Series of 5 memos regarding LMRWMO allowable flow dated March 9, 1988 to June 12, 1992

BARR ENGINEERING CO.

MEMORANDUM

TO: Lower Mississippi River Watershed Management Organization Managers

FROM: James R. Langseth

SUBJECT: Allowable Flow - Summary of Understanding Based on the Discussions at the Informal Meeting Held February 1, 1988

DATE: March 9, 1988

Allowable Flow - Rate of Flow Calculation

Allowable flow is a set of conditions defined for the purposes of cost apportionment. Allowable flow is not a historic condition or a natural condition of the watershed. The application of the Joint Powers Agreement (JPA) provisions for allowable flow calculation was interpreted as described below.

1. The allowable flow calculation shall be based on the following watershed, land use, precipitation event, and drainage system definitions:

   a. Watershed: Consists of the entire tributary watershed, defined by natural flow pathways, overflow routes, and the drainage system existing as of the effective date of the JPA.

      1) Landlocked areas are included.

      2) Areas diverted in by the drainage system existing as of the effective date of the JPA are included.

      3) Areas diverted out by the drainage system existing as of the effective date of the JPA are not included.

4) Natural flow pathways and overflow routes are defined by the topography available as of the effective date of the JPA.

b. Land use: The entire tributary watershed is considered to contribute flow as if it were all in a "natural vegetation" state.

1) Regardless of past or present land use or vegetation, landlocked status, proportion covered by water surface, or other "natural condition" land use variables, all areas are treated as land surface.

2) All stormwater detention basins, including lakes, are considered as though they had been filled and are treated as land surface in the analysis.

3) The runoff coefficient "C" for the Rational Method is to be 0.15 for "natural conditions". Other computational methods shall select variables which provide similar representations of conditions (for example, the percent impervious for the Barr Hydrograph Method will probably be ~~5~~ 0% for "natural conditions").

c. Precipitation event: critical 10-year frequency storm.

1) The Joint Powers agreement examples use the Rational Method and imply the critical frequency storm is a 10-year frequency rainfall intensity for a duration corresponding to the time of concentration of the watershed.

2) For hydrograph methods, the critical storm is that storm resulting in the highest peak flowrate. This will most likely be a storm having its peak rainfall rate at a time approximately equal to the watershed time of concentration.

d. Drainage system: A developed conveyance system is assumed to exist, that is, runoff is efficiently conveyed to the outlet in a system adequate to convey the 10-year runoff rates.

1) Times of concentration are to be appropriate to the typical slopes of the subwatersheds.

2) Flow velocities are to be appropriate to 10-year drainage system design.

3) No storage routing is considered because detention basins are considered not to exist.

2. To determine Excess Flow - Rate of Flow:

a. the allowable rate of flow shall be compared to the greater of:

1) The 10-year frequency critical storm design rate of flow.

2) Where there is a detention basin at the outlet of the upstream community's drainage system: the 100-year frequency critical storm design rate of flow.

b. The design condition will use:

1) Anticipated ultimate tributary watershed

2) Ultimate land use development, with appropriately applied runoff ("C") factors

3) Design storm - the critical duration 10-year or 100-year frequency event

4) Proposed drainage system, including detention basins and including the routing of runoff through those basins

Allowable Flow - Volume of Flow Calculation

1. The meaning of Allowable Flow - Volume of Flow, used for cost sharing on downstream detention basins, was not specifically discussed at this meeting. However, based on the discussion and reading the JPA, I have the following understanding:

    a. Watershed: as above (1.a.)

    b. Land use: as above (1.b.)

    c. Precipitation event: The 100-year frequency storm that is critical for the conveyance system design. (The JPA specifies the 100-year frequency 24-hour precipitation event as the criteria for detention basin design, but I interpret this to mean the critical duration storm.)

    d. Drainage system: as above (1.d.)

    e. Allowable flow: Volume of flow is the total runoff volume from the storm.

2. To determine Excess Flow - Volume of Flow: the allowable volume of flow shall be compared to the total runoff volume from the design storm, less the design volume of the upstream community's detention basins.

LMRWMO/322,0/tmk

BARR ENGINEERING CO.

MEMORANDUM

TO: Jim Langseth/File

FROM: Dennis Palmer

SUBJECT: LMRWMO Cost Allocation Formula

DATE: August 18, 1988

The following paragraphs summarize my interpretation of the cost allocation formula based on my reading of the Joint Powers Agreement, the memorandum from the February 1, 1988 meeting, the memorandum of June 22, 1988 from SEH, the letter of June 22 from the WMO attorney, and what I believe to be a reasonable and workable solution.

In general, an upstream community will be permitted to discharge an "allowable flow" without being required to participate in the cost of the downstream conveyance system. The cost to be apportioned to an upstream community will be based upon flows which exceed the "allowable flow". Calculation of the allowable flow involves: 1) definition of the contributing watershed, and 2) application of hydrologic criteria for the calculation of flow from that watershed.

(1)

- The watershed should be that ". . . area within a line drawn around the extremities of all terrain whose surface drainage is tributary . . ." to the point at which the allowable flow is to be calculated.

  Comment: The quoted portion of the above definition comes from Section 3, Subdivision 10 of the Joint Powers Agreement, where it refers to the watershed of the WMO as being that area tributary to the Mississippi River. A similar definition would include landlocked areas in the watershed area when calculating allowable flow. However, the definition of "allowable flow" in Section 3, Subdivision 3 could be strictly interpreted as excluding any landlocked areas which had not been provided an outlet as of the enactment date of the agreement. Thus, I believe the agreement is technically unclear as to consideration of landlocked areas.

The following thoughts are offered as a rationale for addressing landlocked basins. I have no personal knowledge of the intent of those who framed the Joint Powers Agreement; however, I believe that the tributary watershed should include any landlocked basins tributary to the point in question for the following reasons:

1) I believe we should presume that engineers and planners operating within and designing systems for an urban environment would have included within the design of any existing systems some allowance for future flow from presently landlocked areas. Thus, in Section 3, Subdivision 3 of the Joint Powers Agreement, I believe it would be appropriate to interpret that ". . . drainage system in place . . ." refers to a system which allows for ultimate discharge from such areas, whether or not they were landlocked as of the enactment date of the agreement. Note that I have no firsthand knowledge of discussions that took place between those who drafted this agreement - I am stating an opinion as to what my intent would have been.

2) When the effect of ponding in a landlocked area is considered, the contribution of the landlocked area to the allowable flow at the point in question will probably be negligible, and the inclusion of the landlocked area will therefore have little, if any, effect on cost allocation for the conveyance system or storage facilities downstream.

For landlocked basins entirely within a single community and when a landlocked basin occurs at a drainage boundary between communities, an allowable flow must be determined in order to apply the cost allocation formula in the agreement. I propose the following:

(2) • The allowable flow from landlocked basins will be 0.0252 cfs per acre.

Comment: Under natural conditions, the effective outflow is limited to seepage and is very small. Thus, it follows that a snowmelt event would be critical. The 100 year snowmelt is approximately 6 inches of runoff in 10 days. I propose that the allowable flow from a landlocked basin be defined as the 100 year runoff (6 inches of runoff in 10 days) or an average of 0.0252 cfs per acre. Note that this is much less than the flow which would be calculated using a rational coefficient of 0.15.

An alternative procedure would be to permit discharge from landlocked basins at no cost to the discharging community unless their discharge required oversizing of downstream systems. In that case, the upstream community would pay for the actual cost of oversizing the downstream conveyor to accommodate discharge from the landlocked basin. In practice, this would mean that the upstream community would participate in the cost of a limited length of the downstream system since local peak discharges soon become the prevailing design criteria when compared with outflow rates from upstream storage basins. This alternative is not favored because it differs more greatly from the formula in the agreement than does the defined allowable flow above.

(3) • Delineation of the watershed area should consider the conveyance system in place as of the date of the enactment of the agreement. The conveyance system should be interpreted to include (1) all detention areas which had been constructed as a part of the drainage system in place and (2) all detention areas which happened to occur because of ". . . the characteristics of the land on the date of enactment . . ." (from Section 3, Subdivision 12).

Comment: Storm sewer systems which existed as of the date of enactment may have altered the natural watershed divides. If an area is diverted away from the point where allowable flow is to be calculated, the agreement is clear; Section 3 subdivision 3 excludes any flow which is diverted away by the system in place. However, I believe that the agreement intends to include any water which may have been diverted into the watershed being considered by in-place systems. Likewise for calculating the allowable flow I believe the agreement intends to include any waters contributed by existing systems serving areas which were landlocked in their natural state.

Detention basins should be considered to be a "characteristic of the land on the date of enactment". As such, they are a part of the conveyance system and should be considered in the calculation of allowable flow. To ignore their effects would result in an allowable flow that was unreasonably high, just as to ignore landlocked basins could yield an allowable flow that was unreasonably low.

(4)

- For calculation of allowable flow, the same criteria should be used as was employed for calculation of the design flow, except that runoff factors should be appropriately reduced (C=0.15) to represent undeveloped watershed conditions.

Comment: The design flow at a given point would be (1) that flow calculated to result from a 10-year rainfall event, or 2) the peak outflow from ponds immediately upstream of the point in question (which results from the critical 100-year runoff event), whichever is greater. The allowable flow should be calculated in exactly the same manner, assuming the drainage system at the time of enactment and non-urban conditions. It is conceivable that a well-designed storage basin could actually reduce the peak flow from an urban area to a level below that which would occur under natural conditions, as defined in the agreement. It is therefore necessary to consider both the 10 year and 100 year events when calculating the allowable flow.

The use of a Rational Formula coefficient equal to 0.15 appears to be an agreed upon compromise developed by the technical advisors to those who drew the Agreement. It will adequately serve the purpose for which it was intended. It should not, however, be used to exclude the calculation of allowable flow by hydrograph methods and other standard engineering techniques.

FR/332,0/cmf

BARR ENGINEERING CO.

MEMORANDUM

TO: File

FROM: Jim Langseth

SUBJECT: Allowable Flow

DATE: August 25, 1988

A meeting was held on August 11, 1988 to discuss the meaning of allowable flow as defined in the Joint Powers Agreement (JPA). This meeting was attended by Jim Langseth representing Barr Engineering, John Sachi representing Inver Grove Heights, Bill Price representing Sunfish Lake, Jim Danielson representing Mendota Heights, Skip Stephaniak representing West St. Paul, and Mark Loebermeyer from SEH and Bob Simon representing South St. Paul.

A letter inviting all members and alternates of the Lower Mississippi River Watershed Management Organization to the meeting had been mailed out prior to the meeting. Copies of the letter had also been distributed to all advisors to the LMRWMO. In that letter four topics were identified for discussion at the meeting. A copy of the letter is attached. For each of the topics, a series of reasonable interpretations of the agreement were presented in the letter. It was hoped that the group would agree on one set of interpretations.

