



PEAK FLOW REDUCTION OPPORTUNITIES IN THE
CASCADE CREEK TRIBUTARIES

Final Report

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1. Introduction

Since 2001, Olmsted and Dodge Counties have been working on a watershed-based initiative to integrate storm water management with transportation planning. The premise is that increased watershed storage leads to smaller bridges and culverts and that this improved flood protection can be funded by cost savings in bridge and culvert construction. In the *Hydrologic and Hydraulic Study of Cascade District Major Road Crossings* (April, 2003 aka 2003 Watershed Study), included as Appendix C of the *South Zumbro Watershed Storm Water and Capital Improvement Plan* (September 2003), cost-effective ponding opportunities were identified within the main stem of Cascade Creek.

The County's goals for the 2003 Watershed Study were to use a watershed-based approach in evaluating bridge replacement and improvements and thus consider the potential to downsize bridges, increase flood protection, reduce storm water volumes, improve water quality, and reduce maintenance and construction costs. The 2003 Watershed Study primarily considered temporary floodplain storage along the main stem of Cascade Creek.

This report augments the 2003 Watershed Study by considering storage on tributaries to the main stem. The goals of this and the 2003 Watershed Study are essentially the same: reduce peak flows through storage and thereby reduce the size of select bridges and culverts.

The findings of the 2003 Watershed Study were promising. Several cost-effective ponding opportunities along Cascade Creek were identified to reduce peak flows. These stream corridor improvements could improve road safety, increase flood protection, and reduce construction and road maintenance costs at critical road crossings like 45th Avenue SW and 70th Avenue SW. Other environmental benefits were also identified, such as improved water quality, reduced streambank erosion, restored wetlands, improved aquatic and wildlife habitat, and restored floodplain connectivity.

The Minnesota Department of Natural Resources (DNR) staff has been supportive of the stream corridor improvement concept. However, they advocate implementing structures outside Cascade Creek's main stem since the main stem is a DNR protected watercourse under Minnesota statute. According to statute:

...the state, a political subdivision of the state, a public or private corporation, or a person must have a public waters work permit to:
(1) construct, reconstruct, remove, abandon, transfer ownership of, or make any change in a reservoir, dam, or waterway obstruction on public waters; or
(2) change or diminish the course, current, or cross section of public waters, entirely or partially within the state, by any means, including filling, excavating, or placing of materials in or on the beds of public waters..

Olmsted County could attempt to permit the storage improvements identified in the 2003 Watershed Study. As a practical matter, though, the DNR would be reluctant to grant a permit for the projects described in that study. Consequently, Olmsted County was interested in exploring ponding opportunities on tributaries of Cascade Creek. Map 1 shows these tributaries and Cascade Creek. These tributaries are not protected

by the DNR though they are part of the public drainage system and thus subject to the body of drainage law that regulates such systems.

The objective of this Tributary Study was to explore temporary ponding opportunities in tributaries of Cascade Creek (South Branch). Though the focus is on the tributaries, this study considers the same watershed as the 2003 Watershed Study: 11,540 acres (18 square miles) upstream of the 45th Avenue SW (old bridge L-6262). The HydroCAD model used in both studies originates from the HEC-RAS model used in the 1998 Flood Insurance Study. As discussed in the 2003 Watershed Study, HydroCAD is a better model to simulate storage and attenuation while HEC-RAS is better for hydraulics. If the projects identified here are taken to the feasibility level of detail, the HEC-RAS model should be rerun to determine the hydraulic affects.

The scope of the Tributary Study was limited and focused on a qualitative assessment of 10-16 ponding opportunities in Cascade Creek's tributaries, as well as modeling and estimating preliminary costs for 4-6 promising sites.

2. Peak Flow Reduction Opportunities in Cascade Tributaries

2.1 APPROACH

This effort focused on identifying ponding sites adjacent to roadway crossings, performing a qualitative assessment of these ponding sites, and modeling a few high priority sites to develop a preliminary estimate of the cost and benefit of such projects. It bears repeating that the specific benefit is peak flow reduction within Cascade Creek and not peak flow reduction within the tributary, though this will also occur.

