Coconino County
Kaibab Estates West
ADMS

Area Drainage Master Plan Study

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I. General Location, Description, and Purpose

A. Location of Study Area

The Kaibab Estates West area is located in Sections 10, 11, 14, 15, 22, 23, 26, 27, 28 and portions of Sections 9, 16, 20, 21, 29, and 33, Township 22 North, Range 2 West. Please refer to **Figure 1: General Location Map.**

B. Description of Study Area

The Kaibab Estates West Area Drainage Master Study (ADMS) study area comprises approximately 11 square miles (sm). The area is generally bounded by the Kaibab National Forest. Access to the Kaibab Estates West area is from Double A Ranch Road, off of Interstate 40 (I-40) in the Ash Fork area. The streets within the Kaibab Estates West area are primarily private roads. The land use within the study area is primarily residential with lots varying in size from approximately 1 acre to five 5 acres.

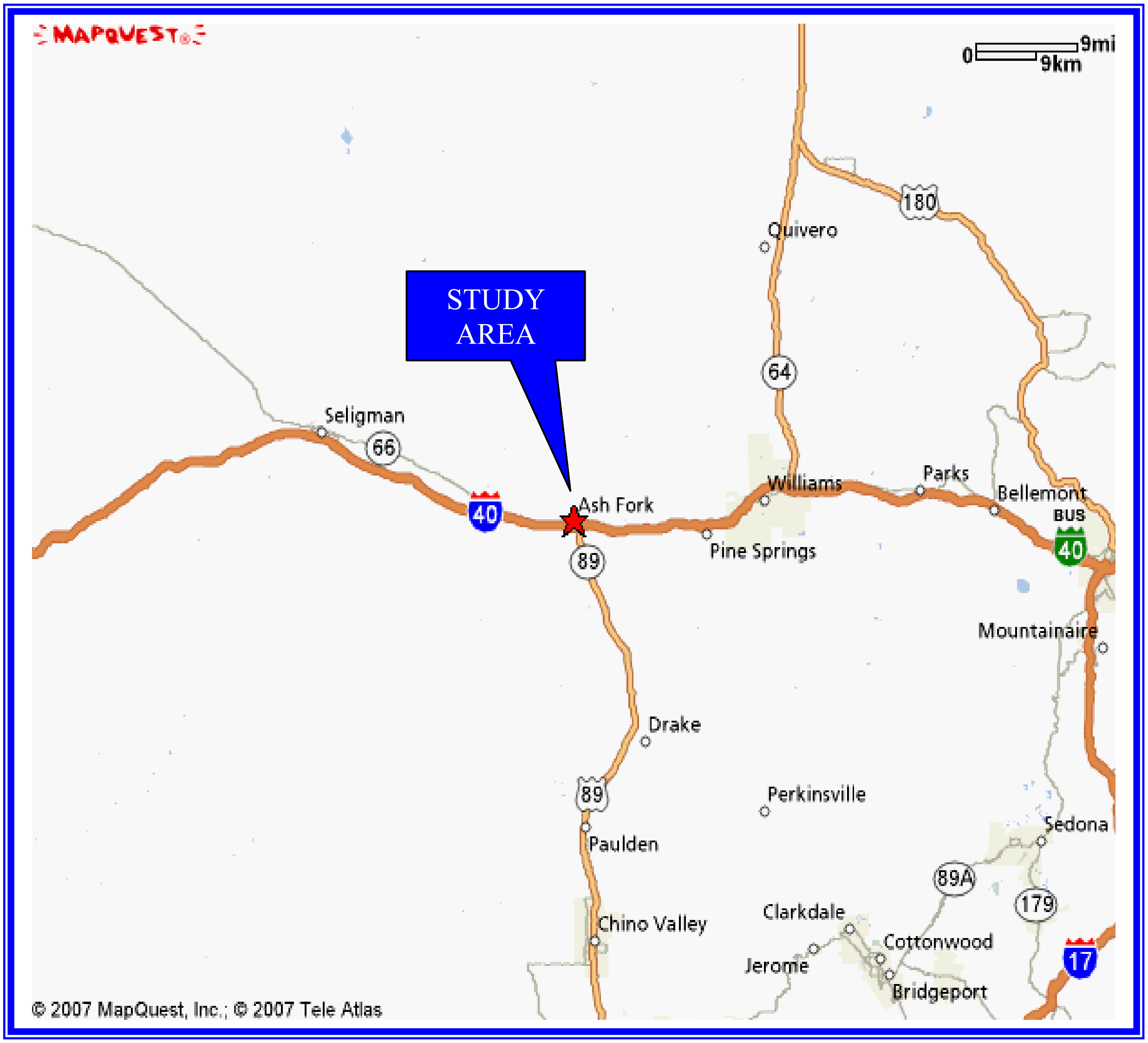
The existing Kaibab Estates West area drainage system generally consists of roadside culverts and open channels. Storm water generated within the study watershed is carried by roadside channels, roadway culverts and driveway culverts adjacent to the streets. Additionally, some of the storm water within the study area is conveyed by open channels and drainage paths which travel across residential properties throughout the site.