Bill Price, Skip Stephaniak, and Jim Danielson had been involved at one level or another in the formulation of the allowable flow definitions in the JPA. Bill Price had been retained by the framers of the JPA to prepare the examples in the JPA. Bill Price explained some of the factors that went into the formulation of the allowable flow concept. First, the upstream communities have the right to discharge some flow downstream without cost. Second, the examples were simplified so that they would be easy to apply and would serve to illustrate the fundamental concepts. Third, the examples in the JPA must be used to interpret the language regarding these matters.

Skip Stephaniak explained that the "C" factor of 0.15 was a compromise number that was arrived at as a way to reduce the variability in the calculation of allowable flow.

Mark Loebermeyer, speaking for South St. Paul, suggested that if the examples defined allowable flow then they could also be used to define excess flow. One could simply change the "C" factor from natural conditions to developed conditions to arrive at the excess flow.

Bob Simon pointed out that the examples might be for illustration but were not definitive. A reference to the examples was found in the JPA. That reference occurs on page A-15 of the JPA in the Watershed Management Plan. Section 9, Subdivision 6(f) of the JPA states "The attached Exhibit A is incorporated by reference and serves as a compilation of general examples of cost allocation under this agreement for the hypothetical circumstances stated in the examples."

Bill Price pointed out that during the discussions leading to the JPA, the possibility was discussed that a community could hold back enough water so that they would not owe any cost sharing for downstream construction.

The position maintained by the representatives from South St. Paul through all of the discussions was that calculation of allowable flow and design flow should be commensurate. They should be done using the same watershed, the same drainage system, the same ponds, and so forth. That is, if allowable flow is calculated without ponds, excess flow should be calculated without ponds. If design flow is calculated including ponds, allowable flow should be calculated including ponds. The South St. Paul representatives maintained that the examples and the language of the Joint Powers Agreement provided no basis for calculation of allowable and excess flows by two different approaches.

After further discussion, the questions raised in the letter of August 5 were discussed directly. A summary of the discussion of those questions follows:

1. What is the allowable flow from landlocked areas (such as the watershed tributary to Sunfish Lake)?

   Three communities indicated that the allowable flow would be an amount determined by the methods in the examples incorporated in the Joint Powers Agreement. By this they meant that the allowable flow is determined by the rational method applying a "C" factor of .15, rainfall intensity according to the time of concentration of the watershed, and the full watershed area. Inver Grove Heights indicated that they would answer D, "other", by which they meant that the allowable flow would be related to the ultimate development drainage system (answer B from Question 2). South St. Paul indicated the answer was B: the allowable flow would depend upon the drainage system in place on October 1, 1985. This implied that if no drainage system were in place there would be no allowable flow in that landlocked area.

2. What is the drainage system in place and the definition of "allowable flow"?

   Four communities indicated that the answer would be C, a hypothetical system adequate to convey only the allowable flow with no ponding considered. One community elaborated to explain that this implied that there would be a whole new hypothetical drainage system in place sufficient to carry the allowable flow rate. South St. Paul indicated that the drainage system in place meant the system in place on October 21, 1985. West St. Paul pointed out that the date was meant to define when waters were considered diverted in or out of a watershed and was not intended to define ponds and detention basins and the drainage system that should be used in the calculation of allowable flow. Bill Price pointed out that the language regarding diversion was added because there was existing diversion even at that stage. Thus the diverted waters in Section 3, Subdivision 3 of the JPA refers to the waters diverted after the signing of the JPA.

There was some discussion of whether or not DNR-protected public waters could be ignored in calculating allowable flow.

3. What shall the allowable flow storm be?

This question was more or less skipped because with allowable flow being defined as incorporating the examples in the back of the JPA, the allowable flow from an upstream community is defined as the 10-year frequency discharge. The initial answers indicated by the parties were that the allowable flow storm should be the 10-year frequency for pipes and 100-year frequency only for open channels and pond volumes, but that the upstream community allowable flow is computed without ponds.

4. How are detention basins treated in calculation of allowable flow?

Four of the communities indicated that the answer is A. Detention basins are ignored as in Example "A" of Exhibit A of the JPA. South St. Paul indicated the answer would be either B, as defined by the topographic data available on October 21, 1985 or C, as defined by the drainage system in-place on October 21, 1985 or a combination of both.

Following this discussion, a vote was taken on what to tell the Board regarding the outcome of the meeting. What we agreed to report to the Board was that the Committee could not come to unanimous agreement on the meaning of allowable flow, but the majority supported the definition as explained in the memo from the February 1, 1988 meeting. The meeting concluded after this vote.

LMRW/322,0/tvo

THIS TO BE A PART OF JPA - AS REFERENCE ONLY "GUIDELINES"

MEMORANDUM

TO: Lower Mississippi River Watershed Management Organization

FROM: James R. Langseth

DATE: February 19, 1992

RE: Allowable Flow, Summary of Understanding Based on the Discussions at the Meeting Held December 13, 1991

This meeting was held to address three topics and a fourth topic was briefly discussed.

1. Allowable flow 100-year frequency storm design conveyance systems.

2. Allowable volume.

3. Cost apportionment downstream of ponds.

4. Cost allocation principles for diversions where more than one city contributes flow.

These interpretations use the definitions for watershed, land use, and drainage system set forth in the March 9, 1988 Allowable Flow memorandum. The current memorandum provides an interpretation of the allowable flow for cases where the design is not based on a 10-year storm.

1. <u>Allowable Flow for 100-Year Frequency Storm Design Conveyance Systems</u>

The Joint Powers Agreement, Section 3, Subd. 3, states that the allowable flow is a rate an volume of flow according to the design criteria in Section 8, Subd. 6. Section 8, Subd. 6 provides that detention basins and open channel conveyance systems be designed for a 100-year return frequency storm.

Consistent with these provisions, for drainage systems for which the design criteria are 100-year return frequency precipitation events, the allowable flow shall be computed as a 100-year rate and volume flow.

The allowable rate of flow shall be computed by Q = CIA
where:

Q is the allowable flow rate in cubic feet per second.

C is the runoff coefficient, defined to be 0.15.

I is the 100-year return frequency rainfall intensity appropriate to the watershed time of concentrations, in inches per hour.

A is the watershed area in acres.

Excess flow is the 100-year design flow less the 100-year allowable flow.

This approach shall be applied for conveyance systems where the design is governed by 100-year return frequency events. This includes [redacted], detention basin outlets, conveyance systems downstream of detention basins, open channels, and other conveyance that is designed for 100-year return frequency events. Similar logic would apply to any system for which the design criteria was neither 10-year or 100-year. See Example F for an illustration of a 100-year excess flow calculation.

2. Allowable Volume

The allowable volume is the total runoff volume from the design storm, for a watershed with the land use defined in the March 9, 1988 memorandum. Where the ponding in the upstream community is negligible, the allowable volume may be estimated as being in the same proportion to the design volume as the allowable flow is to the design flow.

In general, the allowable volume may be computed with the same techniques used to determine the design volume, provided the technique also accurately calculates the allowable discharge rate.

The excess volume is the difference between design and allowable volume.

Where there is upstream ponding, the volume of those ponds is deducted from the excess volume to the extent the upstream detention reduces the volume needed in downstream ponds. Thus, only the storage in upstream detention basin at the time of peak of the downstream detention basin may be used to reduce the excess volume from the upstream community. For instance, assume the peak elevation at a downstream community pond occurs at 6 hours. Assume the upstream community pond stores 10 acre-feet at its peak at 3 hours, but only 5 acre-feet at 6 hours. The "excess volume" from the upstream community would be reduced by 5 acre-feet to account for the storage. See Example G for an illustration of this case.

3. Cost Apportionment Downstream of Ponds

In the Joint Power Agreement, Exhibit A, page 9 of 9, the formula for adjustment to excess flow as a result of ponding is presented:

$$Q_{excess}(\text{outlet}) = Q_{excess}(\text{inlet}) \times \frac{Q_{total}(\text{outlet})}{\Sigma\, Q_{total}(\text{inlet})}$$

The proportioning $Q_{total}^{(outlet)}/\Sigma\, Q_{total}^{(inlet)}$ shall be computed on the same return frequency event used for the pond design. If the pond is designed for a 100-year event, the adjustment in excess flow through the pond shall be based on the 100-year outflow and inflow values. Thus, if a 10-year design governs cost sharing for construction downstream of a pond, the 10-year excess flow would be reduced as follows:

$$Q_{excess}\ 10\text{-year(outlet)} = Q_{excess}\ 10\text{-year(inlet)} \times \frac{Q_{total}\ 100\text{-year(outlet)}}{\Sigma\ Q_{total}\ 100\text{-year(inlet)}}$$

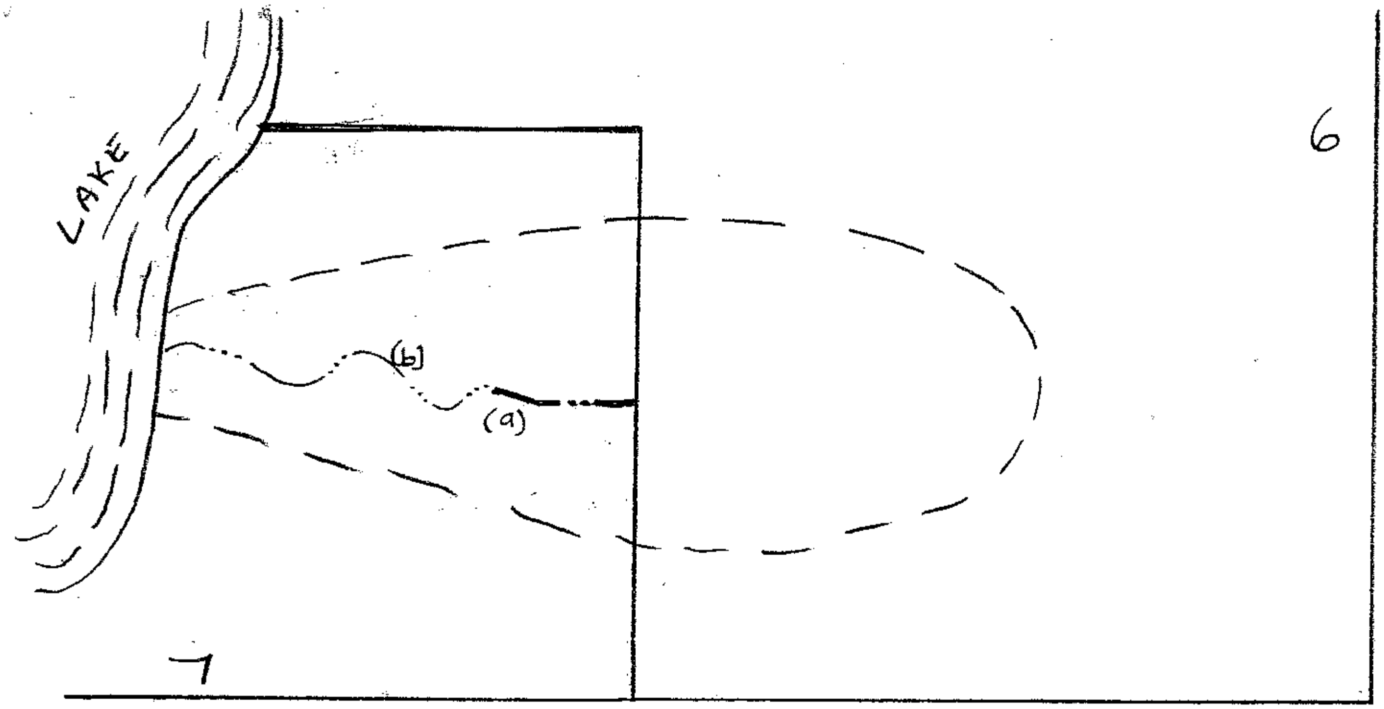
See Example H for an illustration of this case.