The 2003 Watershed Study included a Qualitative Ponding/Restoration Assessment which helped to identify sites where storage could be constructed. The assessment included sites on the main stem as well as sites along the tributaries. Within the tributaries, 17 sites were identified, either adjacent to road and bridge crossings, or within channels immediately upstream of the confluence with the main branch of Cascade Creek.

The physical data used in this study was collected as part of the *South Zumbro Watershed Storm Water and Capital Improvement Plan* and the appended 2003 Watershed Study. Some additional field data was collected for the 17 sites discussed here.

To accurately model the peak flow reduction of each of the 17 sites, it was necessary to further subdivide subwatersheds used in the 2003 Watershed Study. For instance, CT-a630, CT-a650, and CT-a690 were created from what had been one subwatershed in the 2003 Watershed Study. This finer level of detail slightly alters the model's calibrated 100-year flow. The 2003 Watershed Study considered 3,000 cfs to be the calibrated flow at bridge L-6262 though 3,460 cfs was calculated from the 1998 Flood Insurance Study. The additional subwatershed detail used in this study alters the model's calculated 100-year discharge to 3,285 cfs at L-6262 – closer to the discharge obtained for the 1998 Flood Insurance Study.

To allow comparisons, the modeling performed for this study used the same existing conditions as the 2003 Watershed Study. Specifically, the conditions for bridges L-6262 and L-4075 prior to their replacement were used, instead of the current box culverts.

2.2 QUALITATIVE PONDING/RESTORATION ASSESSMENT (QPRA)

The Qualitative Ponding/Restoration Assessment helped to identify the sites for improvements. This assessment was completed for the 2003 Watershed Study though the data collected were augmented by an additional day of field work for this tributary study. The field inventory and assessment considers practical economic and environmental factors such as:

1. flow control structure height and cost (structures above six feet can be designated as dams)
2. presence of buildings or other structures within the potential storage area (buying and removing buildings increases costs and creates negative feelings toward the project)
3. ability of existing topography to provide large storage volume (excavation to create storage is costly)

4. proximity of the site to Cascade Creek's main stem (proximate sites typically provide more flow attenuation) and proximity of the site to existing road and bridge crossings
5. wetland and water quality enhancement potential
6. soil and vegetative indicators of floodplain characteristics (historic floodplain areas might be reestablished).

Through the QPRA process seventeen sites were identified along Cascade Creek's tributaries. As with the main stem sites, most of these tributary sites are adjacent to road and bridge crossings. Unlike the main stem sites, the tributary sites also include those where tributary channels enter Cascade Creek but where no road or bridge crossings occur. The QPRA process was used to identify sites for inclusion in this tributary study. However, the ranking of these sites was strictly a function of their ability to reduce flows in Cascade Creek and did not consider all the economic and environmental factors identified above.

Map 1 shows the 17 sites under consideration by this study. Each site is labeled "CTS-#" with CTS standing for Cascade Tributary Stream. Some of these sites were considered in the 2003 Watershed Study, particularly those in Dodge County. The primary criterion for inclusion here is that the site not be on a DNR protected stream. It is generally understood that the protected portion of Cascade Creek ends at the Dodge County line. However the DNR's Olmsted County Protected Waters Inventory Map shows the protected portion of Cascade Creek extending to the Trunk Highway 14 crossing in Dodge County. Curiously, the Dodge County Protected Waters Inventory Map does not show this reach as protected. For the purposes of this study it is assumed that the protected stream ends at the county line.

2.3 HYDROLOGIC/HYDRAULIC MODELING – SENSITIVITY ANALYSIS

The first round of hydrologic and hydraulic modeling involved a subwatershed sensitivity analysis and not direct modeling of proposed ponding areas. This was considered a first cut to eliminate some of the 17 tributary sites from further consideration.

Some effort was spent in the 2003 Watershed Study to calibrate the model to the 1998 Flood Insurance Study. Calibration of model hydraulics (i.e. stream flow) cannot occur without accurate depiction of model hydrology (i.e. subwatershed runoff rates and depths). Consequently, significant effort was spent in getting the hydrology right.

Accurate hydrologic calculations allow for a subwatershed sensitivity analysis which involves turning off select subwatersheds to determine their impact on the peak flow at bridge L-6262. Essentially, at each tributary site all upstream subwatershed flows are discarded and the tributary site's discharge becomes zero. If zero discharge has no impact on the peak flow at L-6262 then the tributary site does not warrant additional study as a ponding area. If the tributary site's zero discharge has a significant effect on the bridge L-6262 peak flow then the site warrants further study including more detailed modeling of potential storage areas.

