Roadway Retention and Cross-Drainage Study

Maricopa County Department of Transportation

2901 West Durango Street

Phoenix, AZ 85009

Contract No. 1998-28

June 28, 2000

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Roadway Retention and Cross-Drainage Study

1.0 Introduction

Stantec Consulting Inc. (Stantec), was called upon by the Maricopa County Department of Transportation (MCDOT) to investigate the stormwater storage and cross drainage practices of various communities and agencies within the State of Arizona, primarily focusing on Maricopa County. These practices were to be used as a basis for developing draft policies and standards for MCDOT's consideration.

To assist MCDOT's Transportation Planning Division, Stantec was asked to quantify stormwater storage volume for 33.53 m (110') and 39.63 m (130') road right of way sections using the draft stormwater storage policy/standard. In addition, Stantec was to develop cost per mile for stormwater storage and storm sewer.

2.0 Policies and Standards

2.1 Background

Stantec completed its review of the stormwater storage and cross-drainage criteria for the agencies/communities identified in the scope of work. Provided in Appendix A, Table A.1 summarizes these findings. In terms of stormwater storage, the five municipalities investigated generally require retention of the 100-year storm for new roads associated with development. Here, duration and depth varied from community to community. Roadway improvements of existing roads tended not to have stormwater storage provided. The Flood Control District of Maricopa County (FCDMC) also stipulates the retention of the 100-year storm. Pima County DOT requires retention of the 5-year storm. The Arizona Department of Transportation (ADOT) does not have a mandatory requirement for detention[1].

All agencies/communities researched require cross-drainage for new major roads to be designed to pass at least the 50-year storm without over topping[2]. The 100-year, where designated, is allowed to overtop the road by 15 cm (6") to 30 cm (12") depending upon the community/agency. For rural unpaved roads, ADOT sizes cross-drainage to pass the 10-year storm without overtopping.

Stantec understood that MCDOT's goal was to identify stormwater storage and cross-drainage requirements of various regulatory entities to serve as guidance in development of its own policies and standards. Further, the policies/standards are intended to be followed early in the project planning process in order to better estimate total project

[1] A retention stormwater facility stores the entire hydrograph for the design event whereas a detention facility stores primarily the volumetric difference between the pre-development hydrograph and the post development hydrograph.

[2] City of Phoenix capital improvement projects only require cross-drainage to accommodate "bank full" discharge for minor washes.

costs. Besides stormwater volume and rate of runoff, Stantec considered other components of stormwater storage and cross-drainage facilities that may have significant impacts on costs. For stormwater retention facilities, a 36-hour drain time after cessation of rainfall is mandated to prevent mosquito breeding and accommodate subsequent rainfall events. Retention basins are drained by infiltration through the soil horizon, small diameter "bleed-off" pipes, and/or dry wells. Dry wells are problematic in that they are expensive to install and require on-going maintenance. Stantec researched the various communities/agencies position on dry wells to determine if they were typically required (and therefore an important item to consider in the planning process). For the most part, they are allowed but not required. One community did not allow dry wells while another mandated them.

Similarly, Stantec investigated the various communities/agencies positions on dip sections in lieu of culverts. From a cost perspective, dip sections are a low cost alternative to culverts for conveyance of large flows. For the most part, however, dip sections are not allowed or only allowed for broad shallow sections.

Another task to be taken as part of Stantec's contract was the solicitation of community/agency officials to learn how particular policies/standards were chosen. Attached as part of Appendix A are the summaries of these conversations. Most communities developed their stormwater storage requirements as an extension to the adoption of the 1987 Uniform Drainage Policy of Maricopa County (Appendix B).

2.2 Draft Stormwater Storage Policy and Standards

Based on the information gathered, the following draft drainage policy and standards are suggested for MCDOT's consideration (these pertain specifically to stormwater storage volumetric requirements and culvert design storm return period).

Policy:

> Stormwater retention is to be provided for all MCDOT projects where proposed improvements result in an increase in imperviousness from existing conditions and where there is no stormwater outfall capable of accepting higher flows. Without an acceptable outfall, post-project stormwater discharges to downstream abutters shall not exceed pre-project discharges. Stormwater emanating from outside of the right-of-way shall not be directed into retention basins. Stormwater retention facilities shall be provided in accordance with MCDOT's Standards.

Standards:

> Stormwater from the 100–year, 2-hour storm will be retained for the additional impervious areas of roadway projects where downstream outfalls can not accommodate the higher flows without detrimental

consequences[3]. Co-mingling of stormwater emanating from outside the right-of-way with that run-off generated within the right-of-way will be limited to the greatest extent possible. Public access to retention basins shall be limited unless the basin is sized to a maximum design water depth of 0.91 m (3') with side slopes no steeper than 4:1. The rainfall depth shall be obtained from the Drainage Design Manual for Maricopa County, Volume I[4].

The key to this policy is that it only stipulates stormwater retention if there is an increase in overall imperviousness and if there is not an outfall capable of accepting the higher flows without detrimental consequences. Here, the overriding stormwater management objective is to keep post development flows less than pre-development flows for the generally accepted design storm (storm of a given frequency and duration). Subject to counsel verification, this policy does not evoke retention for repaving projects as these would be considered existing conditions provided the road was extant in 1987 (the year the Uniform Drainage Policy was enacted).

2.3 Draft Cross Drainage Policy and Standards

Policy:

Cross-drainage appurtenances shall be provided to safely accommodate vehicular travel across washes during storm events. Cross-drainage structures shall not cause increased water levels or erosive velocities higher than pre-project conditions outside of the right-of-way. Dip sections shall only be allowed where it is impractical to install culverts. Cross-drainage facilities shall be provided in accordance with MCDOT's Standards.

Standards:

Culverts for major roadways[5] shall be sized to convey the 50-year storm without overtopping and the 100-year storm with a maximum of 15.2 cm (6") over the road. Cross-drainage structures shall not cause increased water levels or erosive velocities higher than pre-project conditions outside of the right-of-way for the 100 year event. Dip sections shall only be allowed where it is impractical to install culverts and will have public safety measures such as gates or signage unless the 100-year flow depth is 22.8 cm (9") or less. Culverts and erosion protection shall be designed in conformance with the Drainage Design Manual for Maricopa County, Volume II.

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[3] Detrimental consequences include higher water levels in overbank areas, increased scour, and increased sedimentation.

[4] The 100-year, 2-hour rainfall depth varies within the county from 6.6 cm (2.6") to 8.6cm (3.4")

[5] Major roadways include highways, arterial streets, and collector streets.

3.0 Application and Cost of Stormwater Retention Policy

Goals

Stantec understood its assignment as follows:

- for planning purposes, determine the cost for linear and local retention basins per the draft policy and standards, and
- determine cost for storm sewer.

Basis of Analysis

The basis of design and cost assessment is as follows:

- retention basins placed every 0.31 kilometers (½ mile),
- retention basins located on both sides of right-of-way (minimizes storm sewer),
- longitudinal slope of road set at 0.25%,
- catch basins and storm sewer to be provided to ensure 3.66m (12') dry lane for Q_{10},
- retention volume based upon 3.2 inches rainfall (100-year, 2-hour),
- retention basins sized with 4:1 side slopes, 0.91m (3') maximum water depth, and
- the median in the 39.6m (130') right-of-way was self-retaining.

The analysis started with verifying the retention basin placement every ½ mile on each side of the road. The intent is to minimize storm sewer while meeting the dry lane requirement for the 10 year event. Therefore, assuming no contributing drainage area from outside the right of way, the ten year discharge for half of the right of way for ½ mile of roadway was calculated following the FCDMC methodology. The ADOT gutter flow hydraulic software was used to determine the width of flow. Once the dry lane criteria was verified, the 100 year stormwater retention volume was determined. Local (square) and linear (elongated) stormwater basins were dimensioned to accommodate the retention volume consistent with the above assumptions. For each basin type and right-of-way scenario, the land acreage and excavation volume required was determined. This information along with ADOT cost information for scuppers and rip-rap was used to develop total costs for each alternative. Appendix C provides the hydrologic, hydraulic, and cost analysis.

Results

Stantec was asked to evaluate the stormwater retention policy in terms of volume required per unit length of 33.5m (110') right of way, per unit length of 39.6m (130') right of way, and per unit length of roadway lane (See Figures 3.1 and 3.2). The 100 year, 2-hour storm retention volumes for these scenarios are provided in the following table. These values are based upon weighted "C" values of 0.91 for both road sections, for the 100 year event.

Table 3.1 100 Year Storm Retention Volumes

Unit Length	Retention Volume
12' Lane	$0.28 m^3/m$ ($3.04 ft^3/ft$)
110' R.O.W.	$2.48 m^3/m$ ($26.7 ft^3/ft$)
130' R.O.W.	$2.79 m^3/m$ ($30.0 ft^3/ft$)

In addition, two types of stormwater retention basins were evaluated in terms of cost for both typical roadway sections. These basins have been labeled as local and linear. A local basin minimizes the area needed to store the given volume assuming depth limitations whereas the linear basin parallels the roadway. A six foot set-back from the top of the basins was assumed. These basins are depicted in Figure 3.3.

The focus of this report is dealing with stormwater draining from the impervious roadway. These roadways offer a convenient means of collecting stormwater via curb and gutter flow or roadside ditch flow. The analysis herein assumes that off-site flows, i.e. flows emanating from outside the right of way, are not intermingled with on-site flows. Given the assumptions and constraints presented, no storm sewer would be required. For the given slope and no contributing off-site drainage area, a 3.66m (12') dry lane is provided during the 10 year event[6].

The cost for the four scenarios is summarized in Table 3.2. In general, the local retention basins are less costly due to their more efficient shape. The local basins also offer less opportunity for interference with the development of the adjacent property. The cost per basin is the cost per mile divided by four. The actual cost for land will vary depending upon market rates and parcel configuration. Linear basins may be easier to negotiate with the landowner(s).