There are a total of 44 drainage egress points within the study area. These are concentration points where flows exit the study area. Based on the 44 concentration points, 44 basins have been delineated. The majority of these drainage basins have multiple sub basins included within them. The sub basins were delineated so that peak discharges could be estimated at key points of interest within the study area, such as at existing roadway culvert crossings. The 44 drainage basins have been labeled Drainage Basin 100 through 4400 (100, 200, 300, etc.). Sub basins are typically identified within the larger drainage basins as basins 101, 102, 103 (all within Basin 100) or 4101, 4102, 4103 (all within Basin 4100). There are a total of 270 sub basins within the study area.

C. Purpose of the Study

The purpose of the Kaibab Estates West ADMS is to estimate peak flows for various storm events at key locations within the study area. These peak flow estimates will assist Coconino County and local residents quantify drainage problems in the Kaibab Estates West area. Once the magnitude of the peak flows is better understood, more informed decisions can be made regarding drainage improvements for the area. The study also provides 2 conceptual alternatives for drainage improvements within the study area. These conceptual alternatives help formulate a complete drainage system for the study area. Until this study, the existing drainage system within the study area was not well documented or studied. With the completion of the study, drainage improvements can be systematically implemented with the effects of each improvement readily understood and quantified.

Figure 1: General Location Map



II. Drainage Basins and Sub-Basins Description

A. Description

As previously described, the study area has been divided into 44 basins based on the identification of 44 drainage egress points. These 44 basins are further subdivided into 270 sub basins so that peak discharges can be estimated at key locations such as roadway intersections.

The Kaibab Estates West area generally drains from northeast to southwest or from east to west. The uppermost portions of the watersheds impacting the site are located north and east of the study area within the Kaibab National Forest. Runoff from these hilltop areas generally collects in fairly well defined channels and impacts the site along its northern and eastern edge. Runoff is conveyed throughout the site by open channels cutting across residential properties, by roadside channels, and by roadside culverts. The majority of open channels within the residential properties are in their natural state. However, due to residential development, some of the channels have been diverted or completely filled in.

The majority of the roadways within the Kaibab Estates West area are unimproved dirt roads. The only paved road is Double A Ranch Road. Additionally, most of the roads within the study area are not maintained by the County. This being the case, many roads and their associated roadside channels and culverts are in poor condition. Storm water runoff generally collects at existing roadways. In some cases, existing roadside channels and culverts are capable of handling smaller more frequent storm events. In other cases, drainage structures are non existent and storm water causes frequent damage to the existing unpaved roads.

All storm water runoff from the project site ultimately drains to Partridge Creek. Partridge Creek is located just west of the study area and flows from north to south in the vicinity of the project.

B. Hydrologic Data and Modeling Results

1. Modeling Software

WMS (Watershed Modeling System Version 7.1) is the software which is used to perform the hydrologic modeling for the project. *HEC-1 (Version 4.0e)* is the embedded modeling method used.

2. Aerial Mapping

The aerial mapping for the project was provided by Coconino County. The aerial mapping was developed by an aerial mapping consultant under a separate contract with Coconino County. The coordinate system, datum, and ground control for the mapping was provided by Coconino County.

3. Rainfall

Analytic methods require the estimation of rainfall for the desired flood frequencies.