4. <u>Cost Allocation Principles for Diversion Where More Than One City Contributes Flow</u>

For diversion of water out of its current watershed, into a watershed to which it did not previously flow, there is no allowable flow associated with the diverted water. Consequently, the excess flow from the diverted area equals the design flow. If more than one city contributes water to the diversion, the excess flow from each community is their portion of the design flow from the diverted area. Thus, the cost allocation proportion for each city is their proportion of the design flow.

The "diversion in" is associated with an equal area of "diversion out" of another watershed. The cities retain their allowable flow in the watershed from which the area was "diverted out." This is illustrated for "diversion out" by one city on Page 6 of 9 of Exhibit A to the Joint Powers Agreement.

This principal was applied to the Lexington Avenue drainage case with Lilydale and Mendota Heights. The situation is illustrated conceptually in Example I.



Example F - Other than 10-year Design

Project: Construct storm sewer "a" and open channel "b" in City #7 to provide drainage for Cities #6 and #7 under fully developed conditions.

Cost Allocation:

City #6 Cost Share: $\frac{Q_{E6-10}}{Q_{D-10}}$ X Total Project Cost for "a"

$\frac{Q_{E6-100}}{Q_{D-100}}$ x Total Project Cost for "b"

Q_{E6-10} = 10 year excess flow from City #6 $= Q_{D6-10} - Q_{A6-10}$

Q_{D6-10} = 10 year design flow from City #6

Q_{A6-10} = 10 year allowable flow from City #6

Q_{D-10} = 10 year design flow for storm sewer "a"

Q_{E6-100} = 100 year excess flow from City #6 $= Q_{D_6-100} - Q_{A_6-100}$

Q_{D_6-100} = 100 year design flow from City #6

Q_{A6-100} = 100 year allowable flow from City #6

Q_{D-100} = 100 year design flow for open channel "b"

Example F- Continued

City #7 Cost Share: Total Project Cost − (City #6 Cost Share)

Sample Calculations

City #6 − Watershed area = 100 acres

Q_{D6-10} = .40 x 2"/hr x 100 = 80 cfs

Q_{A6-10} = .15 x 2"/hr x 100 = 30 cfs

Q_{E6-10} = 80−30 = 50 cfs

1. City #6 cost share for storm sewer "a" = $\frac{50 \text{ cfs}}{80 \text{ cfs}}$ x "a" Project Cost =

= 0.625 X "a" Project Cost.

2. City #6 cost share for open channel "b":

Q_{D6-100} = .40 x 4"/hr x 100 = 160 cfs

Q_{A6-100} = .15 x 4"/hr x 100 = 60 cfs

Q_{E6-100} = 160 − 60 = 100 cfs

Assume $Q_{D\text{-}100}$ for channel "b" = 200 cfs

City #6 cost share = $\frac{100 \text{ cfs}}{200 \text{ cfs}}$ x "b" Project Cost

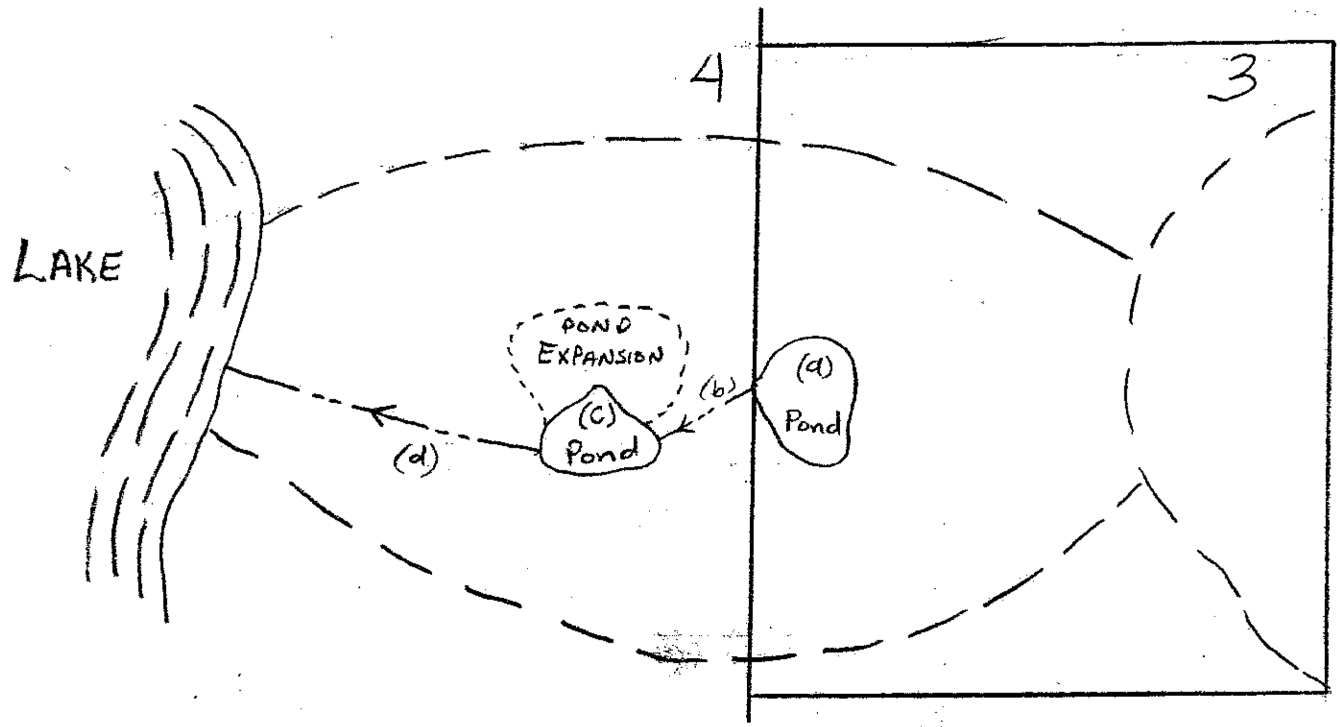
= 0.5 x "b" Project Cost

Summary of Costs:

Segment "a" (10 year design)
City #6 Cost Share = 0.625 X Project Cost for "a"
City #7 Cost Share = 0.375 X Project Cost for "a"

Segment "b" (100 year design)
City #6 Cost Share = 0.5 X Project Cost for "b"
City #7 Cost Share = 0.5 X Project Cost for "b"

EXAMPLE G



EXAMPLE G : ALLOWABLE VOLUME

Pond "c" is to be expanded from a 10 acre-foot (AF) storage capacity to a 50 AF storage capacity detention basin. The critical design storm for Pond "c" will be the 6-hour 100 year return frequency rainfall.

Background & Assumptions:

$Q_{D_b - 100}$ = Design flow (100 year) in segment b = 50 cfs

$Q_{A_3 - 100}$ = Allowable flow (100 year) from City #3 = 60 cfs
i.e. .15 x 4 in/hr x 100 acres = 60 cfs

$Q_{E_3 - 100}$ = Excess flow (100 year) from City #3

$= Q_{D_b - 100} - Q_{A_3 - 100} = 50 - 60 = -10$ cfs

conveyance system

There fore there is <u>no</u> excess flow from City #3, and City #3 does <u>not</u> participate financially in conveyance system improvements and maintenance in the downstream community, City #4.

City #3 may nevertheless be obligated to share in

EXAMPLE "G" continued

the Pond expansion costs, & maintenance costs of entire pond

Excess Volume Calculation

$$V_{E_3} = V_{D_3} - V_{A_3} - V_{P_3}$$

V_{E_3} = Excess volume, from City #3, for the Pond "c" critical design storm (i.e. 100 year-6 hour storm)

V_{D_3} = Design volume of runoff from City #3 for the Pond "c" critical design storm.

V_{A_3} = Allowable volume of runoff from City #3 for the Pond "c" critical design storm.

V_{P_3} = Volume of runoff stored in ponds in City #3 at the time of the peak volume stored in Pond "c" for the Pond "c" critical design storm.

Assume:

V_{D_3} = 75 AF

V_{A_3} = 35 AF

V_{P_3} = 10 AF. Say Pond "a" was designed to store 30 AF for its critical storm - a 1-hour 100 year storm. But, say the time of peak at Pond "c" is 6 hours later, so only 10 AF remains stored in Pond "a" at the time of peak in Pond "c".

$$V_{E_3} = 75\text{ AF} - 35\text{ AF} - 10\text{ AF} = 30\text{ AF}$$

Thus, although there is no excess flow (flowrate) from City #3, there is excess volume from City #3.

The allowable volume should be calculated using the same methodology as used to calculate the design volume, but the land use should be converted to 100% turf or pasture in good condition.

