Lee Moore Wash Basin Management Study - Hydrology and Hydraulic Report
TECHNICAL APPENDICES

December, 2008

Stantec Project No.: 185120071-550

Stantec

Registered Professional Engineer (Civil)
CERTIFICATE NO.
16738
JOHN S.
WISE
Date Signed 5/28/09
ARIZONA, U.S.A.

Expires 12/31/2010

Registered Professional Engineer (Civil)
CERTIFICATE NO.
41207
JOHN B.
PARTRIDGE
Date Signed 5-28-09
ARIZONA U.S.A.

EXPIRES 09/30/2010

Lee Moore Wash Basin Management Study

Hydrology and Hydraulic Report – TECHNICAL APPENDICES

Table of Contents

LIST OF FIGURES (CD)

Registered Professional Engineer (Civil)
CERTIFICATE NO.
16738
JOHN S. WISE
Date Signed 5/29/09
ARIZONA, U.S.A.

Expires 12/31/2010

Registered Professional Engineer (Civil)
CERTIFICATE NO
41207
JOHN B. PARTRIDGE
Date Signed 5-28-09
ARIZONA U.S.A.

EXPIRES 09/30/2010

APPENDIX A
GENERAL PROJECT PARAMETERS

TYPICAL RUNOFF CURVE NUMBERS (RCN)

Cover Type	Hydrologic Soil Type		
	B (includes A soils)	C	D
Cover Density - Assumed 20% average below elevation 4000 All scrub/brush assumed as desert brush below elevation 4000 feet			
Desert Brush	83	88	91
Herbaceous	79	86	91
Urban lawn	79	86	90
Cover Density - Assumed 30% average above elevation 4000 Scrub/brush assumed as mountain brush except those specifically noted as desert species			
Pinyon-Juniper	68	80	89
Mountain Brush	72	81	89
Desert Brush	82	87	90
Herbaceous	76	84	90
Urban lawn	79	86	90

Curve Numbers taken from "Hydrology Manual for Engineering Design and Floodplain Management within Pima County, Arizona", September 1979

Note : Curve Numbers are not adjusted for the "caliche effect"

TYPICAL MANNING'S "n" VALUES

Watercourse Description	Mannings "n" Value	Comment/Source/Description
Time of Concentration Calculations		
Overland Flow		
Mountain Foothill Valley	0.4 0.3 0.15	TR-55, HEC-1 - Dense Shrubbery/Forest Litter HEC-1 - poor grass cover on moderately rough surface TR55/HEC-1 - Short Grass Prairie
Channel (bankfull low-flow channel)		
Upper mountain reaches	0.06	Aldridge - Ref #14 - random boulders/gravel-cobble bed, irregular bedrock banks, sinuous channel
Upper foothills (Note - sinuous nature)	.045-.05	Aldridge - Ref #9/10 - sand/gravel/cobble bed, some boulders/bedrock outcrops, channel bed vegetation
Ill-defined, multiple small channels	.04-.045	Aldridge - Ref 9
Little to no channel significant vegetation	0.05	TSMS - Collector Channel Standard Roughness Coefficients
Sand/gravel low-flow channel - n- f(veg)	0.035-04	TSMS, Aldridge Ref 5,6 & 8
Clean straight earth channel - little veg	0.03	TSMS - Improved channels
Channel Routing Modeling (Floodplain modeling as well)		
Bank to bank full-flow channel		
Defined low-flowchannel, well-vegetated banks/bars	0.045	Aldridge - Ref 6 &9
Multiple channel braids, vegetated bars	0.045	Aldridge - Ref 6 &9
Well-defined sand/gravel bed sparse channel/bank veg	0.035	TSMS, Aldridge Ref 5,6 & 8
Little to no channel significant vegetation	0.05	TSMS - Collector Channel Standard Roughness Coefficients
Natural overbanks, f(vegetation cover)	.04-045	
Developed overbanks low-density development	0.07	

Aldridge reference - Table 5 - Typical roughness coefficients assigned for several types of Arizona stream channels

stantec.com

Memo

Stantec

To:	Bill Zimmerman Pima County RFCD	From:	Sandy Steichen Stantec Consulting
File:	185120071-250	Date:	October 4, 2006

Reference: Lee Moore Watershed
HEC-HMS Modeling

The following summarizes the agreed parameter selection for HMS modeling based on our meetings of September 18 and October 4, 2006.