Table 3.2 Stormwater Retention Basin Characteristics

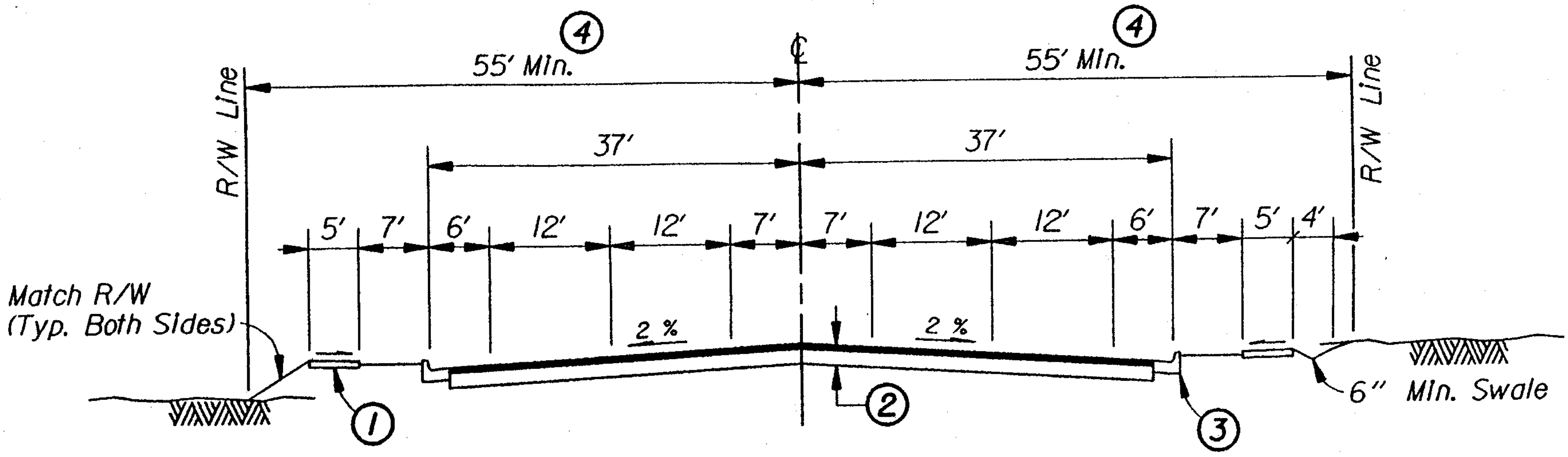
	Local 110'	Linear 110'	Local 130'	Linear 130'
Q_{10} - m^3/s (cfs)	0.19 (6.7)	0.19 (6.7)	0.22 (7.7)	0.22 (7.7)
Volume - m^3 (ac-ft)	999 (0.81)	999 (0.81)	1123 (0.91)	1123 (0.91)
Excavation – m^3 (yd^3)	1001 (1309)	1254 (1640)	1133 (1482)	1398 (1828)
Area[7] – m^2 (acres)	1700 (0.42)	2064 (0.51)	1862 (0.46)	2226 (0.55)
Cost/mile[8]	$110,000	$130,000	$120,000	$140,000

[6] The 10 year event encroaches six inches into the 12' painted lane for the 110' right-of-way. With the 7' set back from the centerline, 18.5' dry width exists on each side of the centerline. Stantec assumed that the 6 inch encroachment did not justify storm sewer as the duration and frequency of encroachment is limited. A full 12' dry lane within the painted lanes is provided for the 130' right-of-way.

[7] Outside right of way.

[8] Excavation cost of $\$5/yd^3$ includes clearing, grubbing, and erosion control/stabilization. Land acquisition @ $40,000/acre. Scupper cost of $2000 each and rip-rap @ $\$75/yd^3$ estimated from ADOT cost summaries. Rip-rap per basin estimated at $24 yd^3$. Cost does not include contingencies or engineering.

Figures



N.T.S.

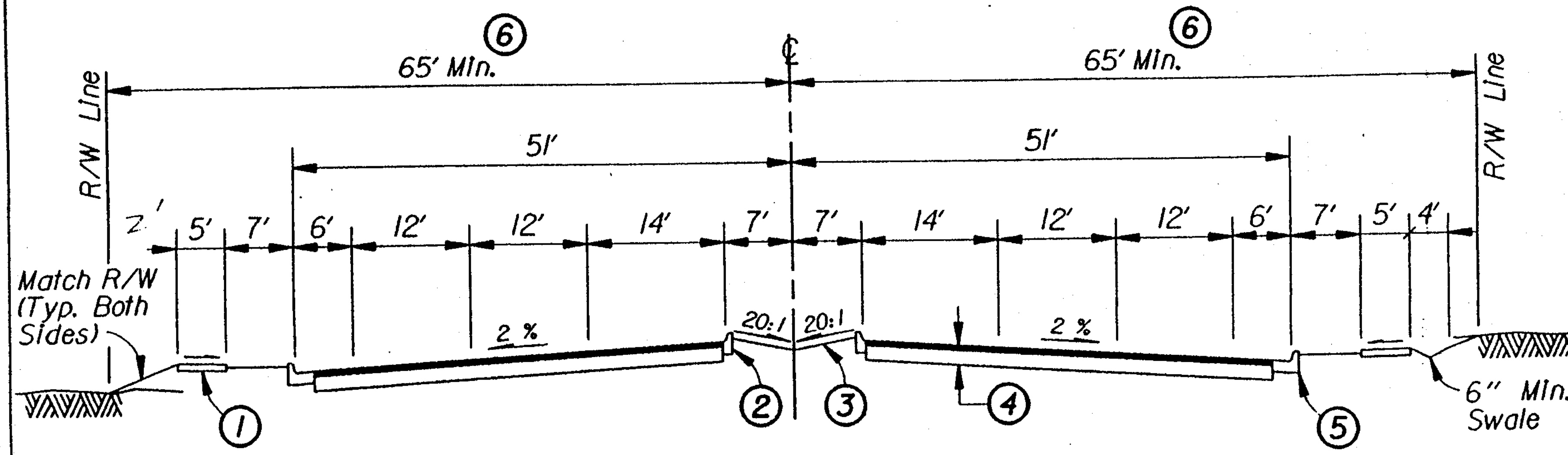
(1) Designer Shall Offset S/W Except at Street Intersections (Typ. Both Sides).

(2) 4" Min. A.C. Over 10" Min. A.B. or Approved Equivalent.

(3) MAG Std. Detail 220, Type A or MCDOT Std. Detail 2030, Curb & Gutter (Typ. Both Sides).

(4) Road of Regional Significance Alignment - 70' Typical Half-Width Min.

Maricopa Co. Dept. of Transportation Standard Typical Section	URBAN MINOR ARTERIAL ROAD WITH BIKE LANES	

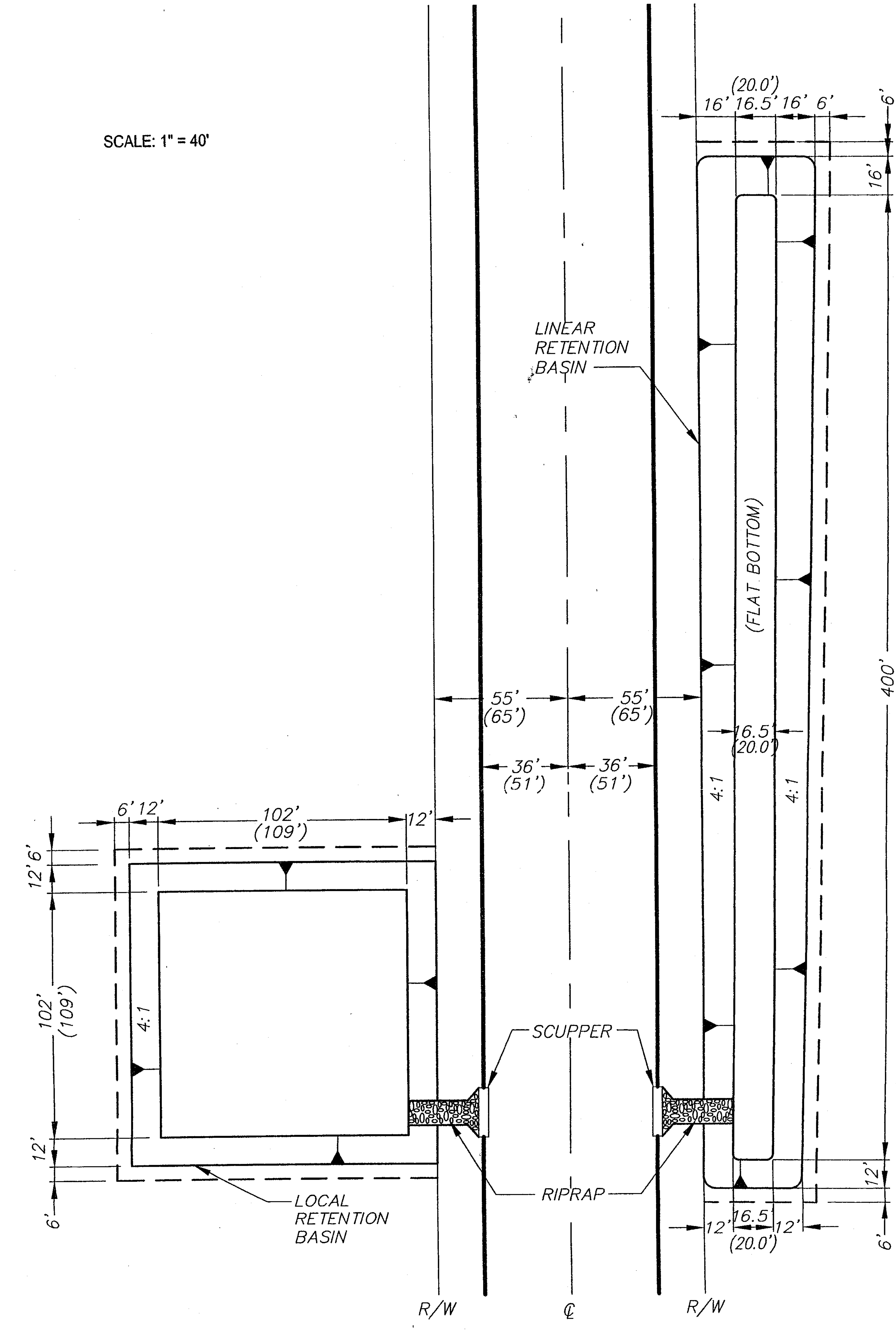


N.T.S.