2.4 ANALYSIS RESULTS

Potential ponding improvement sites were evaluated based on their ability to reduce peak flows at the downstream point of the watershed (Bridge L-6262). Each potential ponding location was disconnected from the model, and the peak flow reduction at the downstream point was evaluated. The existing conditions flow at bridge L-6262 is 3,285 cfs and is demonstrated in the hydrograph shown in figure 1.

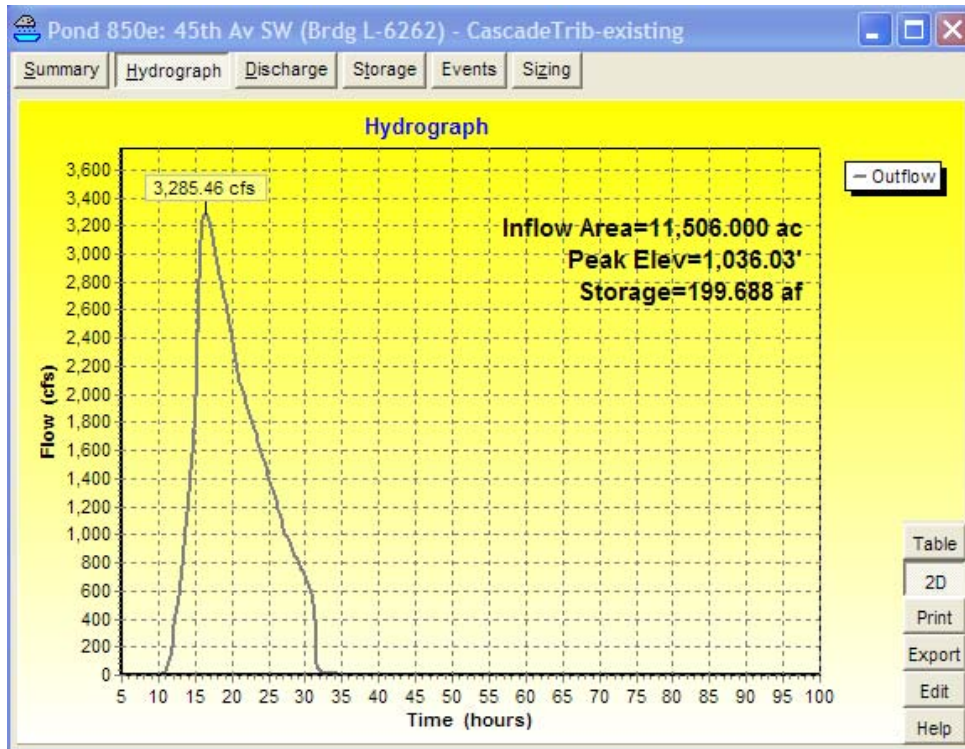


FIGURE 1- EXISTING CONDITIONS 100-YEAR FLOW AT L-6262

As noted previously this 3,285 cfs peak flow is slightly lower than the 3,460 cfs estimated from the 1998 Flood Insurance Study and slightly above the 3,000 cfs calculated in the calibrated model used in the 2003 Watershed Study. The current model includes more subwatersheds and tributary road crossings than that used for the 2003 Watershed Study though both models are identical in every other respect. Both the 2003 Watershed Study model and the current model utilize storage upstream of road and bridge crossings, which tends to reduce the peak flow over that seen in the 1998 Flood Insurance Study.

Table 1 shows the L-6262 peak flow reduction if the tributary site discharge is set at zero. As an example:

CTS-13 lies downstream of subwatersheds CT-a610, CT-a620, and CT-a630 (see map 1). If CTS-13 is disconnected from the model it simulates zero discharge from these three subwatersheds. Overall, zero discharge across this site reduces peak flow at L-6262 by 17%, as indicated in table 1.

Figure 2 provides a hydrograph plot of L-6262 showing the effect of CTS-13.