Example "C" continued

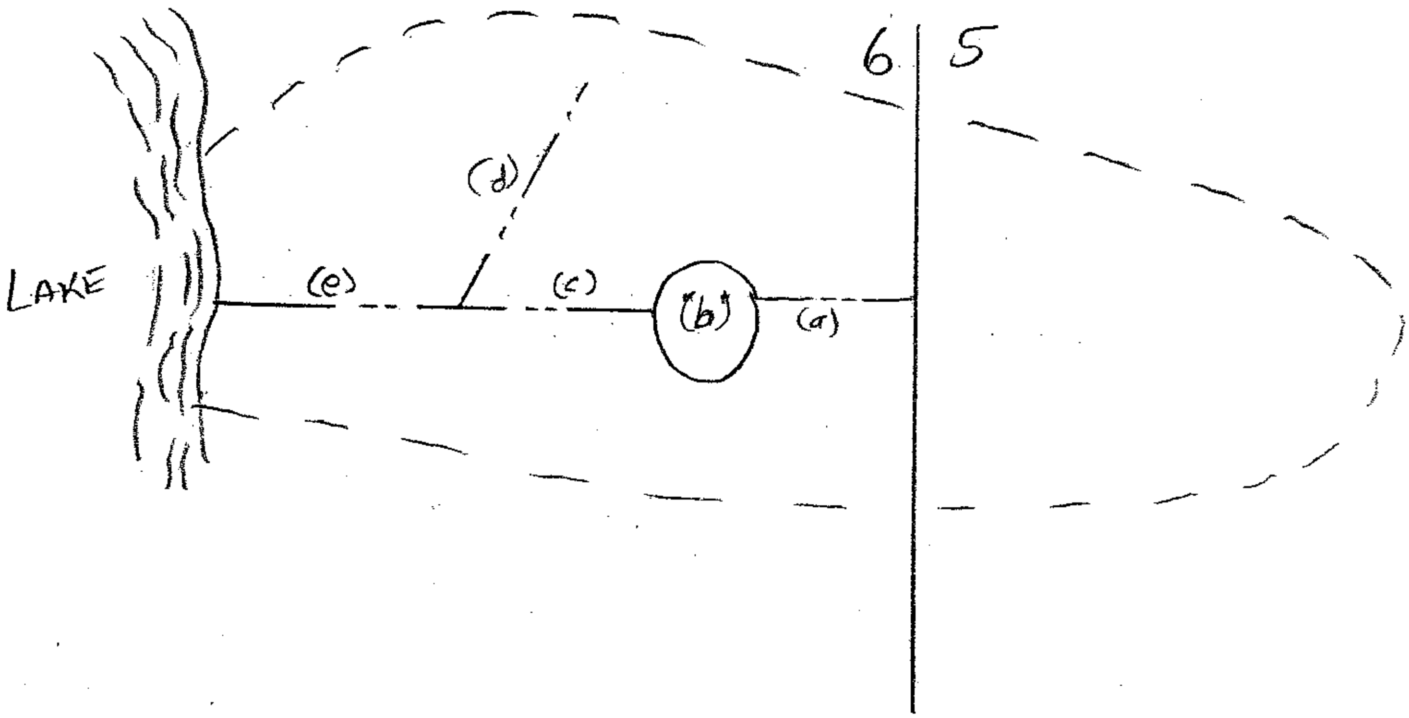
COST ALLOCATION

Cost share for Pond "C" expansion:

City #3 cost share: $\frac{V_{E_3}}{V_T}$ x Project Cost for Pond "C" expansion

where V_T = the design increase in storage volume of Pond "C" for the critical storm. Note – this does not include the former design volume of the pond. The former design volume of the pond (before expansion) should be computed as the volume of detention storage below the 'design level' for the former pond, for the Pond "C" expansion design storm at the time of peak for the Pond "C" expansion.

For instance, say former Pond "C" was designed for a 25-year storm, and held 10 AF. But in the 6-hour-100year design storm, the pond would overtop, cause flooding, and the storage at the pond and surrounding area would be 15 AF. Only the 10AF design volume is counted as the "former design volume" for V_T.



EXAMPLE H

Refer to Example E of the Joint Powers Agreement

Assume

Pond "b" reduces outflow to 10% of inflow.

i.e. $\frac{Q_T\text{(outlet) 100year}}{\Sigma Q_T\text{(inlet) 100year}} = 0.1$

$Q_{E_5\text{-}100}$ = 100-year excess flow from City #5 = 100cfs

$Q_{E_5\text{-}10}$ = 10-year excess flow from City #5 = 70cfs

Then, for segments "c" and "e":

c: 100 year design : $Q_{E_5\text{-}100} = 100 \times .1 = 10$ cfs

e: 10 year design : $Q_{E_5\text{-}10} = 70 \times .1 = 7$ cfs

Assume

$Q_{D_{100}}$ for segment c = 50 cfs

$Q_{D_{10}}$ for segment e = 70 cfs

EXAMPLE H continued

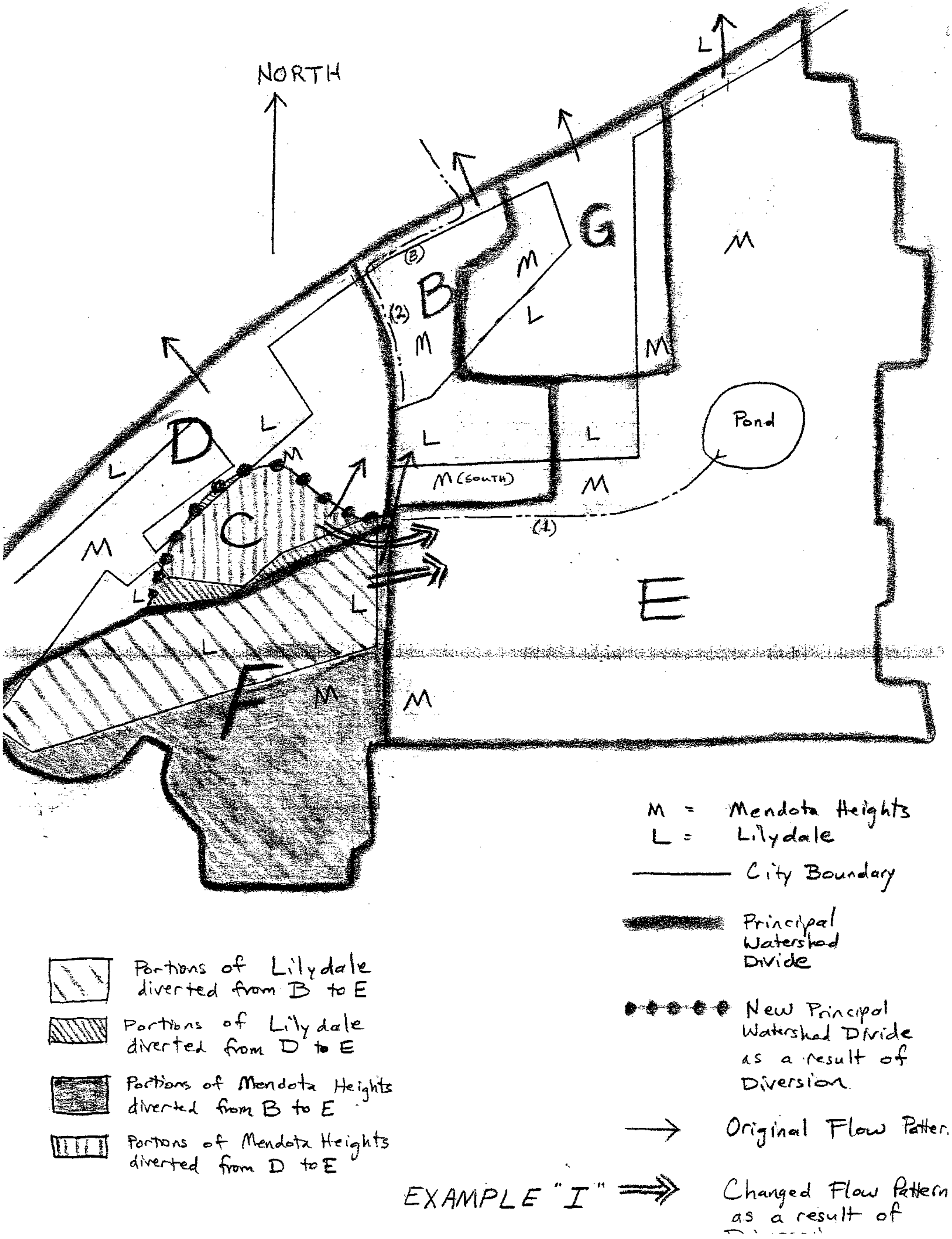
COST ALLOCATION

Segment "c", City #5 cost share = $\frac{10 cfs}{50 cfs}$ x Segment "c" Project Cost

= 0.20 X Segment "c" Project Cost

Segment "e", City #5 Cost Share = $\frac{7 cfs}{70 cfs}$ x Segment "e" Project Cost

= 0.10 X Segment "e" Project Cost


NORTH
B
G
D
C
E
F
M
L
M (SOUTH)
Pond
(1)
(2)
(3)
M = Mendota Heights
L = Lilydale
City Boundary
Principal Watershed Divide
New Principal Watershed Divide as a result of Diversion
Original Flow Pattern
Changed Flow Pattern as a result of
Portions of Lilydale diverted from B to E
Portions of Lilydale diverted from D to E
Portions of Mendota Heights diverted from B to E
Portions of Mendota Heights diverted from D to E

EXAMPLE "I"

EXAMPLE "I" continued

COST ALLOCATIONS, Segment "1" in Watershed E

Segment "1" serves Area C and Area F, which have been diverted into Area E. Because this is a diversion, there is no allowable flow attributable to any of Areas C or F diverted into Area E. The cost allocations for Segment "1" are in proportion to the flow contributions from the 2 communities from Areas C and F.

Q_{D_1} = design flow for segment "1" from Area C plus Area F.

$Q_{D_{1_L}}$ = design flow from Lilydale in Area C plus Area F.

$Q_{D_{1_M}}$ = design flow from Mendota Heights in Area C plus Area F.

$$\text{Lilydale Cost Share} = \frac{Q_{D_{1_L}}}{Q_{D_1}} \times \text{Project Cost for Segment "1"}$$

$$\text{Mendota Heights Cost Share} = \frac{Q_{D_{1_M}}}{Q_{D_1}} \times \text{Project Cost for Segment "1"}$$

COST ALLOCATIONS, Segment "2" in Watershed B

Area F (but not Area C) has been diverted out of Area B and into Area E. The allowable flow from Area F is still counted for cost allocation in Area B and the Watersheds downstream of Area B. In addition, portions of both Mendota Heights and Lilydale contribute to Segment "2". Segment "2" is considered to be constructed entirely in Mendota Heights.

Q_{D_2} = design flow for segment "2"

$Q_{D_{M_S}}$ = design flow from the portion of Mendota Heights labeled "M (south)" in Area B

Q_{A_L} = allowable flow for Lilydale for segment "2"

Q_{E_L} = excess flow for Lilydale for segment "2"

EXAMPLE "I" continued

$$Q_{E_L} = Q_{D_2} - Q_{D_{M_S}} - Q_{A_L}$$

$$Q_{A_L} = Q_{A_{F_L}} + Q_{A_{B_L}}$$

$Q_{A_{F_L}}$ = allowable flow for that portion of Area F which is Lilydale.