1. Designer Shall Offset S/W Except at Street Intersections (Typ. Both Sides).
2. MCDOT Std. Detail 2030, Single Curb (Typ. Both Sides).
3. Under Certain Conditions, the Construction of Median Curb may be Waived by the Department.
4. 4″ Min. A.C. Over 10″ Min. A.B. or Approved Equivalent.
5. MAG Std. Detail 220, Type A or MCDOT Std. Detail 2030, Curb & Gutter (Typ. Both Sides).
6. Road of Regional Significance Alignment - 70′ Typical Half-Width Min.

NOTE: Cross Section may be Flared at Intersections to Provide Dual Left Turn Lanes and/or Right Turn Lanes.

Maricopa Co. Dept. of Transportation Standard Typical Section	URBAN PRINCIPAL ARTERIAL ROAD WITH BIKE LANES	



Notes:

Dimensions shown in parenthesis are for 130' R.O.W. (Not to Scale)

Retention Basins to be located every 1/2 mile.

Stantec

Client/Project
M.C.D.O.T.

Figure No.
Figure 3.3

Title
Local and Linear Retention Basin Configurations

June, 2000 82000172

Appendix A

Agency/Community Stormwater Storage and Cross-Drainage Summary and Correspondence

Table A.1 Summary of Drainage Design Criteria for Selected Communities/Agencies in Arizona

Summary of Drainage Design Criteria for
Selected Communities/Agencies in Arizona

Community	Stormwater Storage			Street Cross Drainage			Reference
	Design Storm	Rainfall depth cm (inch)	Are Drywells Allowed	Design Storm	Criteria	Are dip sections allowed instead of culverts	
City of Chandler	100-YR,2-HR +Additional 10% Retention provided for all new roads	6.4 (2.5)	Yes Required	50-YR 100-YR	No flow over street max. of 15.2 cm (6") above crown or in valley gutter; When no curb exists,max. of 15.2 cm (6") above crown	Allowed,with city approval,for shallow washes.	City of Chandler, Technical Design Manual Number 3, Storm Drainage System Design,1987
City of Goodyear	100-YR,6-HR Waived for discharges to major drainage outfalls New roads built in concert with development require retention Some stand alone road projects and roadway improvement require retention, while others only need to satisfy pre & post analysis	7.6 (3.0)	No	Major Collector and Arterial Streets: 50-YR 100-YR Local and Minor Collector Streets: 25-YR 100-YR	 No flow over street max. of 15.2 cm (6") over street max. of 15.2 cm (6") over street max. of 30.4 (12") over street	Allowed only for small private driveways and walkways	City of Goodyear,Engineering Design Stndards and Policies Manual,July 22,1997.
City of Mesa	100-YR,2-HR Developers provide retention for collector & local streets Retention generally not provided for arterial streets	From FCDMC IDF Charts	Allowed,with city approval, for basins with no public street runoff. City approval is also required when maintenance will be city responsibility	50-YR * 100-YR *:10-YR in Desert Uplands Area	No flow over street max. depth over street not specified	No.;It is allowed only in addition to the 50-YR* criteria	-City of Mesa Procedural Manual,Engineering & Design Standards. -City of Mesa,Desert Upland Guidelines;Desert Upland Goals & Objectives,Dec.,1988; Desert Upland Development Standards,Dec.,1989

Table A.1 Summary of Drainage Design Criteria for Selected Communities/Agencies in Arizona

City of Scottsdale	100-YR,2-HR	7.2 (2.8)	Allowed,with city approval. Waived for discharges to major drainage outfalls Waived for conflicts with environmentally sensitive areas New roads require retention, road improvements do not	Collector and Arterial Streets: 50-YR No flow over street 100-YR max. of 15.2 cm (6") over street Local and Minor Collector Streets: 25-YR max. of 15.2 cm (6") over street 100-YR max. of 30.4 (12") over street	Allowed only for small private driveways and walkways	City of Scottsdale,Arizona,Design Standards and Policies Manual,Chapter 2,Drainage,July,1996
Pima County	2-YR,1-HR 2-YR Threshold Retention {which is (Vpost-Vpre) 2yr,1-hr} applied for : - Residential development > 1 acre with density of 3-->6 units per developed acre not located in a balanced or critical basin 5-YR,1-HR 5-YR Threshold Retention* {which is (Vpost-Vpre) 5yr,1-hr} applied for : - Commercial or industrial areas > 1 acres - Residential development > 1 acre with density > 6 units per developed acre, regardless of basin type. - Residential development > 1 acre with density > 3 units per developed acre, located in a balanced or critical basin *: For areas classified as balanced or critical basins, Det/Ret requirements should also accommodate that: (Q2,10,100)post-dev. < or = (Q2,10,100)pre-dev. for balanced bsin (Q2,10,100)post-dev. < (Q2,10,100)pre-dev.	2.8 (1.1) 3.8(1.5)	Yes	Major arterials,minor arterials,major collectors: 50-YR No flow over street 100-YR Contained within dip over road Minor collectors,urban collectors 25-YR No flow over street 50-YR max. of 30.4 (12") over street 100-YR Contained within dip over road Local collector,local streets 10-yr No flow over street 25-YR max. of 30.4 (12") over street 100-YR Contained within dip over road	Not allowed ?	-Pima County,Department of Transportation & Flood Control district;City of Tucson,Stormwater Detention/ Retention manual -Pima County,Department of Transportation & Flood Control district, Drainage and Channel Design Standards for Local Drainage

Table A.1 Summary of Drainage Design Criteria for Selected Communities/Agencies in Arizona

	for critical basin (consult with pima county)						
ADOT	Detention may be provided Design storm frequency same as for cross drainage, by drainage class as a minimum.	Per ADOT Hydrologic Manual	Not as primary means for dewatering	Drainage Class-1 50-YR Drainage Class-2 50-YR** Drainage Class-3 25-YR Drainage Class-4 10-YR *: Provide Adequate free board (see reference) **:Upgrade reconstruction projects only if existing capacity < 25-YR frequency See Appendix B of reference for "Operational Drainage Class Maps for State Highways"	 No flow over street* No flow over street* No flow over street* No flow over street*	Not allowed ?	Arizona Department of Transportation, Roadway Engineering group, Roadway Desig[n] Guidelines May,1996
FDCMC	100-YR, 2-HR	From FCDMC IDF Charts	Yes	50-YR 100-YR (Collectors & Arterials)	No flow over street, max. of 15.2 cm (6") over street	Generally not allowed except for broad, shallow washes	Drainage Design Manual For Maricopa County, Volume II Hydraulics, 1996
City of Phoenix	100-YR, 2-HR Waived for discharges to major drainage outfalls or projects under 1/2 acre provided no detrimental impact Developers provide retention for new roads Capital improvement roadway projects do not provide retention	6.4 (2.5)	Yes	50-YR 100-YR Capital improvement projects provide 100 year cross-drainage for major washes, bank full capacity for minor washes (per verbal communication)	No flow over street max. of 15.2 cm (6") over street		Storm Drain Design Manual Subdivision Drainage Design, 1988

Correspondence Summary

City of Phoenix

Telephone Notes: April 26, 2000

Jesse Gonzales, (Floodplains, formerly with Development Services Department), City of Phoenix
Frank Thomas, Stantec

In the early 1970s, staff required retention for the 10 year 2 hour storm on an informal basis. In April 1974; a private party challenged the grading and drainage ordinance, citing that the ordinance did not specify retention. The ordinance was then amended by City Council to require stormwater retention. On January 1, 1986; the design storm for retention was changed to the 100 year, 2 hour storm. Although some outside input was sought, this was primarily an internal decision. George Horvath, head of engineering, held internal meetings to discuss the issue of stormwater storage, prior to making a decision regarding the quantity of storage.

Meeting Notes: May 9, 2000

Ralph Goodall, Street Transportation Depart., Design & Construction Management Div., City of Phoenix
Frank Thomas, George Sabol, Stantec

Mr. Goodall is taking the lead for the City of Phoenix in updating its Drainage Manual. Presently there are differences between its "Storm Drain Design Manual-Subdivision Drainage Design" (1988) and "Storm Drain Design Manual – Storm Drains With Paving of Major Streets". The latter document does not address stormwater storage nor cross-drainage. Mr. Goodall indicated that his department does not routinely provide stormwater storage for its road improvement projects. Cross-drainage design is typically designed to the 100 year storm for major structures (major washes) while cross-drainage design for minor washes is set to bank full capacity.

Flood Control District of Maricopa County

Meeting: April 13, 2000
Email: May 5, 2000

Amir Motamedi, FCDMC
Frank Thomas, Stantec

During the mid-1980s, a collaborative process was undertaken to develop a stormwater storage standard for Maricopa County. Public meetings were held with municipalities and the development community in which a compromise was struck to call for the 100-year, 2-hour storm to be retained. This criteria was incorporated into the FCDMC's "Uniform Drainage Policies and Standards" document. Cross drainage requirements identified herein stem from Section 6.4 of the 1968 edition of the City of Denver manual. The Denver manual appears to be the model for the FCDMC Hydraulics Manual.

City of Scottsdale

Telephone Notes: May 5, 2000

Collis Lovely, City of Scottsdale
Frank Thomas, Stantec

On 25February1987, the FCDMC issued its "Uniform Drainage Policies and Standards" document, which detailed stormwater retention and cross-drainage requirements. This document was the result of a countywide collaborative effort. The City of Scottsdale adopted this document and incorporated it into its City ordinances.

Telephone Notes: May 8, 2000

Collis Lovely, City of Scottsdale
Frank Thomas, Stantec

For new roads, developers are responsible to provide retention since their responsibility is to the centerline of the road. This also applies in situations where the developer provides funds to the City for the City to have the road constructed. Here, the developer is still required to accommodate retention as part of its overall master plan or infrastructure plan. For capital improvement projects undertaken directly by the City's public works group, the projects are usually too small to have an impact on stormwater runoff. Mr. Lovely indicated that retention was generally not considered for minor roadway improvement projects.

City of Goodyear

Telephone Notes: May 5, 2000

Harvey Krauss, City of Goodyear
Frank Thomas, Stantec

The City of Goodyear adopted its present stormwater storage/cross- drainage requirements in 1997 following a public involvement process. The City started by having an internal committee review the requirements of various communities in the valley and develop proposed standards. Communities reviewed included Scottsdale and Glendale. The City then sought feedback from the development community. Once completed, they went to public hearing and then to City Council for adoption.

