Tomahawk Creek WWTP
Updates to Process Improvements Pre-Design Study
Wet Weather Flow Evaluation and Alternative Definition

PREPARED FOR: Johnson County Wastewater

PREPARED BY: Mike Kalis/HDR
Ryan Eisele/HDR
Dale Gabel, CH2M HILL

DATE: ~~July 28, 2011~~ Updated July 31, 2013

Introduction

The purpose of this technical memorandum is to document the criteria and assumptions that will serve as the basis for the wet weather flow analysis for the Tomahawk Creek WWTP, and to identify the reasonable alternatives for accommodating these flows. These wet weather alternatives will then be combined with the preferred dry weather alternatives identified in TM No. 3, and subjected to a comparative analysis to determine the preferred overall dry weather/wet weather improvement plan. This TM No. 4 will include the following steps:

- Provide an interpretation and analysis of the assumptions, design wet weather event, flows, and sizing of facilities incorporated by the City of Kansas City, Missouri (KCMO) into its Overflow Control Plan (OCP).

- Define the design wet weather event at the Tomahawk Creek WWTP based on JCW criteria, and its implications on sizing of facilities such as storage and peak flow treatment. Reconcile the flows and facility sizes from the OCP with those based on JCW criteria to the greatest extent possible to allow for an "apples-to-apples" comparison between the two.

- Develop assumptions with respect to Tomahawk Creek's existing lagoon storage capacity and its ability to shave peaks.

- Based on the above, identify the set of wet weather treatment and/or storage alternatives to be evaluated.

KCMO OCP Flow and Storage Summary

The OCP adopted a 5 year, 24 hour storm as the design wet weather event for the Blue River South Watershed, which includes service areas on both sides of the State Line. Details on this event are explained in a document entitled, "Blue River South Basin, Wet Weather Flow Rates and Volumes at 87th Street Pumping Station, February 26, 2008", which is an appendix to the OCP, and which is included as Appendix A to this TM. The following information is a summary of the above document's findings, and reference to the document itself is made to pursue a more detailed understanding of the assumptions and methodologies involved.

In summary, the OCP considered four alternatives which included various combinations of wet weather treatment at the Tomahawk Creek Wastewater Treatment Plan, and I/I removal by KCMO, defined as follows:

Alternative Description

Alternative 1
- 35 mgd wet weather treatment at Tomahawk Creek (THC)
- Existing KCMO flows with no I/I removal

Alternative 2
- 35 mgd wet weather treatment at THC
- Future KCMO flows with I/I removal

Alternative 3
- No JCW flows
- Future KCMO flows with I/I removal

Alternative 4
- No wet weather treatment at THC
- Future KCMO flows with I/I removal

The peak hour flowrates associated with each alternative per the OCP are presented in Table 1.

Table 1 – OCP Flow Summary				
	Peak Hour Flows (mgd)			
Alternative	1	2	3	4
Total Flow to 87th Street	245	204	107	239
KCMO Portion	125	84	84	84
JCW Portion				
• Total	120	120	23	155
• From THC (IMF 6) (See Note 1)	97**	97**	0	132*
• Other JCW (See Note 2)	23	23	23	23
87th Street Flow Breakdown				
• Pump Station Capacity	85	85	85	85
• To Storage	160	119	22	154
• KCMO	40	0	0	0
• JCW – Total	120	120	0	154
- THC (IMF 6)	97	97	0	131
- Other	23	23	22	23

* IMF 6 Peak Flow = 132 mgd

** Assume 35 mgd wet weather treatment at THC. (132 mgd – 35 mgd) = 97 mgd

Notes:

1) "IMF 6" is JCW Interconnect Monitoring Facility 6 which includes Lower Indian Creek, Tomahawk Creek, and Dykes Branch Watersheds.

2) "Other JCW" includes IMF's 10, 11, 12, 13, 13a, 14, and 16.

Table 2 presents the storage requirements and the proposed storage allocation to each entity per the OCP. The hydrograph upon which these storage volumes are based can be found on page 13 of 14 in Appendix A.

Table 2 – OCP Storage Summary				
Alternative	1	2	3	4
	— Volume (mgal) —			
Total Storage Volume	104	68	2	82
Storage Allocation (per OCP)				
KCMO	38	2	2	2
JCW – Total	66	66	0	80
- THC (IMF 6)	52	52	0	66
- Other	14	14	0	14

KCMO OCP Flow and Storage Analysis

The allocation of storage presented in Table 2 is not flow proportional but rather treats KCMO flows as base flows and JCW's flows as additive. A redistribution of storage allocation on a flow proportional basis would be more equitable for JCW, as illustrated in the following discussion.

Per the OCP, total peak hour flow originating in the Blue River South Watershed is 239 mgd, 84 mgd from KCMO (after I/I removal) and 155 mgd from JCW (132 mgd from THC and 23 mgd from other sources, assuming no wet weather treatment at THC). The following Table 3 shows a breakdown of the total flow volumes presented in Table 1 Alternative 4 (i.e., scenario without wet weather treatment at THC) into dry weather and wet weather flow components for each contributor.

Table 3 – Blue River South Watershed Flow Breakdown (Alternative 4)			
	Flow (mgd)		
	Annual Average Dry Weather	Wet Weather Peak Hour	Total Peak Hour
KCMO	5*	79	84
JCW – THC (IMF 6)	15	117	132
- Other	3	20	23
Total	23	216	239

* Dry weather flow for KCMO is based on service area population per the OCP and 100 gpcd .

From the above table, JCW contributes approximately 63% of the wet weather flow, 137 mgd out of a total of 216 mgd. Therefore, JCW would be responsible for 63% of the 82 mgal storage in Alternative 4 (see Table 2), or 52 mgal. Of this, 85% or 44 mgal would be attributable to Tomahawk Creek WWTP (IMF 6).

The OCP adopts Alternative 2 as the selected alternative, subject to negotiating with JCW. Total storage for this alternative is 68 mgal. Updated cost information on KCMO's website presents the cost of this storage as follows:

Storage Cost (per Table on KCMO website as of 6/1/11):

Initial Tank (20 mgal)		$83.2 million	(2016)
Final Tank (48 mgal)		$153.5 million	(2024)
	Total	$236.7 million	
	÷	68 million	gallons
		$3.48/gallon	
Initial Tank	=	$4.16/gallon	
Final Tank	=	$3.20/gallon	

It should be noted that, in Alternative 2, the flowrate from JCW at Tomahawk IMF 6 is 97 mgd. This is equivalent to the 97 mgd figure that was arrived at in prior discussions between JCW and KCMO as the maximum flow that KCMO could accept at IMF 6. Previous NPDES permits called for Tomahawk to maximize flow to KCMO before sending flow to its wet weather lagoon, and Tomahawk's current Diversion Structure is set up to accomplish this by diverting a maximum of 80 mgd to KCMO. For purposes of this study, the 97 mgd figure will be taken as the maximum hydraulic flowrate diverted to KCMO at IMF 6.

JCW Flow and Storage Summary

JCW has adopted a 10 year return interval as its design basis. In TM No. 1, a series of storms in June, 2008 were presented (see Figure 1 from TM No. 1, also reproduced as Figure 1 of this TM). The June 3rd storm consisted of 2.75 inches of rain over 6.5 hours. The majority of this fell in a 4-hour period which is the approximate time of concentration for the THC service area. This equates to slightly over a 2 year return interval storm. Also in TM No. 1, this storm's hydrograph was "scaled up" to a peak hour flow (PHF) of 135 mgd which is the 10-year peak flow previously adopted for THC (Figure 2 in TM 1, reproduced as Figure 2 in this TM). This event will be used as the design wet weather event for flows at THC. It should be emphasized that the peak hour flow adopted by JCW at IMF 6 is 135 mgd, while the corresponding flow used by KCMO in the OCP analysis was 83% of that amount, or 112 mgd. The reason for this difference is primarily attributable to the different design storms used in the respective analyses. The JCW figure is based on a 10-year storm with a 4-hour duration (corresponding with the tributary watershed's time of concentration), with a total rainfall of 3.5 inches and an average intensity of 0.88 in/hr. The KCMO figure is based on a 5-year storm with a 24-hour duration, with a total rainfall of 4.44 inches and a rainfall distribution with a maximum intensity over a 4-hour period of 0.46 in/hr.