$Q_{A_{B_L}}$ = allowable flow for that portion of Area B which is Lilydale

Assume: Q_{D_2} = 20 cfs

$Q_{D_{M_S}}$ = 6 cfs

$Q_{A_{F_L}}$ = 12 cfs

$Q_{A_{B_L}}$ = 6 cfs

$$Q_{E_L} = 20\text{cfs} - 6\text{cfs} - (12\text{cfs} + 6\text{cfs}) = -4\text{ cfs}$$

Thus Lilydale has no excess flow in Segment "2".

Lilydale Cost Share = Zero Dollar.

Mendota Heights Cost Share = 100% of Project Cost for Segment "2".

(note - these are assumed values. The analysis of the actual case may lead to other conclusions.)

COST ALLOCATION, Segment "3" in Watershed B (and immediately downstream of Watershed B).

This case is similar to the cost allocation for Segment "2", except that Mendota Heights has an allowable flow, since segment "3" is constructed in Lilydale.

Q_{D_3} = design flow for segment "3".

Q_{D_L} = design flow for the portion of Lilydale in Area B.

Q_{A_M} = allowable flow for Mendota Heights for segment "3".

Q_{E_M} = excess flow for Mendota Heights for segment "3".

EXAMPLE "I" continued

$$Q_{E_m} = Q_{D_3} - Q_{D_L} - Q_{A_m}$$

$$Q_{A_m} = Q_{A_{F_m}} + Q_{A_{B_m}}$$

$Q_{A_{F_m}}$ = allowable flow for that portion of Area F which is Mendota Heights

$Q_{A_{B_m}}$ = allowable flow for that portion of Area B which is Mendota Heights

Assume:

Q_{D_3} = 40 cfs

Q_{D_L} = 14 cfs

$Q_{A_{F_m}}$ = 15 cfs

$Q_{A_{B_m}}$ = 10 cfs

Then:

$$Q_{A_m} = 15\text{cfs} + 10\text{cfs} = 25\text{cfs}$$

$$Q_{E_m} = 40\text{cfs} - 14\text{cfs} - 25\text{cfs} = 1\text{cfs}$$

Lilydale Cost Share = $\dfrac{Q_{D_3} - Q_{E_m}}{Q_{D_3}}$ x Project Cost for Segment "3"

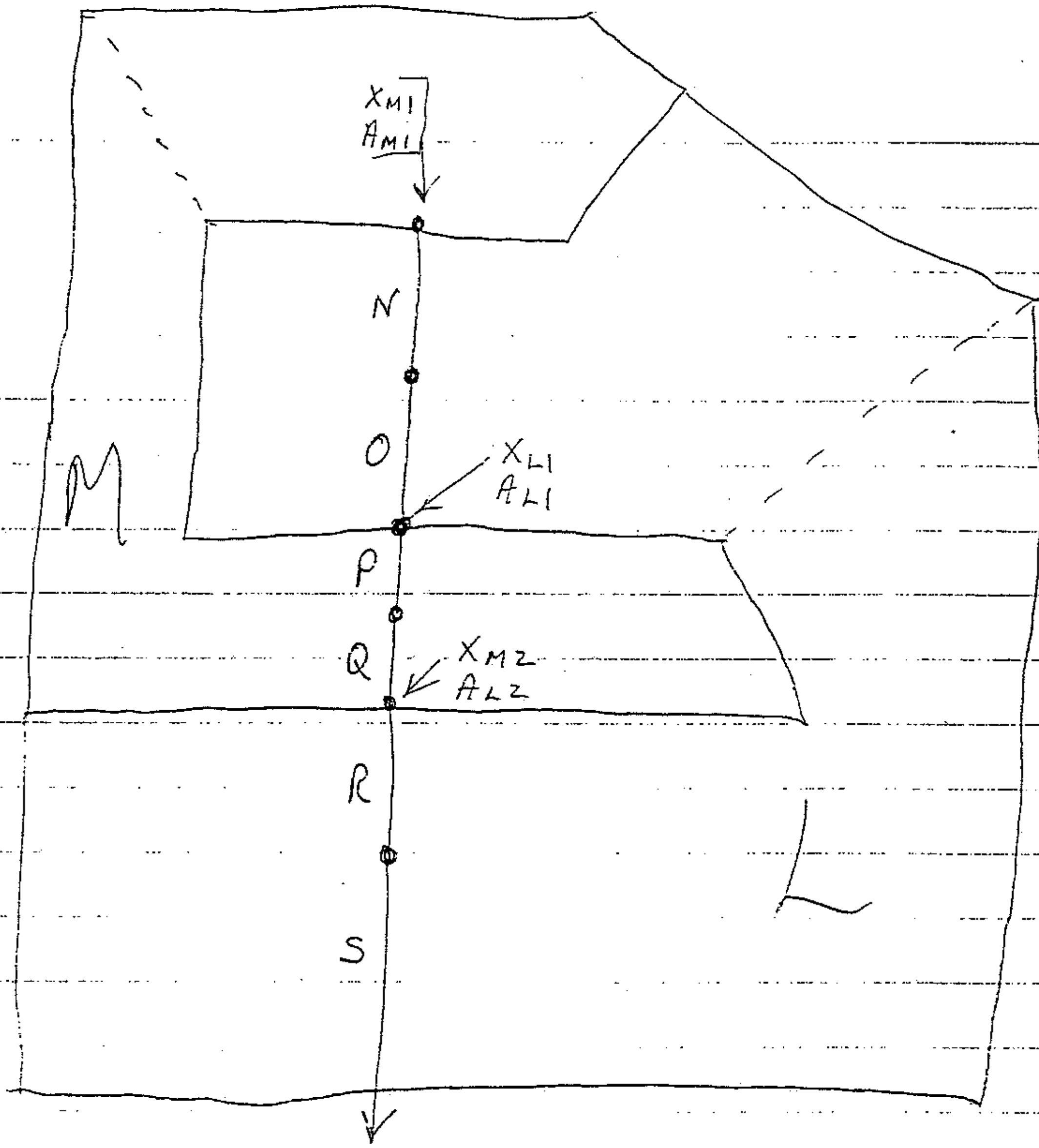
= $\dfrac{40-1}{40}$ x Cost = $\dfrac{39}{40}$ x Project Cost, Seg. "3"

Mendota Heights Cost Share = $\dfrac{Q_{E_m}}{Q_{D_3}}$ x Project Cost for Segment "3"

= $\dfrac{1}{40}$ x Project Cost for Segment "3".

(note - these are assumed values. The analysis of the actual case may lead to other conclusions)

M = COMMUNITY M
L = COMMUNITY L
X = EXCESS FLOW
A = ALLOWABLE FLOW
C = COST
D = DESIGN FLOW



COST SHARES

SECTION N $\quad M_N = C_N\left(\frac{X_{M1}}{D_N}\right) \qquad L_N = C_N\left(\frac{A_{M1}}{D_N}\right)$

SECTION O $\quad M_O = C_O\left(\frac{X_{M1}}{D_O}\right) \qquad L_O = C_O\left(\frac{A_{M1}}{D_O}\right)$

SECTION P $\quad M_P = C_P\left(\frac{D_P - X_{L1}}{D_P}\right) \qquad L_P = C_P\left(\frac{X_{L1}}{D_P}\right)$

SECTION Q $\quad M_Q = C_Q\left(\frac{D_Q - X_{L1}}{D_Q}\right) \qquad L_Q = C_Q\left(\frac{X_{L1}}{D_Q}\right)$

SECTION R $\quad M_R = C_R\left(\frac{X_{M1} + X_{M2}}{D_R}\right) \qquad L_R = C_R\left(\frac{D_R - X_{M1} - X_{M2}}{D_R}\right)$

SECTION S $\quad M_S = C_S\left(\frac{X_{M1} + X_{M2}}{D_S}\right) \qquad L_S = C_S\left(\frac{D_S - X_{M1} - X_{M2}}{D_S}\right)$

MEMORANDUM

TO: Lower Mississippi River Watershed Management Organization

FROM: James R. Langseth

DATE: June 12, 1992

RE: Allowable Flow, Summary of Understanding Based on the Discussions at the Meetings Held December 13, 1991 and May 15, 1992

These meetings addressed four topics.

1. Allowable flow for conveyance systems designed for 100-year frequency storms.

2. Allowable volume.

3. Cost apportionment downstream of ponds (detention basins).

4. Cost allocation principles for diversions where more than one city contributes flow.

These interpretations use the definitions for watershed, land use, and drainage system set forth in the March 9, 1988 Allowable Flow memorandum. The current memorandum provides an interpretation of the allowable flow for cases where the design is not based on a 10-year storm, as well as amplifying the principles to be used for diversion of drainage.

1. Allowable Flow for 100-Year Frequency Storm Design Conveyance Systems

The Joint Powers Agreement, Section 3, Subd. 3, states that the allowable flow is a rate an volume of flow according to the design criteria in Section 8, Subd. 6. Section 8, Subd. 6 provides that detention basins and open channel conveyance systems be designed for a 100-year return frequency storm.

Consistent with these provisions, for drainage systems for which the design criteria are 100-year return frequency precipitation events, the allowable flow shall be computed as a 100-year rate and volume flow.

The allowable rate of flow shall be computed by Q = CIA
where:

Q is the allowable flow rate in cubic feet per second.

C is the runoff coefficient, defined to be 0.15.

I is the 100-year return frequency rainfall intensity appropriate to the watershed time of concentrations, in inches per hour.

A is the watershed area in acres.

Excess flow is the 100-year design flow less the 100-year allowable flow.

This approach shall be applied for conveyance systems where the design is governed by 100-year return frequency events. This includes detention basin outlets, conveyance systems downstream of detention basins, open channels, and other conveyance that is designed for 100-year return frequency events. Similar logic would apply to any system for which the design criteria was neither 10-year or 100-year. See Example F for an illustration of a 100-year excess flow calculation.

2. Allowable Volume

The allowable volume is the total runoff volume from the design storm, for a watershed with the land use defined in the March 9, 1988 memorandum. Where the ponding in the upstream community is negligible, the allowable volume may be estimated as being in the same proportion to the design volume as the allowable flow is to the design flow.

In general, the allowable volume may be computed with the same techniques used to determine the design volume, provided the technique also accurately calculates the allowable discharge rate.

The excess volume is the difference between design and allowable volume.

Where there is upstream ponding, the volume of those ponds is deducted from the excess volume to the extent the upstream detention reduces the volume needed in downstream ponds. Thus, only the storage in upstream detention basins at the time of peak of the downstream detention basin may be used to reduce the excess volume from the upstream community. For instance, assume the peak elevation at a downstream community pond occurs at 6 hours. Assume the upstream community pond stores 10 acre-feet at its peak at 3 hours, but only 5 acre-feet at 6 hours. The "excess volume" from the upstream community would be reduced by 5 acre-feet to account for the storage. See Example G for an illustration of this case.

