METROPOLITAN SEWER DISTRICT of greater CINCINNATI

Date: October 19, 2012

To: Christian Sigman, County Administrator

From: Tony Parrott, Executive Director

Subject: Responses to County Monitor's September 24th Risk Assessment Memo

MSD has addressed each of the potential risks identified by the County monitor team. A brief summary of MSD's responses to the potential risks listed in the County monitor's September 24th memo is provided herein.

1. Potential Risk: *"The SI Alternative is relying on estimates of storm water separation effectiveness that are not supported by local data...."*

MSD's Response: On October 3rd, MSD provided the County with a white paper regarding the use of local data within MSD's hydraulic and hydrologic modeling update process. The County monitor explicitly questioned flow meter data presented in May 2012. MSD has attached a brief explanation of the May 2012 data. This information, combined with other previously provided documentation, demonstrates how expansive local data was a key element used to estimate separation effectiveness according to applicable industry standards. Mr. Roe's statement at the October 10th County public hearing that "a vast amount of MSD's local data was determined by consultants and MSD to be not useful" wildly distorted the nature and character of MSD's use of local data. MSD has explained repeatedly, as it did with the state and federal Regulators, that MSD's model is fully calibrated and validated even with some limitations of data for CSO 5. The Regulators agree with MSD that ample local data has been demonstrated. Local data is not an issue for alternative selection.

2. Potential Risk: *"...However, additional information is necessary to explain to the County how the current data adequately supports the cost and project sizing details on which the SI proposal is based."*

MSD's Response: Please refer to response provided under Potential Risk #1 and additional documents previously provided. Ample current data support the SI Alternative recommended by MSD. Should the SI Alternative be selected, continuing data will be integrated during detailed design, consistent with all WWIP projects and MSD practice.

3. Potential Risk: *"Potential CSO volume shortfall replacement costs have not been provided based on a sensitivity analysis to provide a remedy for instances where the SI program may not be as effective as currently predicted."*

MSD's Response: This statement improperly presumes inherent problems with the SI Alternative and MSD disagrees with this supposition. Please see the of sensitivity analyses in MSD's Response to the County Monitor's Cost Certainty Document as well as MSD's LMCPR Recommendation Report. Last February MSD met with the County monitor team and discussed the additional SI projects that were considered but not included in the recommended alternative (CSOs 10, 12, and 24). These projects were discussed in detail in MSD's Preliminary Alternatives Evaluation Report as well as the Sustainable Projects Technical Memorandum prepared by Arcadis and discussed with the Regulators. The Adaptive Management process was incorporated into the WWIP to address situations such as that described under Potential Risk #3. This is not a risk that would impact alternative selection in that the same argument could be made for a tunnel solution for rainfall events exceeding the "typical year" scenario.

4. Potential Risk: *"It is unclear how CSO's in the Mill Creek below CSO 5 (Lick Run) can or will be dealt with in the LMCFR."*

MSD's Response: The County requested MSD refrain from discussions regarding the Final Remedy. Both Mr. Roe and Mr. Aluotto were present when this specific request was made prior to the July 26th Technical Workshop with the Regulators. Since the details of planning LMCFR projects are reserved for the end of Phase 2 of the WWIP, this question is premature. MSD has demonstrated how the LMCPR could fit into a viable LMCFR and the suggested 'risk' is not relevant for alternative selection.

5. Potential Risk: *"Consensus has yet to be reached on the ownership and operation/maintenance of new storm drains to be constructed in SI projects, as well as who bears future responsibility for new stormwater outflows."*

MSD's Response: The County has not provided MSD direction regarding this issue. The County monitor team has brought the issue up during multiple Legislative Dry Run sessions, but has yet to propose any discussion or resolution. As MSD explained during the September 26th public hearing, for the purpose of the LMC Study, MSD assumed ownership and operation and maintenance responsibility and included those costs in the life-cycle cost analyses consistent with state law and the route to most cost-effective compliance with the WWIP.

6. Potential Risk: *"A methodology for complying with existing MS4 permits and newly created stormwater discharges to streams has yet to be demonstrated....."*

MSD's Response: Contrary to all experience to date, this statement presumes MSD routinely advances projects that do not comply with existing MS4 permits. This level of technical scrutiny is not appropriate at this time. These details are typically worked out during the design phase and technical review of a project. All projects will be designed and constructed to meet requirements of applicable MS4 permit under the Clean Water Act. Treatment amenities are not required under existing or even reasonably-anticipated regulation. Inclusion of any treatment amenity would have to be based on engineering judgment, cost-benefit analysis and policy preference.