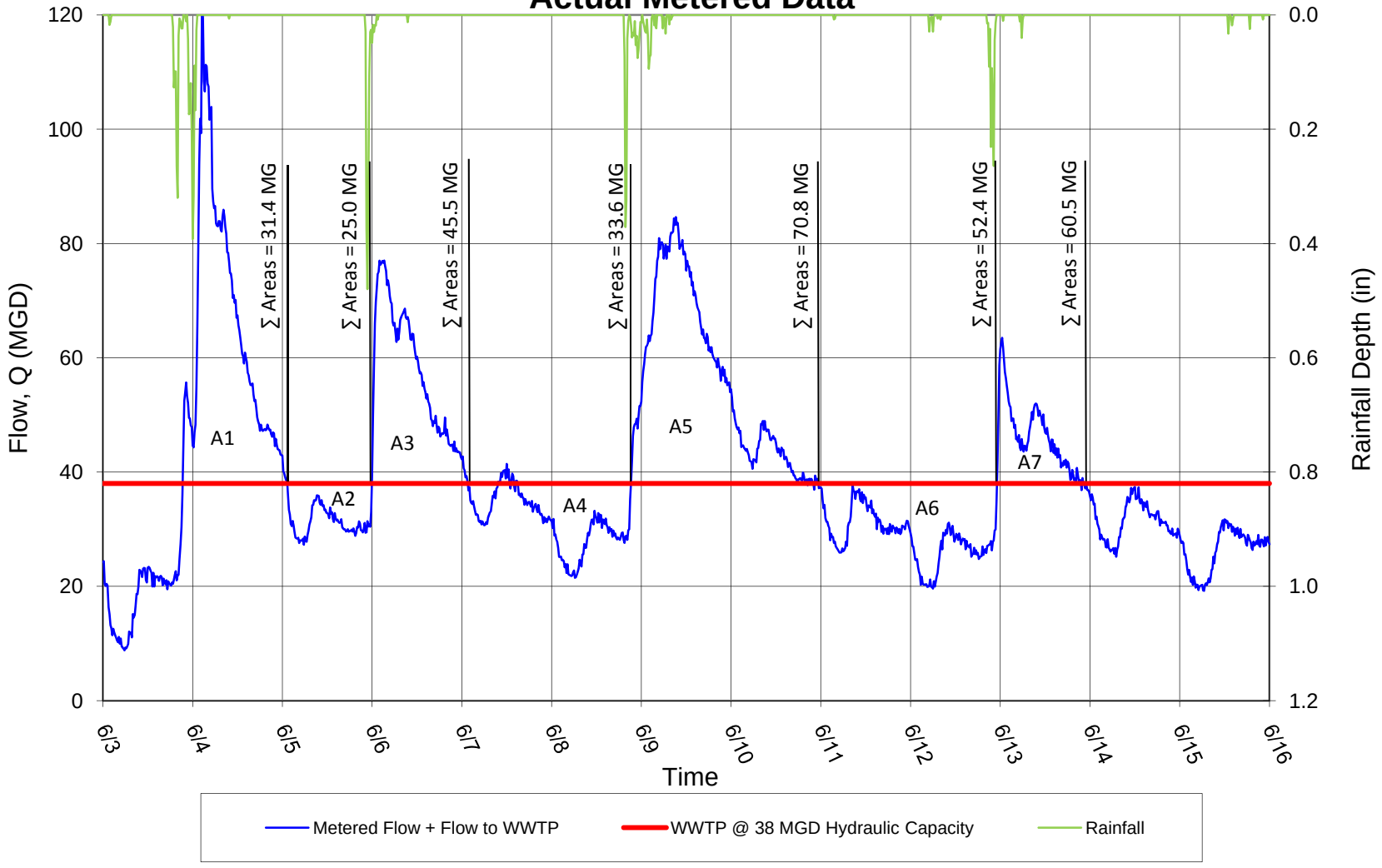
Figure 2 shows that the volume above the maximum anticipated wet weather throughput of an expanded THC WWTP of 38 mgd (2 times the 19 mgd rated capacity) is 42 mgal. This

would be the storage volume required at THC in alternatives where storage at that location is considered in conjunction with a 19 mgd plant.

The JCW analysis calls for addressing 42 mgal to accommodate a 97 mgd flow component (135 mgd PHF – 38 mgd maximum plant wet weather throughput = 97 mgd), or 0.43 mgal/mgd. This value will be used as a basis for determining storage requirements for the various alternatives evaluated under this study. A more detailed flow and storage analysis is recommended prior to final design.

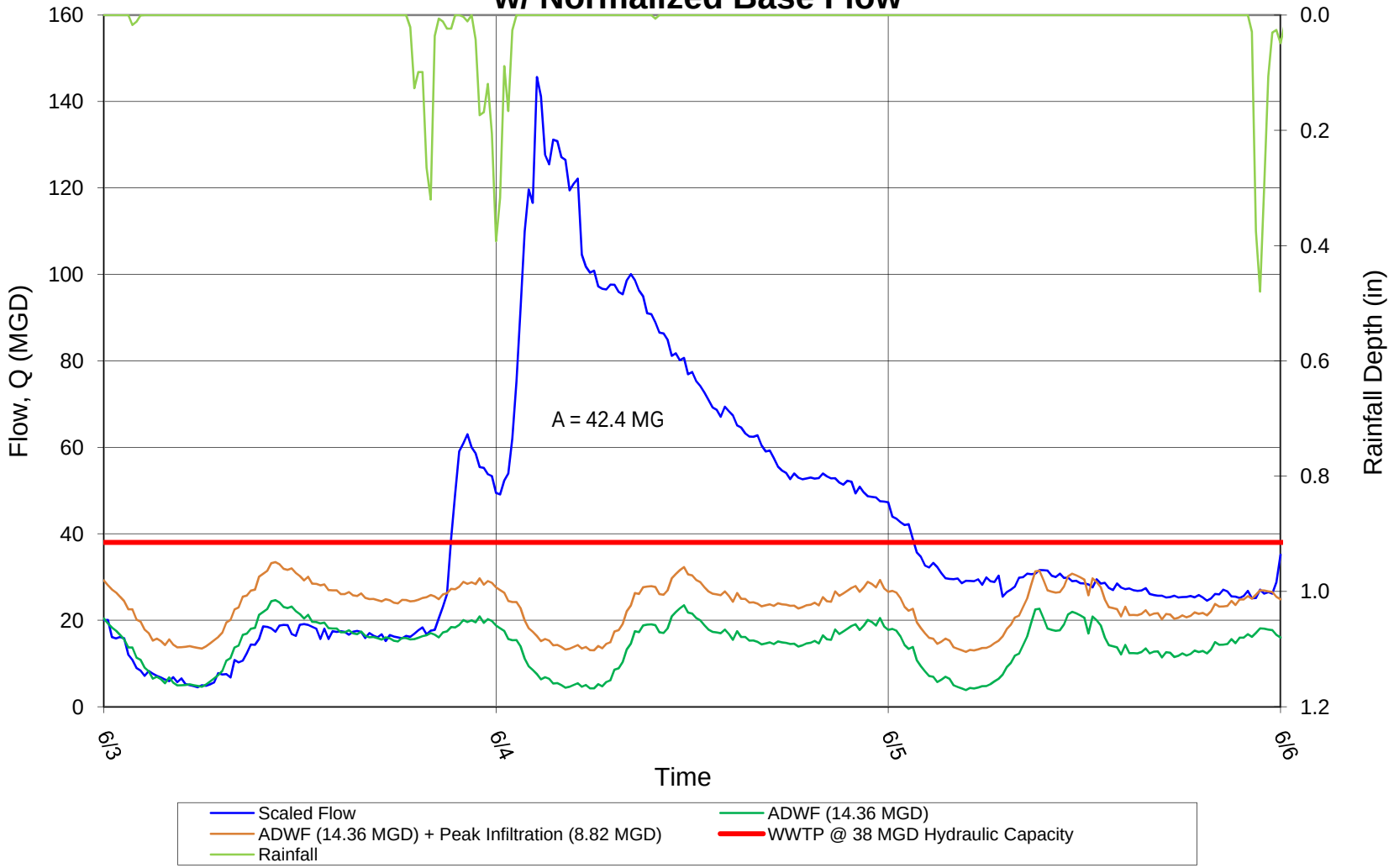
Meter ID #: 26
Manhole #: 251001

Figure 1
June 3 - June 12 2008 Storm Events
Actual Metered Data



Meter ID #: 26
Manhole #: 251001

Figure 2
June 3, 2008 Storm Event Scaled to 135 MGD Hourly Peak w/ Normalized Base Flow



Existing Lagoon

The existing lagoon at THC is currently well below the 100-year flood elevation. The berms would need to be raised by 6 feet to Elevation 846 to provide the required 2 feet of freeboard. As is readily evident from the site maps presented in TM No. 2, this would create a severe restriction in the flow channel immediately downstream of the confluence of Tomahawk Creek and Indian Creek. It is likely that such a restriction would result in a significant rise in the upstream base flood elevation, requiring either significant modifications to the flow channel, approval from the City of Leawood for a higher flood level (Conditional Letter of Map Revision, or CLOMR, involving an extensive public participation process), or a combination of both. This is further complicated by the fact that the proposed dry weather improvements will also impact the base flood elevation.

A detailed flood study is required to better define these impacts. However, at this conceptual stage, a reasonable assumption is that the footprint of the lagoon will need to be reduced at such time as the berms are raised. For purposes of this study, it will be assumed that the lagoon surface area will be reduced to 3 acres, one half its current area, and increased in depth by 6 feet to 11 feet, total. This results in approximately 10 mgal of useable storage.