3. Cost Apportionment Downstream of Ponds

In the Joint Power Agreement, Exhibit A, page 9 of 9, the formula for adjustment of excess flow as a result of ponding is presented:

$$Q_{excess}(\text{outlet}) = Q_{excess}(\text{inlet}) \times \frac{Q_{total}(\text{outlet})}{\Sigma\, Q_{total}(\text{inlet})}$$

The proportioning $Q_{total}(\text{outlet})/\Sigma\, Q_{total}(\text{inlet})$ shall be computed on the same return frequency event used for the pond design. If the pond is designed for a 100-year event, the adjustment in excess flow through the pond shall be based on the 100-year outflow and inflow values. Thus, if a 10-year design governs cost sharing for construction downstream of a pond, the 10-year excess flow would be reduced as follows:

$$Q_{excess}\ 10\text{-year(outlet)} = Q_{excess}\ 10\text{-year(inlet)} \times \frac{Q_{total}\ 100\text{-year(outlet)}}{\Sigma\ Q_{total}\ 100\text{-year(inlet)}}$$

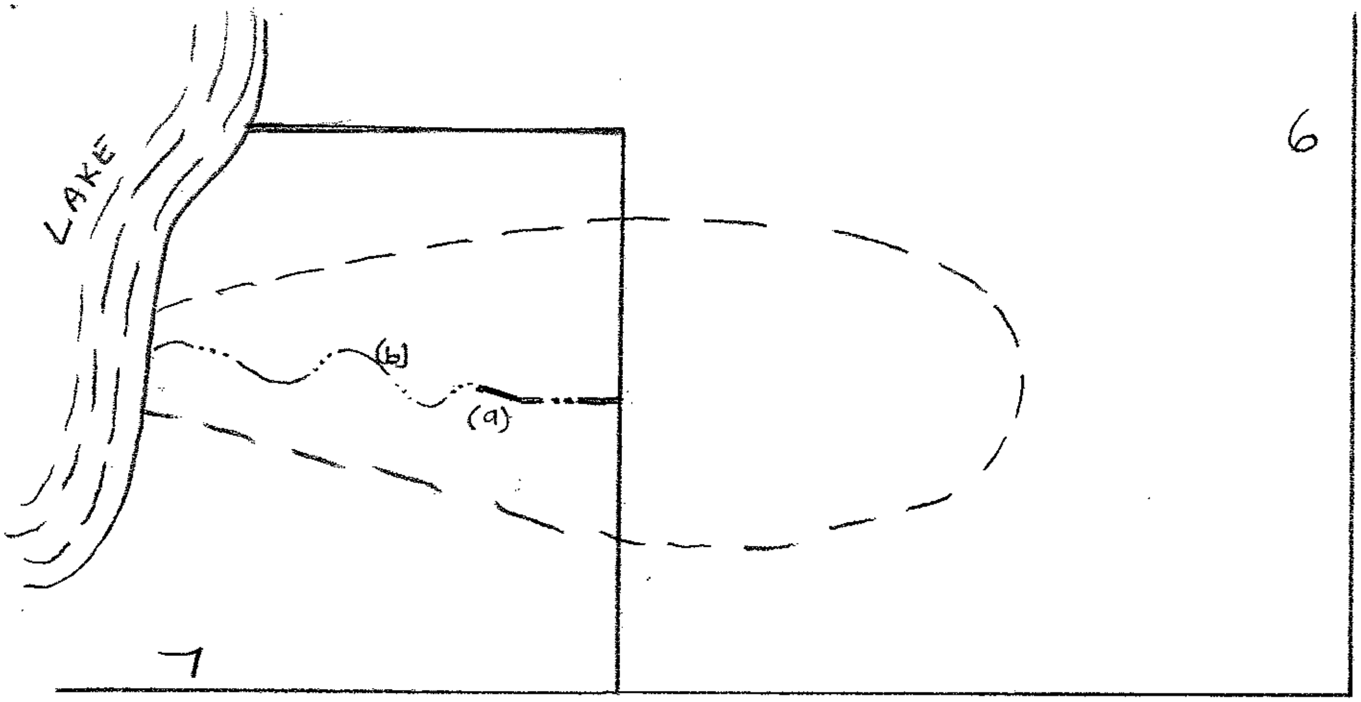
See Example H for an illustration of this case.

4. Cost Allocation Principles for Diversion Where More Than One City Contributes Flow

For diversion of water out of its current watershed, into a watershed to which it did not previously flow, there is no allowable flow associated with the diverted water. Consequently, the excess flow from the diverted area equals the design flow. If more than one city contributes water to the diversion, the excess flow from each community is their portion of the design flow from the diverted area. Thus, the cost allocation proportion for each city is their proportion of the design flow.

The "diversion in" is associated with an equal area of "diversion out" of another watershed. The cities retain their allowable flow in the watershed from which the area was "diverted out." This is illustrated for "diversion out" by one city on Page 6 of 9 of Exhibit A to the Joint Powers Agreement.

This principal was applied to the Lexington Avenue drainage case with Lilydale and Mendota Heights. The situation is illustrated conceptually in Example I.



Example F - Other than 10-year Design

Project: Construct storm sewer "a" and open channel "b" in City #7 to provide drainage for Cities #6 and #7 under fully developed conditions.

Cost Allocation:

City #6 Cost Share: $\frac{Q_{E6-10}}{Q_{D-10}}$ X Total Project Cost for "a"

$\frac{Q_{E6-100}}{Q_{D-100}}$ x Total Project Cost for "b"

Q_{E6-10} = 10 year excess flow from City #6 = $Q_{D6-10} - Q_{A6-10}$

Q_{D6-10} = 10 year design flow from City #6

Q_{A6-10} = 10 year allowable flow from City #6

Q_{D-10} = 10 year design flow for storm sewer "a"

Q_{E6-100} = 100 year excess flow from City #6 = $Q_{D6-100} - Q_{A6-100}$

Q_{D6-100} = 100 year design flow from City #6

Q_{A6-100} = 100 year allowable flow from City #6

Q_{D-100} = 100 year design flow for open channel "b"

Example F- Continued

City #7 Cost Share: Total Project Cost − (City #6 Cost Share)

Sample Calculations

City #6 − Watershed area = 100 acres

q_{D6-10} = .40 × 2"/hr × 100 = 80 cfs

q_{A6-10} = .15 × 2"/hr × 100 = 30 cfs

Q_{E_6-10} = 80−30 = 50 cfs

1. City #6 cost share for storm sewer "a" = $\frac{50\text{ cfs}}{80\text{ cfs}}$ × "a" Project Cost =

= 0.625 × "a" Project Cost.

2. City #6 cost share for open channel "b":

Q_{D6-100} = .40 × 4"/hr × 100 = 160 cfs

q_{A6-100} = .15 × 4"/hr × 100 = 60 cfs

q_{E_6-100} = 160 − 60 = 100 cfs

Assume $Q_{D\text{-}100}$ for channel "b" = 200 cfs

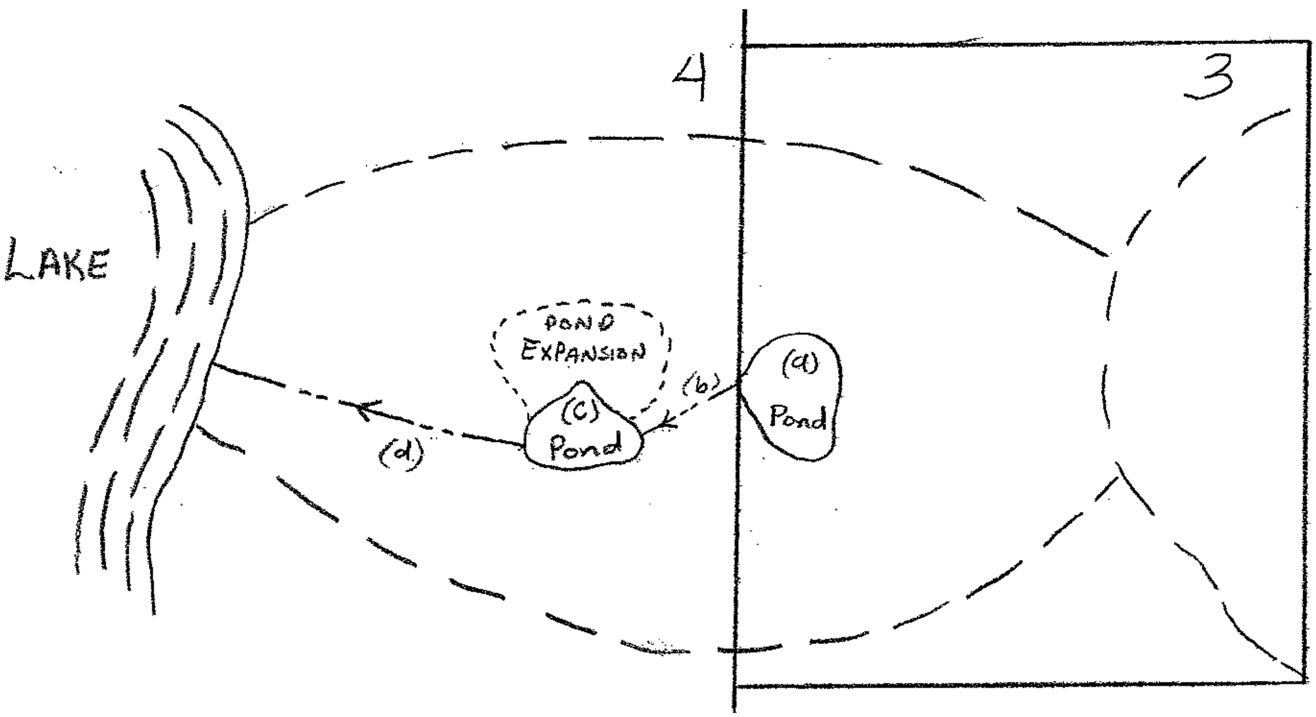
City #6 cost share = $\frac{100\text{ cfs}}{200\text{ cfs}}$ × "b" Project Cost

= 0.5 × "b" Project Cost

Summary of Costs:

Segment "a" (10 year design)	City #6 Cost Share = 0.625 × Project Cost for "a" City #7 Cost Share = 0.375 × Project Cost for "a"
Segment "b" (100 year design)	City #6 Cost Share = 0.5 × Project Cost for "b" City #7 Cost Share = 0.5 × Project Cost for 'b"

EXAMPLE G



EXAMPLE G : ALLOWABLE VOLUME

Pond "c" is to be expanded from a 10 acre-foot (AF) storage capacity to a 50 AF storage capacity detention basin. The critical design storm for Pond "c" will be the 6-hour 100 year return frequency rainfall.

