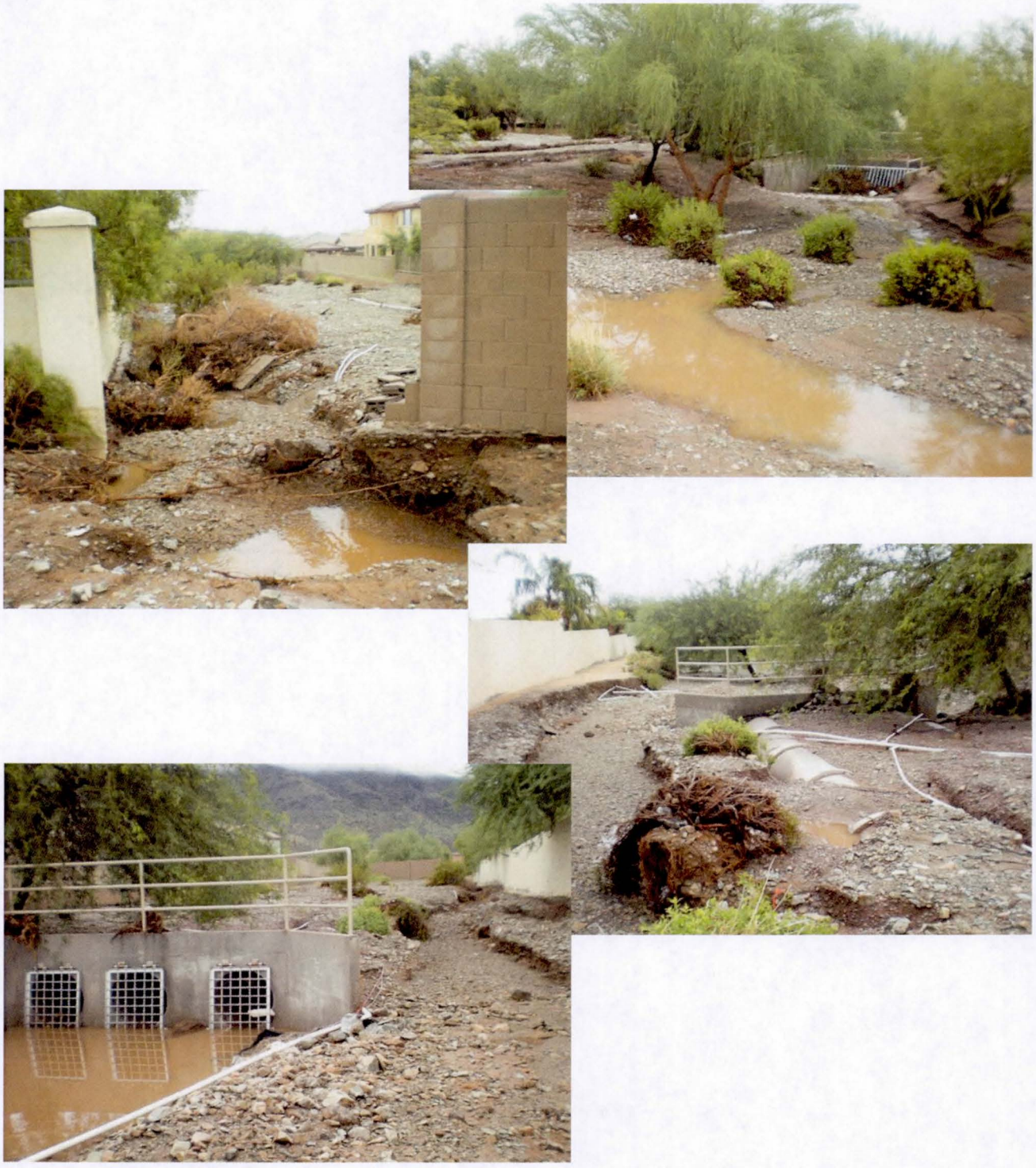
Photo 25 – Rear yards of homes on south side of Heyduk Road where flow had entered from the south during the August 12, 2014 storm

The drainage channel on the north side of Olney Drive begins just west of 24th Drive. The partial grading and drainage plan as-built for the subdivision illustrates a 4-barrel 24" diameter pipe culvert under Olney Drive at this location. The as-built indicates a 100-year flow rate of 213 cfs near the inlet to this culvert. The culvert under Olney Drive near 24th Drive corresponds to the concentration point for SP/LDIP Addendum HEC-1 sub-basin WC4A. In contrast to the as-built, the 100-year, 24-hour flow rate from the regional hydrology is 433 cfs. The SP/LDIP Addendum 100-year, 24-hour volume at this location is 34 acre-feet.

The offsite flow collected in the channel along the north side of Olney Drive is conveyed to the inlet of the 3-36" storm drain pipes at the southwest corner of Southern Highlands that takes the flow under the Telegraph Pass Canal 42" pipe. The grading and drainage plan for the subdivision calls out four 36" pipes under the canal but three were constructed. The inlet to the 3 – 36" storm drain has a large sloping trash / debris rack.

Like many storm drain and culvert inlets in this area during the monsoon storms, debris clogging was a factor affecting inlet performance, especially where there was a trash / debris rack or access barrier. During the monsoon storms, flow backed up at the 3 – 36" storm drain inlet and spilled north and west out of the channel.

A portion of the overflow collapsed about a 10 foot wide panel section of the Southern Highlands perimeter block fence north of the 3 – 36" storm drain inlet. When the fence collapsed, overland flow entered the drainage easement and joined the flow downstream at the outlet of the 3 – 36' storm drain. The combined flow goes north to the outfall point at the Citrus Mountain subdivision mentioned previously.



Photos 26 - 29 – Inlet to 3-36" storm drain under SRP Telegraph Pass Canal near southwest corner of Southern Highlands looking north (top right photo); collapsed panel of perimeter block fence looking north (middle left); outlet of 3-36" storm drain looking north (middle right); and outlet of 3-36" storm drain looking south (bottom left). Photos taken September 8, 2014.

The drainage channel between Southern Highlands and Citrus Mountain is situated in 'Tract J' of the Southern Highlands plat. Tract J is a drainage / multi-use easement that is roughly 50 feet wide.

The extent of flooding within the Southern Highlands Subdivision during the 2014 monsoon storms is depicted in the Entellus study titled *"South Phoenix / Laveen Stormwater Infrastructure Evaluation Report*" mentioned in Section 1.3 of this report.

3.3.2 Hydrology

Discharges and volumes for Southern Highlands from the SP/LDIP Addendum regional HEC-1 model have been included in various parts of this section. There was no additional breakdown of regional sub-basins or additional concentration points or any attempt to evaluate flow splits or other hydrologic / hydraulic phenomenon that happened during the monsoon storms of 2014.

The regional hydrology HEC-1 sub-basin that includes Southern Highlands had been updated in 2013 for the SP/LDIP Addendum to reflect development that had occurred since around 2000. For the 2013 update, most but not all of Southern Highlands was included in (then new) HEC-1 sub-basin DR27CS.