Wet Weather Flow Treatment and/or Storage Alternatives

Based on the assumptions developed in the preceding sections of this TM, including adoption of the 135 mgd peak hour flow and the hydrograph in Figure 2 as the design wet weather event, the following is the list of wet weather alternatives to be evaluated:

A. 19 mgd WWTP at THC

<u>Wet 19.1:</u>

Treat 19 mgd Dry Weather Flow (DWF) plus 19 mgd Peak Wet Weather Flow (PWWF) at THC (total of 38 mgd)

Store (then treat) 23 mgd PWWF at THC (23 mgd X 0.43 mgal/mgd = 10 mgal storage)

Discharge 74 mgd PWWF through Auxiliary Treatment Facility

See Note 1 below

<u>Wet 19.2:</u>

Treat 38 mgd at THC (19 mgd DWF and 19 mgd PWWF)

Store (then treat) 23 mgd PWWF at THC (23 mgd X 0.43 mgal/mgd = 10 mgal storage)

Send 74 mgd PWWF to KCMO (74 X 0.43 = 32 mgal storage at 87th Street Pumping Station required)

<u>Wet 19.3:</u>

Treat 38 mgd at THC (19 mgd DWF and 19 mgd PWWF)

Store (then treat) 97 mgd PWWF at THC = 97 X 0.43 = 42 mgal storage required, 10 mgal lagoon, 32 mgal new storage at THC

B. 10 mgd WWTP at THC

Wet 10.1:

Treat 20 mgd at THC (10 mgd DWF and 10 mgd PWWF)

Send 18 mgd to KCMO (9 mgd DWF and 9 mgd PWWF, requiring 4 mgal PWWF storage at KCMO)

Store (then send to KCMO) 23 mgd PWWF at THC (23 mgd X 0.43 mgal/mgd = 10 mgal storage)

Discharge 74 mgd PWWF through Auxiliary Treatment Facility

See Notes 1 and 2 below

Wet 10.2:

Treat 20 mgd at THC (10 mgd DWF and 10 mgd PWWF)

Send 92 mgd to KCMO consisting of 9 mgd DWF and 83 mgd PWWF (36 mgal PWWF storage at 87th Street Pumping Station)

Store (then send to KCMO) 23 mgd PWWF at THC (23 mgd X 0.43 mgal/mgd = 10 mgal storage)

See Note 2 below

C. No WWTP at THC

Wet 0.1:

Send 19 mgd DWF to KCMO (assumes no storage of DWF required)

Send 19 mgd PWWF to KCMO (8 mgal storage at 87th Street Pumping Station)

Store (then send to KCMO) 23 mgd PWWF at THC (23 mgd X 0.43 mgal/mgd = 10 mgal storage)

Discharge 74 mgd PWWF through Auxiliary Treatment Facility

See Note 1 below

Wet 0.2:

Send 97 mgd to KCMO consisting of 19 mgd DWF and 78 mgd PWWF (34 mgal PWWF storage at 87th Street Pumping Station)

Store (then send to KCMO) 38 mgd PWWF = 16 mgal storage required at THC, 10 mgal lagoon, 6 mgal new storage at THC

Wet 0.3:

Send 19 mgd DWF to KCMO (assumes no storage of DWF required)

Send 19 mgd PWWF to KCMO (8 mgal storage at 87th Street Pumping Station)

Store (then send to KCMO) 97 mgd PWWF = 42 mgal storage required at THC, 10 mgal lagoon, 32 mgal new storage at THC

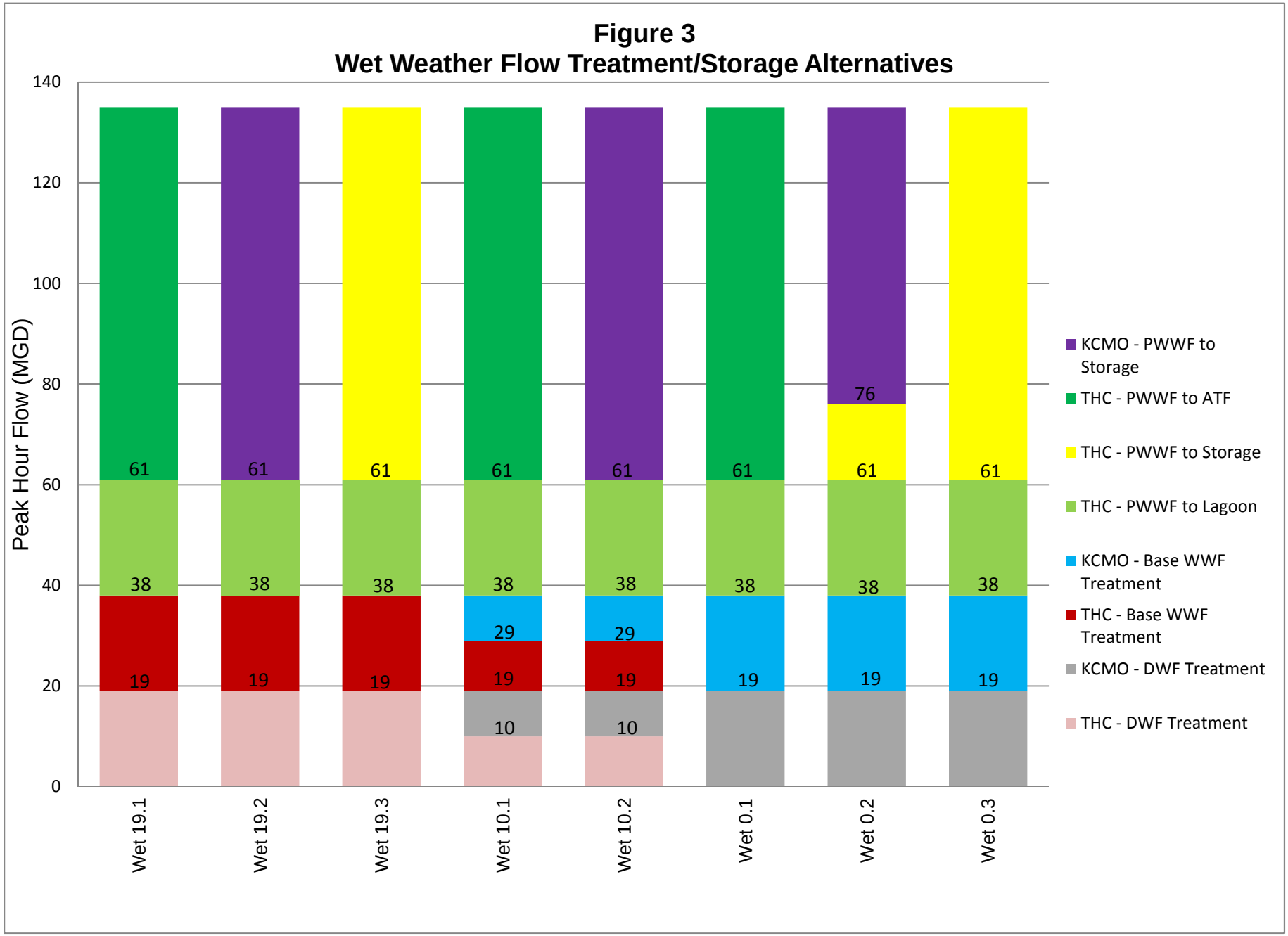
Note 1: It is assumed that a total of 38 MGD (2 x annual average flow) must be sent to treatment at either THC, KCMO, or a combination of the two, and onsite storage maximized prior to sending any flow to the Auxiliary Treatment Facility.

Note 2: In the 10 mgd alternatives, it is assumed that flows stored at THC are subsequently sent to KCMO for treatment. In practice, it may be possible in some cases to treat some or all of this flow at THC after the wet weather event subsides.

The above Wet Weather Treatment/Storage Alternatives are illustrated in Figure 3 on the following page. Working from the bottom of the graph upwards, the order in which the steps for each of the alternatives would be implemented is illustrated.

A number of simplifying assumptions have been adopted in developing these flows and storage requirements. Although believed to be appropriate for purposes of comparative analysis, it is recommended that a more detailed storm routing analysis be performed prior to final design to confirm and further refine the storage volume requirement for the preferred alternative. Similarly, the alternatives may be further refined when determining the sizing and costs of the wet weather components in subsequent technical memorandums under this overall study.

Figure 3
Wet Weather Flow Treatment/Storage Alternatives



Appendix A

Blue River South Basin
Wet Weather Flow Rates and
Volumes at 87th Street Pumping Station
February 26, 2008

From KCMO Overflow Control Program

Blue River South Basin
Wet Weather Flow Rates and
Volumes at 87th Street Pumping Station
February 26, 2008
File 0770-04-27-00

Summary

This memorandum summarizes current estimates of peak rates and volumes of inflow to the 87th Street Pumping Station and compares those estimates to the hydraulic capacity of the pumping station, resulting in determination of the quantity of storage needed at that pumping station to eliminate overflows under the design rainfall event. For the Blue River South Basin, the design rainfall is an event having an average return period of 5 years and duration of 24 hours; the total rainfall depth during that design event is 4.68". The design rainfall hyetograph is patterned in accordance with the National Resource Conservation Service (NRCS) Type II distribution, resulting in peak 1-hour, 3-hour, and 6-hour rainfall depths of 2.2", 3.0" and 3.6", respectively.