TABLE 1- SENSITIVITY ANALYSIS

Potential Improvement Site	Bridge Number	Location Description	Peak Flow Reduction at L-6262 if disconnected from the system
CTS-1		Upstream of railroad	0%
CTS-2		270th Ave/CR 15	0%
CTS-3		Old Hwy 14	1%
CTS-4		Upstream of railroad	1%
CTS-5	2380	280th Ave	4%
CTS-6		270th Ave/CR 15 (1250 ft south of TH 14)	0%
CTS-6b		270th Ave/CR 15 (2514 ft south of TH 14)	0%
CTS-7		275th Ave	1%
CTS-8		Frontier Rd (by Twite's farm)	2%
CTS-9		Frontier Rd	5%
CTS-10		Frontier Rd	4%
CTS-11	8057	Country Rd	8%
CTS-12	88708	CR 3	11%
CTS-13		10th St	17%
CTS-14		70th Ave	1%
CTS-15		10th St	2%
CTS-16		John Connelly's	18%

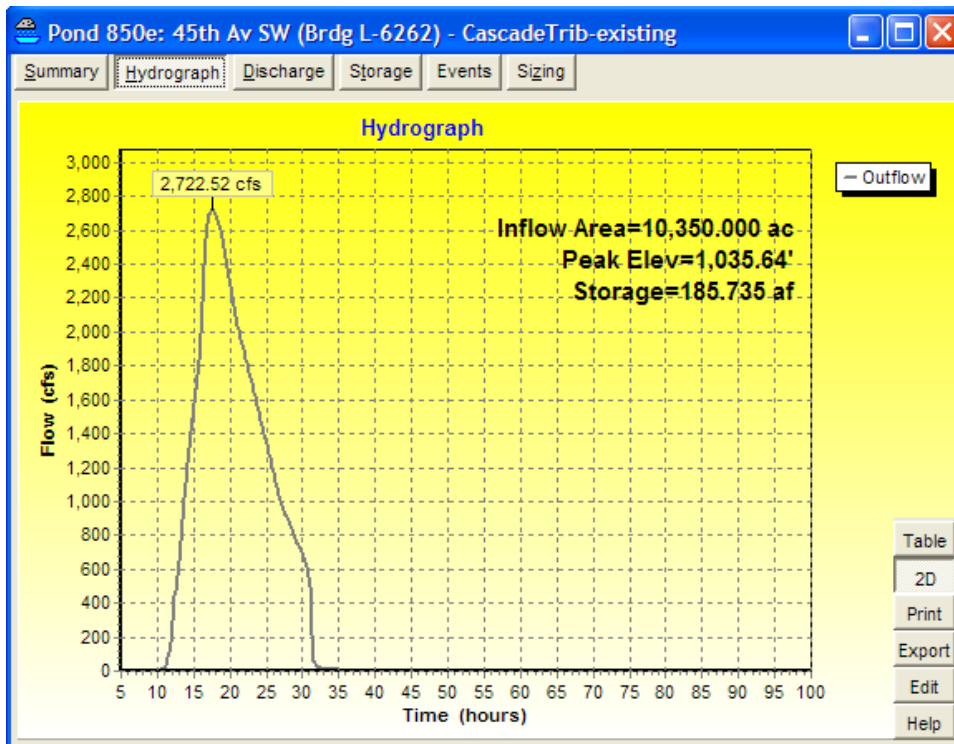


FIGURE 2- EFFECT OF CTS-13 AT L-6262

The levels of peak flow reduction make sense. Generally sites that have a large drainage area produced a large peak flow reduction than those with smaller drainage areas, because larger drainage areas have more of an overall impact at the downstream end of the Cascade Creek drainage area. Sites closer to Bridge L-6262 also had a higher impact because their peak flows are more likely to align with the peak at the bridge.

Among the 17 sites, 10 have little or no effect on the L-6262 flow (less than 3%). These tributary sites have no potential to reduce peak flow at bridge L-6262. Seven sites that lie closer to L-6262 or are found in larger subwatersheds have more potential. These are highlighted in bold in table 1. These seven sites were modeled in detail in HydroCAD. In order to model a feasible improvement strategy the following were assumed for the seven sites:

- an in-stream berm adjacent to the roadway (if located at a roadway) would be constructed at an approximate height of twelve feet (approximately six feet above the current top of bank).
- the berm would contain a sheet-pile weir with a notch to allow the passage of low flows, and a spillway for high flows.