7. Monitor Request: *"The April 2006 CSO Long Term Control Plan Update Report, Volume II indicated that once CSO's are addressed, existing dry weather pollution and stormwater pollution will become the focus in the Mill Creek for meeting water quality standards......"*

MSD's Response: The conclusion asserted in this statement is based on a highly speculative, isolated potentiality attributed to future stormwater regulation and an assumption of automatic imposition of costs resulting from those regulations. The blanket conclusion is asserted without data or evidence or analysis. MSD can not share the asserted certainty of cost implications arising from speculative future regulations that have not been proposed.

8. Potential Risk: *"Funding for traffic pattern modifications at a cost of between $20-$30 million has not been secured."*

MSD's Response: During multiple public hearings, MSD explained the Sustainable Alternative does not require modifications to existing traffic patterns, with the exception of Beekman Avenue. MSD also presented detailed information regarding coordination that has taken place with CDOTE, ODOT, and local utilities. This is not a potential risk for the recommended alternative.

9. Potential Risk: *"The Lick Run SI project includes significant surface features and related costs that extend beyond CSO abatement and are still in flux."*

MSD's Response: During the October 8th and 10th public hearings, MSD discussed the surface features associated with the recommended alternative. This issue has been discussed at length with the Regulators. A limited number of features totaling approximately $600,000 have been identified to integrate the alternative into the community. This is clearly not a risk related to alternative selection.

10. Potential Risk: *"A number of aesthetic items shown in the SI Alternative drawings are not currently included in the cost estimates, or the sources of alternative funding."*

MSD's Response: During the public hearings MSD explained all features have been included in the cost estimates. This statement is not accurate.

11. Potential Risk: *"Maintenance of traffic cost estimates during construction of the projects appears to be underestimated."*

MSD's Response: The County monitor team offers no credible basis for making this bare assertion, without support of local data or local experience. MSD has gone to great lengths to minimize local traffic impacts and coordinate projects phasing with local entities including CDOTE, ODOT, GCWW, Duke, Time Warner, and Cincinnati Bell. Engineers from multiple local firms have reviewed the cost estimates for maintenance of traffic and agree with the values included in the cost estimates. Maintenance of traffic costs for constructing sewers is significantly less than that incurred from constructing tunnels. This is not a risk associated with alternative selection in that similar issues will be faced with a deep tunnel solution.

12. Potential Risk: *"Analysis is required related to the potential for new flooding routes and areas affected in heavy storms after the SI Alternative is constructed."*

MSD's Response: The County team has raised the specter of potential extensive flooding under an SI Alternative for more than a year. During the October 3rd public hearing, MSD explained in detail the flood-related analyses that were performed during the LMC Study. A detailed white paper was provided to the County on this issue. Measures have been incorporated into the Sustainable Alternative to mitigate the risk of flooding from heavy storms up to a 100-year storm event.

13. Potential Risk: *"The effects that the peak flows from the proposed storm sewers in the SI Alternative will have on the Mill Creek and its tributaries have not been evaluated."*

MSD's Response: Refer to response provided for Potential Risk #12 and the White Paper previously provided. This analysis was completed by the LMC Study Team.

Flow Monitoring in Separate Sanitary and Storm Sewers

In April 2011, MSD initiated flow monitoring in four subcatchments that had existing separated sewers to determine relative wet weather volumes captured in the sanitary sewer system and in the storm sewer system. Three subcatchments were in Lick Run and one in Bloody Run. The intent of this flow monitoring program was to obtain local data on the likely effectiveness of sewer separation when existing storm sewers in fully developed areas are re-routed to a new storm trunk or interceptor sewer. The wet weather volume in the sanitary sewers will remain in the combined system, while the wet weather volume in the storm sewers is removed from the combined sewer system.

The analysis described herein is only relevant for fully developed sewered areas. Runoff from undeveloped land and open space that discharges into one or more separate storm sewer or combined sewer inlets would be totally removed from the combined sewer system following strategic sewer separation. There are many examples of this type of sewer separation in undeveloped areas that are proposed for the Denham, Kings Run, Lick Run, Ludlow Run, and West Fork Channel sub-basins. There are two large golf courses in the Bloody Run sub-basin that contribute runoff directly to the combined sewer system.