Under existing conditions, the developed area tributary to the 87th Street Pumping Station totals 44,568 acres, of which 29,341 acres (66%) are tributary to the Blue River South Basin at State Line Road. Upon full development in the Blue River South Basin, the developed area tributary to the 87th Street Pumping Station will increase to approximately 52,791 acres, with 56% of that area tributary at State Line Road (Johnson County Wastewater Interconnect). The sewer system west of State Line Road is owned and operated by Johnson County (Kansas) Wastewater (JCW). Under existing conditions, approximately 70% of the dry weather flow at the 87th Street Pumping Station is delivered from JCW at State Line Road. The majority (over 80%) of the flow from JCW is delivered to the Indian Creek Interceptor near the intersection of Interstate 435 and State Line Road, downstream of JCW's Tomahawk Wastewater Treatment Plant (WWTP).

An XP-SWMM model of the area tributary to that principal point of delivery was calibrated to flows measured at a temporary flow meter in early June 2005, using rainfall data developed through a radar analysis of actual rainfall over the tributary area. The maximum basin-wide 24-hour rainfall depth during that storm event was 4.44", with peak 1-hour, 3-hour, and 6-hour rainfall depths of 0.81", 1.37" and 2.65", respectively. That calibrated model was then applied to the design storm rainfall to develop the estimated discharge hydrograph from JCW at the location of the temporary flow meter. That discharge hydrograph was then adjusted assuming that wet weather flow facilities at the Tomahawk Creek WWTP are operated to reduce the peak rates of flow entering the Indian Creek Interceptor near State Line Road. During the design event, a peak rate of 35 mgd and a volume of roughly 14 million gallons was routed to the Tomahawk WWTP wet weather lagoon system and considered removed from the system. The wet weather lagoon system at the Tomahawk WWTP was not in operation during the June 2005 event. JCW reported that the lagoon system is operable as of October 2007.

The adjusted (truncated) flow hydrograph was then input to the XP-SWMM model of the Blue River South Basin and routed through that model concurrent with flows from the remaining area tributary to the 87th Street Pumping Station. Three separate analyses were developed given the assumed operation of wet weather treatment facilities at the Tomahawk WWTP:

- Alternative No. 1: Existing conditions (with truncation of the JCW flow hydrograph as described above);
- Alternative No. 2: Year 2030 estimated conditions, developed assuming:
    - No change in the existing inflow hydrograph from Johnson County Wastewater, and
    - Revised inflows from the Blue River South Basin following completion of recommended Inflow and Infiltration (I/I) reduction work in the basin.
- Alternative No. 3: Blue River South Basin flows in 2030 (e.g., after completion of I/I reduction efforts in the basin) with **no** inflows from JCW at the location of BLSM006. This alternative is not considered a realistic management option, and is included for the sole purpose of assessing the influence of inflows from Johnson County at BLSM006 on storage requirements at the 87th Street Pumping Station.

An additional alternative was considered under which the operation of JCW facilities at the Tomahawk WWTP are modified:

- Alternative No. 4: Year 2030 estimated conditions, developed assuming:
    - Wet weather treatment facilities at the Tomahawk WWTP are removed from service, increasing the peak rate of inflow to the Blue River South basin by roughly 35 mgd and the volume of inflow under the 5-year rainfall event by roughly 14 million gallons; and
    - Revised inflows from the Blue River South Basin following completion of recommended Inflow and Infiltration (I/I) reduction work in the basin.

The firm capacity of the 87th Street Pumping Station is 85 mgd (using the normal duty pumps), and 130 mgd if existing flood pumps at the station are used. The following is a summary of the estimated excess peak inflow rates and inflow volumes (e.g., flows in excess of firm pumping capacity) considering the capacities of both the duty pumps and the flood pumps at the 87th Street Pumping Station.

Pumps	Parameter	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Duty (85 mgd)	Excess Flow Rate (mgd)	160	119	22	154
	Excess Volume (mg)	104	68	2	82
Flood (130 mgd)	Excess Flow Rate (mgd)	115	74	0	109
	Excess Volume (mg)	54	27	0	41

Hydraulic Capacity of 87th Street Pump Station

The 87th Street Pump Station contains four normal duty pumps, plus four larger capacity "flood" pumps. The flood pumps are not presently in use due to capacity limitations in the downstream system.. All pumps discharge to a header system that discharges to a force main that eventually discharges to the Blue River Interceptor Sewer north of Brush Creek. The firm capacity of the station with three of the four normal duty pumps operating was estimated at 80 mgd (Burns & McDonnell, 1999), for a TDH of approximately 48 feet. The firm capacity of the station with three of the four "flood" pumps operating was estimated at 130 mgd. More recent analyses (HDR, 2006) estimated the firm capacity of the station with three of the four normal duty pumps running as 85 mgd. The difference between the two estimates was associated with analysis of flow characteristics in the force main and their effect on the system curve of TDH. The more recent analysis did not update the estimated firm capacity during use of the "flood" pumps. For this

analysis, the firm capacity of the station for discharge through the 72" force main is taken as 85 mgd (using the normal duty pumps) and 130 mgd (using the "flood" pumps).

87th Street Pump Station Service Area

The 87th Street Pump Station serves the Blue River South basin and areas in Johnson County, Kansas. The total area of the Blue River South basin is 23,450 acres, of which 15,227 acres are presently developed (HDR, 2007a). The 2005 Kansas City, Missouri population in the Blue River South basin is estimated to be 51,800, projected to increase slightly to 53,000 by 2030, and to further increase to an ultimate population of 72,900 (HDR, 2007a). The ultimate population was estimated upon the assumption of full development of the basin and 100% occupancy. An additional population of approximately 2,640 persons in Grandview, Missouri discharges to the Blue River South Basin.

Upstream areas in Johnson County, Kansas contribute wastewater flows to not only the 87th Street Pump Station, but also to two wastewater treatment plants owned and operated by JCW. Those plants include the Indian Creek Middle Basin plant (near U.S. Highway 69and College Boulevard) and the Tomahawk Creek WWTP at 109th Street and Mission Road. The Middle Basin WWTP discharges to Indian Creek. Areas tributary to that plant do not contribute significantly to downstream areas. The Tomahawk Creek WWTP discharges to Indian Creek in the immediate vicinity of its confluence with Tomahawk Creek. Kansas City serves a total of approximately JCW 58,000 customers. Of that total, approximately 550 customers are in Mission Hills, Kansas and not tributary to the Blue River South Basin. Table 1 summarizes current (end of first quarter, 2007) data on JCW interconnection points discharging to Kansas City's Blue River South Basin.

Table 1 JCW Wastewater Discharges to Blue River South Basin

Point No.	Location	Metered?	Unmetered Service Area			Metered Flow (mgd)**
			Residential Connections (No.)	Commercial Accts.		
				No.	Water Use* (mgd)	
4	West 137th & Wyandotte	Yes	N/A	N/A	N/A	0.36
5	West 143rd & Overbrook	No	0	2	0.001	N/A
5a	West 141st & State Line Road	No	1	14	0.004	N/A
6	West 109th & Mission (Tomahawk WWTP)	Yes	N/A	N/A	N/A	13.85
7	1105 W. 120th Terrace	No	216	3	0.007	N/A
8	West 124th & State Line Rd.	No	315	3	0.003	N/A
9	Tam-O-Shanter & State Line	No	0	2	0.003	N/A
10	9001 State Line Rd.	Yes	N/A	N/A	N/A	0.10
11	9000 State Line. Rd.	Yes	N/A	N/A	N/A	1.59
12	9246 State Line Rd.	No	153	0	0	N/A
13	10308 State Line Rd.	Yes	N/A	N/A	N/A	0.25
13a	2009 West 104th	Yes	N/A	N/A	N/A	0.58
14	Leawood Park***	No	123	0	0	N/A
16	Leawood Park	No	122	2	0.010	N/A
Total for Blue River South Service Area			930	26	0.028	16.73

* Metered Water Usage for Commercial Accounts

** Average Daily Flow, January-March 2007 (90 days), from JCW flow meters

*** Approximately 150 residential customers in KCMO also tributary at Interconnection Point 15 (112th & Overbrook)

JCW estimates that the service area tributary to the Tomahawk WWTP is at present approximately 85% developed, with full build-out projected within the next 20 years. JCW does not anticipate that wastewater flows (either dry or wet weather) to the Tomahawk WWTP will change significantly in the future, due principally to changed operations (e.g., elimination of inflows to the Tomahawk Creek WWTP service area from other basins).

In the first three months of 2007, 83% of the metered flows from JCW were delivered at Interconnection Point No. 6. In the second three months of 2007 (a much wetter period, resulting in the maximum historic metered inflow of 23.84 mgd from JCW), 80% of the metered flows from JCW were delivered at Interconnection Point No. 6.