Twenty four (24) hour rainfall depths and a cumulative precipitation time series were used in the models to specify the rainfall events. The cumulative precipitation time series corresponds to the Soil Conservation Service (SCS) Type II Dimensionless Unit Hydrograph. The precipitation depths were obtained from the *Arizona Department of Transportation (ADOT) Highway Drainage Design Manual, Hydrology*. The precipitation maps in the ADOT Manual are derived from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume VIII, Arizona (Miller and others, 1973). Precipitation depths obtained from the ADOT Manual were transformed into Depth Duration Frequency (DDF) statistics for the desired recurrence intervals (2, 10, 25, 50, and 100 year events) by using the *PREFRE* software package developed by the Flood Control District of Maricopa County.

Table 1: Design Rainfall

Recurrence Interval (yr)	Depth (in)
2	1.70
10	2.46
25	2.91
50	3.25
100	3.60

4. Rainfall Losses

The soils within the study area watershed are predominantly classified as Hydrologic Soil Group (HSG) C and D. However there are some HSG B type soils in the study area as well. Soils information was obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) National Cooperative Soil Survey, Web Soil Survey 1.1. This survey does not include soils within the Kaibab National Forest. The Kaibab National Forest Terrestrial Ecosystem Survey has recently been completed. However, this study does not include HSGs. The Kaibab National Forest soil scientist reports that most soils within the National Forest in the vicinity of project area are HSG D and recommends that HSG D should be used for modeling purposes. Therefore, HYG D was assigned to all off site drainage basins impacting the site within the Kaibab National Forest. These areas are the uppermost portions of the watershed and are typically mountainous areas with steep slopes.

The vegetation within the study watershed is typical of the Ash Fork area. Juniper and high plains grasslands are predominant within the study area. Juniper mixed with some ponderosa pine can be found in the upper mountainous regions of the watershed. The vegetation then transitions to high plains grasslands with scattered juniper within the study area. The topography of the study watershed varies greatly. The upper regions within the Kaibab National Forest are generally steep with up to 35% slopes. Slopes within the study area generally range from approximately 2% to 15% with a few exceptions.

Rainfall losses from infiltration were modeled using the Soil Conservation Service (SCS) Curve Number Method as described in the SCS's *Technical Release 55 Manual, Urban Hydrology for Small Watersheds* (TR 55, June 1986).

Rainfall amounts are assumed uniformly over the entire watershed using a specified time distribution. Mass rainfall is converted into mass runoff using a curve number (CN). CNs combine infiltration losses with surface storage and estimate rainfall excess (runoff).

Runoff is transformed into a hydrograph using a dimensionless unit hydrograph (SCS Type II). A unit hydrograph is defined as the hydrograph of one (1) inch of direct runoff from a storm of a specific duration for a watershed. Synthetic unit hydrographs are used for watersheds which do not have an adequate data base to develop a site specific unit hydrograph. Synthetic unit hydrographs are empirically based.

Timing parameters in the hydrologic models depend on lag times (Tl). The lag time is the time from the center of mass of the effective rainfall to the peak of the runoff hydrograph. Tls were derived using the SCS Lag Time Equation.

Curve numbers were estimated based on HSG, vegetative cover, and field observations. All sub basins and within the study area were assigned a CN based on Table 2-2a of the *TR-55 Manual* for two (2) acre lots. Off site sub basins were assigned a CN based on Table 2-2d of the *TR-55 Manual* for juniper with a grass under story in a fair condition. Area weighted averages were used to derive CNs for sub-basins with areas lying both within the study area and off site. All soil data and maps are included in **Appendix A.**

Table 2: Soil Data

SOIL ID	HSG
Off-site	D
CdC	D
49	D
15	C
10	D
5	D
53	C
43	D
45	C/D
12	D
72	B/C
47	D
37	C

5. Modeling Results

The results of the hydrologic modeling are presented in the following table. It should be noted that there are a few detention/retention facilities located throughout the study area. They have not been included in the modeling. These facilities appear to have been constructed by local residents and are on private property. Since these facilities have apparently not been engineered, and the County does not currently maintain these facilities, these facilities were not included in the modeling.

It should also be noted that split flows may occur throughout the study area for some storm events. Locations such as intersections are a good example of this. Split flows are not modeled in the hydrologic models. Field observation was used to determine the apparent predominant flow directions used in the models.