This approach was used in the 2003 Watershed Study, however in that case the berms were kept to an elevation of six feet. An initial run using the same six-foot berm height for the tributaries yielded a negligible reduction in flow rate at L-6262. In order to develop beneficial projects, a revised strategy of measuring the six-foot berm height from top of bank was used. Discussions with the DNR dam safety staff indicate that this approach might be acceptable to avoid a dam safety permit under the six-foot maximum embankment criteria.

It should be emphasized that the attenuation obtained by any storage create by flow restriction depends on how the upstream floodplain is configured and how much storage can be obtained before the road or bridge overtops. Understanding that storage can be created at the roads or just upstream of the roads by berms, it is nonetheless useful to consider the maximum storage behind each roadway. Table 2 provides this for the five 2003 Watershed Study high priority projects.

TABLE 2- 2003 WATERSHED STUDY FLOW VOLUMES AND FLOOD STORAGE

Bridge number	100-year flow volume as this point (acre-feet)	Storage volume behind roadway (acre-feet)	Storage volume used with proposed improvements (acre-feet) ¹	Ratio of volume behind roadway to 100-year flow volume	% peak flow attenuation immediately downstream ²
L-6262	2667	162	103	6%	1%
4075	2156	77	148	4%	6%
89155	1582	392	425	25%	28%
89160	1046	715	222	68%	57%
L2380	578	80	103	14%	9%

1) Where storage volume used exceeds that behind roadway, road is overtopped.

2) Equals % change in flow upstream of bridge versus downstream with proposed improvements

It is noteworthy that over 90% of the flow attenuation from the 2003 Watershed Study (3,000 cfs to 1,800 cfs) occurred at 89155 and 89160. Clearly the landscape elsewhere does not lend itself as well to storage below the existing roadway elevations. The analysis reflected in table 2 implies that approximately a 25% threshold for ratio of available volume to 100-year flow volume is a good rule of thumb in evaluating storage potential.

Table 3 provides similar information of the tributary project sites.

TABLE 3- CURRENT STUDY FLOW VOLUMES AND FLOOD STORAGE

Potential improvement site	100-year flow volume (acre-feet)	Volume of storage behind roadway (acre-feet)	% of total flow volume that can be detained
CTS-5 = L2380	578	80	14%
CTS-9	101	18	18%
CTS-10	84	10	12%
CTS-11	104	56	54%
CTS-12	139	14	10%
CTS-13	267	9	3%
CTS-16 ¹	299	---	---

¹CTS-16 is not located at a roadway

Using table 2 and the 25% flow volume/flood storage as a guide, only CTS-11 appears to have potential for significant peak flow attenuation without raising the road or constructing a high berm to provide additional storage volume. Table 3 suggests that the roadways at the tributary sites (except for CTS-11) do not

provide sufficient storage which leads to consideration of upstream berms for creating storage rather than raising the roadway.

Although the amount of storage at each site differed, to simplify analysis and discussion a standard berm height of 12 feet was used. This elevation was picked because it was above the road elevation for all sites so that additional storage volume could be provided. The sheet-pile weir with a notch to provide rate control was modeled as a two foot notch 10 feet high to allow the passage of low flows, and then expanding to a 20 foot wide spillway at the top. If the two foot wide notch did not allow sufficient passage of flows and the berm was overtopped, the notch was widened up to four feet in the modeling. A schematic drawing of the proposed berm and weir structure improvement is shown in figure 3.