Table 2 summarizes basin areas in Johnson County tributary to the Blue River South Basin in Kansas City. The extent to which wastewater flows from those areas are delivered to Kansas City is influenced by JCW operations.

Table 2 JCW Areas Tributary to Blue River South Basin

Basin	Tributary To	Basin Area (ac)	Remarks
Indian Creek	Interconnection Pt. 6	9,612	Downstream of Middle Basin WWTP
Tomahawk Creek	Interconnection Pt. 6	14,646	4 mgd plant; 30-40 mgd PEFTF*
Dykes Branch	Interconnection Pt. 6	792	Approx. 10 mgd pump station
Dykes Branch	Interconnection Pts. 10-12	1,975	Site 12 Unmetered (146 ac.)
Indian Creek	Interconnection Pts. 13, 13a	1,280	
Indian Creek	Interconnection Pts. 14, 16	441	
Upper Blue River	Pts. 4, 5, 5a, 7, 8 & 9	595	Site 4 Metered (292 ac.)
Total Potential Tributary Area		29,341	

*Peak Excess Flow Treatment Facility (wet weather lagoons)

A total of approximately 56,500 JCW customers (including 54,800 residential connections) are in the basins tributary to the metered interconnection points.

The total population tributary to the 87th Street Pump Station is estimated at approximately 179,240 comprised of:

- 51,800 in Kansas City, Missouri;
- 2,640 in Grandview, Missouri; and
- Approximately 124,800 in Johnson County, Kansas, distributed (based on estimated residential population provided by JCW) as:
    - 103,300 to Interconnection Point No. 6 (Tomahawk WWTP);
    - 5,160 to Interconnection Points 13 and 13a;
    - 10,750 to Interconnection Points 10, 11 and 12 (Dykes Branch);
    - 4,890 to Interconnection Points 4, 5a, 7, 8 and 9 (Upper Blue River Basin); and
    - 700 to Interconnection Points 14 and 16.

An additional basin area of 14,712 acres is tributary to the JCW Middle Basin WWTP at College Boulevard and U.S. Highway 69. Figure 1 presents a schematic diagram of the JCW wastewater collection system tributary to the Blue River South Basin.

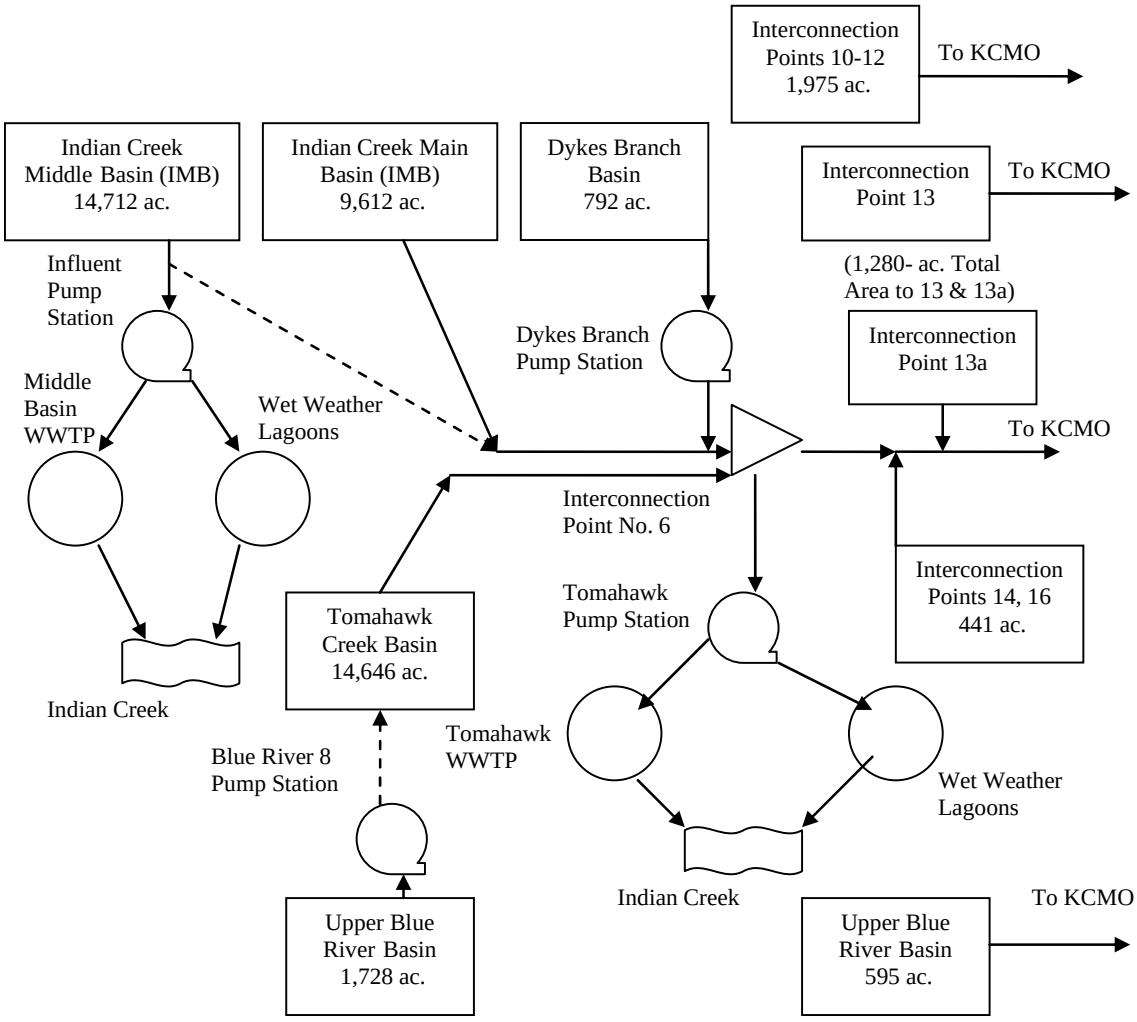


Figure 1 JCW System Schematic

At present, JCW delivers approximately 1.5 million gallons per day of dry weather flow from the Indian Creek Middle Basin to the Indian Creek Interceptor leading to the Tomahawk WWTP. That operation, generally conducted during daytime hours (10:00 a.m. to 8:00 p.m.) is essentially a "shaving" of peak dry weather flows delivered to the Middle Basin WWTP, and is scheduled for discontinuation by the end of 2010. Those flows are delivered through a manually operated diversion structure upstream of the Middle Plant influence pump station, discharging to a 21-inch sewer having a full-flow capacity of approximately 6 mgd. JCW reportedly closes that diversion structure during wet weather. In addition, an average dry weather flow of approximately 0.5 mgd has until recently been delivered to the Indian Creek Interceptor from JCW's Blue River 8 Pump Station; that discharge is was discontinued in December 2007. The capacity of the Dykes Branch Pump Station is reported to be approximately 10 mgd; the dry weather flow to the Dykes Branch Pump Station has been reported by JCW as approximately 0.67 mgd. Flow to the Tomahawk WWTP is reportedly maintained in a relatively narrow range of 3-5 mgd, and is taken as 4 mgd

for this analysis. Wet weather lagoons at the Tomahawk plant are reportedly now operational; the nominal capacity for diversion of wet weather flows to the lagoons is 40 mgd (analyses prepared for this memorandum were based on an estimated capacity of 35 mgd).

Figure 2 presents a schematic diagram of Kansas City's wastewater collection system in the Blue River South Basin. The locations of selected temporary flow meters installed and monitored in 2005 are indicated on that diagram.