Rainfall Depth:	NOAA 14, Upper 90 percentile.
Rainfall Distribution:	TWMS 3-hour and SCS 24-hour Type I.
Design Storm:	Storm (3-hour or 24-hour) which produces the highest discharge.
Depth-Area Reduction:	Pima County methodology.
Rainfall Losses:	SCS Curve Number method utilizing Pima County Curve Numbers (no adjustments).
Runoff Transformation:	SCS Unit Hydrograph utilizing SCS Segmental Approach for Time of Concentration computation (as defined in TR-55).
Runoff Translation:	Modified Puls eight-point cross-section or normal depth routing. Currently HEC-HMS does not offer this option for channel routing. The City of Tucson will provide Stantec a program to aid in the conversion of the Modified Puls methodology from HEC-1 to HEC-HMS.

STANTEC CONSULTING INC.

Sandra Steichen
Senior Hydrologist
ssteichen@stantec.com

c. Joaquin Solis -City of Tucson
Frank Sousa -City of Tucson
Jane Duarte -City of Tucson
John Wallace – JE Fuller
John Partridge -Stantec
John Wise -Stantec

stantec.com

Memo

Stantec

To:	Bill Zimmerman Pima County Regional Flood Control District	From:	John Partridge, PE Tucson, AZ
File:	185120071	Date:	October 25, 2006

Reference: Lee Moore Watershed Study – Time of Concentration Calculations

As per numerous discussions, it has been decided that the time of concentration calculations for the HEC-HMS modeling of the Lee Moore study will utilize the SCS Segmental approach to develop the Tc parameters, with the lag equation (T(lag) = 0.6 Tc) employed to develop the SCS unit hydrograph. The SCS segmental approach employs the three basic factions of surface flow to assess the watershed timing of an individual subarea: overland flow, shallow concentrated flow and channel flow. Given the overall size of the study area and the number of subareas that will be employed in the modeling efforts, along with the nature of the study, it has been agreed that the recommended approach to developing time of concentration computations is to develop a systematic, consistent set of parameters to be utilized that are anticipated to yield practical and reasonable results that will differentiate watershed timing based on the overall shape of the watershed and existing drainage evolution of the channel system. Since evaluation of the study area reveals that the majority of watershed areas can be characterized as long, linear features, the flow time within the channel system will be the predominant element that affects the peak timing of the drainage area, and ultimately the time of concentration. Thus, the initial two components of the Segmental Tc approach, overland flow and shallow concentrated flow, will have less impact on the watershed timing than drainage areas with shapes that exhibit greater contributory areas within their headwaters. With that in mind, and given the topographical constraints of attempting to estimate the concentration of flows on the order of 0.1 foot (overland flow) up to perhaps several inches (shallow concentrated), the most prudent approach to estimating these flow lengths is to consider a practical, average value that is employed for all watershed areas, thus providing a consistent, replicable approach. Based on our discussion and concurrence, the approach to be employed with the subject study is outlined for your reference in the following paragraphs.

Available literature generally considers overland flow lengths in natural watersheds to typically range from 100 feet to a maximum of 300 feet. There are a considerable number of these references that argue that overland flow lengths in excess of 100 feet are an exception, and as noted in our meeting, the new windows version of the SCS TR-55 program (WinTR55) limits the overland flow component to 100 feet. Thus, it was agreed that all overland flow lengths for the Lee Moore study will be estimated as 100 feet. The remaining factors that will vary, depending on watershed location and land cover, will be the Manning's "n" value and the 2-year 24-hour precipitation value. The precipitation value will be based on the overall watershed (Franco, Flato, etc.) NOAA 14 24-hour rainfall depth employed for the HEC-HMS modeling efforts. The roughness coefficients will range from 0.4 in the upland mountains to 0.15 within the valley areas. These values correspond to the coefficients recommended in the HEC-1/HEC-HMS technical references for dense shrubbery/forest litter to an average value of sparse rangeland (20% cover) and/or short prairie grass, respectively.