The flow monitoring data from the sanitary sewer systems can be used to examine the percentage of rainfall volume over the tributary area that ends up being conveyed as wet weather volume in the sanitary sewer system. This is the same type of analysis as that used to determine RTK values for estimating rainfall derived infiltration/inflow (RDII). The three variables in the RTK procedure are used to determine the peak flow and runoff volume from an increment of rainfall. R is the percent of the rainfall volume that enters the sewer system from the tributary area. T is the time to peak of the storm event wet weather flow response from the onset of rainfall. K is the ratio of time to recession of the unit hydrograph to the time to peak. Using the three variables together, a triangle, where time is on the horizontal axis and flow is on the vertical axis, is constructed with R equal to the area of the triangle and T multiplied by (1+K) equal to the base of the triangle. The height of the triangle is equal to the peak flow from the tributary area, so using the known area and base of the triangle, the peak inflow can be determined. Multiple RTK values (i.e. multiple overlapping triangles) are generally used to represent short-term, moderate, and long-term wet weather responses as a storm event progresses to emulate the shape of the wet weather flow hydrograph. The total area of the three triangles (equivalent to the area under the wet weather flow hydrograph) is the wet weather flow volume.

The flow monitoring data from the storm sewer systems can be used to examine the percentage of rainfall volume over the tributary area that is converted to sewer inflow and is subsequently captured in the storm sewer system. This wet weather volume would be totally removed from the combined sewer system following disconnection of the storm sewers from the combined sewer system. The percent capture by the storm sewer system will be lower than expected in sewered areas that have roof drains and downspouts connected to the sanitary sewer system. These types of connections would conversely increase the percent of rainfall capture by the sanitary sewer system.

The analyses presented herein are not precise, but provide reasonable estimates of the fate of rainfall that falls on a sewered tributary area. The analyses do not attempt to estimate all the variables involved nor describe the exact physical processes at work which would fully explain the whys and wherefores of the results. A simple mass water balance is used whereby measured wet weather volumes are compared to overall rainfall volumes. The key to the analyses is the comparison of the relative percent capture by the storm sewer system and the sanitary sewer system. This is determined directly from the flow monitoring data. The actual or precise amount of rainfall that fell on the tributary area does not have to be known, but is useful for assessing the reasonableness of the flow monitoring data. For instance, consider the values in Table 1 below.

Table 1 – Lisa Ridge Apartments Separate Sewer Flow Monitoring: June 2011 - January 2012

Month	Total Rainfall, in	Rainfall Volume, MG		Wet Weather Volume in Sewers, MG		% of Rainfall Captured		% of Total Rainfall Captured	% of WW Vol in Storm
		Storm	San	Storm	San	Storm	San		
June	10.08	2.19	2.19	1.337	0.386	61%	18%	79%	78%
July	1.08	0.23	0.23	0.135	0.028	58%	12%	69%	83%
August	3.76	0.82	0.82	0.270	0.151	33%	18%	52%	64%
Sept	8.80	1.91	1.91	0.800	0.297	42%	16%	57%	73%
October	5.00	1.09	1.09	0.405	0.300	37%	28%	65%	57%
November	8.56	1.86	1.86	0.703	0.162	38%	9%	47%	81%
December	7.00	1.52	1.52	0.453	0.248	30%	16%	46%	65%
January	5.96	1.29	1.29	0.183	0.164	14%	13%	27%	53%
Totals	50.24	10.91	10.91	4.29	1.74				
Averages						39%	16%	55%	71%
Storm sewer and sanitary sewer tributary areas approximately the same at 8 acres									

The columns in Table 1 are briefly explained below:

- Column 2 is the total rainfall from the nearest rain gauge, which is approximately 2 miles away
- Column 3 is the total rainfall volume calculated over the storm sewer tributary area of 8 acres
- Column 4 is the total rainfall volume calculated over the sanitary sewer tributary area of 8 acres
- Column 5 is the total measured storm sewer flow volume
- Column 6 is the total measured sanitary sewer flow volume minus the average dry weather flow volume, which is the total wet weather flow volume in the sanitary sewer
- Column 7 is equal to Column 5 divided by Column 3
- Column 8 is equal to Column 6 divided by Column 4
- Column 9 is equal to Column 7 plus Column 8
- Column 10 is equal to Column 7 divided by Column 9