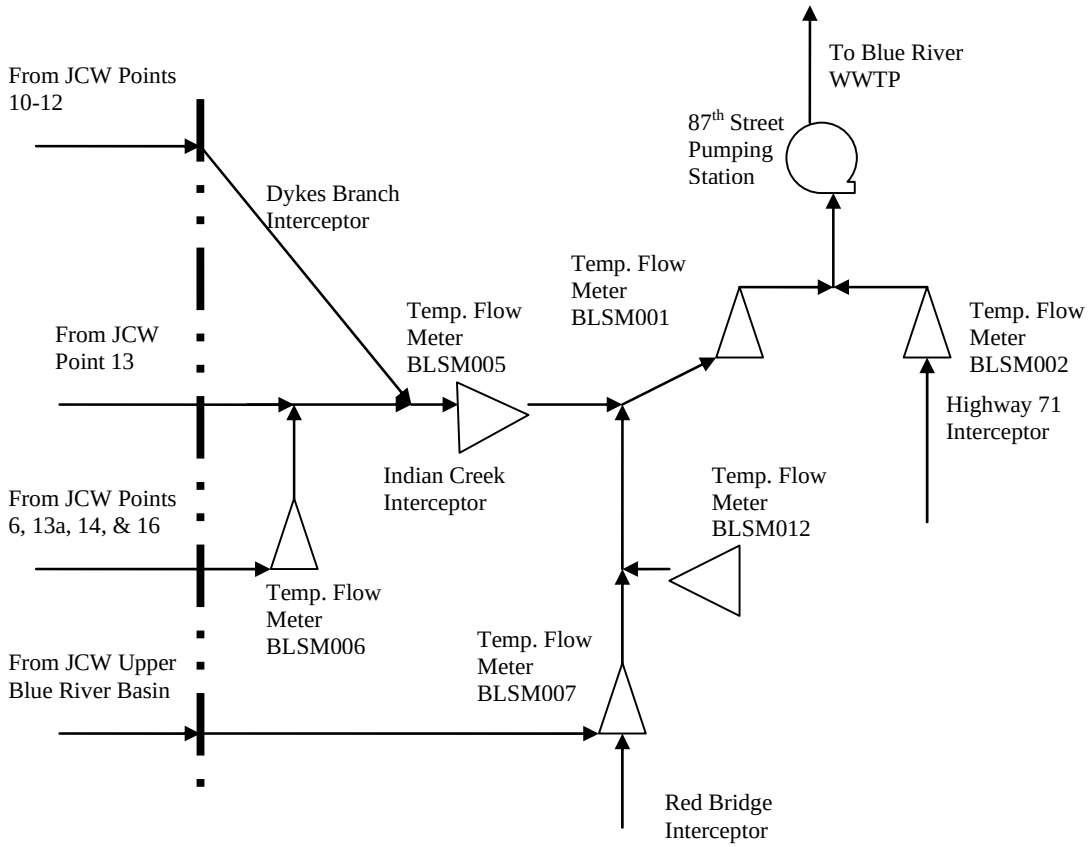


Figure 2 Blue River South Basin Schematic

Temporary Flow Meter Results

Table 3 summarizes the Average Dry Weather Flow (ADWF) and Peak Dry Weather Flow (PDWF) determined from monitoring of temporary flow meters in the Blue River South Basin during the period May 25 through October 29, 2005 (Hydromax, 2006). The peak hourly wet weather flow (PWWF) during that period is included in Table 3 as well.

Table 3 Metered Flows in Blue River South Basin (05/25/07-10/29/07)

Temporary Meter	ADWF (mgd)	PDWF (mgd)	PWWF (mgd)
BLSM001	16.4	27.4	124.4**
BLSM002	2.2	3.7	23.8
BLSM005	13.9	23.2	95.3**
BLSM006*	12.2	22.4	124.1***
BLSM007	2.5	3.5	24.8
BLSM012	0.3	0.5	7.0

*Flow contribution only from JCW Interconnection Points 6, 13a, 14, and 16.

** PWWF apparently influenced (reduced) by system surcharges and overflows.

*** Temporary flow metering conducted by JCW from 5/2005-11/2005 upstream of BLSM006 indicates PWWF from Interconnection Points 6 and 13a of 90 mgd.

The total ADWF to the 87th Street Pump Station is estimated at 18.6 mgd (sum of ADWF at temporary flow meters BLSM001 and BLSM002).

Existing Dry Weather Flows

The total ADWF in the system under existing conditions is taken as 22.6 mgd (18.6 mgd at the 87th Street Pump Station, plus 4 mgd treated at the Tomahawk WWTP). Of that total, 2 mgd are from sources outside the nominal service area (i.e. diverted flows from the Middle Basin WWTP and Blue River 8 Pump Station), resulting in an estimated ADWF from the area served directly by the 87th Street Pump Station of 20.6 mgd.

Year 2030 Dry Weather Flow Estimates

The KCMO population in the Blue River South Basin is projected to increase from 51,800 to 53,000 in 2030. JCW estimates their area tributary to the 87th Street Pump Station to be approximately 85% built-out under current conditions, with full build-out projected by 2030. The 2030 total estimated ADWF at the 87th Street Pump Station is estimated as 19.4 mgd.

Full Build-Out Dry Weather Flow Estimates

The ultimate (full build-out) KCMO population in the Blue River South Basin is estimated at 72,900, an increase of 19,900 above the 2030 population. Little or no growth in the City of Grandview service area population is expected. As full build-out in the JCW service area was assumed for Year 2030, there would be no further increase in ADWF expected from that source. The estimated ADWF at full build-out in the basin would then be estimated as 19.4 mgd plus 2.0 mgd (19,900 persons at 100 gpcd) or 21.4 mgd.

Wet Weather Flows Under Existing Conditions

The largest single rainfall event during operation of the temporary flow meters occurred in early June, 2005. Figure 3 summarizes total metered flow at BLSM006 from 0:00 on June 1 to 20:45 on June 8, 2005 (Hydromax, 2006). Figure 3 also shows the estimated diurnal dry weather flow hydrograph during that period (based on average DWF estimates from Hydromax, 2006); the difference between those two hydrographs is the estimated Rainfall Derived Inflow and

Infiltration (RDII). In Figure 3, hydograph time 0:00 hours corresponds to 0:00 June 3, 2005. Rainfall data provided by One-Rain for that period were analyzed to determine rainfall patterns over the 26,500 acres tributary to temporary flow meter BLSM006. The rainfall data were in the form of accumulated 15-minute rainfall depths over one square kilometer pixels covering the area tributary to BLSM006. Radar estimates of rainfall depth in each pixel were averaged to obtain the estimated basin-average rainfall depth. The average rainfall depth over the basin during the period represented in Figure 3 was 5.82", which correlated well with rainfall depths taken from 13 Stormwatch rain gages in Johnson County (range of 5.12" to 6.46", with weighted averages of 5.73" in the Indian Creek basin and 5.71" in the Tomahawk Creek basin).

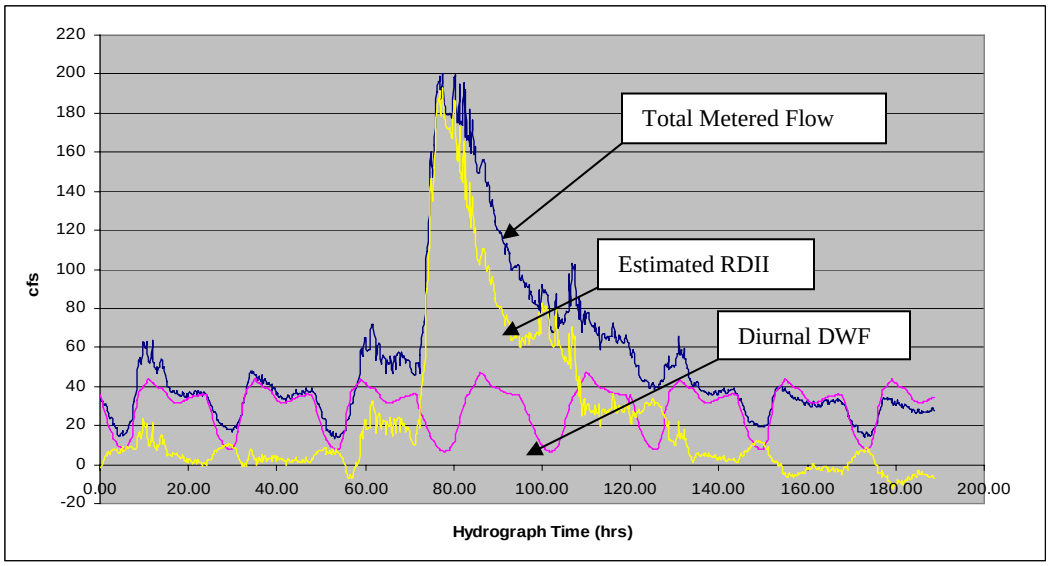


Figure 3 BLSM006 Flows, 6/01/2005-6/08/2005

Following inspection of data summarized in Figure 3, the period from 07:15 June 3, 2005 through 18:00 June 6, 2005 (hydrograph time 55.25 through 138.00) was selected for additional analysis. That period was preceded by 42 hours without rainfall following a 0.93" rainfall depth early on June 1. The basin-average rainfall depth over the selected period was 4.77", with a maximum 24-hour rainfall depth of 4.44" (period ending at 08:00 on June 4, 2005). The total volume of estimated RDII at BLSM006 over that period was equal to 3.5% of the total rainfall on the tributary area.

JCW reports that the results of temporary flow metering that JCW conducted just upstream of BLSM006 suggest the maximum rate of flow during this event was 88 mgd (136 cfs). This difference in the peak rate of flow between the two temporary flow meters has not been resolved.

Modeling of the Blue River South Basin was conducted by HDR under contract to the KCMO Water Services Department. The JCW connection was calibrated for dry weather flows and wet weather flows; calibration includes comparison of the resulting hydrographs to flow meter data collected in 2005 at site BLSM006, similar to calibration methods previously applied for the Blue River South hydraulic model.

The interconnection point was first calibrated to simulate dry weather flows. Analysis of dry weather flows at meter BLSM006 shows that the average dry weather flow at this meter is approximately 12.2 MGD. The census-based method within XP-SWMM was used to generate dry weather flows. The contributing area within Johnson County was estimated as 26,131 acres

and the population was estimated as 117, 580 people. Based on the above area, population, and average dry weather flow, a flow rate of 0.000163 cfs and a density of 4.5 people were applied in the model to generate dry weather flows. Additionally, the diurnal pattern previously defined by HDR for this meter was applied to simulate the variation of flows throughout the day. Figure 4 shows the comparison of the model results, flow meter data, and diurnal flow pattern. The model results compared favorably with the meter data and diurnal analysis.