The volume of onsite retention basins within Southern Highlands was estimated and modeled differently than the level pool routing step described in Citrus Mountain Section 3.2. This was mainly because there was no new topography available for Southern Highlands as had been the case for the north portion of Citrus Mountain. But even if there were new topography, there were a total of 11 retention basins in Southern Highlands, some of which had multiple parts. This would have involved a level of complexity beyond that typically applied in regional modeling.

The 2013 HEC-1 update therefore used the standard 80% of the total volume required by City of Phoenix development standards estimated based on land use and runoff coefficients. Then, the estimated volume was simply subtracted from the hydrograph for the sub-basin where the subdivision is located using the standard volume-divert step approach. Since the offsite flow entering Southern Highlands from the east passes through the majority of the onsite retention basins, onsite and offsite hydrographs were combined first, then the estimated 80% volume was subtracted from the combined hydrograph.

The combined total volume of all the retention basins found within Southern Highlands for the volume-divert step in HEC-1 was estimated at 6 acre-feet for the 2013 regional hydrology update. The estimated total volume of offsite runoff from east of Southern Highlands plus onsite runoff from within the subdivision (sub-basins WC2.1A + WC2A + DR27CS) is around 22 acre-feet.

3.4 Talasera Subdivision

3.4.1 Description

Talasera is a medium / low density gated residential subdivision located southeast of 19th Avenue and Olney Drive within the City of Phoenix' incorporated limit. The subdivision consists of 118 lots on around 100 acres. There are significant open space / drainage tracts corresponding to offsite washes that run through the subdivision. Drainage is generally from south to north. Talasera is bounded on the south and the east by portions of the Phoenix South Mountain Park which is the primary source of offsite drainage contributing to the subdivision. The location, vicinity and layout of the subdivision, including street names, is illustrated on Figure 3.4.1 on the following page.

The subdivision was platted in 2002. A partial as-built grading and drainage plan for the subdivision was provided by City of Phoenix consultant Entellus, Inc. The partial as-built is dated 2004. Entellus also provided a partial paving plan as-built for Talasera. These partial as-built plans are included in the data collection report and deliverables for this project. There was no drainage report provided for the subdivision to go along with the partial as-built grading and drainage plan and paving plan.

Offsite washes running through Talasera are typically very well defined. They range in depth from around 5 feet to over 10 feet. Some of the culverts under roadways at the various wash crossings have trash rack / access barriers and some do not. There does not appear to be any onsite stormwater retention or detention designed into the subdivision improvements. There may be some transient peak flow attenuation that occurs at the various culvert locations from temporary in-channel storage that would occur if flow backs up at the culverts.

Photos 30 and 31 – Inlet of 2 - 30" concrete pipe culvert under 17th Drive (left) and wash downstream from 17th Drive (right photo looking downstream)

Figure 3.4.1 – Talasera Subdivision aerial view

Talasera is a gated community with private interior streets as opposed to public right-of-way and public improvements. Therefore, maintenance and repairs of roadway improvements in Talasera are the primary responsibility of the Talasera Property Owners Association.

The extent of flooding within the Talasera Subdivision during the 2014 monsoon storms is depicted in the Entellus study titled *"South Phoenix / Laveen Stormwater Infrastructure Evaluation Report*" mentioned in Section 1.3 of this report.

3.4.2 Hydrology

Stanley analyzed the hydrology of the two offsite washes / culvert locations within Talasera at Capistrano Boulevard between 15th Drive and 16th Avenue mentioned previously. The western-most of these two locations consists of 2-36" concrete culvert pipe barrels. The other (eastern) location consists of a single 36" concrete culvert pipe.

Both locations have CMU headwalls / wing walls on both the upstream and downstream sides of Capistrano. Both of these culverts have top hinges for trash racks / access barriers at the culvert inlets but not the racks / barriers themselves.

Photos 32 and 33 – Inlet ends of culverts under Capistrano Drive between 15th Drive and 16th Avenue; double 36" culvert (left) and single 36" culvert (right)

The two concentration points analyzed are located within SP/LDIP Addendum regional HEC-1 sub-basin DRW2C. The DRW2C sub-basin has a total area of 0.53 square miles at its downstream concentration point at Dobbins Road. The 100-year, 24-hour peak flow for this sub-basin according to the regional HEC-1 model is 401 cfs. The upstream limit of the sub-basin originates within the South Mountain Park Preserve. Upstream from Talasera, the sub-basin is comprised mainly of undeveloped upland desert.

Two new sub-basins were delineated within the DRW2C sub-basin. The area contributing to the western-most wash crossing at Capistrano Boulevard is 0.06 square miles and the area contributing to the eastern crossing is 0.03 square miles. Soil parameters from the overall sub-basin were updated corresponding to the new smaller sub-basins. The percent impervious was kept the same as was used for the original DRW2C sub-basin. The times of concentration were also updated for the new smaller sub-basins.

The 100-year peak flow estimated by the HEC-1 model was 62 cfs for the western-most (2-36") crossing and 36 cfs for the eastern (single 36") crossing. The grading and drainage partial as-built plan prepared for Talasera includes discharges for many of the offsite washes, presumably from the subdivision drainage report. A 100-year flow of 30 cfs is noted on the grading and drainage as-built for the western-most wash crossing and 82 cfs is noted for the eastern crossing. Figure 3.4 on the next page illustrates the offsite drainage area for Talasera.