Table 3: Summary of Peak Flow Rates

CONCENTRATION POINT	DRAINAGE AREA (ac)	PEAK FLOW (cfs)				
		2-yr	10-yr	25-yr	50-yr	100-yr
100	5632	479	1185	1675	2070	2492
101	3904	319	786	1111	1372	1652
102	192	26	81	122	154	190
103	173	24	76	114	144	177
104	99	14	37	52	64	77
105	3044	264	655	926	1144	1376
106	51	7	19	28	35	43
107	39	5	14	20	25	30
108	435	60	151	213	263	316
109	115	17	52	78	98	118
110	109	17	51	75	95	114
111	64	11	33	48	60	72
112	13	2	7	11	14	17
113	103	25	65	92	113	136
114	45	8	23	33	41	49
115	21	6	15	21	26	31
116	31	8	19	27	34	40
117	22	5	14	19	24	29
118	17	5	11	16	20	24
119	3	1	2	3	4	4
200	72	9	26	38	47	57
300	1414	237	646	925	1141	1396
301	448	77	197	288	348	417
302	422	75	191	270	335	403
303	17	3	8	12	15	18
304	922	186	495	709	879	1071
305	403	73	184	260	322	388
306	7	2	4	6	8	10
307	890	182	484	698	863	1050
308	704	157	408	576	708	850
309	391	72	182	256	316	381
310	180	48	119	167	207	249
311	288	64	165	235	288	347
CONCENTRATION	DRAINAGE AREA	PEAK FLOW (cfs)				

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
312	307	66	170	243	300	361
313	358	88	223	317	392	474
314	77	14	39	58	72	87
315	21	4	12	17	22	27
316	11	3	9	12	15	18
317	5	2	5	7	8	10
318	10	2	5	7	9	11
319	297	80	197	280	345	415
320	9	4	9	13	16	19
321	20	8	19	27	33	39
322	38	7	21	31	39	48
400	1363	219	564	805	996	1201
401	37	5	13	20	25	30
402	1050	173	441	622	769	926
403	45	7	20	29	36	44
404	1018	171	434	614	757	909
405	32	5	15	23	28	34
406	9	2	5	7	9	11
407	938	158	400	565	698	840
408	46	10	26	37	46	55
409	17	5	12	17	21	25
410	33	8	19	27	34	41
411	51	10	26	37	46	56
412	128	27	69	97	121	145
413	11	2	6	8	10	12
414	1344	217	559	798	987	1189
500	70	21	51	71	87	103
501	45	13	31	42	52	62
502	14	3	8	11	14	17
503	2	1	2	2	3	3
600	749	136	345	495	610	737
601	8	3	6	9	11	13
602	19	7	16	22	27	32
603	27	6	16	23	29	35
604	77	5	22	35	47	59
CONCENTRATION	**DRAINAGE AREA**	**PEAK FLOW (cfs)**				

CONCENTRATION POINT	DRAINAGE AREA (ac)	PEAK FLOW (cfs)				
		2-yr	10-yr	25-yr	50-yr	100-yr
605	5	1	2	4	5	7
606	179	29	82	120	150	183
607	212	37	100	145	181	220
608	50	17	38	52	63	75
609	230	46	114	160	196	233
610	250	47	117	164	201	239
611	70	17	41	57	69	83
612	198	38	96	136	168	202
613	3	1	3	4	5	6
614	10	4	10	13	16	19
615	122	22	54	75	92	110
616	51	12	30	42	52	62
617	186	37	93	130	159	188
618	160	34	85	119	146	173
619	6	2	5	7	9	10
620	96	21	51	72	88	105
621	30	7	16	23	28	33
622	51	12	28	40	49	58
623	34	6	16	22	28	33
624	56	12	30	42	52	63
625	8	2	6	8	10	12
700	70	24	57	79	96	115
701	19	5	11	15	18	21
702	4	2	4	6	7	8
703	6	2	4	6	7	9
800	160	39	98	138	170	204
801	90	18	48	70	87	106
802	45	9	27	42	53	65
803	64	10	31	46	59	72
804	25	3	12	19	25	32
900	25	3	9	12	15	18
1000	45	17	38	53	64	76
1100	205	39	98	137	167	200
1101	45	9	27	39	49	60
1102	32	5	17	27	34	43