Telephone Notes: May 8, 2000
Chris Stevens, City of Goodyear Engineer (Yost & Gardner)
Frank Thomas, Stantec

The City of Goodyear requires new development adjacent to a roadway to provide retention for the area to the centerline of the street. Some stand alone roadway improvements have also provided retention. The City's position here is that as adjacent areas develop, the retention basins may be re-located at the discretion of the developer. Mr. Stevens indicated that some roadway improvement projects have not provided retention, but the City looks for post project conditions not to exacerbate pre-project conditions. He acknowledged that there may be situations where the City's retention requirements were not uniformly applied at public works projects. Roadway projects are considered on a case by case basis.

City of Mesa

Telephone Notes: May 5 & 8, 2000

Peter Knudsen, City of Mesa
Frank Thomas, Stantec

Mr. Knudsen indicated that the City of Mesa adopted the FCDMC's "Uniform Drainage Policies and Standards" for retention and cross-drainage. In a follow-up call to the engineering department on May 8, Stantec was told that developers provide retention for collector and local streets. Neither developers nor the City provides retention for arterial streets, except for two locations within the City where existing outfalls do not exist. Public works projects outside the right of way are required to provide retention.

City of Chandler

Telephone Notes: May 8, 2000

Tom Little, City of Chandler
Frank Thomas, Stantec

The City of Chandler developed its drainage standards in the mid-1980s. It used the FCDMC's Uniform Drainage Policies & Standards as a basis. The City added 10% volume to the 100-yr, 2-hr storm to account for the degradation of basins due to sedimentation. This was accomplished in the 1980s by a public hearing process. Developers are required to provide retention for road right of ways. The City's public works group is required to provide retention for stand-alone roads. The City is presently in the process of updating its drainage manual as it is about to be submitted to City Council for adoption.

Appendix B

Uniform Drainage Policies and Standards For Maricopa County, Arizona

UNIFORM DRAINAGE POLICIES AND STANDARDS

for

MARICOPA COUNTY, ARIZONA

February 25, 1987

Approved by the Maricopa County Board of Supervisors and
Flood Control District Board of Directors
April 20, 1987
Resolution FCD 87-7

Flood Control District of Maricopa County
3335 W. Durango St.
Phoenix, AZ 85012
602/262-1501

ACKNOWLEDGEMENTS

This document is the culmination of one and a half years of intense interagency cooperation through the Task Force on Uniform Drainage Standards. It constitutes the most complete multijurisdictional recognition to date of the need to uniformize drainage policies, standards, and procedures throughout Maricopa County.

The following individuals represented agencies and other organizations participating actively in this effort:

Kebba Buckley, Flood Control District of Maricopa County

Tom Ankeny, City of Tempe

John Baldwin, City of Phoenix

Lindy Bauer, Maricopa Association of Governments

Dave Bixler, Homebuilders Association of Central Arizona

Skip Blunt, Town of Wickenburg

Joe Kissel, Salt River Project

Collis Lovely, Arizona Consulting Engineers Association

Keith Nath, City of Mesa

Doug Plasencia, Flood Control District of Maricopa County

Ken Reedy, City of Glendale

Dick Schaner, City of Scottsdale

In addition to the regular Task Force members, several communities maintained regular contact with our efforts and contributed data and other assistance. These were Chandler, Gilbert, Goodyear, Peoria, and Tolleson.

Special recognition and thanks go to Ken Lewis of Boyle Engineering Corporation, who authored the first nine drafts of this document under contract to the Flood Control District. Mr. Lewis also played a key role in facilitating the discussions for the Task Force meetings in the first five months of the writing process. After the close of the Boyle Engineering Corporation contract, he still continued as an active and valued member of the Task Force.

Ms. Kebba Buckley, of the Flood Control District of Maricopa County, served as Project Manager for the Boyle Engineering Corporation contract and as overall facilitator for the Task Force and the Phase I process.

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RESOLUTION FCD 87-7

UNIFORM DRAINAGE POLICIES AND STANDARDS FOR MARICOPA COUNTY

WHEREAS, the incorporated municipalities and Maricopa County now have widely differing requirements for handling of stormwater drainage by developers; and

WHEREAS, many communities, agencies, and organizations recognize the need to apply uniform drainage policies, standards, and procedures throughout incorporated and unincorporated areas of Maricopa County, and a Task Force on Uniform Drainage Standards was formed consisting of the municipalities of Tempe, Phoenix, Wickenburg, Mesa, Glendale, and Scottsdale, the Maricopa Association of Governments, Homebuilders Association of Central Arizona, Salt River Project, Arizona Consulting Engineers Association, and the Flood Control District, with the municipalities of Chandler, Gilbert, Goodyear, Peoria, and Tolleson maintaining regular contact with the Task Force; and

WHEREAS, the municipalities that participated in the Task Force are prepared to adopt these policies and standards as part of their regulatory structures because they recognize that these policies and standards will result in consistency of analysis of drainage requirements, less staff time and cost in annexing County areas, and residents will be afforded equal and common protection from the hazards of stormwater drainage; and

WHEREAS, developers will find it advantageous to have only one set of drainage standards with which they must comply in developing lands within the incorporated or unincorporated areas of Maricopa County; and

WHEREAS, On September 12, 1983, the Board of Supervisors of Maricopa County and the Board of Directors of the Flood Control District entered into an Intergovernmental Agreement whereby the Flood Control District, through its Chief Engineer and General Manager, assumed all drainage administrative and enforcement responsibilities as enumerated by the Subdivision Regulations and Zoning Ordinance for the Unincorporated Area of Maricopa County, and whereby the District was to develop and recommend to the Board for adoption, a comprehensive Drainage Regulation for the Unincorporated Area of Maricopa County; and

WHEREAS, adoption of policies is a necessary step in the development and adoption of a comprehensive Drainage Regulation; and

WHEREAS, the Flood Control Advisory Board, at its February 1987 meeting, recommended adoption by the Board of Supervisors, the Board of Directors, and the communities of Maricopa County; and

NOW, THEREFORE, BE IT RESOLVED that the Board of Supervisors of Maricopa County and the Board of Directors of the Flood Control District hereby approve the Uniform Drainage Policies and Standards for Maricopa County, Arizona, as a policy framework for the preparation of a comprehensive Drainage Regulation.

Chairman, Board of Supervisors
Maricopa County

Chairman, Board of Directors
Flood Control District of Maricopa County

ATTEST:

Clerk of the Board

1.0 INTRODUCTION

The governmental agencies of Maricopa County seek to establish a common basis for drainage management in all jurisdictions within Maricopa County. The Flood Control District of Maricopa County, in April 1985, invited all interested entities to a meeting to establish an agreement in principle. At that meeting, a Task Force was formed to guide the effort.

The Task Force determined that the effort should be in three phases:

Phase 1 Research, evaluate, develop and produce uniform policies and standards for drainage of new development within Maricopa County.

Phase 2 Establish a Stormwater Drainage Design Manual for use by all jurisdictional agencies within the County.

Phase 3 Prepare an in-depth evaluation of regional rainfall data and establish precipitation design rainfall guidelines and isohyetal maps for Maricopa County.

The Task Force spent two months writing a scope of work for a consultant to use as a basis for Phase 1, the establishment of a draft uniform policies and standards document. In July, 1985, the Flood Control District, on behalf of the interested agencies, contracted to Boyle Engineering Corporation for this Phase. Boyle interviewed most of the jurisdictions within the County and some in other areas of the country, wrote the first drafts of the Phase 1 document, and collated and integrated commentary from diverse sources for each draft. Boyle, specifically Mr. Ken Lewis, served as facilitator for the Task Force's discussions of the developing document during 1985.

This document is the culmination of the work of the Task Force for Phase 1. The adoption of these Drainage Policies and Standards by all agencies involved in drainage management will result in a common standard of drainage design across the County and will reduce the time and effort by both designers and government review staff for submitted drainage proposals and designs.

2.0 POLICIES

The following policies express the approach to drainage management of the jurisdictional agencies (AGENCIES) in Maricopa County.

1. The AGENCIES, through the Flood Control District of Maricopa County (DISTRICT), shall establish and publish criteria for drainage planning and design. Guidance relative to construction, operation and maintenance of drainage systems shall also be provided. The AGENCIES shall adopt criteria relevant to all public and private drainage interests. Such criteria shall be periodically reviewed and revised in the light of new knowledge, changing circumstances, and adjustments in overall comprehensive goals and objectives. Until the publication of the stormwater drainage design manual (DESIGN MANUAL), Chapter 4 of this document, "Basis of Design", sections 4.0 through 4.5.4, shall be utilized as a basis for design guidance, criteria, and standards.

2. Drainage planning shall involve concerned publics.

3. Master drainage planning for developments shall be carried out in the earliest stages of the planning process. The proposed methods of managing drainage and associated land use shall be reviewed by the AGENCY early in the process.

4. Drainage planning and design shall be based on the principle of not increasing or transferring detrimental drainage effects to other areas.

5. Basinwide master drainage planning by the AGENCIES is necessary, has started and shall be continued. The plans are being prepared on a priority basis and shall be continued subject to need and available financing.

6. Basinwide master drainage plans shall be periodically reviewed and revised in the light of new knowledge, changing circumstances, and adjustments in comprehensive planning goals and objectives. Unless otherwise determined, such reviews shall be at intervals of about 5 years.

7. The cooperation of the AGENCIES and other affected entities, including the land development industry, shall be sought to coordinate individual development and drainage schemes with the basinwide plans. To facilitate the cooperation of the AGENCIES and other affected entities, each agency shall submit to the District one copy of each draft and final drainage report it receives for any development larger than 160 acres. The DISTRICT shall catalogue and file the reports for library use by those with relevant drainage interests.

8. Drainage planning is for the purpose of minimizing inconvenience and reducing flood damage and potential loss of life. The benefits of this planning reduce overall public and private costs, including the long and short

term costs of new housing, while providing a drainage infrastructure that will account for the implementation of long-term development goals.

9. Uniform drainage policies and standards are intended to improve processing of development requests and equitable application of regulations.