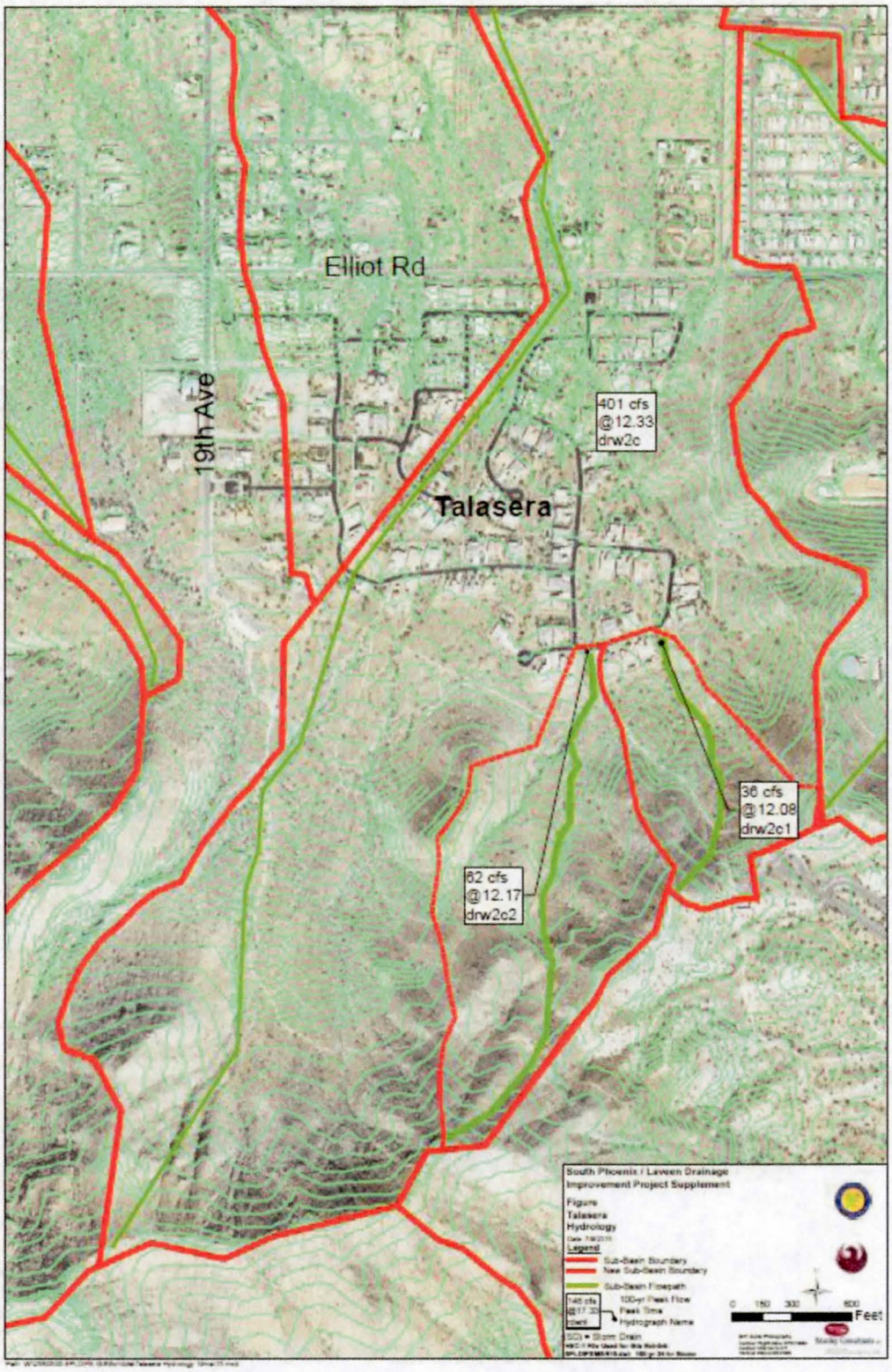


Figure 3.4.2 – Offsite contributing drainage area to Talasera Subdivision

One observation worth noting is the 100-year discharge labeled on the Talasera grading and drainage as-built for the large wash crossing Olney Drive with the 3-barrel 8' x 4' concrete box culvert just west of 16th Avenue is 704 cfs. This is significantly greater than the 401 cfs from the regional HEC-1 model for all of sub-basin DRW2C at Dobbins Road where the drainage area is roughly double what it is at Olney.

Photo 34 – Inlet end of 3 - 8' x 4' concrete box culvert under Olney Drive just west of 16th Ave

There are currently no future regional drainage improvements recommended in the SP/LDIP Addendum upstream from the Talasera subdivision. As it stands now, therefore, there would be no reduction in offsite drainage for this subdivision in the future. Since virtually all of the offsite drainage area to the subdivision is within the Phoenix South Mountain Park and will not be developed or improved, the future land use condition hydrology in the regional HEC-1 model is essentially the same as the existing condition.

3.5 Humane Society

3.5.1 Description

The Arizona Humane Society facility is located on just less than19 acres at the southwest corner of Dobbins and 15th Avenue. It was originally constructed in the early 2000's. The location is subject to significant offsite runoff from the south and southeast. Runoff from a storm of unknown size entered the property sometime after it was developed and buildings were flooded. Retrofit drainage improvements were constructed in 2012 to address the offsite drainage problem. These improvements included perimeter channels to intercept and convey offsite drainage along the south, east and north sides of the facility.

The channel improvements were constructed by the City of Phoenix and FCDMC as part of the Small Project Assistance Program (SPAP). There is an earth channel along the south side of the facility that intercepts drainage from the south and directs it east toward 15th Avenue. The south channel outfalls to a riprap lined channel along the west side of 15th Avenue. The 15th Avenue channel also intercepts flow from the southeast and conveys the combined flow north toward Dobbins Road. At Dobbins Road, flow turns west and is conveyed in another riprap lined channel along the south side of Dobbins. There are two driveway crossings for the Humane Society on Dobbins Road, each with a multi-barrel box culvert for the channel flows. The channel along Dobbins Road has a daylight outfall to the shoulder of the road at the northwest corner of the Humane Society facility.

A drainage report dated revised January 2001 was found for the original Humane Society site development improvements but there was no drainage report or improvement plans found for the 2012 SPAP channel improvements. The original 2001 drainage report is included in the data collection report and deliverables for the South Phoenix Two Basins Project.

The perimeter channels constructed in 2012 generally appear to have provided the intended flood protection for the Humane Society during the monsoon storms of 2014. There was some minor erosion and movement of some of the riprap lining from the monsoon storm flows, mainly in the 15th Avenue channel. But none of the perimeter offsite channels appear to have been overtopped during the 2014 storms.

The upstream reach of the channel along 15th Avenue, approximately 300 feet in length, is trapezoidal in section and lined with riprap on its sides and bottom. The downstream reach of the 15th Avenue channel, about 900 feet in length, is lined with riprap on its bottom and east side slope along 15th Avenue but is side-boarded along its west side by a vertical CMU retaining wall / flood wall approximately 4 to 4.5 feet in height above the channel bottom. There are vertical expansion joints in the CMU retaining wall / flood wall at a more or less uniform spacing of around 20 feet. The gaps in the wall at these expansions joints are typically around ½ inch wide. There are also weep holes around 2 inches in diameter at the base of the CMU wall at a uniform spacing of around 4 feet.

During the 2014 storms, a small portion of flow conveyed in the 15th Avenue channel passed thru the open expansion joint gaps and through some of the weep holes and collected on the outboard side of the wall.

Photos 35 and 36 – 15th Avenue channel looking south (upstream) from Dobbins Road (top photo) and back side of flood wall / retaining wall adjacent to Humane Society structures showing erosion from leakage through weep holes and expansion joints (lower photo).

3.5.2 Hydrology

Hydrology and hydraulics for the 15th Avenue channel is described previously in this report in Section 2 – Comparison of Regional and 2014 Storm Hydrology. The discharge for the channel from the SP/LDIP Addendum regional design model is about 440 cfs. That hydrology assumes future land use conditions are present in the watershed and also that the future recommended regional drainage infrastructure is in place. There was a flow rate of about 550 cfs for the 15th Avenue channel estimated using a partial existing condition HEC-1 model that incorporated rainfall record from the August 12, 2014 monsoon storm. Based on preliminary hydraulic analysis for the channel, it carried a flow of between about 750 – 1,000 cfs during the August 12, 2014 storm. The future extension of the regional storm drain in 7th Avenue as recommended in the SP/LDIP Addendum will reduce offsite flows reaching the 15th Avenue Channel, but this will probably be only a moderate reduction.