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
1103	16	1	7	11	15	19
1200	41	8	22	32	39	48
1300	179	21	61	90	113	138
1301	1	0	1	1	2	2
1302	45	3	13	21	29	37
1400	186	29	80	116	145	175
1401	10	1	4	7	10	12
1402	40	3	13	22	30	38
1403	77	11	33	49	62	76
1500	22	5	11	15	19	22
1600	76	13	31	43	52	62
1700	118	23	54	75	91	108
1800	90	26	62	87	108	130
1801	64	18	46	65	81	96
1802	18	8	19	25	31	36
1803	26	4	14	21	26	33
1900	8	3	7	9	11	13
2000	26	12	26	36	44	52
2100	8	4	10	14	17	20
2101	6	4	8	11	13	16
2200	70	24	55	76	92	109
2201	12	6	13	17	21	25
2300	3	2	4	6	7	8
2400	9	2	6	8	9	11
2500	5	3	7	9	11	13
2600	64	18	49	69	85	103
2601	4	2	5	7	8	10
2602	30	5	17	27	34	42
2700	19	7	17	24	29	34
2800	147	36	99	144	181	220
2801	13	6	14	18	22	26
2802	109	24	67	101	128	157
2803	64	9	34	52	67	84
2804	21	2	10	16	21	26
2805	9	1	5	8	10	13
CONCENTRATION	**DRAINAGE AREA**	**PEAK FLOW (cfs)**				

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
2806	3	0	2	3	4	5
2807	9	1	4	6	9	11
2808	15	3	10	15	18	22
2809	4	2	4	5	6	7
2900	109	40	94	129	157	188
2901	64	21	52	73	90	108
2902	32	8	21	30	38	45
2903	6	1	4	6	8	10
2904	9	2	5	7	8	10
2905	16	8	17	24	29	34
2906	4	2	5	6	8	9
2907	11	6	13	18	22	26
3000	12	3	8	12	15	18
3100	19	4	11	16	20	25
3101	8	2	6	9	11	13
3200	12	2	7	10	13	16
3300	4	0	2	4	5	6
3400	192	17	65	101	131	164
3401	6	1	4	6	7	9
3402	13	2	8	13	17	21
3403	26	3	11	16	21	26
3404	127	8	37	60	79	100
3405	4	0	2	3	5	6
3406	2	0	1	2	2	3
3407	4	0	2	4	5	6
3500	46	7	17	24	30	36
3600	1024	189	469	663	818	980
3601	35	5	12	17	21	26
3602	966	183	456	643	789	947
3603	474	100	249	355	440	529
3604	486	90	225	318	390	467
3605	467	99	249	353	437	523
3606	18	7	17	23	28	33
3607	76	20	46	63	77	91
3608	429	93	232	328	405	484
CONCENTRATION	**DRAINAGE AREA**	**PEAK FLOW (cfs)**				

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
3609	6	3	6	10	10	11
3610	4	3	6	8	9	11
3611	11	5	12	17	21	25
3612	301	66	160	225	278	331
3613	416	91	225	317	391	466
3614	96	23	58	81	100	119
3615	269	59	142	200	248	295
3616	83	20	51	71	87	103
3617	63	17	41	57	70	83
3618	3	2	4	5	6	8
3619	15	7	16	23	28	33
3620	160	36	90	129	159	193
3621	29	9	21	29	35	42
3622	199	52	125	174	213	256
3623	26	8	19	26	32	37
3624	96	21	53	75	92	111
3625	57	11	30	44	55	67
3626	25	10	22	30	36	43
3627	22	5	14	20	25	30
3628	38	4	15	24	32	40
3629	1	0	0	1	1	1
3700	2003	325	817	1151	1421	1718
3701	1984	324	812	1151	1415	1705
3702	19	7	18	26	32	38
3703	3	1	3	4	5	6
3704	1	1	1	2	3	3
3705	13	3	7	10	13	15
3706	70	19	46	65	80	96
3708	58	17	40	57	70	84
3709	6	2	5	7	8	10
3710	45	14	34	48	59	71
3711	3	1	3	5	6	7
3712	38	11	27	38	46	55
3713	448	94	249	362	452	550
3714	26	8	21	29	35	42
CONCENTRATION	**DRAINAGE AREA**	**PEAK FLOW (cfs)**				