10. Development and basinwide master drainage plans shall include a full range of preventive and corrective approaches, including the following:

-- Maintaining the integrity of existing drainage patterns,

-- Establishment of selected major drainage routes by the use of purchase, dedication, development rights, and easements;

-- Storage and attenuation of stormwater runoff; and

-- Construction of drainage works.

The combination of strategies shall balance engineering, economic, environmental, and social factors in relationship to stated comprehensive planning goals and objectives.

11. Multiple use of drainage works is encouraged, provided the use does not adversely impact the functional design of the system.

12. In accordance with priorities and fiscal capabilities, the AGENCIES shall develop and implement corrective drainage plans which shall mitigate existing drainage problems. Such plans shall be coordinated with comprehensive planning goals and objectives, and shall consider a combination of structural and nonstructural measures. The level of protection shall be determined on the basis of economic analyses, availability of funds and physical constraints.

13. Water conservation will be considered as an adjunct to drainage planning where feasible.

3.0 PLANNING

Drainage planning helps to achieve orderly, efficient, pleasant and diverse development of a community or group of communities. Accomplishment of the comprehensive goals and objectives can be assisted by a broad drainage planning process. Such a process should be considered within the context of the total environmental system and should be compatible with comprehensive regional plans.

The design team should think in terms of natural drainage paths and street drainage patterns and should coordinate its efforts with its drainage engineers and the drainage engineers of the AGENCIES. Drainage measures are costly when planning is poor or mediocre, whereas good planning results in lower cost drainage facilities.

It is vitally important that planning precede development for the following reasons: to ensure drainage problems are not transferred from one location to another, multiple use opportunities are not lost, and the cost for overall drainage facilities are kept to a minimum. This is best accomplished with comprehensive master drainage plans.

3.1 MASTER PLANNING

A master drainage plan describes in detail the recommended plan for drainage and the course of action for implementation in terms of priorities. It shows sizes, types and location of drainage facilities on maps in sufficient detail to allow for planning new development.

Each AGENCY in Maricopa County shall be responsible for master planning stormwater drainage facilities in its jurisdiction. Cooperation among governmental units is desirable, including joint efforts between AGENCIES and the DISTRICT. Any master planning effort shall include consultation with those entities potentially affected by such planning.

Detailed master drainage plans for various designated areas within Maricopa County are in process by both the DISTRICT and individual cities and towns. A number of these are cooperative projects of two or more AGENCIES together with the DISTRICT and one or more other sponsors. These plans are primarily focused on areas of rapid development and areas with existing stormwater problems.

3.2 TRANSFER OF ADVERSE IMPACTS

Planning and design of stormwater drainage systems shall include consideration of impacts on upstream and downstream properties and/or existing drainage systems. Adverse impacts shall be eliminated wherever possible. Any unavoidable adverse impacts shall be mitigated in coordination with affected property owners and/or AGENCIES. Specifically, the diversion of storm runoff from one drainage area to another introduces significant legal and social problems and shall be avoided unless specific reasons justify such a transfer and the affected jurisdictions agree on the transfer.

3.3 IRRIGATION FACILITIES

Irrigation facilities shall not be utilized for conveyance of stormwater drainage without the prior approval of the owner or operator of such facilities. Such approval shall be required whether or not such facilities are currently used to transport water for irrigation purposes. Any approval shall specify the discharge rate permitted, the location of facilities into which the discharge is permitted, and the length of time such a discharge shall be permitted.

3.4 DRAINAGE REPORTS

When a drainage report is required, it must be prepared in accordance with the AGENCY's requirements and sealed by a civil engineer registered as a professional engineer in the State of Arizona. Drainage reports are required for the following reasons: to analyze the effect that a proposed development would have on the runoff in the vicinity of the development; to provide data to insure that the development is protected from flooding; and to provide data supporting the design of facilities to be constructed for the management of runoff.

At this time, the AGENCIES have varying requirements for whether a drainage report is required and at what point in the planning and review process. **This will be covered in the DESIGN MANUAL by a table which will list the AGENCIES and their specific requirements.**

4.0 BASIS OF DESIGN

Until the publication of the DESIGN MANUAL, this chapter, comprised of sections 4.0 through 4.5.4, is to be utilized as a basis for design guidance and criteria.

4.1 DRAIN CLASSIFICATION

The following classification of drains into minor, major and regional drains is presented as an aid for system analysis:

Minor drains serve watershed areas up to 160 acres and are normally the drains associated with subdivision development.

Major drains include natural and man-made channels, conduits and washes, and serve watershed areas from 160 acres to about 10 square miles.

Regional drains are the main outfalls for drainage. They serve watershed areas generally greater than 10 square miles, and include rivers and washes.

4.2 HYDROLOGIC ANALYSIS

Hydrologic procedures for general application in Maricopa County shall:

-- Provide reliable and consistent results;

-- Be capable of estimating peak discharges for various return periods and degrees of urban development;

-- Produce a hydrograph corresponding to the peak discharge;

-- Utilize input data which is readily available;

-- Be workable for main frame, microcomputer and hand calculations.

For Maricopa County two procedures shall be developed: one for areas less than 160 acres and one for areas greater than 160 acres. The primary differences between the two are ease of use and range of applicability. The specific input parameters required for each procedure shall be established and published in the Design Criteria Manual and shall be periodically updated as required.

For drainage areas less than 160 acres the Rational Method shall be used. This method is the simplest and most widely used procedure for small urban basins.

For drainage areas greater than 160 acres, the SCS dimensionless unit hydrograph procedure shall be used at this time. A new procedure, to be called the Maricopa County Urban Hydrograph Procedure (MCUHP), shall be developed for this area. The procedure shall be described in the DESIGN MANUAL. In the interim, excess rainfall shall be computed using the SCS curve number method; runoff shall be determined by the SCS dimensionless unit hydrograph method, and the resultant hydrographs routed, where necessary, by such methods as those available in SCS TR-20/TR-55 or in HEC-1.

The peak discharges determined by either of the methods are approximations. Emphasis should be placed on the design of practical and hydraulically balanced works based on sound logic and engineering, as well as on dependable hydrology.

4.3 HYDRAULIC ANALYSIS

4.3.1 Storm Sewers

Manning's formula is to be used for calculating the capacity of continous stormwater drains, with appropriate allowances for headloss at inlets, bends, junctions and manholes. Manning's "n" factors and minor energy loss coefficients shall be published in the DESIGN MANUAL. The maximum capacity for circular sections under open channel flow conditions is not to exceed full flow conditions. Uniform flow assumptions may be used in calculating the capacities of minor drains. For major drains, or where a higher degree of accuracy is required, backwater or drawdown curves should be calculated using the Standard Step method. Pressure and momentum theory may be used at bends, junctions, and manholes.

For systems flowing under pressure, the maximum pressure allowed must consider the structural limitations of both the pipe and joint. The hydraulic grade line must be maintained below ground level unless special consideration is taken to prevent water from escaping from sewers or to handle it once it does escape. Whether the system is under pressure or in open channel flow conditions, the hydraulic controls are to be clearly indicated.

4.3.2 OPEN CHANNELS

Open channels have advantages in cost, capacity, multiple use for recreational and aesthetic purposes, and potential for detention storage. However, disadvantages exist in right-of-way needs, maintenance costs and hazards to traffic and pedestrians. Careful planning and design are needed to minimize the disadvantages and to maximize the benefits.

Natural channels have velocities that are usually low, resulting in longer concentration times, increased storage and generally lower downstream peaks. If flows in natural channels are increased, consideration must be given to maintaining their stability. Channels in hillside development areas are to be be retained in their natural state unless otherwise approved by the AGENCY.

If right-of-way is limited, requiring velocities higher than allowable for the existing channel to convey the design discharges, then channel lining is required to prevent scour. The choice of lining is subject to allowable velocities, costs and aesthetics. Man made channel alignments for drains are to coincide with the natural watercourse locations, except as approved by the AGENCY. They are to discharge runoff as nearly as possible in the location and with approximately the same velocities as existed prior to construction. If diversion within a proposed development is required, sufficient work is to be done upstream and/or downstream of the diversion to provide affected properties at least the same level of flood protection as existed prior to the diversion.

Open channels adjacent to public streets are discouraged and require approval from the AGENCY. When it is necessary to locate a channel adjacent to a street, it will be placed a reasonable distance from traffic.

Open channels should maintain subcritical flow conditions wherever possible. Any channel that is not designed for subcritical conditions shall require approval from the AGENCY. Open channels should be designed to allow interception of surface flows. If it is unavoidable to construct the channel without creating a barrier to surface flow, a means of draining must be indicated. In preliminary layouts of the routing of proposed channels, it is desirable to avoid sharp curves. If this is unavoidable, design considerations are to include the reduction of superelevations and the elimination of initial and compounded wave disturbances.

Manning's formula is to be used for uniform flow computations in open channels. Water surface profile calculations are to be calculated using the Standard Step method and confluences and bridge piers are to be analyzed using pressure and momentum theory.

Unlined channels should have side slopes of 3 (horizontal) to 1 (vertical) or flatter. A minimum Manning's "n", applicable for the channel under design, is to be used for checking sections susceptible to scour, and the normal or maximum value used for determining the required cross section. Where the channel roughness changes significantly with depth, a composite Manning's "n" is to be used.

4.4 STREETS

Design standards for the collection and conveying of runoff on public streets is based on an acceptable frequency of traffic interference.

Street drainage shall be governed by Table 1, as illustrated in Figure 1.

Table 1. Design Storm Frequencies for Street Drainage (Years)

	Frequency
<u>A. LONGITUDINAL STREET FLOW</u>	
No curb overtopping. *	10
Flow to be calculated assuming contained in ROW with: . 0.3 feet maximum depth over curb * . 100 cfs maximum flow . 10 fps maximum velocity	50
<u>B. CROSS STREET FLOW (bridges, culverts, and dip sections)</u>	
No flow across street	50
0.5 feet depth at crown or in valley gutter *	100

* Where no curb exists, maximum depth to be 0.5 feet over crown.
** No new inverted crown streets.

Regardless of the size of the culvert or bridge, street crossings are to be designed to convey the 100-year storm runoff under and/or over the road to an area downstream of the crossing to which the flow would have gone in the absence of the street crossing. In no instance shall flows up to or including 100-year frequencies cause inundation of the lowest finished floors.