3.6 Fire Station No. 57

3.6.1 Description

City of Phoenix Fire Station No. 57 is situated on roughly two acres on the north side of Dobbins Road between the 15th Avenue alignment and the Western Canal. The site was developed sometime around 2006 – 2007. The project team arranged a meeting on March 26, 2015 with representatives of the Phoenix Fire Department who were familiar with the 2014 monsoon storms and the flooding that occurred at this location. An onsite grading and drainage plan and an offsite roadway improvement plan were provided by fire department staff. However, there was no drainage report on file that went with the improvement plans. Fire department staff also provided photos and video of flooding at and near the fire station. The improvement plans, photos and video are included in the data collection report for this project.

The property to the north, east and west of the fire station is owned by the City of Phoenix. It had been purchased some years ago by the City for a future water treatment facility. The City's property to the north and east of the fire station is currently leased to an agricultural business operation. The City's property to the west is currently a vacant dirt lot and is sometimes used as a parking lot for public meetings that have been held at the fire station's conference room. During the 2014 monsoon storms, this lot was used as a distribution center for sand and sandbags made available by the City of Phoenix to area residents.

Dobbins Road adjacent to the fire station is a paved two-lane arterial road with left turn lanes at significant intersections. Dobbins Road in this area typically has gravel shoulders and no curb, gutter or sidewalk except where improvements have recently been constructed. The fire station improvements included 6" vertical curb, concrete driveways, sidewalk and an equestrian path along its Dobbins Road frontage. Across the street from the fire station is an open Salt River Project irrigation ditch running along the south shoulder of the road and a large vacant residential parcel to the south of that.

Fire Station No. 57 was partly flooded during the August 12, 2014 monsoon storm. Flow in Dobbins Road entered the eastern-most of the two fire station driveways and began filling the retention basin along the east and north sides of the station's rear yard, driveway and parking area. This area is enclosed by a six foot high block fence and has a six foot high rolling security gate across the driveway on the station's east side yard. Per the original fire station design, there was a small drainage opening under the block fence in the northwest corner of the station's rear yard. This opening served as an outlet for the station's rear yard retention basin. Flow passing through the drainage opening goes into another retention basin at the northwest corner of the fire station site, outside of the fenced rear yard area.

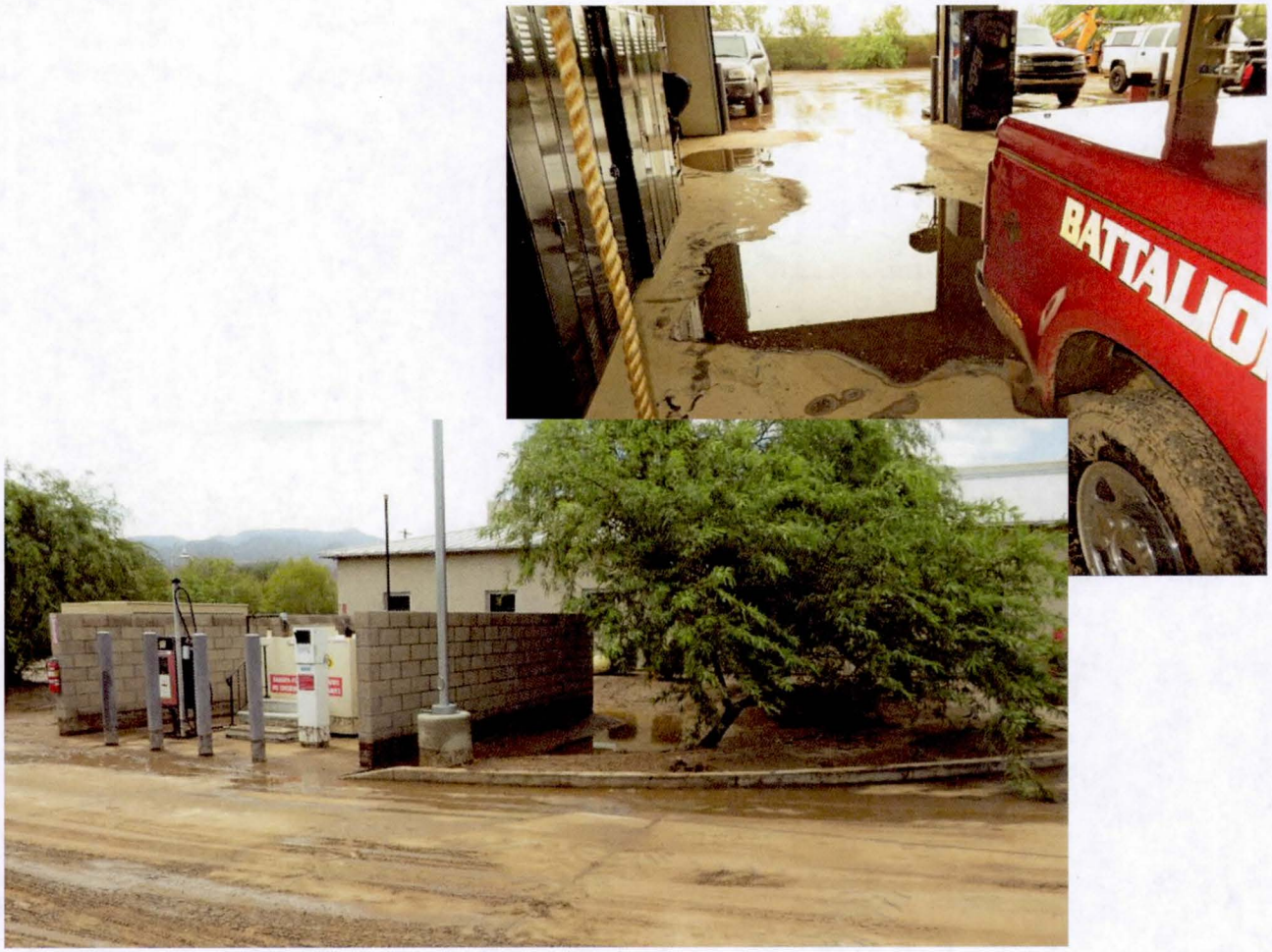
When offsite flow from Dobbins Road entered the fire station's rear yard via the east driveway during the August 8, 2014 storm, it filled the retention basin there rather quickly. The combination of onsite and offsite runoff was also too much for the original drainage outlet opening under the block fence. The combined onsite and offsite runoff backed up and rose in the basin, then began to flood the adjacent parking area and driveway. After a short time, water reached a stage where it entered the fire station and flooded the building.