Background & Assumptions:

Q_{D_b}-100 = Design flow (100 year) in segment b = 50 cfs

Q_{A_3}-100 = Allowable flow (100 year) from City #3 = 60 cfs
i.e. .15 x 4 in/hr x 100 acres = 60 cfs

Q_{E_3}-100 = Excess flow (100 year) from City #3
= $Q_{D_6-100} - Q_{A_3-100}$ = 50 - 60 = -10 cfs

There fore there is no excess flow from City #3, and City #3 does not participate financially in conveyance system improvements or conveyance system maintenance in the downstream community, City #4. City #3 may nevertheless be obligated to share in the Pond expansion costs and maintenance costs of the pond expansion (not of the whole pond).

Excess Volume Calculation

$$V_{E_3} = V_{D_3} - V_{A_3} - V_{P_3}$$

V_{E_3} = Excess volume, from City #3, for the Pond "c" critical design storm (i.e. 100 year - 6 hour storm)

V_{D_3} = Design volume of runoff from City #3 for the Pond "c" critical design storm.

V_{A_3} = Allowable volume of runoff from City #3 for the Pond "c" critical design storm.

V_{P_3} = Volume of runoff stored in ponds in City #3 at the time of the peak volume stored in Pond "c" for the Pond "c" critical design storm.

Assume:

V_{D_3} = 75 AF

V_{A_3} = 35 AF

V_{P_3} = 10 AF. Say Pond "a" was designed to store 30 AF for its critical storm - a 1-hour 100 year storm. But, say the time of peak at Pond "c" is 6 hours later, so only 10 AF remains stored in Pond "a" at the time of peak in Pond "c".

$$V_{E_3} = 75\text{ AF} - 35\text{ AF} - 10\text{ AF} = 30\text{ AF}$$

Thus, although there is no excess flow (flowrate) from City #3, there is excess volume from City #3.

The allowable volume should be calculated using the same methodology as used to calculate the design volume, but the land use should be converted to 100% turf or pasture in good condition.

Example "C" continued

COST ALLOCATION

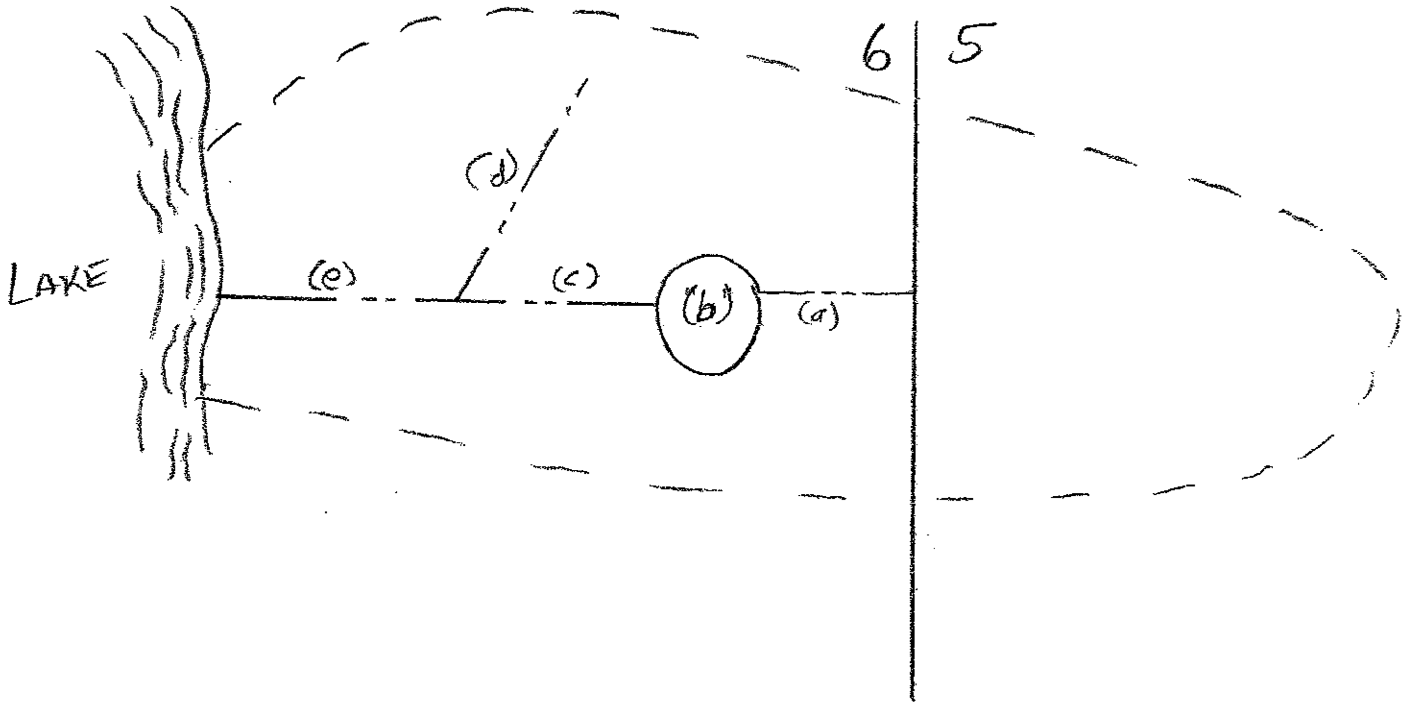
Cost share for Pond "C" expansion.

City #3 cost share: $\frac{V_{E_3}}{V_T}$ x Project Cost for Pond "C" expansion

where V_T = the design increase in storage volume of Pond "C" for the critical storm. Note— this does not include the former design volume of the pond. The former design volume of the pond (before expansion) should be computed as the volume of detention storage below the 'design level' for the former pond, for the Pond "C" expansion design storm at the time of peak for the Pond "C" expansion.

For instance, say former Pond "C" was designed for a 25-year storm, and held 10 AF. But in the 6-hour-100year design storm, the pond would overtop, cause flooding, and the storage at the pond and surrounding area would be 15 AF. Only the 10AF design volume is counted as the "former design volume" for V_T.

Note that for maintenance costs, the City #3 share applies only to the pond expansion, not to maintenance of the whole pond.



EXAMPLE H

Refer to Example E of the Joint Powers Agreement

Assume

Pond "b" reduces outflow to 10% of inflow,

i.e. $\frac{Q_T\text{(outlet) 100year}}{\Sigma Q_T\text{(inlet) 100year}} = 0.1$

$Q_{E_5 \cdot 100}$ = 100-year excess flow from City #5 = 100cfs

$Q_{E_5 - 10}$ = 10-year excess flow from City #5 = 70cfs

Then, for segments "c" and "e":

c: 100 year design : $Q_{E_5-100} = 100 \times .1 = 10$ cfs

e: 10 year design : $Q_{E_5-10} = 70 \times .1 = 7$ cfs

Assume

$Q_{D_{100}}$ for segment c = 50 cfs

$Q_{D_{10}}$ for segment e = 70 cfs

EXAMPLE H continued

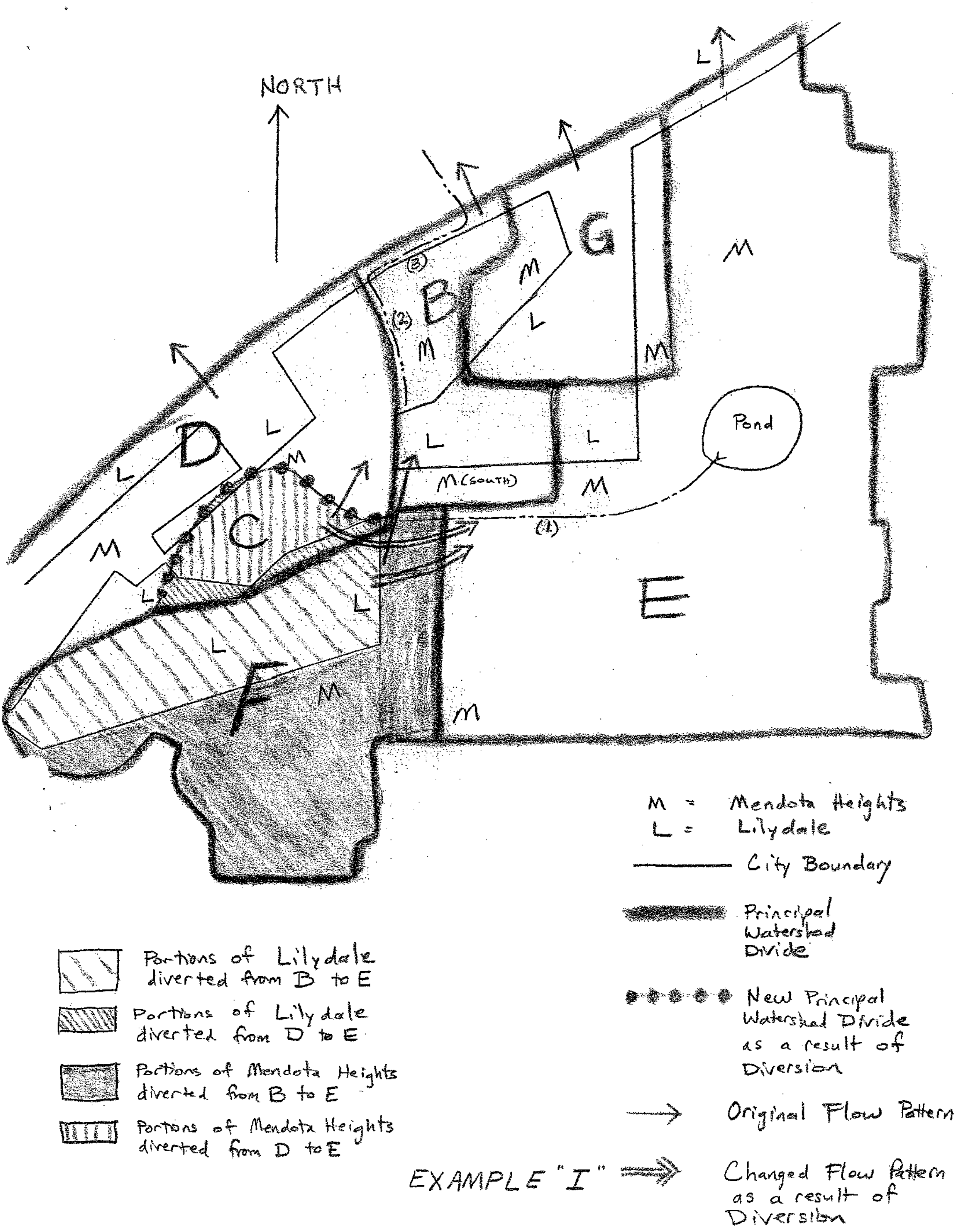
COST ALLOCATION

Segment "c", City #5 cost share = $\frac{10\,cfs}{50\,cfs}$ x Segment "c" Project Cost

= 0.20 X Segment "c" Project Cost

Segment "e", City #5 Cost Share = $\frac{7\,cfs}{70\,cfs}$ x Segment "e" Project Cost

= 0.10 X Segment "e" Project Cost


NORTH
L
G
M
B
M
L
M
M
D
L
L
M
L
Pond
M (SOUTH)
M
C
M
(1)
(2)
(3)
L
L
L
E
F
M
M
M = Mendota Heights
L = Lilydale
City Boundary
Principal Watershed Divide
New Principal Watershed Divide as a result of Diversion
Original Flow Pattern
Changed Flow Pattern as a result of Diversion
Portions of Lilydale diverted from B to E
Portions of Lilydale diverted from D to E
Portions of Mendota Heights diverted from B to E
Portions of Mendota Heights diverted from D to E

EXAMPLE "I"

EXAMPLE "I" continued

COST ALLOCATIONS, Segment '(1)' in Watershed E

Segment '(1)' serves Area C and Area F, which have been diverted into Area E. Because this is a diversion, there is no allowable flow attributable to any of Areas C or F diverted into Area E. The cost allocations for Segment '(1)' are in proportion to the flow contributions from the 2 communities from Areas C and F.