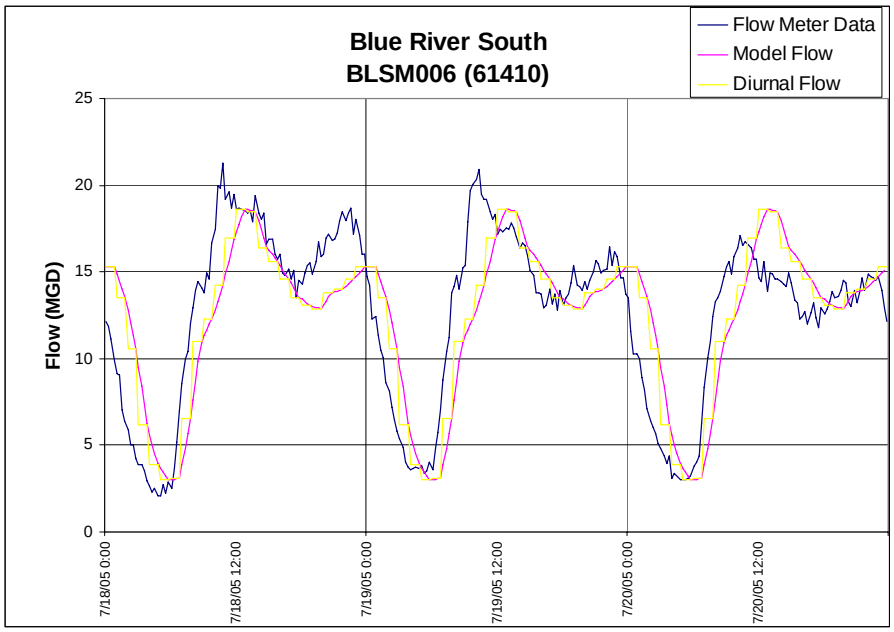


Figure 4 Comparison of Model Results and Meter Data for Dry Weather Flows

Next the interconnection point was calibrated to represent surface runoff that enters the separate system (RDII). The June 3, 2005 storm event was used for calibration since this storm event was close to meeting the capacity of the interceptor, and was the largest flow event during the OCP's temporary (2005) flow monitoring. XP-SWMM requires four inputs to calculate the RDII: area of the catchment, slope of the catchment, width of the catchment, and percent impervious. The area of the catchment is the same as described above for dry weather flows. From discussions and evaluation it appears that approximately 3.5% of the surface runoff from Johnson County enters the system as RDII. This percentage was used as a starting point for setting percent impervious. Slope and width of the catchment are more difficult to determine with limited data about the area; however, these values are normally calibrated to measured data. Slope and width similar to what had previously been calibrated for the BRS model were used as a starting point for the JCW contributing area.

Slope, width and percent impervious were adjusted to achieve a calibration within 5% of the meter data for peak flow and volume. The percent impervious was increased to 5.5% to increase the volume during calibration. Slope and width were adjusted simultaneously to try to match the rising and recession portions of the hydrograph as well as the peak flow. The peak flow was achieved within +1.9% of the meter data and volume was achieved within +0.6% of meter data (June 3 – June 5). Figure 5 shows the comparison of the model results and the flow meter data for the June 3, 2005 storm event. The peak flow for the June 3, 2005 storm event is 131.7 MGD. Facilities for the diversion of peak wet weather flows to the lagoon system at the Tomahawk

WWTP were reportedly not in operation during the June 2005 event, with the result that the entire hydrograph was delivered to the Blue River South system (Indian Creek Interceptor).

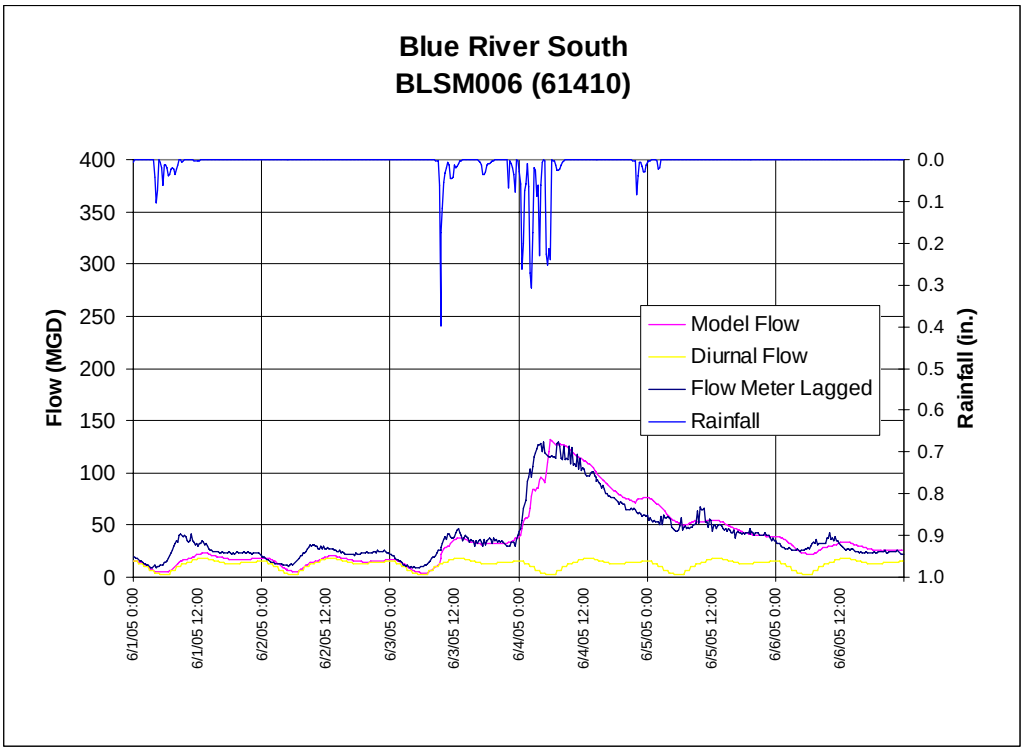


Figure 5 Comparison of Model Results and Meter Data for Wet Weather Flows
(June 3, 2005 Storm Event)

The above comparison shows that the timing of the peak flow calculated by the model does not quite match the flow data. The peak of the flow data occurred at 4:30 AM on June 4, 2005 whereas the model peak occurs at 6:00 AM. Width and slope were further adjusted to try to achieve the correct timing of the peak flow. Typically an increase in width and/or an increase in slope will decrease the time to peak. Table 4 describes the scenarios that were tested and the resulting peak flow and timing. All other parameters that were not tested were kept constant.

Table 4
Model Runs to Adjust Peak Timing

Test	Width	Slope	Peak Flow (MGD)	Time of Peak
Calibration	75	6%	131.7	6:00 AM
1	125	6%	185.7	6:00 AM
2	75	10%	157.0	6:00 AM
3	125	10%	216.7	6:00 AM
4	300	10%	337.7	6:00 AM

As shown in Table 4, varying the width and/or slope did not have any impact on the timing of the peak. To achieve a better peak match, the interconnection could be simulated as several different watersheds, each with its own set of runoff parameters that contribute flow at different times to the interconnection point. HDR concluded that the calibrated match as shown in Figure 5 will be sufficient for determining required storage volumes for the Blue River South project area, and OCP concurs.

Design Storm Inflow Hydrographs to 87th Street Pumping Station

The design storm established by the OCP for capacity analysis in the Separate Sanitary Sewer System throughout Kansas City is the 5-year, 24-hour storm, with the rainfall hyetograph developed in accordance with APWA Section 5600. The calibrated dry weather and wet weather parameters were applied to the model to determine the resulting flow hydrograph at the location of BLSM006 to the Blue River South Basin for the 5-year, 24-hour design storm. Figure 6 shows the hydrograph for the 5-year storm event using the same dry weather flow and RDII parameters as the calibration. The peak flow for the 5-year, 24-hour design storm event at that location is 132 MGD.