Shallow concentrated flow is generally considered to occur at the point that overland flow ceases to be shallow sheetflow, and runoff becomes concentrated in shallow rills and gullies across the surface until flow becomes more defined and coalesces into channels. It is often defined as the length between overland flow in the extreme headwaters until a blue line is displayed on a USGS map, but this may often be a few to several thousand feet. Velocities of shallow concentrated flow are minimal on gentle slopes, and overestimation of the length can lead to an excessive watershed time of concentration. The shallow concentrated flow lengths for the Lee Moore study will be estimated by reviewing the available 2-foot contours in conjunction with aerial photography, and it will be assumed that channel flow is initiated when a few to several shallow swales combine together. In the absence of a well-defined confluence of shallow concentrated flow paths, a maximum of 2000-3000 feet will be employed to limit the flow path. As we discussed at our meeting, a flow length of this magnitude may have +/-20 acres tributary to the flow path at this point, and 100-year peak flows close to a regulatory 100 cfs may be conveyed along this flow path. Given this circumstance, it is anticipated that velocities and consequent travel time would be more representative of channel conditions than shallow concentrated flow.

Upon initiation of channel flow, representative channel reaches will be determined on the basis of apparent channel geometry and/or slopes, and the bankfull channel geometry will be estimated from the available 2-foot contour data. The travel time along these reaches will be estimated using the standard Manning's equation to determine average velocity and channel length. The Manning's "n" values that will be employed with these calculations will be consistent with standard values employed in southwest Arizona and the City of Tucson TWMS modeling, with an "n" value of 0.035 employed for well-defined channels with sandy beds, and a roughness coefficient of 0.05 for well-vegetated swale/channel corridors with little channel bed definition. A roughness coefficient of 0.06 will be used for channels within the mountain headwaters to account for vegetation and a larger distribution of the bed load consisting of cobble and boulder sized material.

The time of concentration will be the summation of the travel times estimated using the above-noted procedures, and will be used to determine the lag time within the HEC-HMS modeling efforts. One further note that should be made to support the discussion presented above, and as we briefly discussed, is that a sensitivity analysis was performed on a watershed within the Franco Wash watershed to evaluate the impact of employing variations of the overland flow length within the initial 4000 feet of the flow path. The lag time for the watershed assuming a 100 foot overland flow path and 3800 foot shallow concentrated flow path was modeled in the HEC-HMS, and compared to a model run assuming the overland flow path was 300 feet and the shallow concentrated flow path reduced by 200 feet. Based on this analysis, the difference in the 100-year peak flow varied from 551 cfs (300 feet) to 598 cfs (100 feet), or a variation of about 8%. If the shallow concentrated flow was limited to 2000 or 3000 feet, this variation would be even less, and indicates the nominal impact that variations in the initial two components of surface flow may have on the overall peak flows for the study.

STANTEC CONSULTING INC.

John B. Partridge, P.E.
Senior Hydrologist
jpartridge@stantec.com

stantec.com

Memo

Stantec

To:	Bill Zimmerman Pima County Regional Flood Control District	From:	John Partridge, PE Tucson, AZ
File:	185120071	Date:	December 22, 2006

Reference: Lee Moore Watershed Study – Modified Puls Channel Routing Subreach Discussion

The HEC-HMS modeling efforts for the Franco and Flato watersheds has employed the use of the Modified Puls channel routing method, also known as storage routing or level pool routing. The initial modeling efforts have been performed utilizing the standard criteria noted in the U.S Army Corps of Engineers Technical Reference Manual for the Hydrologic Modeling System HEC-HMS (March 2000). These procedures recommend that main channel routing reaches be subdivided into an estimated number of subreaches based on the channel velocity, and is computed by dividing the total reach length (L) by the product of the average channel velocity and the modeling time step. The goal, as noted in the technical reference referenced above, is to divide the reach into a specific number of individual subreaches that will have a travel time that is approximately equal to the modeling time step, which in the case of the Lee Moore modeling efforts is six (6) minutes for the 24-hour storm event. It is also noted that the selection of the number of subreaches is a critical parameter, as it has significant impact on the attenuation of an inflow hydrograph through the routing reach. The selection of a single routing reach provides maximum attenuation, while increased time steps reduces the hydrograph attenuation.