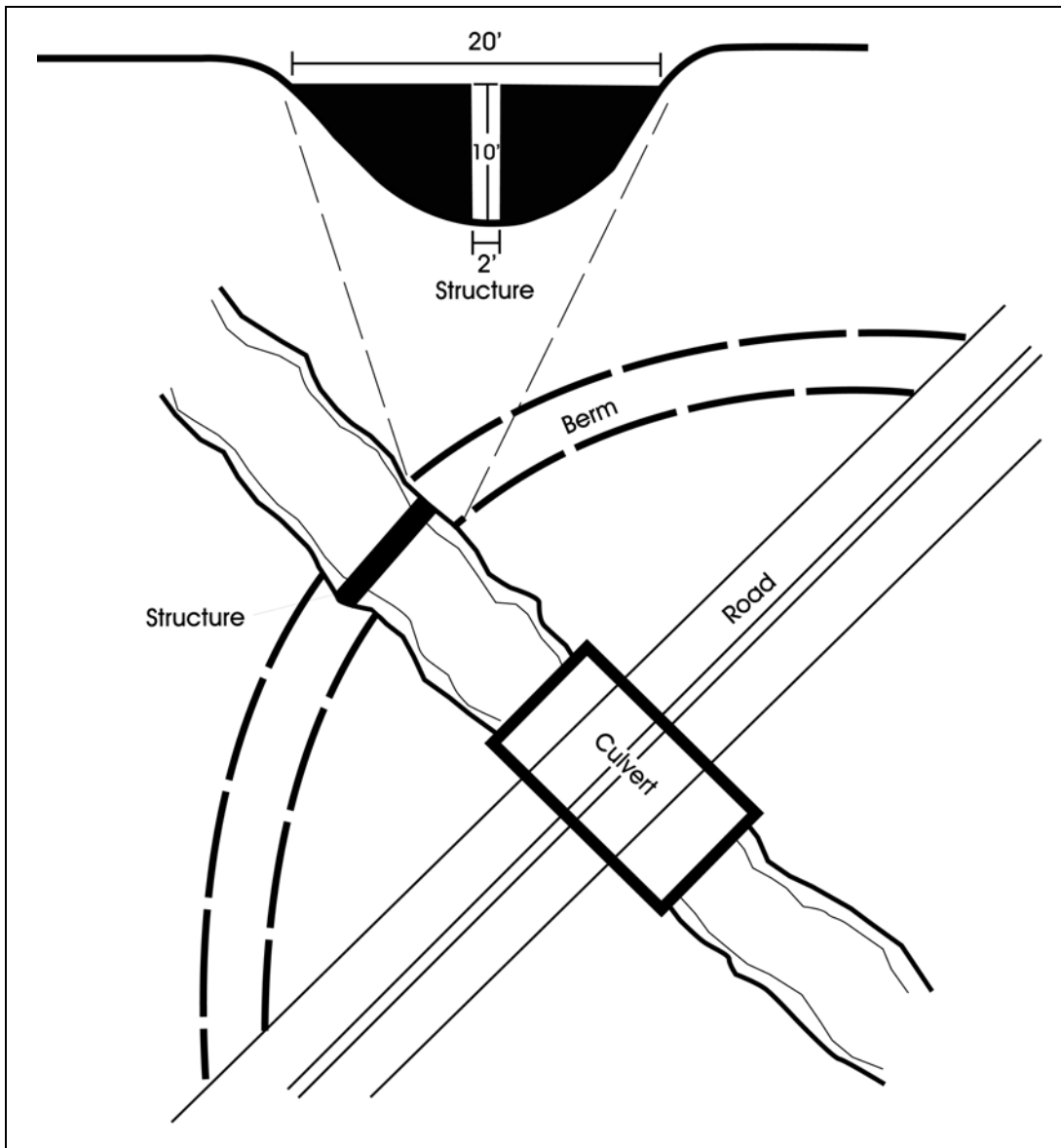


FIGURE 3-PROPOSED BERM AND WEIR STRUCTURE

One foot of freeboard was provided to the top of the berm. Additional excavation was not considered because relatively little is known about the site topography. Detailed survey information would be needed at each crossing to determine the storage available behind each berm. Because of their height and the storage created behind them, each project should be reviewed with DNR dam safety staff. It is anticipated that the following factors would allow a dam safety exemptions:

1. the 12-foot height only occurs over the stream, at streambank a six-foot height occurs
2. the upstream high water level divided by the effective diameter of the outlet notch (in terms of an equivalent pipe diameter) is less than two
3. the gradient between the upstream and downstream side of the berm is small or short-lived
4. the time water sits behind the berm is low i.e. storage fills and empties relatively quickly

None of these factors are numerically defined in the DNR dam safety program but they do form subjective criteria upon which to base an exemption.

Each of the seven sites is discussed in more detail below including proposed outlets and modeling results.