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
3715	166	25	83	126	163	204
3716	262	69	168	234	288	347
3717	17	6	13	17	21	25
3718	154	21	75	114	148	183
3719	256	68	163	230	282	339
3720	13	5	12	17	20	24
3721	8	4	8	11	14	16
3722	4	2	4	6	7	8
3723	205	56	134	188	231	277
3724	25	10	23	32	39	47
3725	10	1	6	9	12	14
3726	115	11	49	77	101	129
3727	77	7	32	50	66	84
3728	41	3	15	25	33	43
3729	12	1	5	8	10	13
3730	26	2	9	15	20	25
3731	173	48	118	164	201	240
3732	10	4	10	13	16	19
3733	10	4	9	13	16	18
3734	474	85	214	303	375	450
3735	12	5	10	14	18	21
3736	15	4	10	14	17	20
3737	16	6	13	18	22	26
3738	410	74	186	262	324	389
3739	20	5	12	16	20	24
3740	17	6	14	19	23	27
3741	26	9	21	29	35	41
3742	16	6	13	18	22	26
3743	371	66	168	236	293	352
3744	4	2	4	6	7	9
3745	333	61	155	220	272	327
3746	28	5	12	17	21	25
3747	17	6	14	19	23	27
3748	659	119	273	377	459	546
3749	24	8	18	24	29	35
CONCENTRATION	**DRAINAGE AREA**	**PEAK FLOW (cfs)**				

POINT	(ac)	2-yr	10-yr	25-yr	50-yr	100-yr
3750	1	0	1	1	1	1
3751	1242	215	514	715	871	1041
3752	33	5	16	25	33	41
3753	64	13	39	57	72	90
3754	38	12	29	40	49	59
3755	3	2	4	5	6	7
3800	58	17	41	58	71	84
3801	45	15	36	49	60	72
3802	2	2	3	5	6	7
3803	6	3	7	10	12	14
3804	13	5	12	17	21	25
3805	5	2	5	7	8	9
3806	3	2	3	5	6	7
3807	3	1	3	4	5	6
3900	4	2	4	5	6	8
4000	4	2	4	6	7	9
4100	70	19	48	69	86	104
4101	58	14	38	55	68	82
4102	32	10	24	35	43	52
4103	19	5	13	19	24	29
4104	5	0	3	4	5	7
4200	550	51	129	183	227	274
4201	96	7	28	45	59	74
4202	22	2	8	12	15	18
4203	430	45	112	159	196	236
4300	1584	179	449	636	786	946
4400	6	3	7	9	11	13

C. Hydraulic Calculations

1. Modeling Software

The hydraulic calculations pertaining to this study include a simplified analysis of existing and possible future drainage structures and channels.

The existing and proposed culvert analyses were performed using *Culvertmaster Version 3.0* by Haestad Methods. This software uses the methodolo*gy from the Hydraulic Design Series No. 5, Hydraulic Design of Highway Culverts (1985)***,** prepared by the U.S. Federal Highway Administration. The program solves for both inlet and outlet control. The controlling headwater depth is then the greater of the two solutions.

The proposed open channel analysis was performed using *Flowmaster Version 7.0* by Haestad Methods. Flowmaster uses Manning's Equation to estimate capacities of open channels.

2. Existing Structures Inventory

A comprehensive site survey was performed to identify all visible existing drainage structures within the study area. The site survey was performed by visual inspection. Five hundred sixty five (565) structures were found at the time of the inventory. It is likely that additional structures have been added since that time. The approximate location, size, approximate length, material type, and condition of the structures were all recorded. Simplified analyses were performed using *Culvertmaster* and *Flowmaster* to approximate the capacity of each structure. Structure slopes for the analyses were assumed to be 2%. One (1) foot of cover was also assumed for the structures analyses. The existing structures inventory is presented on **Sheet 2** of the **Drainage Map** as well as in **Appendix A.**

3. Possible Future Structures and Channels

A simplified structures analysis was also used to estimate the capacity of the possible future drainage structures (CMPs). The analyses included CMPs ranging in size from twelve (12) inch to seventy two (72) inch. The analyses assume a thirty (30) foot length, and one (1) foot of cover. The structure's slopes are assumed at 2%. The estimated capacity of possible future structures is presented on **Sheet 1** of **Conceptual Alternative 1** and **Conceptual Alternative 2,** as well as in **Appendix A.**

A channel analysis was also performed for possible future channels. This analysis includes possible future roadside channels. The simplified analysis assumes a triangular shaped channel with a 4:1 inslope side slopes and a 3:1 backslope side slope. The channel depth is varied from one (1) foot to four (4) feet, and the channel slope is also varied from one percent (1%) to five percent (5%). A rating table has been generated for this analysis and is presented on **Sheet 1** of **Conceptual Alternative 1** and **Conceptual**