For flows crossing broad shallow washes where the construction of a culvert is not practical or desirable, the road should be dipped to allow the entire flow to cross the road. The pavement through the dip section should have a one way slope and curbing and medians must not be raised. For these situations approval shall be obtained from the AGENCY.

4.5 STORAGE FACILITIES

4.5.1 Requirements for Storage

To reduce the significant cost of handling stormwater runoff and to control increased peaks and volumes from development areas, all development shall make provisions to retain the peak flow and volume of runoff from rainfall events up to and including the 100- year 2-hour duration storm falling within the boundaries of the proposed development. The 100-year 2-hour rainfall event shall be established using DISTRICT procedures.

The development shall be considered to extend to the centerline of all existing and/or future streets on the exterior boundaries, and shall include all property within the development. In some areas it may be required to retain runoff generated from adjacent arterial streets. These areas shall be designated by the AGENCY during the preliminary planning stages.

Offsite flows may not be routed through the storage facilities unless approved by the AGENCY.

Storage facilities are to be located so they can intercept the flow from the entire development area. If portions of the area cannot drain to a primary storage facility, then additional facilities are to be added for these areas as approved by the appropriate AGENCY. Wherever possible, the facilities shall be located in parks or other recreational facilities to offset the cost of open space and to encourage improved maintenance.

4.5.2 Conditions When Storage May Be Waived

If the downstream drainage system is adequate for future conditions, storage requirements may be waived by the AGENCY under the following circumstances:

1. The runoff has been included in a storage facility at another location;

2. The runoff can be directly carried to a regional drain;

3. Development of an existing parcel under one-half acre in an area where it can be demonstrated that no significant increase in the potential for flood damage shall be created by the development of that parcel.

If onsite storage is waived, the development may be required to contribute to the cost of drainage works on the basis of runoff contribution.

4.5.3 Method of Storage

Common storage facilities shall be used in preference to individual lot storage wherever possible. Common storage provided for two or more mutually adjoining properties is encouraged, subject to review by the AGENCY(IES). Such arrangements can significantly reduce maintenance costs and increase the potential for multiple uses of the facility.

Residential developments shall have no single lot storage unless approved by the AGENCY, and the design of common facilities shall not assume any individual lot onsite storage, unless approved by the AGENCY. Developments with Homeowners Associations shall locate their facilities in private drainage tracts or public sites dedicated by the developer, in accordance with requirements determined by the AGENCY. The private facilities shall be maintained by the Homeowners Association. Public tracts shall be maintained by the AGENCY. Common storage facilities from single family developments without a Homeowners Association and with public streets shall have maintenance determined by the AGENCY. The number and location of storage facilities within a development is to be approved by the AGENCY. Dedication to the public may require the inclusion of recreational facilities or other features deemed necessary by the AGENCY.

Non-Residential Developments that are not included in a public storage facility, shall provide the required storage on the lot itself without depressing the right-of-way area. Asphalt parking areas, landscape areas and underground tanks may be used for storage purposes.

4.5.4 Drainage of Storage Facilities

Storage facilities are to be drained within a period of 36 hours by either controlled bleed-off, discharge pump, infiltration or dry well.

Controlled bleed-off or pumping is the preferred method and may be required if the AGENCY considers a public nuisance would be created by surface spreading or dry wells. Responsibility for maintenance and operation of the bleed-off and/or pumping system shall be determined by the AGENCY.

Dry wells may be used with the approval of the AGENCY. The maximum disposal rate is not to exceed 0.1 cfs per well unless supported by a detailed certified soils report. Should the soils report indicate a higher rate, a conservative value of 50% of the higher rate (not to exceed 0.5 cfs) shall be used to compensate for deterioration over time. Dry wells that cease to drain a project area in a 36-hour period shall be replaced by the maintenance authority with new ones, unless an alternate method of drainage becomes available.

APPENDIX A

DEFINITIONS

AGENCY	The governmental authority in whose jurisdiction an aspect of the drainage system is regulated.
Channel	A natural or artificial watercourse with definite bed and banks for conducting flowing water.
Detention System	A system which delays runoff in a controlled manner through the combined use of temporary storage facilities and an open outlet. The duration of downstream runoff is increased and the flow peak immediately downstream is reduced.
DISTRICT	The Flood Control District of Maricopa County.
Drainage Basin	The contributing area to a single point of drainage concentration. Also called catchment area, watershed, or river basin.
Dry Well	A shaft or hole, covered and designed to allow the percolation of drainage water into the ground.
Irrigation Facilities	Channels, pipes, canals, hydraulic structures, and any other facilities through which irrigation water flows.
Outfall	The point, location or structure where drainage discharges from a channel, conduit or drain.
Retention System	A system which retains runoff in a controlled manner through the use of storage facilities. Stored water is either evacuated by percolation or released to the downstream drainage system after the storm event.
Storage Facilities	Reservoir, tank, pipes or other space for either the detention or retention of drainage.

APPENDIX B

REFERENCES

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Appendix C

Hydrologic, Hydraulic, and Cost Analysis

Basis of Design

- Retention Basins placed every ½ mile, both sides of R.O.W.
- Road Grade 0.25 %
- 12' dry lane for Q_{10}
- Retention for 100 yr - 2 Hr

Goals

- Determine Cost for Linear & Local Retention Basins
- Determine Cost for Storm Sewer if needed
- Assessments To Be Made for 110' & 130' Typical Sections

Assumptions

- $P_{100} = 3.2''$
- Retention Basins On Both Sides of R.O.W.
- Median in 130' R.O.W. is self retaining
- 4:1 side slopes
- 3' depth of water in basin (no freeboard required)
- Cost for excavation includes clearing, grubbing, & stabilization/landscaping

110' R.O.W.

$$Q = CIA$$

$$C_{10yr} = \frac{(0.85)(37) + (0.65)(18)}{55'_{ROW}} = 0.78$$

$$A = \left[(0.5)(5280\ ft/mi)(55')\right] / 43560\ ft^2/ac = 3.33\ ac$$

$K_b = m \log A + b$ where $m = -0.00625$ $b = 0.04$ for Type A landforms

Type A landforms have minimal roughness

$$K_b = 0.0367$$

Stantec

Project: MCDOT Roadway Retention Study | Project Number: 82000172
Notes: | Scale:

Computed By: FWT | Date: 6 23 00 | Checked By: | Date:

$T_c = 11.4 L^{0.5} K_b^{0.52} S^{-0.31} i^{-0.38}$

Assume $i_{10} = 3.2$ in/hr for Duration = 20 min

$S = 0.25\% = 13.2$ ft/mi

$K_b = 0.0367$

$L = 0.51 = 2640 + 55$

$T_c = 0.42$ hr $= 25$ min.

Assume $i_{10} = 3.0$ in/hr for Duration 22.5 min

$T_c = 0.43$ hr $= 26$ min

Assume $i_{10} = 2.8$ in/hr for Duration = 25 min

$T_c = 0.44$ hr $= 27$ min

Assume $i_{10} = 2.6$ in/hr for 28 min Duration

$T_c = 0.46$ hr $= 27$ min

$Q_{10} = CIA = (0.78)(2.6 \text{ in/hr})(3.33 \text{ ac}) = 6.75$ cfs

At 18' spread, $Q_{\text{road capacity}} = 6.21$ cfs

At $Q = 6.75$ cfs,

Roadway Spread = 18.58'

∴ No storm sewer needed since available roadway = 18.42'

Note that scupper at this location will reduce spread

Stantec

Project: MCDOT Roadway Retention Study Project Number: 82000172

Notes: Scale:

Computed By: FWT Date: 6 23 00 Checked By: Date:

130' R.O.W. (min) Actual Width = 138'

$C_{10} = \frac{(0.95)(44) + (0.65)(18)}{62} = 0.79$

$A = (62')(2640')/43560 = 3.76\ ac$

$K_b = m \log A + b = -0.00625 \log(3.76) + 0.04 = 0.0364$

Assume $i_{10} = 2.6$ in/hr @ $T_c = 28$ min

$T_c = 11.4\ L^{0.5}\ Kb^{0.52}\ S^{-0.31}\ i^{-0.38} = 0.45\ hr = 27\ min$

$Q_{10} = (0.79)(2.6\ in/hr)(3.76\ ac) = 7.7\ cfs$

Spread = 19.2'

Available for spread = 30'

∴ No storm sewer needed

ARIZONA DEPARTMENT OF TRANSPORTATION
DRAINAGE DESIGN SECTION

06-23-2000

PROJECT NAME- MCDOT Roadway Retention Study TRACS NO.-
HIGHWAY NAME- DESIGNER - FWT 6/23
LOCATION - 110' ROW. ~ Q10 CHECKER - JK PAGE 4 of 15
Ver 3.40: December 1995

GUTTER FLOW HYDRAULICS
GUTTER DESCRIPTION

Roadway Grade-% Per cent--G	=	0.250
Roadway Cross-Slope-Ft./Ft.--Sx	=	0.020
Shoulder Width-Ft.--	=	1.417
Shoulder Slope-Ft./Ft.--Ss	=	0.020
Gutter Width-Ft.--W	=	1.417
Gutter Slope-Ft./Ft.--Sw	=	0.042
Gutter Depression-Inches--	=	0.708
Manning's 'N	=	0.015
Flow-CFS--Q	=	6.750
SPREAD-Ft.--T	=	18.575 ←
Average Velocity-V-fps	=	1.944
FLOW in Gutter-CFS--Q	=	1.363
% Flow in Gutter-CFS	=	20.187
Velocity of Flow in Gutter-fps	=	2.581
Depth at Curb Line-Inches--d	=	4.826

ARIZONA DEPARTMENT OF TRANSPORTATION
DRAINAGE DESIGN SECTION

06-23-2000

PROJECT NAME- MCDOT Roadway Retention Study TRACS NO.-
HIGHWAY NAME- DESIGNER - FWT 6/23
LOCATION - 130' R.O.W. ~ Q10 CHECKER - PAGE 5/15
Ver 3.40: December 1995