During the September 8th storm, firefighters broke holes in the rear yard block fence to let more water out, which helped limit the high water during that storm. The drainage opening now has a large permanent lockable steel grate which hinges along its top edge. The grate can be unlocked so it can swing free when there is a large offsite runoff event. Water is thus able to

move through the rear yard, exit to the basin at the northwest corner of the fire station site, and back out onto Dobbins Road.

Photos 37, 38 and 39 – Fire Station 57 rear yard block fence drainage opening after flood of August 12, 2014 (top photo); after flood of September 8, 2014 (middle); and new permanent lockable steel swing grate (lower photo)

It does not appear that the water surface in Dobbins Road reached a high enough stage to enter the station building directly from the front, only from the rear as described above, then exited out the front, returning to Dobbins Road. Water may have come part way into the site from Dobbins Road at the west driveway but that does not appear to have contributed to flooding in the building.



Photos 40 and 41 – Fire Station 57 truck bay (top) and rear yard area (bottom) with mud on driveway and high water mark on wall after flood of August 12, 2014

3.6.2 Hydrology

Dobbins Road adjacent to Fire Station No. 57 is a major regional drainage corridor. The 100-year, 24-hour peak flow at this location according to the recommended alternative HEC-1 model is about 740 cfs. Only a portion of the flow in Dobbins Road enters the fire station site through the east driveway. The project team did not perform any hydrologic or hydraulic analysis to estimate how much flow entered the fire station site at the east driveway or analyze any routing of this flow as it passed through the fire station. The future storm drain and detention basin improvements in the offsite area as recommended by the SP/LDIP Addendum will provide a moderate reduction of offsite flows reaching Dobbins Road at Fire Station 57. Future additional conveyance and regional detention on the south side of Dobbins Road will also improve flooding conditions along Dobbins Road.

3.7 South Mountain Regional Park Access Roads

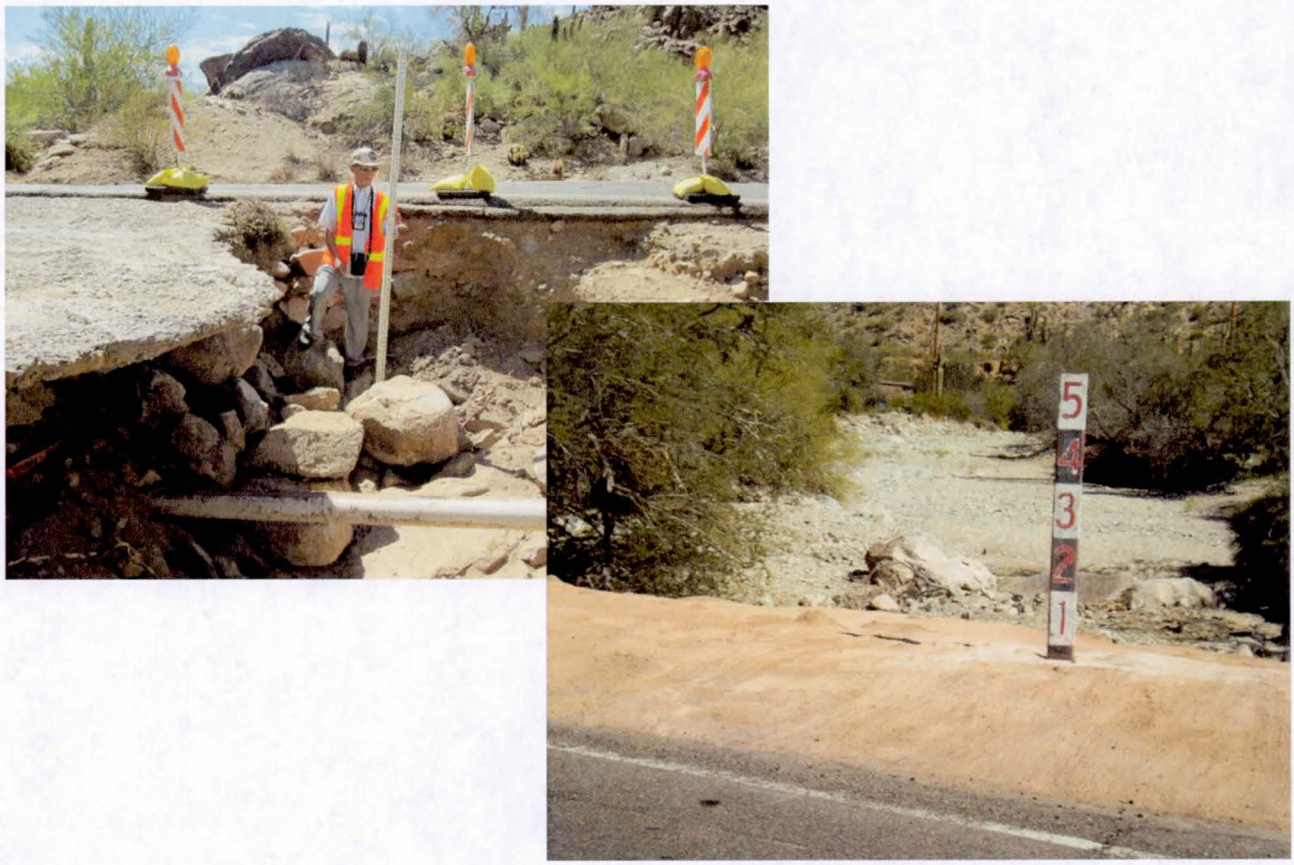
3.7.1 Description

This location was included because of extensive erosion and deposition of soil, rock and debris on and near the access roadways within the park. Damage and deposition occurred to South Central Avenue about three quarters of a mile southwest of the park ranger station where there is a very large wash crossing. Erosion and deposition also occurred at a number of smaller wash crossings beyond that along South Central and East San Juan Road. A few local but very steep washes deposited significant rock, mud and debris on Summit Road where they cross as the road ascends out of the central valley.

A few of the larger washes have culverts that convey a portion of the flow under the road but most wash crossings have either no culvert or a small culvert and hence, a very large surface or dip crossing component. There are a few locations where roadside ditches are situated just off the edge of pavement and caused erosion damage to the adjacent road or deposition of coarse sediment.

Photos 42 and 43 – South Mountain Park Summit Road rock slides during / after cleanup.
Photo upper-left is courtesy ABC15 news.

Both Summit Road and East San Juan Road were closed for months while cleaning and repairs were being done by the City of Phoenix. Summit Road was re-opened in March of 2015. At that point in time, significant repairs to culverts, headwalls, dip crossings and cutoff walls had been made. Similar repairs have also been made along East San Juan Road. Park staff indicated that the ranger station office had local runoff enter the building from the hill slope behind it. Staff simply opened the front door and let the water run through. Cleanup was relatively minor.