Alternative 2, as well as in **Appendix A.** The analysis also includes possible future trapezoidal channels. These channels are part of **Conceptual Alternative 2.** Specifically, these are the possible future channels through the private properties. The channel depth is varied from one (1) foot to five (5) feet, the bottom width is varied from two (2) to six (6) feet, and the channel slope is also varied from one percent (1%) to five percent (5%). A rating table has been generated for this analysis and is presented on **Sheet 1** of **Conceptual Alternative 2,** as well as in **Appendix A.**

III. Conceptual Alternatives

Two (2) conceptual alternatives were formulated to help minimize drainage and flooding problems within the study area. They are entitled **Conceptual Alternative 1** and **Conceptual Alternative 2.**

A. Conceptual Alternative 1 – Roadside Improvements Only

Conceptual Alternative 1 includes the construction of roadside channels and roadside culverts. Please refer to the **Conceptual Alternative 1** drawings. **Conceptual Alternative 1** can be constructed at various levels of improvement (2, 10, 25, 50, or 100 year event).

Many portions of the study area lack adequate roadside drainage channels, culverts at intersections, and driveway culverts. In some areas, storm water runoff collects on the unpaved streets themselves and is conveyed to various outfall points. Also, in some cases, flows are conveyed directly across low points in the existing roadways. This creates problems for the local residents in that the streets can become inundated, slippery, and damaged by ruts created by vehicles. As a result, frequent repairs and grading by local residents and County staff has been needed to keep the roads in service. As previously mentioned, many of the roads within the study area are not maintained by the County. Therefore, a significant portion of the expense and burden of road maintenance falls upon local residents. Minimizing damage and maintenance of the roads will be of significant benefit to the local residents.

In some instances, roadside channels, culverts at intersections, and driveway culverts apparently existed at one time. However, the structures and channels have not been properly maintained and their capacities are limited.

The addition of adequately sized roadside channels, culverts at intersections, and driveway culverts will significantly improve the drainage system within the study area. The hydrologic models for the study area provide estimated discharges at key concentration points such as at intersections and where existing drainage paths impact roadways. Having this information readily available will allow the County to make better informed decisions in terms of determining which areas have the greatest need for improvement as well as potential channel and culvert sizing.

The hydrologic models represent existing conditions (at the time of the modeling). Since the completion of the modeling, some additional structures may have been added to somewhat alter the drainage patterns shown in the model. However, the major drainage patterns should remain the same.

Some areas within the study area have recently been improved. In these areas, existing structure and channel capacities can readily be compared to the estimated peak flow rates to determine if additional improvements are necessary.

Conceptual Alternative 1 as presented generally maintains existing flow patterns. However, in some locations, due to existing drainage problems and the desire to minimize drainage patterns through residential lots, some flow diversions are shown. The flow diversion areas are identified on the **Conceptual Alternative** 1 drawings. Caution should be taken when altering existing flow patterns. It is essential to provide adequate downstream facilities for any flow diversion so that drainage problems are not created where they previously did not exist. If the diversions may cause problems, then it is recommended that existing flow patterns are maintained. While this alternative solution will provide significant improvements to the overall drainage system, it will not solve all drainage and flooding problems to individual properties. If this alternative is implemented partially in phases, care should be taken to provide a drainage system that will not adversely impact properties downstream of the improvements.

In summary, Conceptual Alternative 1 is a simple, cost effective way to make improvements to the study area which improve the overall drainage system, minimize road maintenance, and also maintain the rural character of the study area.

B. Conceptual Alternative 2 – Roadside and Interior Improvements

Conceptual Alternative 2 includes the improvements outlined in **Conceptual Alternative 1**. Additionally, it also includes the construction of open channels on private property throughout the study area and a possible detention/retention facility. Please refer to the **Conceptual Alternative 2** drawings. **Conceptual Alternative 2** can also be constructed at various levels of improvement (2, 10, 25, 50, or 100 year event).

Open channels through private property are proposed at locations where existing flows drain across private property. Based on the topographic mapping, these channels are proposed at locations where existing channels are either non existent, or appear too small to adequately handle the flows.