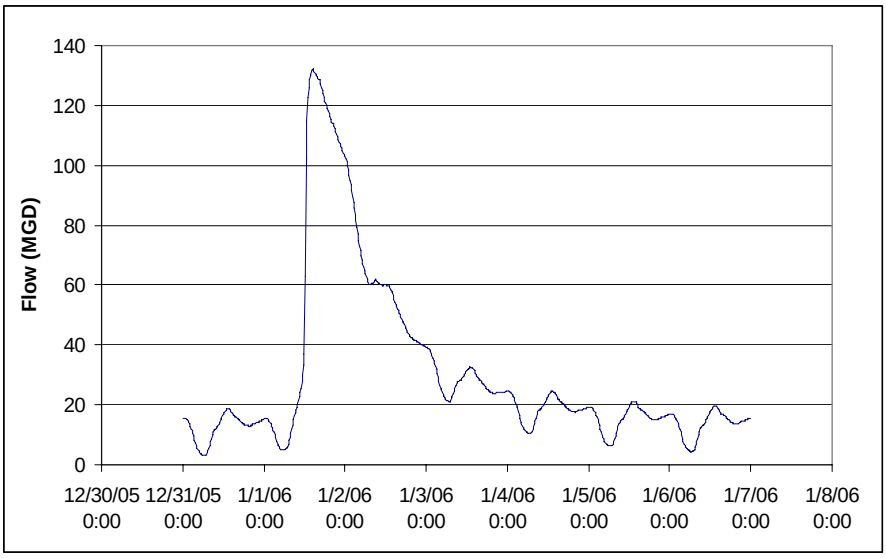


Figure 6 JCW 5-Year, 24-Hour Flow Hydrograph at BLSM006

For this analysis, it has been assumed that the flow hydrograph in Figure 6 can be truncated at approximately 97 mgd (150 cfs) through operation of the wet weather diversion facilities at the Tomahawk WWTP (peak diversion capacity of 35 mgd). Under that 5-year, 24-hour rainfall event, the total volume diverted to the lagoon system at the Tomahawk WWTP is estimated to be roughly 14 million gallons.

The adjusted (truncated) flow hydrograph was then input to HDR's XP-SWMM model of the Blue River South Basin at BLSM006 and routed through that model concurrent with flows from the remaining area tributary to the 87th Street Pumping Station. Three separate analyses were developed given the assumed operation of wet weather treatment facilities at the Tomahawk WWTP:

- Alternative No. 1: Existing conditions (with truncation of the flow hydrograph at BLSM006 as described above);

- Alternative No. 2: Year 2030 estimated conditions, developed assuming:
    - No change in the existing inflow hydrograph from Johnson County Wastewater at BLSM006, and
    - Revised inflows from the Blue River South Basin following completion of recommended Inflow and Infiltration (I/I) reduction work in the basin. Overall, that work is expected to reduce I/I in the Blue River South Basin by roughly 40 percent, at an estimated cost (mid-2006 dollars) of $35.3 million.
- Alternative No. 3: Blue River South Basin flows in 2030 (e.g., after completion of I/I reduction efforts in the basin) with **no** inflows at the location of BLSM006. This alternative is not considered a realistic management option, and is included for the sole purpose of assessing the influence of inflows from Johnson County at BLSM006 on storage requirements at the 87th Street Pumping Station.

An additional alternative was considered under which the operation of JCW facilities at the Tomahawk WWTP are modified:

- Alternative No. 4: Year 2030 estimated conditions, developed assuming:
    - Wet weather treatment facilities at the Tomahawk WWTP are removed from service, increasing the peak rate of inflow to the Blue River South basin by roughly 35 mgd and the volume of inflow under the 5-year rainfall event by roughly 14 million gallons; and
    - Revised inflows from the Blue River South Basin following completion of recommended Inflow and Infiltration (I/I) reduction work in the basin.

If necessary, additional alternatives can be developed in which the inflow hydrograph from Johnson County Wastewater at BLSM006 is truncated at varying flow rates to assess the impact of a range of possible flow restrictions on storage requirements or other necessary improvements at the 87th Street Pumping Station.

Computed inflow hydrographs at the 87th Street Pumping Station for Alternatives 1 through 3 (as described above) are graphically depicted in Figure 7.

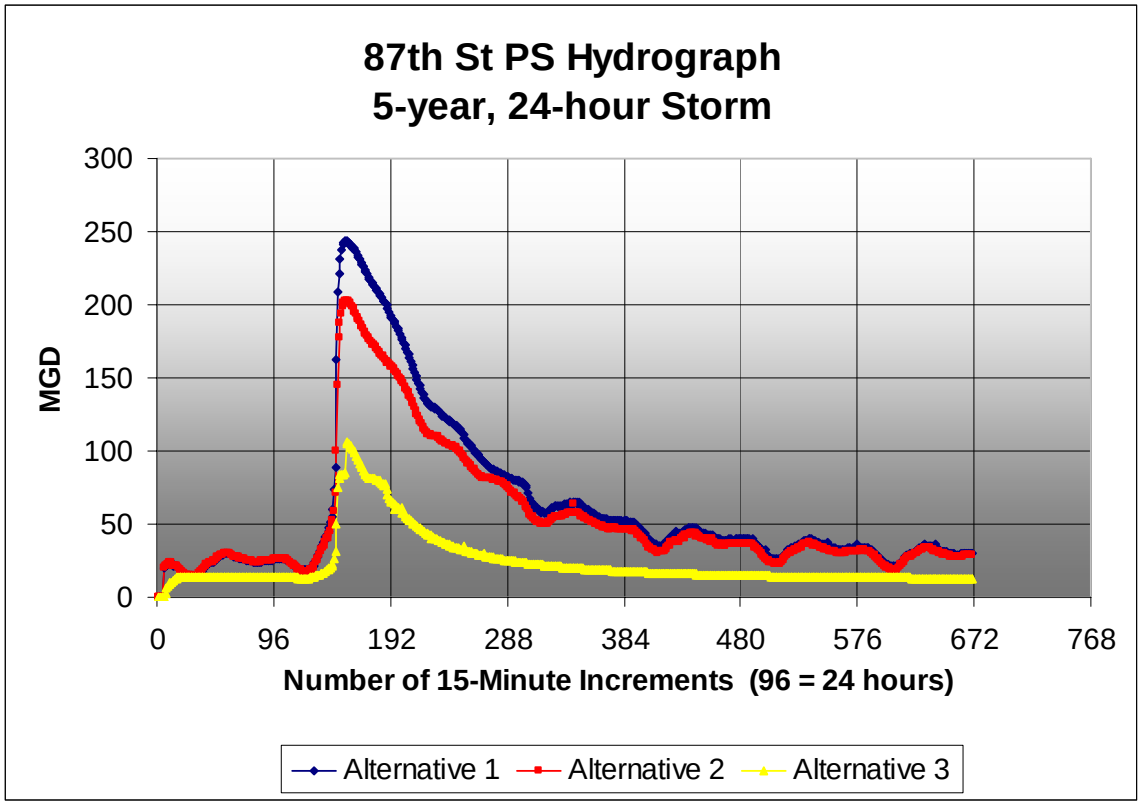


Figure 7 Design Storm Inflow Hydrographs at 87th Street Pumping Station

Table 8 summarizes excess peak inflow rates and inflow volumes (e.g., flows in excess of firm pumping capacity) considering the capacities of both the duty pumps and the flood pumps at the 87th Street Pumping Station.

Table 8 Excess Inflows at 87th Street Pumping Station

Pumps	Parameter	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Duty (85 mgd)	Excess Flow Rate (mgd)	160	119	22	154
	Excess Volume (mg)	104	68	2	82
Flood (130 mgd)	Excess Flow Rate (mgd)	115	74	0	109
	Excess Volume (mg)	54	27	0	41

"Design Year" Flows to 87th Street Pumping Station

A comprehensive analysis of KCMO area rainfall and streamflow historical data was conducted to identify typical conditions in the CSS area. This analysis was used to identify a set of design storms and a "design year" recreation season to support the CSS and receiving water modeling efforts. The selection of the design storms and design year and discussion of the approach are documented in previous memoranda (OCP, 2006a; OCP, 2006b). Those design year rainfall events were input to the XP-SWMM model of the Blue River South basin, and estimates of the "design year" inflows to the 87th Street Pumping Station were developed.

In the design year, the total inflow to the 87th Street Pumping Station under Year 2030 conditions is estimated to be 7.91 billion gallons. Of that total, 7.08 billion gallons result from the projected dry weather flow of 19.4 mgd. The balance (0.83 billion gallons) is composed of RDII.

Of that total inflow volume, 5.07 billion gallons (64% of the total) are projected to enter the Blue River South basin from JCW at the previous location of temporary flow meter BLSM006, including an estimated 0.47 billion gallons of RDII (57% of the total RDII at the 87th Street Pumping Station). Additional volume would be contributed by inflows at other JCW interconnection points.

References:

Burns & McDonnell, 1999: *Wastewater Master Plan, Kansas City South of the Missouri River*; August 31, 1999.

HDR, 2006: *87th Street Pumping Station Technical Memorandum – Final, Task A-3.5 and 3.2.4*; September 1, 2006.

HDR, 2007a: *Blue River South Project Area, Existing Conditions Technical Memorandum – Final, Task 6*; June, 2007.

HDR, 2007b: *Blue River South Project Area, Model Calibration Technical Memorandum – Final, Task 6*; June, 2007.

Hydromax, 2006: *Final Data Submittal*; January, 2006.

Overflow Control Program (OCP), 2006: *Overflow Control Program, Basis of Cost Manual*; January 8, 2007

Overflow Control Program (OCP), 2006a. *Design Storms for CSS Areas.* Final Memorandum submitted on May 18.

Overflow Control Program (OCP), 2006b. *Design Year for CSS Analyses.* Final Memorandum, submitted on September 20.