Photos 44 and 45 – South Mountain Park Central Avenue wash crossings before / after repair

3.7.2 Hydrology

There are two drainage sub-basins in the regional HEC-1 model that comprise the total contributing area from within the South Mountain Regional Park. These sub-basins are large and together they total 4.24 square miles. There are no concentration points in the regional HEC-1 model that would correspond to any of the locations where park access roads were damaged. Regional 100-year hydrology would not typically be a direct basis for design of any remediation for this type of infrastructure. Repairs and cleanup performed by the City of Phoenix seem to have addressed the drainage issues created by the 2014 monsoon storms. Therefore, no additional hydrologic analysis has been performed for this location. There are currently no future regional storm drain or detention basin improvements recommended as part of the SP/LDIP Addendum that would reduce offsite flows reaching any of the South Mountain Park access roads.

3.8 Cheyenne Drive near 29th Avenue Alignment

3.8.1 Description

Cheyenne Drive runs east – west about a mile and a quarter south of Dobbins Road. It crosses very well defined washes draining northward from moderately steep slopes at the base of the Phoenix South Mountains. Near the 29th Avenue alignment, there is a significant wash that crosses Cheyenne Drive from southeast to northwest. Cheyenne Drive crosses the wash on fill with a multi-barrel culvert conveying the wash flows. During the monsoon storms of 2014, the culvert capacity was exceeded and water overtopped the road causing extensive damage to the roadway fill slope on the downstream (north) side of Cheyenne Drive. It is not believed that any residences at this location were flooded when this roadway overtopping occurred.

The wash at this location ranges in depth from around 6 feet to over 12 feet in places. The roadway profile is relatively flat in its longitudinal direction with the roadway grade being about even with the tops of the wash banks. There is no perceivable dip in the roadway profile over the culvert. Flow that overtopped the roadway went more-or-less straight over the road directly above the culvert, cascaded down the north fill embankment and re-joined the wash downstream. It is not known how deep the water was overtopping the road. Based on hydraulic analysis, geometry of the crossing and field judgement, the overflow may have been in the range of 6" – 12" at its deepest point. It is also not known if the culvert overtopping occurred during the August 12 or the September 8, 2014 storm, or both storms.

The culvert that conveys the wash flows under the road consists of 5-24" corrugated metal pipe barrels. It has a slight skew to the road, perhaps 10 – 15 degrees southeast to northwest. The culvert barrels are approximately 60' long with about 4.5 feet of fall from the inlet to the outlet. The culvert slope is hydraulically fairly steep. There is approximately 7 feet of available headwater at the culvert inlet before overtopping of Cheyenne Drive would occur. The culvert barrels are projecting from the roadway fill slope with no headwall on the inlet or outlet. There is no access barrier or debris grate on either the inlet or outlet end of the culvert barrels.

This area is just outside of (just north of) the Phoenix South Mountain Park Preserve. The area consists of both unincorporated Maricopa County and incorporated City of Phoenix. Much of this area appears to have been developed by splitting larger land parcels into smaller ones as opposed to development through the formal subdivision process. At this particular location, residential parcels appear to have been created via lot splits. Cheyenne Drive and the area north of it are in unincorporated Maricopa County. The parcels south of Cheyenne are within incorporated City of Phoenix jurisdiction. The property line between two adjacent parcels on the north side of Cheyenne Drive bisects the wash.

Roadways in this area generally exist as both public improvements in public right-of-way and private improvements in private right-of-way. Roadway maintenance is typically a private responsibility where there is no public right-of-way and a public responsibility where there is public right-of-way.

Cheyenne Drive provides access to low density residential parcels in this area. It is a two-lane paved surface with no curb and gutter. It is not known if the culvert and roadway were originally constructed as private or as public improvements. However, for the most part, the improvements appear to be situated on private property. Most likely, the road is within a private access easement on the parcels that extend north of the road in unincorporated Maricopa County. The residential parcel southeast of the culvert within incorporated City of Phoenix has

a 25' easement that was dedicated to the City. Although none of the Cheyenne roadway improvements appear to be located within the 25' easement, the easement's west limit bisects the inlet end of the culvert. Figure 3.8.1 below illustrates this location and its vicinity.

Figure 3.8.1 – Cheyenne Drive / 29th Avenue vicinity

According to accounts of the overtopping from local residents, the culvert inlet had become significantly clogged by debris swept down the wash channel from the watershed above. Most of the damage from the overtopping is in the form of erosion from water rushing down the relatively steep fill embankment on the north side of Cheyenne. The outlet ends of the culvert barrels near the base of the fill embankment were exposed and cantilevered several feet out over the wash bed. There also appears to have been erosion of the wash bed itself on the north side of Cheyenne which is around 12' – 14' lower than the roadway grade over the culvert. The erosion on the north side of Cheyenne cut back to the south and took out a portion of the roadway. The inlet end of the culvert does not appear to have been damaged, other than being partly silted.

Field reconnaissance was done a few months after the monsoon storms at this location. Culvert inlets were clogged about one third to one half with sediment and debris. Fill dirt and rubble had been dumped from the roadway down the fill embankment on the north side of Cheyenne to try and build the damaged grade back up. It did not appear that there was any compaction of this material and its slope was fairly steep. This work has been initiated by the property owners to the northwest of the culvert as the road is on private property. They had been in touch with both Maricopa County and with the City of Phoenix after the monsoon storms but there was nothing being done to repair the culvert and road, so they took it upon themselves to initiate the work.

Photos 46 and 47 –
Cheyenne Dr. Culvert near 29th Ave in December 2014. Outlet end looking east (top photo) and looking south (bottom photo).

Photo 48 – Cheyenne Drive culvert near 29th Ave inlet end (looking north)

3.8.2 Hydrology

The hydrologic concentration point corresponding to the culvert is located within sub-basin WC11A of the South Phoenix / Laveen regional HEC-1 model. The WC11A sub-basin has a total area of 0.29 sq. miles and a 100yr – 24hr peak flow of 295 cfs. The upstream limit of the sub-basin originates at the prominent north ridge line of the Phoenix South Mountain within the park preserve. There are a few large privately owned residences in the offsite contributing area to the culvert but for the most part, it is comprised of undeveloped upland desert.

The WC11A sub-basin was divided at Cheyenne Drive to create a new sub-basin corresponding to the culvert location. The area contributing to Cheyenne Drive is 0.24 square miles. Soil parameters were updated for the newly created sub-basin. The percent impervious was kept the same as it was used for the overall WC11A sub-basin. The time of concentration was also updated for the new sub-basin. The peak flow estimated by the HEC-1 model was 262 cfs for the 100yr – 24hr storm. There were no other return frequencies analyzed for the new concentration point. There was also no analysis of the hydrology using the rainfall records from the monsoon storm. That storm hydrology is something that could be considered but it is currently not in the scope for this project.

A hydraulic analysis for the culverts was done using CulvertMaster. The culverts have a capacity of 165 cfs with 7 feet of headwater. This assumes that the culverts are 100% open and clear and not obstructed by sediment or debris. Based on Table 6.1 from the FCDMC Drainage Design Manual for Maricopa County, Arizona Hydrology, the clear capacity of 165 cfs for the culvert would correspond to a little greater than a 10-year storm event. This would indicate a fairly normal and appropriate level of service for such a culvert, even under current design criteria. However, the debris and sediment clogging that can occur at the inlet of this culvert is obviously an issue that impacts its hydraulic performance. And the consequence of overtopping is significant to the steep, relatively unprotected roadway fill embankment on the downstream side.