Review of the modeling results corroborate these observations, with noticeable attenuation of peak flow hydrographs occurring along reaches utilizing only a few subreaches as defined bt the above-described procedures, while reaches with increased numbers of subreaches display limited attenuation effects. However, further scrutiny of the modeling efforts suggests that in certain instances, these results appear almost counter-intuitive, as reaches with significant channel and overbank storage tend to exhibit lower channel velocities, which consequentially result in an increased subreach parameter and decreased attenuation. In one specific case, a hydrograph with an estimated peak flow of 6533 cfs and 3974 ac-ft of runoff volume (J15) will flow through a routing reach (R0J15) that provides about 710 acre-feet of storage volume at the given discharge. While the reach provides storage representing up to 18% of the total inflow volume, the resultant peak discharge reduction is estimated as less than 2% (6414 cfs). Based on this apparent inconsistency in the channel routing technique, further research of the procedures noted above was performed, and revealed that the noted Technical

Reference manual suggests a single subreach is commonly used for routing through ponds and lakes, as well as wide, flat floodplains. Review of the three HEC-RAS sections employed to develop the storage-outflow characteristics for the above-referenced channel reach R0J15 reveals floodplain widths varying from 560 to 1400 feet with average hydraulic depths of 1.26 to 2.16 feet. Given these parameters, it is evident that this reach may best be represented using a single subreach, along with others exhibiting similar hydraulic characteristics.

Based on these observations, a meeting was held on December 19, 2006, including yourself, myself, John Wise of Stantec and John Wallace of J.E. Fuller Hydrology & Geomorphology Inc. to discuss the approach of employing the single subreach parameter to better represent the potential attenuation effects of existing overbank storage in specific reaches which satisfy the conditions for wide, flat floodplains. At this meeting, the results of several model runs were reviewed (summary table attached), including a comparison of models employing the standard USACE HEC-HMS criteria for subreach determination, a similar model using a single subreach for specific reaches exhibiting broad, shallow overbank flow hydraulics, as well as comparative models using criteria recommended from a "white paper" developed for Harris County, Texas. This paper discussed procedures to determine the number of subreaches by utilizing an increased factor of the channel flow velocity to simulate the actual "flood wave" velocity. On the basis of these comparisons, the attenuation effect resulting by employing the single subreach approach ranges from 12% to 25% reductions in peak discharge (cumulative effect downstream) relative to the original models. Given that the total storage volume of the reaches modeled as a single reach is about 1500 acre-feet, representing as much as 30-35% of the total runoff volume impacting the representative reaches, the results appear to more accurately represent the anticipated attenuation impact associated with the existing overbank storage that would be available during large, infrequent storm events (100-year storm in this case.) Given these circumstances, it was agreed that the continued modeling efforts would employ the standard HEC-HMS criteria to define the number of subreaches within routing reaches that would be characterized predominantly by flow within a defined channel, while those areas characterized by shallow flow within broad floodplain areas would be defined as a single reach. It should also be noted that the use of a single subreach is also employed in City of Tucson TSMS watershed model for theModified Puls channel routing procedures.

At the request of the County, as an additional validation item for comparison, the USGS regression equation for Region 13 was employed at various locations along the Flato and Franco watersheds to compare with the peak flows developed by the HEC-HMS modeling efforts. A summary table of these computations is appended for reference. The results of these efforts indicates that the regression equation consistently estimates peak discharges in excess of the HEC-HMS model (specifically Flato Model 3) as locations are evaluated in a downstream direction. However, this is to be expected, as the Flato and Franco watersheds are very long, narrow drainage areas that are consistent with alluvial fan/distributary flow systems. Thus, the regression equation does not account for the attenuation effects that occur within these systems due to significant overbank flood storage and shallow sheetflow conditions. In fact, the literature associated with the USGS regression equation specifically notes that the equations may not be appropriate for "Alluvial Fan/Distributary Flow/Sheet Flow Areas", as "the recommended equations will tend to overestimate peak discharges" (Page G-2, ADWR "Delineation of Riverine Floodplains and Floodways in Arizona", July 1996). It is notable, however, that the peak discharge estimated at J12 of the Flato watershed is fairly consistent relative to the HEC-HMS model. This location represents the cumulative watershed that is generally comprised of the mountain and foothill areas, and does not yet display the long, narrow watershed configuration associated with the distributary and/or sheetflow areas that characterize downstream areas.

STANTEC CONSULTING INC.

John B. Partridge, P.E.
Senior Hydrologist
jpartridge@stantec.com

Attachments: Flato Model Comparison Table
Regression Equation Comparison Table

cc: John Wallace, JE Fuller Hydrology and Geomorphology Inc.