CTS-5

CTS-5 is behind Bridge L-2380, at the Dodge County/Olmsted County border under 19th Avenue NW in Kalmar Township. Disconnecting CTS-5 from the model reduced peak flows at bridge L-6262 by 4%. The crossing is currently a 9-foot wide by 7-foot tall CMP arch pipe, and the road overtops during the 100-year storm. The constructed 12 foot high berm will be approximately 1800 feet long to tie into the existing roadway. A small amount of flow will still overtop the road, but this amount has been greatly reduced. The impact of the improvements would reduce the peak flow from 753 cfs to 430 cfs immediately downstream of the crossing (an attenuation of 43%).

CTS-9

CTS-9 is a crossing of Frontier Road SW in Olmsted County just west of County Road 5 and just north of the main stem of Cascade Creek. Disconnecting CTS-9 from the model reduced peak flows at bridge L-6262 by 5%. The crossing is currently a 7.8-foot wide by 6.4-foot high CMP arch pipe. The road does not currently overtop during the 100-yr storm. The constructed 12 foot high berm will be approximately 600 feet long to tie into the existing roadway. The improvements reduced the peak flow from 292 cfs to 209 cfs in the reach immediately downstream of this crossing (an attenuation of 28%).

CTS-10

CTS-10 is a crossing of Frontier Road in Olmsted County, north of the main stem of the Creek. Disconnecting CTS-10 from the model reduced peak flows at bridge L-6262 by 4%. The crossing is currently a 48-inch diameter RCP pipe. The road currently overtops during the 100-yr storm. The constructed 12 foot high berm will be approximately 2400 feet long to tie into the existing roadway. A small amount of flow will still overtop the road, but this amount has been greatly reduced. The improvements reduced the peak flow from 275 cfs to 155 cfs in the reach immediately downstream of the crossing (an attenuation of 44%).

CTS-11

CTS-11 is a crossing of Country Club Road in Olmsted County on the border between Kalmar and Salem Townships. Disconnecting CTS-12 from the model reduced peak flows at bridge L-6262 by 8%. The

crossing is currently a 10-foot wide by 6-foot high box culvert. The road does not currently overtop during the 100-year storm. The constructed 12 foot high berm will be approximately 1200 feet long to tie into the existing roadway. The improvements reduced the peak flow from 378 cfs to 182 cfs in the reach immediately downstream of this crossing (an attenuation of 52%).

CTS-12

CTS-12 is a crossing of County Road 3 in Olmsted County immediately downstream of CTS-11. Disconnecting CTS-12 from the model reduced peak flows at bridge L-6262 by 11%. The crossing is currently a 10-foot wide by 6-foot high box culvert. The road does not currently overtop during the 100-year storm. The constructed 12 foot high berm will be approximately 1000 feet long to tie into the existing roadway. The improvements reduced the peak flow from 490 cfs to 213 cfs in the reach immediately downstream of this crossing (an attenuation of 57%).

CTS-13

CTS-13 is a crossing of 10th Street in Olmsted County. Disconnecting CTS-13 from the model reduced peak flows at bridge L-6262 by 17%. The crossing is currently a 10-foot wide by 7-foot high box culvert. The road currently overtops during the 100-year storm. The constructed 12 foot high berm will be approximately 1000 feet long to tie into the existing roadway. A small amount of flow will still overtop the road, but this amount has been greatly reduced. The improvements reduced the peak flow from 932 cfs to 530 cfs in the reach immediately downstream of the crossing (an attenuation of 43%).

CTS-16

CTS-16 is located just upstream of the main channel of Casacade Creek in Olmsted County. Disconnecting CTS-16 from the model reduced peak flows at bridge L-6262 by 18%. The site is currently a ditched channel. The constructed berm will be approximately 1500 feet to tie into existing contours. The improvements would reduce the peak flow from 904 cfs to 365 cfs in the channel immediately downstream of this location (an attenuation of 60%).

2.5 BENEFIT

The seven tributary sites were modeled as described above. Table 4 presents the individual impact of each improvement on the reach immediately downstream as well as the cumulative impact of all seven improvements on Cascade Creek at L-6262.