There are currently no future regional drainage improvements recommended in the SP/LDIP Addendum upstream from the Cheyenne Drive at this location. As it stands, therefore, there will be no reduction in offsite drainage for this location in the future. Since virtually all of the offsite drainage area to the culvert at Cheyenne Drive is within the Phoenix South Mountain Park and will not be developed or improved, the future land use condition hydrology in the regional HEC-1 model is essentially the same as the existing condition. Figure 3.8.2 below illustrates the offsite contributing area for the Cheyenne Drive culvert near 29th Avenue.

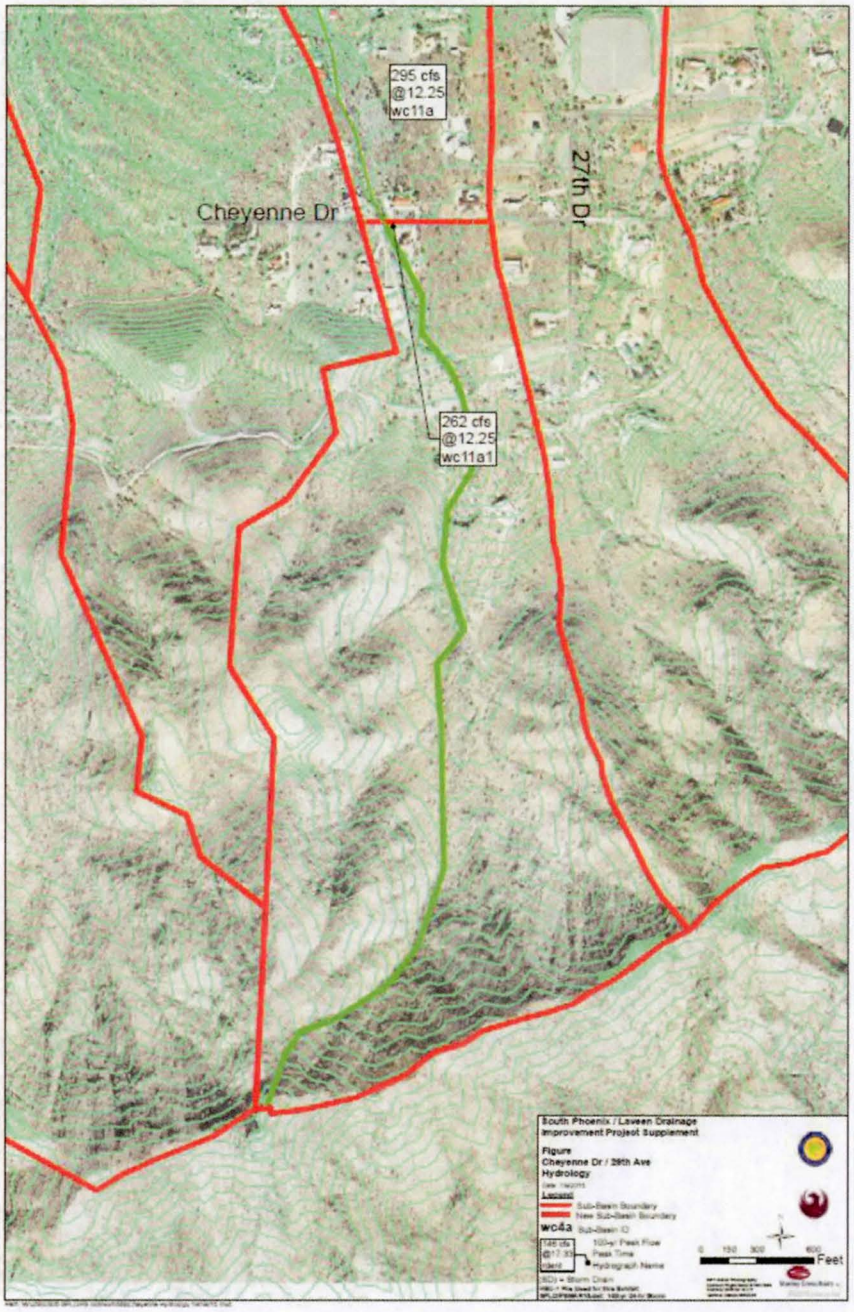


Figure 3.8.2 – Cheyenne Drive / 29th Avenue offsite drainage area

A field recon visit back to this site on September 2, 2015 showed that significant repairs have been made to the roadway fill slope on the downstream side of the culvert. The culvert inlet still has issues with silt and debris clogging. There had been a locally heavy rain / runoff event a few days earlier and it was evident from the high water mark and sediment on the roadway that the culvert had again backed up and the roadway was overtopped. But it appeared the repair work, although still perhaps not totally complete, had survived the event.

Photos 49, 50 and 51 – Cheyenne Drive culvert near 29th Ave on September 2, 2015. Inlet (upper left), roadway (middle) and outlet (lower).

3.9 West Beautiful Lane about 1,000 feet west of 29th Avenue

3.9.1 Description

West Beautiful Lane runs east - west about a block or so south of Baseline Road. The road is a little less than ¼ mile long from the intersection with 29th Avenue on its east end to where it dead-ends on the west. There are a total of 16 approximately one acre residential lots on West Beautiful Lane, 8 on the north side and 8 on the south side. Eleven of the lots have homes constructed on them including the ten western-most lots. Figure 3.9.1 below illustrates West Beautiful Lane and its vicinity.

Figure 3.9.1 – West Beautiful Lane vicinity

This area is in unincorporated Maricopa County. It is believed that the residential parcels were created by lot splits over the years as opposed to being subdivided. West Beautiful Lane is a private drive. It is a paved two-lane road with no curb and gutter. There is a 6-foot high rolling steel picket security gate at the midpoint of West Beautiful Lane separating the eight lots at the west end of the street from the eight lots at the east end. A small concrete lined irrigation canal is located along the west side of 29th Avenue with gates that discharge water to the west.

3.9.2 Hydrology

This location is within sub-basin BR35CW of the Recommended Alternative 6 regional HEC-1 model. There is no nearby concentration point in the regional HEC-1 model that corresponds to this location making it difficult to estimate what the future condition discharge would be. On the assumption that all the offsite area east of 27th Avenue and south of Dobbins Road is essentially controlled by future regional drainage infrastructure, the only offsite area contributing to West Beautiful Lane in the future would be the eastern portion of sub-basin BR35CW east of this location. Based on the unit discharge of flow from sub-basin BR35CW in the regional HEC-1 model and on unit discharges for other sub-basins in the Alternative 6 regional HEC-1 model of similar size and characteristic, the future flow rate would be in the range of 100 - 200 cfs.