For instances where there are well incised or well defined flow paths, no channel improvements are proposed. In these instances, the existing channels are likely to accommodate the more frequent low flow or larger events and may not be currently causing drainage problems for the property owners. Therefore, County resources should be focused on constructing a complete drainage system within the study area in which benefits from construction costs and maintenance costs can be maximized.

The proposed detention/retention area is located on the west side of Double A Ranch Road near Zabala Road (sub basin 3701). There is an existing non functioning stock tank at this location. The property owner has expressed an interest in enlarging the tank and allowing storm water to be stored at this location. Given the large upstream drainage area, storm water detention/retention would likely only be beneficial for the smaller more frequent storm events unless the tank can be enlarged within several properties to provide more of a regional type detention/retention facility.

A preliminary unit cost estimate has been prepared for possible improvements associated with **Conceptual Alternatives 1 and 2**. The unit cost estimate can be used as a basis for calculating future improvement costs depending on proposed culvert sizing and the amount (linear footage) and type of channel improvements (unlined or riprap lined) desired.

Table 4: Preliminary Unit Cost Estimate

ITEM	UNIT	UNIT COST
12" CMP	LF	$35
18" CMP	LF	$45
24" CMP	LF	$50
30" CMP	LF	$55
36" CMP	LF	$60
42" CMP	LF	$70
48" CMP	LF	$80
54" CMP	LF	$90
60" CMP	LF	$100
66" CMP	LF	$110
72" CMP	LF	$120
Channel/Detention Earthwork	CY	$8
8" Diameter Riprap (D50)	SY	$70
12" Diameter Riprap (D50)	SY	$100

C. Public Meetings

The first of two (2) public meetings was held on September 25, 2006, at the Kaibab Estates West Fire Station. The purpose of the first meeting was to inform the local residents of the scope of work for the study, and to obtain input from the public about known drainage and flooding problems within the study area. Subsequently, approximately ten (12) local residents contacted Civiltec to discuss problem areas. Every resident was personally met on site to discuss their concerns.

The second public meeting was held on March 28, 2007. The purpose of the second public meeting was to present the results of the hydrologic modeling to the public and discuss any items regarding the study with local residents.

IV. Conclusion

The existing Kaibab Estates West area drainage system primarily consists of roadside culverts, roadside channels, and other open channels. The majority of streets in the study are unpaved and do not have adequate drainage facilities. The majority of the streets are also not maintained by Coconino County. Storm water generally collects at the roadways. Inadequate drainage facilities located along the existing roads results in frequent damage to the roads. The resulting maintenance is a primary concern to the local residents.

There are forty four (44) drainage basins within or impacting the study area. They have been identified as drainage areas 100 through 4400. These drainage basins have been further subdivided into 270 sub basins to estimate peak flow rates at key locations within the study area.

The purpose of this study is to provide Coconino County a useful tool to help minimize drainage and flooding problems in the study area. Concentration points have been developed in the hydrologic modeling at key points such as intersections and drainage/roadway crossings. The study should be used to quantify storm water runoff at points of interest. The proposed conceptual alternatives presented here within are not the only potential solutions to the drainage and flooding problems in the study area. The conceptual alternatives proposed were formulated in an effort to provide realistic, cost effective solutions which maintain the rural character of the area. The alternatives can be constructed at various levels of improvement (2, 10, 25, 50, or 100 year event). The study should be used as a guide when planning future improvements, but should not be used exclusively for the construction of proposed improvements. The phasing and downstream impact of improvements should be carefully considered prior to constructing improvements. Care should be taken not to cause diversions or concentrations of storm water which adversely impact downstream properties.

V. References

National Cooperative Soil Survey, Web Soil Survey 1.1, USDA, NRCS, 2007

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Haestad Methods Culvert Master Version 3.0, 2004

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WMS, Watershed Modeling System, Version 7.1 (HEC-1 Version 4.0e, 2006), EMS-1

Ash Fork Quadrangle 7.5 Minute Series (Topographic), USGS, 1983

Cathedral Caves Quadrangle 7.5 Minute Series (Topographic), USGS, 1983

Fitzgerald Hill Quadrangle 7.5 Minute Series (Topographic), USGS, 1983

Horse Trap Mesa Quadrangle 7.5 Minute Series (Topographic), USGS, 1983

Prefre, Flood Control District of Maricopa County