The most important data to use for determining the effectiveness of sewer separation in fully developed sewered areas are the averages at the bottom of the table. Sewer separation effectiveness and reduction in CSO volumes are modeled for the Typical Year, so average conditions throughout the year are of greater importance than either monthly values or individual storm event values. Column 8 shows the percent of rainfall captured in the sanitary sewer system, which represents RDII. This wet weather volume component will remain in the combined sewer following sewer separation. It can only be lowered through RDII source control and sewer rehabilitation measures. The average value of 16 percent is relatively high, but the monitoring period is the wettest period on record for Cincinnati, and it is probable that temporary elevated groundwater levels existed during portions of the flow monitoring period that increased the infiltration volume. In this context, it is likely that this percentage is higher than normal, so it could well overstate the volume of wet weather flow remaining in the combined sewer system after sewer separation for the Typical Year. It should be noted that MSD has compiled RTK values for 90 flow meters installed in separate sanitary sewers of the Mill Creek Basin over a number of years. The average of the median R values for the 90 flow monitors is 4.5%, and the average of the maximum R values for the 90 flow monitors is 14%. This gives a pretty good indication that the R value of 16% shown here is higher than would be expected for a typical year.

Of the data represented in Table 1, the monitored sanitary sewer data is believed to be the most precise. This is due to the fact that monitoring of the sanitary sewers was performed continuously in a small pipe (8-inch diameter) with a flow monitoring instrument well-suited for the application that measured both flow depth and velocity. Any unexpected changes in meter calibration are relatively easy to detect by studying the flow hydrographs over the entire data collection period. In the separate storm sewers, there were long periods with zero flow and the resulting data is less precise and reliable. A flow monitor that goes from no flow to a sudden influx of high flow does not always remain calibrated nor provide consistent results from storm event to storm event. This is more apparent in some of the other meter installations that are discussed later.

Average rainfall volume capture by the separate storm sewer system is 39 percent, as shown in Table 1 at the bottom of Column 7. This represents the runoff volume that is captured by the storm sewer system. Average rainfall volume capture by the two separate sewer systems is 55 percent, as shown at the bottom of column 9. Dividing the former value by the latter value equals 71 percent, which is the percentage of the total wet weather volume to the combined sewer system that is captured by the storm sewer system and which will be removed from the combined sewer system as a result of sewer separation. For this small, fully developed sewershed, the 29 percent of the wet weather volume in the sanitary sewer system will remain in the combined sewer system following sewer separation.

In summary then, from the bottom row of Table 1:

- Rainfall captured in the sanitary sewer system is 16%
- Rainfall captured in the storm sewer system is 39%
- Total rainfall capture volume is 55%
- The fraction of the wet weather volume captured by the storm sewer system is 71%

Another apartment complex, the Four Towers Apartments in the western-most area of the Lick Run sub-basin was also monitored in 2011-2012. Results are summarized in Table 2. The total tributary area to both the sanitary and storm sewers is approximately the same and is 7 acres.

Table 2 – Four Towers Apartments Separate Sewer Flow Monitoring: April 2011 - January 2012

Month	Total Rainfall, in	Rainfall Volume, MG		Wet Weather Volume in Sewers, MG		% Rainfall Captured		% of Total Rainfall Captured	% of WW Vol in Storm
		Storm	San	Storm	San	Storm	San		
April	9.05	1.72	1.72	0.603	0.232	35%	13%	49%	72%
May	6.24	1.19	1.19	0.362	0.057	31%	5%	35%	86%
June	10.08	1.92	1.92	0.279	0.173	15%	9%	24%	62%
July	1.08	0.21	0.21	0.029	0.036	14%	18%	32%	45%
August	3.76	0.71	0.71	0.091	0.092	13%	13%	26%	50%
Sept	8.80	1.67	1.67	0.323	0.194	19%	12%	31%	62%
October	5.00	0.95	0.95	0.242	0.204	25%	21%	47%	54%
November	8.56	1.63	0.84[1]	0.966	0.253	59%	30%	89%	66%
December	7.00	1.33	1.33	0.723	0.152	54%	11%	66%	83%
January	5.96	1.13	1.06[2]	0.505	0.050	45%	5%	49%	90%
Totals	65.53	12.46	11.60	4.12	1.44				
Averages						33%	12%	46%	73%

Storm sewer and sanitary sewer tributary areas approximately the same at 7 acres

[1] Total rainfall was 4.44 inches on days with sanitary sewer flow data

[2] Total rainfall was 5.60 inches on days with sanitary sewer flow data

Examining the averages from Table 2, the following conclusions could be made:

- Rainfall captured in the sanitary sewer system is 12%
- Rainfall captured in the storm sewer system is 33%
- Total rainfall capture volume is 46%
- The fraction of the wet weather volume captured by the storm sewer system is 73%

However, the total rainfall volume capture by the storm sewer system is lower than expected during the summer and early fall months, averaging just 17% for the period June through October. If it were assumed that the storm sewer flow is not being fully accounted for by the two storm sewer flow monitors during this period, and the capture values are raised to 33%, then the overall average capture would increase to 39% for the storm sewers, and to 51% for overall wet weather volume capture. This would increase the fraction of the wet weather volume captured by the storm sewer system from 73% to 76%. This would decrease the wet weather volume captured by the sanitary sewer system from 27% to 24%. It can be concluded that for this small, fully developed sewershed, the 24 to 27 percent of the wet weather volume in the sanitary sewer system will remain in the combined sewer system following sewer separation.