Although this location will be significantly protected from flooding in the future, there was interest in estimating an existing condition discharge as the basis for considering a possible interim condition drainage protection for West Beautiful Lane. In other words, what alternatives could be considered to provide flood protection for this location in the interim until the future system was constructed.

Runoff originates from the southeast and approaches this location as overland and shallow concentrated flow. Several sub-basins within the HEC-1 model contribute runoff to West Beautiful Lane with the upstream limit of the watershed extending all the way up into South Mountain Park.

One way to approximate an existing condition flow rate at this location is to use the USGS StreamStats application to estimate the contributing watershed for West Beautiful Lane. Then, use an indirect method, such as a regional regression approach, to make a simple estimate of peak flow.

USGS StreamStats is a GIS based application that utilizes digital elevation data derived from the National Elevation Dataset (NED). The application has the ability to estimate 100-year flows in some states. At this time, however, Arizona is not included among those states. The total offsite contributing area per the StreamStats application is illustrated on Figure 3.9.2 on the next page.

The delineation produced a watershed that is approximately 7.4 square miles in total. The delineation was compared to the Recommended Alternative HEC-1 sub-basin delineation and found to be in reasonable agreement. It is important to note that the watershed delineation includes a regional detention basin within South Mountain Park that intercepts runoff from an area within the park that is approximately 4.25 square miles. The regional detention basin attenuates the peak flow from the contributing area to less than 100 cfs during the 100-year design storm.

Chapter 8 of the FCDMC Hydrology Manual provides three indirect methods for estimating 100-year peak flows. The drainage area used in the peak flow estimate for the three methods was

3.15 square miles which recognizes that the regional detention basin within South Mountain Park essentially attenuates all of the peak flow from the area above the basin.

The first method gives seven unit peak discharge curves versus watershed areas shown on Figure 8.1 of the Hydrology Manual. The watershed area produces a peak flow range of approximately 1,500 cfs to 8,000 cfs based on this method. The second indirect method uses USGS streamflow data for Arizona. Equation 8.1 of the Hydrology Manual produces a 100-year peak flow of 1,580 cfs. The third indirect method utilizes regional regression equations. The watershed is located within flood region 12. The 100-year peak discharge is approximately 2,500 cfs based on the regional regression method.

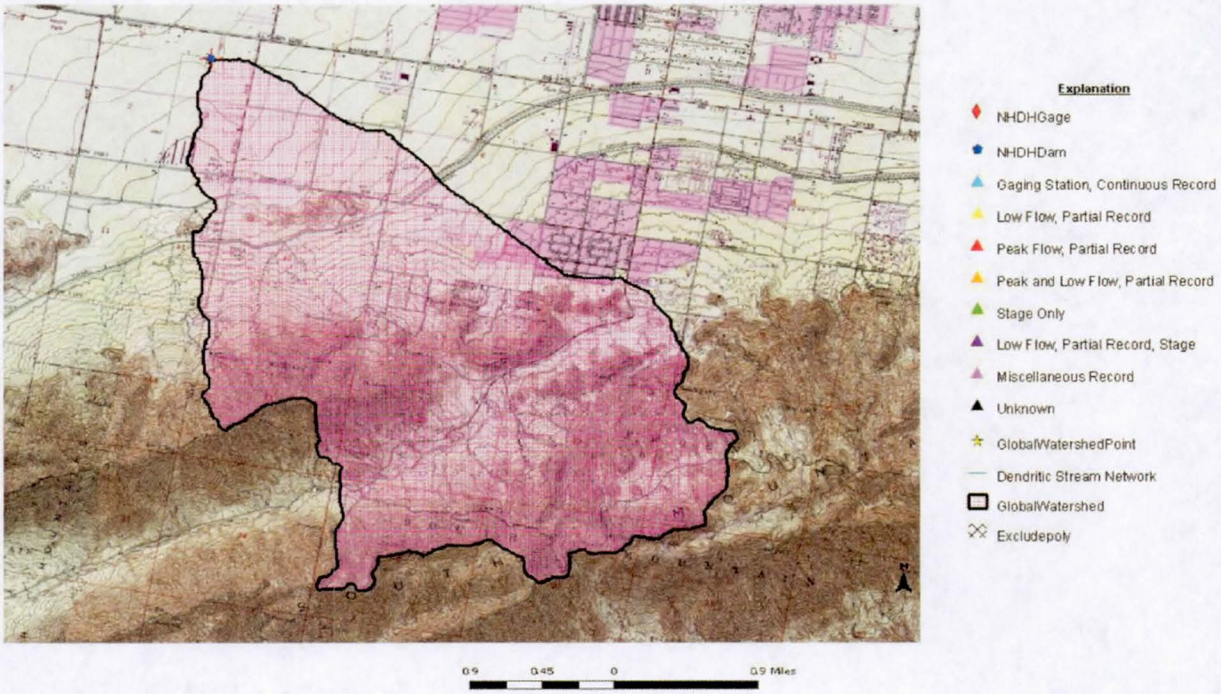


Figure 3.9.2 – West Beautiful Lane StreamStats existing condition drainage area

During the design phase of the regional detention basin at 27th Avenue and South Mountain Avenue Stanley prepared a partial existing conditions HEC-1 model to estimate flows reaching the basin along South Mountain Avenue. The model had a total watershed area of almost 6.9 square miles at its downstream limit and incorporated the outfall discharge from the regional detention basin in South Mountain Park. This model produced a 100-year peak discharge of approximately 1,500 cfs at a concentration point near 27th Avenue and South Mountain Avenue. The area of this model is comparable to the watershed for West Beautiful Lane and provides a reasonable estimate of the peak for this location with results that are in part comparable to indirect methods in Chapter 8 of the FCDMC Hydrology Manual.

One of the initial interim flood protection alternatives considered at this location involved constructing a detention basin on the three vacant lots on the south side of West Beautiful Lane just west of 29th Avenue. The combined area of the three lots is approximately 3.3 acres. A basin utilizing the entire area of the three parcels could store a volume of approximately 12 acre-feet.

The partial existing condition HEC-1 model prepared for the 27th Avenue and South Mountain Avenue basin design produced a total 100-year runoff of 442 acre feet. Therefore, on the basis of volume alone, a basin at this location would provide only minimal benefit in a 100-year event. The volumes of more frequent storms like a 10-year event would also be significantly greater than the 12 acre-foot volume that could be provided on the three vacant lots.

In addition to the basin itself, additional infrastructure such as a storm drain system would be necessary to collect runoff and direct it to the basin as well as additional storm drain to discharge flow from the basin. The required infrastructure and land acquisition costs plus the minimal benefit the basin would provide make the cost, viability and benefit of this basin concept an unlikely alternative.

There are other vacant parcels to the south of West Beautiful Lane which could potentially be considered for the same detention basin concept. However, their size and potential volume along with similar need for collection and outfall storm drain infrastructure would put the cost, viability and benefit on par with the three vacant parcels at the southwest corner of West Beautiful Lane and 29th Avenue.