GUTTER FLOW HYDRAULICS
GUTTER DESCRIPTION

Roadway Grade-% Per cent--G	=	0.250
Roadway Cross-Slope-Ft./Ft.--Sx	=	0.020
Shoulder Width-Ft.--	=	1.417
Shoulder Slope-Ft./Ft.--Ss	=	0.020
Gutter Width-Ft.--W	=	1.417
Gutter Slope-Ft./Ft.--Sw	=	0.042
Gutter Depression-Inches--	=	0.708
Manning's 'N	=	0.015
Flow-CFS--Q	=	7.700
SPREAD-Ft.--T	=	19.525
Average Velocity-V-fps	=	2.008
FLOW in Gutter-CFS--Q	=	1.480
% Flow in Gutter-CFS	=	19.223
Velocity of Flow in Gutter-fps	=	2.668
Depth at Curb Line-Inches--d	=	5.054

ARIZONA DEPARTMENT OF TRANSPORTATION
DRAINAGE DESIGN SECTION

06-21-2000

PROJECT NAME- MCDOT Roadway Retention Study TRACS NO.-
HIGHWAY NAME- DESIGNER - J Kelley
LOCATION - 110 R.D.W. ~ Q10 CHECKER - FWT PAGE 6 of 15
Ver 3.40: December 1995

GUTTER FLOW HYDRAULICS
GUTTER DESCRIPTION

Roadway Grade-% Per cent--G	=	0.250
Roadway Cross-Slope-Ft./Ft.--Sx	=	0.020
Shoulder Width-Ft.--	=	1.417
Shoulder Slope-Ft./Ft.--Ss	=	0.020
Gutter Width-Ft.--W	=	1.417
Gutter Slope-Ft./Ft.--Sw	=	0.042
Gutter Depression-Inches--	=	0.708
Manning's 'N	=	0.015
Flow-CFS--Q	=	6.213 ←
SPREAD-Ft.--T	=	18.000
Average Velocity-V-fps	=	1.905
FLOW in Gutter-CFS--Q	=	1.293
% Flow in Gutter-CFS	=	20.817
Velocity of Flow in Gutter-fps	=	2.528
Depth at Curb Line-Inches--d	=	4.688

Retention Volume $= V = C\left(\frac{P}{12}\right)A$

110' R.O.W.

$$C_{100} = \frac{(0.95)(37) + (0.82)(18)}{55} = 0.91$$

$A = 3.33$ Ac

$P = 3.2''$

$$V = (0.91)\left(\frac{3.2''}{12}\right)(3.33\text{ Ac}) = 0.81 \text{ Ac-ft}$$

130+ R.O.W.

$$C_{100} = \frac{(0.95)(44) + (0.82)(18)}{62} = 0.91$$

$A = 3.76$ Ac

$P = 3.2''$

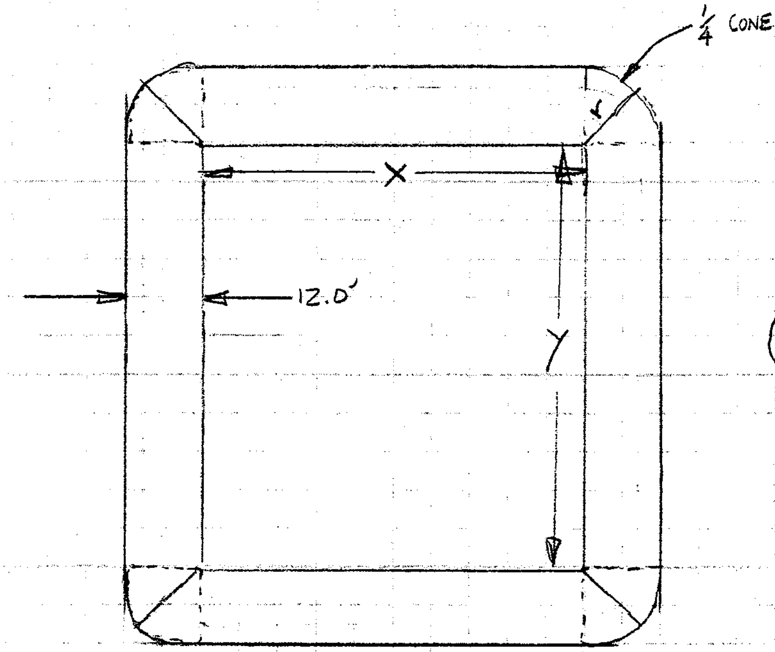
$$V = (0.91)\left(\frac{3.2''}{12}\right)(3.76\text{ Ac}) = 0.91 \text{ Ac-ft}$$

TOTAL AREA, A_T = 10.50 acres (including R.O.W.)

ASSUME $P_{100-2hr}$ = 3.2 inches

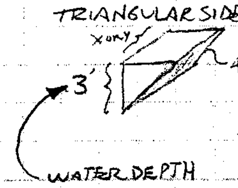
$V_{Q_{100}} = (0.91)(10.50)(3.2/12) = 2.55$ acre-feet $= 110,991$ ft^3

ISOLATED BASIN



CONE VOLUME = $\frac{\pi r^2 h}{3}$

TRIANGULAR SIDE VOLUME = $\frac{1}{2}(3)(12)\cdot x$ OR $\frac{1}{2}(3)(12)\cdot y$



= 18x and 18y

RETANGULAR VOLUME = $3xy$

TOTAL VOLUME, $V_T = \frac{\pi r^2 h}{3} + 18x + 18y + 3xy$ where water depth = 3.0' = h

ASSUME x = y, THEN $V_T = \frac{\pi r^2 h}{3} + 36x + 3x^2$ where r = 12 (4:1 SIDE-SLOPE, 3.0' DEEP)

$110,991 = \frac{\pi(12)^2(3)}{3} + 36x + 3x^2$

$3x^2 + 36x - 110,539 = 0$

$x^2 + 12x - 38,846 = 0$

TRY

$(215)^2 + (215)(12) = 48,805$

$(190)^2 + (190)(12) = 38,380$

$(192)^2 + (192)(12) = 39,168$ ⟸ USE 192 ft

$(191)^2 + (191)(12) = 38,773$

Local Retention Basin

110' R.O.W.

$V = 0.81$ Ac-ft $= 3x^2 + 36x + 452 = 35284$ ft^3

$x = 95$ $V = 30947$ ft^3

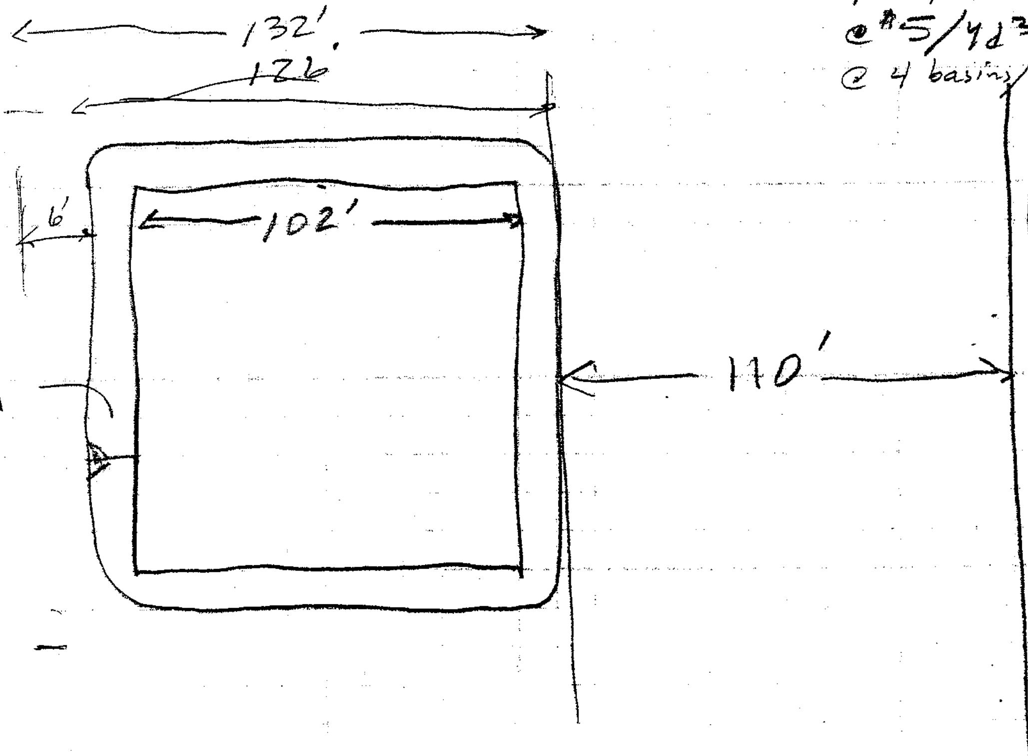
$x = 100$ $V = 34052$ ft^3 $= 0.78$ Ac-ft

$x = 102$ $V = 35336$ ft^3 $= 0.81$ Ac-ft

$= 1309$ yd^3

@ $5/yd^3

@ 4 basins/mi ⇒ $26,180



$93,400

⇒ $95,000/mi

w/ Scupper & rip-rap

$108,400

Say $110,000

$\frac{138' \times 132'}{43560} = 0.42$ Ac / ½ mile / ½ street

$= 1.68$ Ac / mi of street (both sides

@ $40,000/Ac = $67,200

Stantec

Project: MCDOT POLICY | Project Number: 82000172

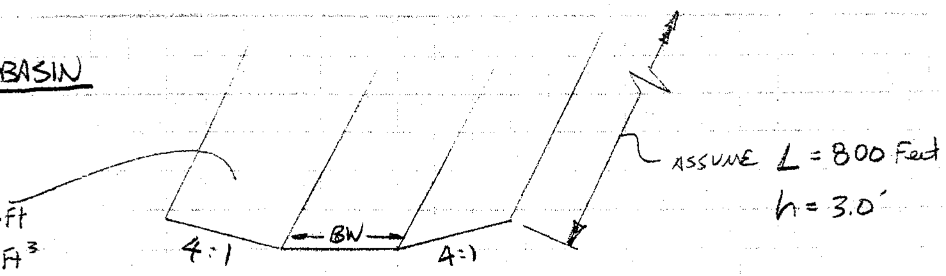
Notes: URBAN MINOR ARTERIAL ROAD | Scale:

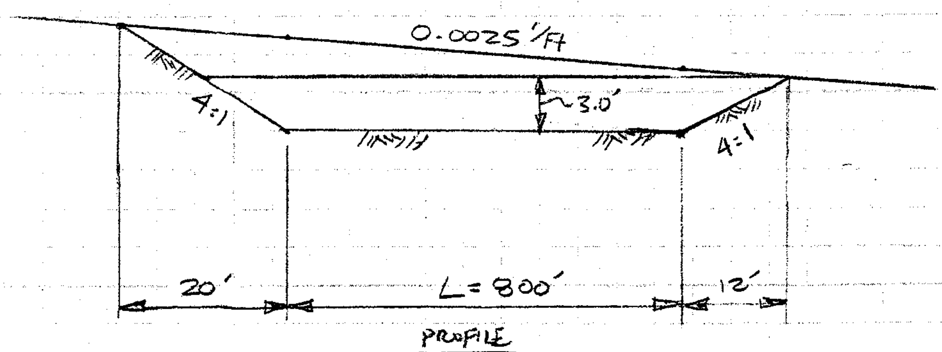
RETENTION BASIN VOLUME AND SIZING | Page 10 of 15 Page(s)

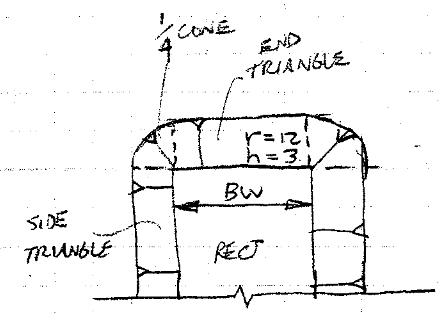
Computed By: JKC | Date: 6 16 00 | Checked By: RJT | Date: 6/19/00

LINEAR BASIN

$V = 2.55$ ac-ft
$= 110{,}991$ ft^3



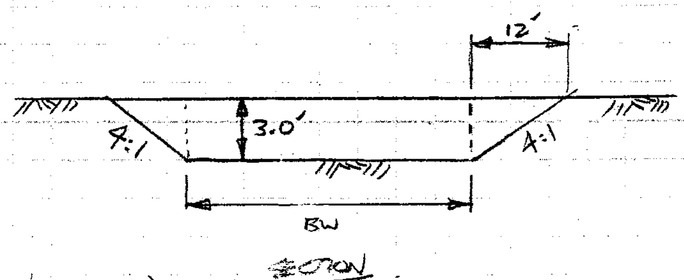




$V_{CONE} = \frac{\pi (12)^2 \cdot 3}{3} = 452.4 \text{ ft}^3$

$V_{END\,\Delta's} = 2(BW)(\tfrac{1}{2})(12)(3) = 36BW$

$V_{SIDE\,\Delta's} = [(800)(\tfrac{1}{2})(12)(3)] \cdot 2$
$= 28{,}800 \text{ ft}^3$



$V_{RECT} = (800)(3)(BW)$

VOLUME (WATER AT 3.0' DEPTH)

NEED: $V_{TOTAL} = V_{CONE} + V_{END\,\Delta's} + V_{SIDE\,\Delta's} + V_{RECT}$

$V_{TOTAL} = 453 + 36BW + 28{,}800 + 2400BW = 110{,}991 \text{ ft}^3$

$2436BW + 28{,}800 + 453 = 110{,}991$

$\frac{2436\,BW}{2436} = \frac{81{,}738}{2436}$

$BW = 33.6$ Feet ⇒ USE 34 Feet

CHECK: $V_{TOTAL} = 453 + 36(34) + 28{,}800 + 2400(34)$

$V_{TOTAL} = 112{,}077$ O.K.

130' R.O.W. => $105K/mi. for local

Linear ~ 110' R.O.W.

V = 0.81 ac-ft = 35,284 ft³ = 453 + 36 BW + 28,800 + 2400 BW

BW = Bottom Width for 800' level basin

BW = 2.5'

∴ Inefficient

For 400' Long Basin

$V_{cone} = \frac{\pi (12)^2 (3)}{3} = 452 \text{ ft}^3$

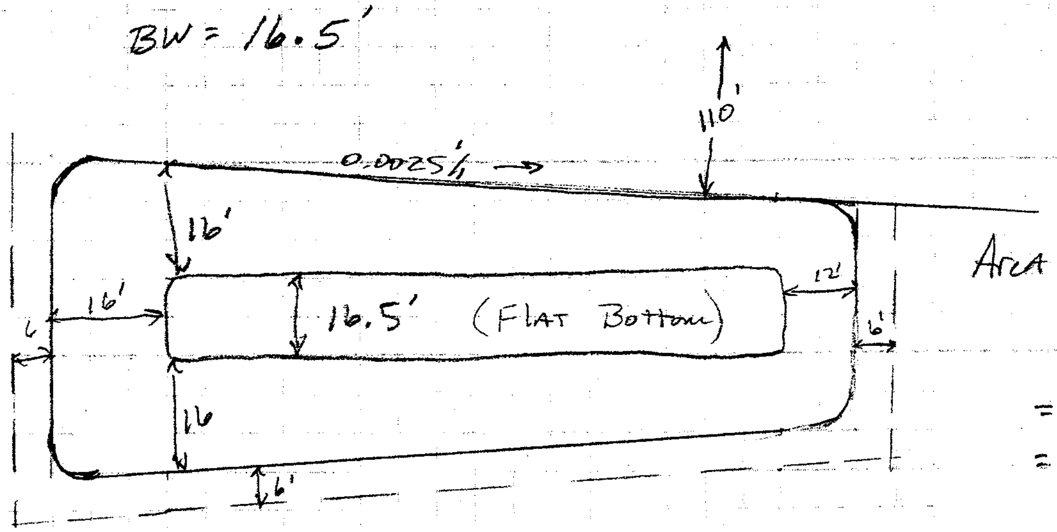
$V_{ends} = 2(BW)(1/2)(12)(3) = 36\ BW$

$V_{sides} = [(400')(1/2)(12)(3)](2) = 14,400 \text{ ft}^3$

$V_{rect} = (400)(3')(BW)$

V = 452 + 36BW + 14,400 + 1200 BW = 1236 BW + 14,852 = 35,284 ft³

BW = 16.5'



Area = [1/2(54.5' + 46.5)] × [400' + 12' + 16 + (2)(6')]

= 22,220 ft²

= 0.51 Ac

Volume Excavated =

$$V_{cone\,(12')} = \frac{\pi (12)^2 (3)}{3}\left(\tfrac{1}{2}\right) = 226\ ft^3$$

$$V_{cone\,(16')} = \frac{\pi (16)^2 (4)}{3}\left(\tfrac{1}{2}\right) = 536\ ft^3$$

$$V_{end\,(12')} = \left(\tfrac{1}{2}\right)(12')(16.5')(3') = 297\ ft^3$$

$$V_{end\,(16')} = \left(\tfrac{1}{2}\right)(16')(16.5)(4) = 528\ ft^3$$

$$V_{Trap} = (400')\left(\frac{4'+3'}{2}\right)\left(\frac{\left(\frac{16.5'+40.5'}{2}\right)+\left(\frac{16.5'+48.5'}{2}\right)}{2}\right) =$$

$$= (400')(3.5')(30.5') = 42{,}700\ ft^3$$

$$V_{TOTAL} = 44{,}287\ ft^3 = 1640\ CY$$

Excavation Cost = \$8200 @ \$5/CY

Land Cost @ \$40,000/AC = \$20,400

For Both sides Per Mile = (4)(\$28,600) = \$114,400

⇒ \$115,000/mi

w/ Scupper & rip-rap

129,400

Say \$130,000

Stantec

Project: MCDOT Roadway Retention Study Project Number: 82000172

Notes: Scale:

Computed By: FWT Date: 6 23 00 Checked By: Date:

Linear 130' R.O.W. (400' Basin)

$V = 0.91$ Ac-ft $= 39{,}640$ ft^3 $= 1236\,BW + 14{,}852$ ft^3

$BW = 20'$

Additional Volume Excavated =

$$\left[\left(\frac{4'+3'}{2}\right)(20'-16.5')(400')\right] + \left[(\tfrac{1}{2})(16')(4')(3.5')\right]$$

$$+\left[(\tfrac{1}{2})(12')(3')(3.5')\right] = 5075 \text{ ft}^3$$

$= 188$ yd^3 ⇒ \$940/basin

Additional Land

$(3.5')(400'+12'+16'+6'+6') = 1540$ ft^2 $= 0.035$ Ac

⇒ 1414/basin

Additional Cost Per Mile For 130' R.O.W = \$9400

Total Cost For 130' ROW = \$124,400 ⇒ \$125,000

W/ Scupper: rip-rap

\$139,400

Say \$140,000

Local 130' R.O.W.

V = 0.91 Ac-ft = 39,640 ft³

109' Bottom ⇒ 40,019 ft³

139' x 145' = 0.46 Ac x 4 = 1.85 AC ⇒ $74,031

Excavation → $29,644

$103,675

Say $105,000/mi.

w/ Rip-Rap; Scupper ⇒ $119,000

Say $120,000

Cost for Scuppers; Rip-rap

(Estimate Based upon Review of ADOT cost for Catch Basin (1996))

95 YD³ 12" Rip-rap/mile (16' x 20' x 2') 4

@ $75/yd³

$7125

4 Scuppers @ $2,000 ⇒ $8,000

Total/mile = $15,125 ⇒ $15,000

Retention Volume Per Lineal Foot Per Road Lane

$$V = C\left(\frac{P}{12}\right)A$$

C = Coefficient of Runoff for Pavement, 100 Year Event = 0.95

P = 3.2 inches

A = Area = $1' \times 12' = 12\ ft^2$

V = Retention Volume (ft^3) $= (0.95)\left(\frac{3.2}{12}\right)(12\ ft^2) = 3.04\ ft^3/ft$

$$= \left[(3.04\ ft^3)\left(\frac{1\ m^3}{(3.2808\ ft)^3}\right)\right] \Big/ \left[(1\ ft)\left(\frac{1\ m}{3.2808\ ft}\right)\right] = 0.28\ m^3/m$$

1 m = 3.2808 ft

Retention Volume Per Unit Length R.O.W.

	ft^3/ft	m^3/m
110'	26.7	2.48
130'	30.0	2.79