Q_{D_1} = design flow for segment '(1)' from Area C plus Area F.

$Q_{D_{1_L}}$ = design flow from Lilydale in Area C plus Area F.

$Q_{D_{1_M}}$ = design flow from Mendota Heights in Area C plus Area F.

$$\text{Lilydale Cost Share} = \frac{Q_{D_{1_L}}}{Q_{D_1}} \times \text{Project Cost for Segment '(1)'}$$

$$\text{Mendota Heights Cost Share} = \frac{Q_{D_{1_M}}}{Q_{D_1}} \times \text{Project Cost for Segment '(1)'}$$

COST ALLOCATIONS, Segment '(2)' in Watershed B

Area F (but not Area C) has been diverted out of Area B and into Area E. The allowable flow from Area F is still counted for cost allocation in Area B and the Watersheds downstream of Area B. In addition, portions of both Mendota Heights and Lilydale contribute to Segment '(2)'. Segment '(2)' is considered to be constructed entirely in Mendota Heights.

Q_{D_2} = design flow for segment "2"

$Q_{D_{M_S}}$ = design flow from the portion of Mendota Heights labeled "M (south)" in Area B

Q_{A_L} = allowable flow for Lilydale for segment "2"

Q_{E_L} = excess flow for Lilydale for segment "2"

EXAMPLE "I" continued

$$Q_{E_L} = Q_{D_2} - Q_{D_{MS}} - Q_{A_L}$$

$$Q_{A_L} = Q_{A_{F_L}} + Q_{A_{B_L}}$$

$Q_{A_{F_L}}$ = allowable flow for that portion of Area F which is Lilydale.

$Q_{A_{B_L}}$ = allowable flow for that portion of Area B which is Lilydale

Assume: Q_{D_2} = 20 cfs

$Q_{D_{MS}}$ = 6 cfs

$Q_{A_{F_L}}$ = 12 cfs

$Q_{A_{B_L}}$ = 6 cfs

$$Q_{E_L} = 20\text{cfs} - 6\text{cfs} - (12\text{cfs} + 6\text{cfs}) = -4\text{ cfs}$$

Thus Lilydale has no excess flow in Segment "(2)".

Lilydale Cost Share = Zero Dollar.

Mendota Heights Cost Share = 100% of Project Cost for Segment "(2)".

(note - these are assumed values. The analysis of the actual case may lead to other conclusions.)

COST ALLOCATION, Segment "(3)" in Watershed B (and immediately downstream of Watershed B).

This case is similar to the cost allocation for Segment "(2)"; except that Mendota Heights has an allowable flow, since segment "(3)" is constructed in Lilydale.

Q_{D_3} = design flow for segment "(3)".

Q_{D_L} = design flow for the portion of Lilydale in Area B.

Q_{A_M} = allowable flow for Mendota Heights for segment "(3)".

Q_{E_M} = excess flow for Mendota Heights for segment "(3)".

EXAMPLE "I" continued

$$Q_{E_m} = Q_{D_3} - Q_{D_L} - Q_{A_m}$$

$$Q_{A_m} = Q_{A_{F_m}} + Q_{A_{B_m}}$$

$Q_{A_{F_m}}$ = allowable flow for that portion of Area F which is Mendota Heights

$Q_{A_{B_m}}$ = allowable flow for that portion of Area B which is Mendota Heights

Assume:
Q_{D_3} = 40 cfs
Q_{D_L} = 14 cfs
$Q_{A_{F_m}}$ = 15 cfs
$Q_{A_{B_m}}$ = 10 cfs

Then:
Q_{A_m} = 15 cfs + 10 cfs = 25 cfs

Q_{E_m} = 40 cfs − 14 cfs − 25 cfs = 1 cfs

Lilydale Cost Share = $\frac{Q_{D_3} - Q_{E_m}}{Q_{D_3}}$ x Project Cost for Segment "(3)"

= $\frac{40-1}{40}$ x Cost = $\frac{39}{40}$ x Project Cost, Seg. "(3)"

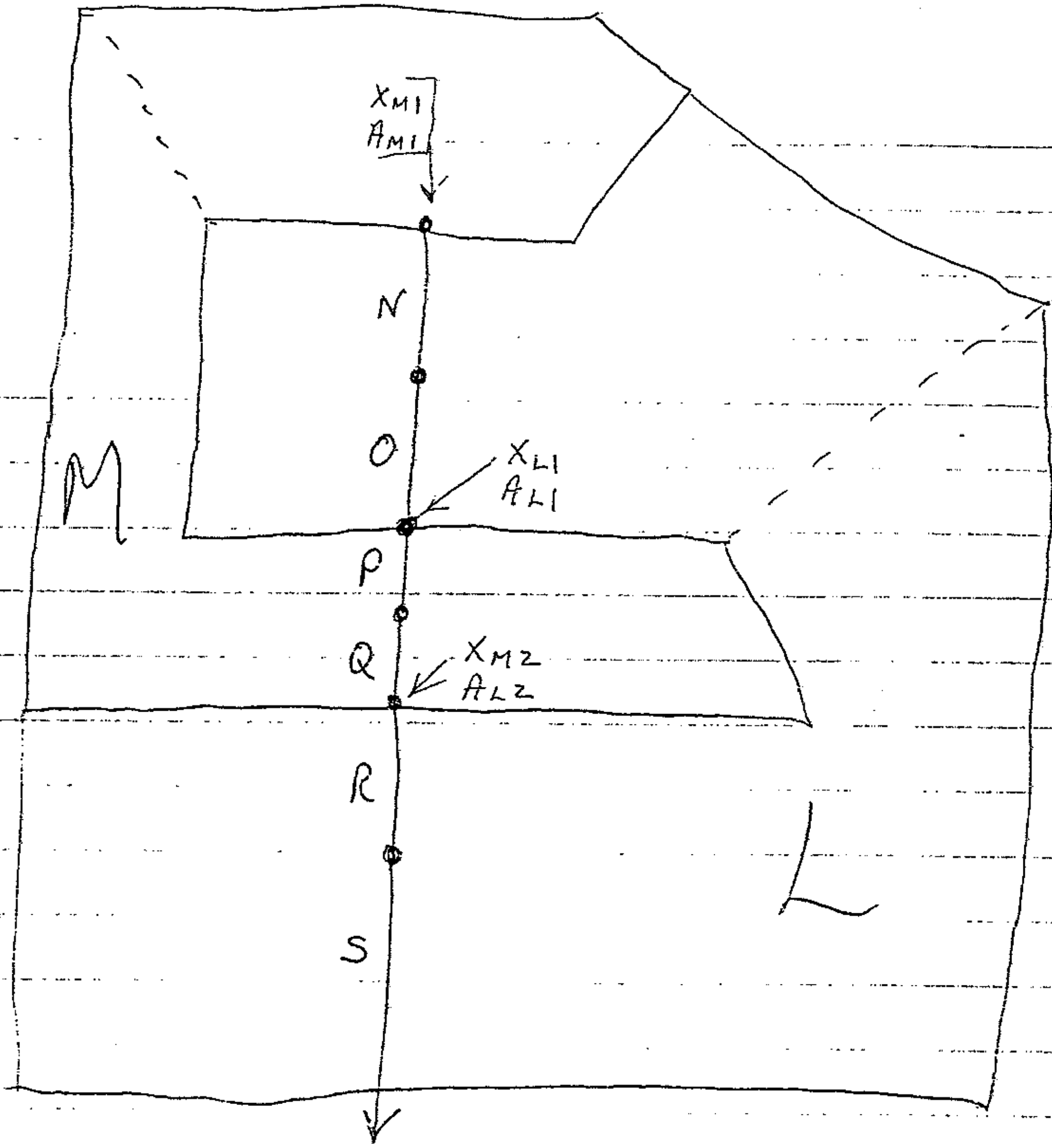
Mendota Heights Cost Share = $\frac{Q_{E_m}}{Q_{D_3}}$ x Project Cost for Segment "(3)"

= $\frac{1}{40}$ x Project Cost for Segment "(3)".

(note - these are assumed values. The analysis of the actual case may lead to other conclusions)

The attached sheet, Appendix A, presents cost allocation for the case of no diversion, but flow re-entering communities after it has once left them.

M = COMMUNITY M
L = COMMUNITY L
X = EXCESS FLOW
A = ALLOWABLE FLOW
C = COST
D = DESIGN FLOW



COST SHARES

SECTION N $\quad M_N = C_N\left(\frac{X_{M1}}{D_N}\right) \qquad L_N = C_N\left(\frac{A_{M1}}{D_N}\right)$

SECTION O $\quad M_O = C_O\left(\frac{X_{M1}}{D_O}\right) \qquad L_O = C_O\left(\frac{A_{M1}}{D_O}\right)$

SECTION P $\quad M_P = C_P\left(\frac{D_P - X_{L1}}{D_P}\right) \qquad L_P = C_P\left(\frac{X_{L1}}{D_P}\right)$

SECTION Q $\quad M_Q = C_Q\left(\frac{D_Q - X_{L1}}{D_Q}\right) \qquad L_Q = C_Q\left(\frac{X_{L1}}{D_Q}\right)$

SECTION R $\quad M_R = C_R\left(\frac{X_{M1} + X_{M2}}{D_R}\right) \qquad L_R = C_R\left(\frac{D_R - X_{M1} - X_{M2}}{D_R}\right)$

SECTION S $\quad M_S = C_S\left(\frac{X_{M1} + X_{M2}}{D_S}\right) \qquad L_S = C_S\left(\frac{D_S - X_{M1} - X_{M2}}{D_S}\right)$