A residential neighborhood constructed in the 1990s, Woodcrest Park, in the Lick Run sewershed was also selected for separate sewer monitoring. Using the parcel boundaries for the sanitary sewer tributary area, the total area is approximately 13 acres. Using the front halves of the parcels that drain to the street, the storm sewer tributary area is approximately 7 acres. Flow monitoring results are summarized in Table 3.

Table 3 – Woodcrest Park Subdivision Separate Sewer Flow Monitoring: April 2011 - January 2012

Month	Total Rainfall, in	Rainfall Volume, MG		Wet Weather Volume in Sewers, MG		% Rainfall Captured		% of Total Rainfall Captured	% of WW Vol in Storm
		Storm	San	Storm	San	Storm	San		
April	9.05	1.72	3.19	0.970	0.026	56%	1%	57%	99%
May	6.24	1.19	2.20	0.620	0.036	52%	2%	54%	97%
June	10.08	1.92	3.56	0.534	0.026	28%	1%	29%	97%
July	1.08	0.21	0.38	0.044	0.090	21%	24%	45%	48%
August	3.76	0.71	1.33	0.140	0.126	20%	9%	29%	67%
Sept	8.80	1.67	3.11	0.472	0.083	28%	3%	31%	91%
October	5.00	0.95	1.76	0.411	0.085	43%	5%	48%	90%
November	8.56	1.63	3.02	0.555	0.147	34%	5%	39%	88%
December	7.00	1.33	2.47	0.409	0.125	31%	5%	36%	86%
January	5.96	1.13	2.10	0.383	0.113	34%	5%	39%	86%
Totals	65.53	12.46	23.13	4.54	0.86				
Averages						40%	4%	40%	91%
Storm sewer tributary area approximately 7 acres; sanitary sewer tributary area approximately 13 acres									

Examining the averages from Table 3, the following conclusions could be made:

- Rainfall captured in the sanitary sewer system is 4%
- Rainfall captured in the storm sewer system is 36%
- Total rainfall capture volume is 40%
- The fraction of the wet weather volume captured by the storm sewer system is 91%

Housing lots in this residential subdivision are relatively flat and are located on top of a ridge. Downspouts along the front of each house are turned underground and exit to the street through the curb. Percentage-wise, there is more vegetated area in the storm sewer tributary area than in either of the apartment complexes. However, the total rainfall volume capture by the storm sewer system is lower than expected during the summer and early fall months, averaging just 24% for the period June through September. If it were assumed that the storm sewer flow is not being fully accounted for by the two storm sewer flow monitors during this period, and the capture values are raised to 35%, then the overall average capture would increase to 40% for the storm sewers, and to 43% for overall wet weather volume capture. The fraction of the wet weather volume captured by the storm sewer system remains at 91%. It can be concluded that for this small, fully developed sewershed, the 9 percent of the wet weather volume in the sanitary sewer system will remain in the combined sewer system following sewer separation.

In the Tier 1 areas of Lick Run that are proposed for sewer separation, there is a larger proportion of multi-family housing complexes than single family neighborhoods, so the overall rainfall captured in the sanitary sewer system would be weighted more toward the values observed for the two apartment complexes. Based on a 60%/40% split of multi-family to single family housing, the weighted average rainfall capture would be 0.6 x 14% + 0.4 x 4% = 10%. If total rainfall capture is 50%, then the percentage of wet weather flow in the sanitary sewer system would be 10%/50% = 20%. It is important at this point to understand that the 20 percent sanitary sewer wet weather capture volume that will remain in the combined sewer system from sewered developed areas does not translate to a sewer separation effectiveness of 80 percent. Sewer separation effectiveness will be higher, because all of the runoff captured from undeveloped areas will be removed from the combined sewer system.

If the total capture of rainfall volume over the sewered developed area were increased from 50% to 60% or higher, as is expected, then the percentage of the total rainfall capture that is in the sanitary sewer system would be lowered to 10%/60% = 17%. This would make sewer separation even more successful than currently predicted, since the rainfall volume remaining in the combined sewer system following separation would be lower.