TABLE 4- PEAK FLOW REDUCTION

Potential improvement site	100-year existing peak outflow (cfs)	100-year proposed improvements peak outflow (cfs)	Peak flow reduction at the site (%)
CTS-5	753	430	43%
CTS-9	292	209	28%
CTS-10	275	155	44%
CTS-11	378	182	52%
CTS-12	490	213	57%
CTS-13	932	530	43%
CTS-16	904	365	60%
Peak flow reduction at L-6262 due to all proposed improvements	3285	2900	12%

While the peak flow reduction at each specific site is substantial, the cumulative impact downstream at Bridge L-6262 is significantly smaller. The 2003 Watershed Study considered five high potential improvements along the main stem of Cascade Creek. These improvements were proposed for the following crossings:

- L-6262, 45th Avenue SW
- 4075, 70th Avenue SW
- 89155, County Road 3
- 89160, County Road 5
- L-2380, 19th Avenue SW

As generally described in the 2003 Watershed Study, the projects involved construction of weirs and berms with a 6-foot average height. The ponding improvements allowed a reduction in capacity at each crossing, which leads to smaller bridges and cost savings on future bridge replacement. Overall, the five high priority projects reduced peak flow in Cascade Creek from 3,000 cfs to 1,800 cfs at bridge L-6262. As can be seen from table 4, tributary ponding is not as effective in reducing Cascade Creek flows.

At any of the seven tributary sites additional storage could be obtained by providing a higher berm, raising the road, or by excavating additional flood storage. Quite simply, additional storage leads to further reduction in peak flow in the downstream tributary reach. However, if the project intent is reduction of peak flow at L-6262 additional expense to reduce tributary flow is probably not warranted.

2.5 COST ESTIMATES

Table 5 presents the estimated improvement costs for the seven potential improvement sites. The costs include the construction of weirs and berms with a 12-ft average height. They do not include easement costs.

TABLE 5- COST ESTIMATES

Potential improvement site	Bridge number	Location description	Cost
CTS-5	2380	280th Ave	\$73,000
CTS-9		Frontier Rd	\$55,000
CTS-10		Frontier Rd	\$87,000
CTS-11	8057	Country Rd	\$59,000
CTS-12	88708	CR 3	\$84,000
CTS-13		10th St	\$54,000
CTS-16		John Connelly's	\$66,000
Total			\$478,000

3. Conclusions and Recommendations

The following conclusions and recommendations complement those stated in the *Hydrologic and Hydraulic Study of Cascade District Major Road Crossings* (aka 2003 Watershed Study).

An integrated watershed-based stormwater management approach is vital to identify and implement cost-effective and sustainable measures that protect infrastructure from flood impacts, improve water quality, and enhance the natural environment.

In considering the role ponding can play within Cascade Creek’s tributaries this much is clear: the benefit of peak flow reduction at bridge L-6262 along the main stem is proportional to the size of the tributary subwatershed and its proximity to L-6262. This conclusion could have been anticipated without this study.

It is concluded from this Tributary Study that some among the 17 tributary sites have no value in reducing peak flow at L-6262. The sensitivity analysis does suggest that all 17 tributary sites could have local value if peak flow reduction is needed at the subwatershed, and not watershed, scale. In fact, as table 2 indicates, subwatershed attenuation of peak flow generally exceeds 40% and in some cases 60%. These can be significant benefits at the subwatershed scale of reference.

What this Tributary Study does establish is that 10 of the 17 sites have no value in reducing peak flow at L-6262. The remaining seven tributary sites have project costs that are similar in magnitude to the in stream improvements in the 2003 Watershed Study and yet the benefits of these tributary sites are significantly less than those of the in-stream improvements.

Economies of scale and geomorphic characteristics (such as temporary floodplain storage) yield higher benefit to cost ratios for storm water measures in the main stem, because the main stem usually has wider floodplains and larger storage volumes than those in the tributaries. Locations in the main stem of Cascade Creek are also more likely to have peak flow times that align with the peak flow at Bridge L-6262. While the sites studied in the tributaries can provide some peak flow reduction benefit at L-6262, many areas in the main channel provide greater opportunities to increase safety and reduce flooding impacts. While the seven improvements identified in this tributary study reduce 100-year peak flow about 12% at L-6262, the five high priority improvements in the main stem reduce 100-year peak flow 40%.

In summary, ponding opportunities in the floodplain of Cascade’s main creek offer a greater benefit-to-cost ratio to reduce flooding impacts and increase safety than ponding opportunities in the tributaries, and the ponding opportunities in the tributaries should probably not be pursued unless there is a local value at the subwatershed level in reducing peak flows.

