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Centennial Brook Phase II Documentation and QA/QC Notes
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Introduction:

The following is a documentation of the key geomorphic processes and adjustments occurring in the Centennial Brook watershed at the reach scale. The intent of this documentation is twofold: 1) concisely summarize Centennial Brook watershed zones and geomorphic processes; 2) highlight for those using the data the key steps containing important or extraordinary information. When used in conjunction with the Phase I and II data in the DMS, and the SGA Watershed Maps, this documentation also provides explanation for questions that may arise concerning discrepancies in the data. At the end of each reach summary is a discussion of potential projects that could protect, sustain, or restore fluvial geomorphic equilibrium conditions, through the implementation of either passive or active stream corridor management strategies. Following the discussion text is Appendix 1, which summarizes QA/QC notes and other relevant information for the Phase I and II databases. Cross-sectional plots are included in Appendix 2. Reach summary statistics and maps are found respectively in Appendices 3 and 4.

Centennial Brook Summary:

The Centennial Brook watershed is greatly affected by both beaver activity in the low-gradient reaches and urban runoff in the higher-gradient reaches. These two stressors can have a confounding effect in the determination of predominant fluvial processes in many reaches in the watershed. However, in the high-gradient reaches the effect of urban runoff is clearly observed. Care has been taken to document the difference between these two stressors when they can be clearly teased apart in the lower-gradient reaches. In addition to these current day stressors, historic impacts from floodplain encroachment around the urban centers makes assessment of the current stage of channel evolution difficult in some reaches of the watershed. Specific zones of the watershed and the dominant fluvial processes observed within each are discussed below.

Reach M01

The last reach of Centennial Brook, M01, contains unique, high-gradient channel features not found elsewhere in the watershed. Before emptying in the Winooski River approximately 1300 feet below Grove Street, the brook drops into a confined valley setting that has become more confined due to historic and current encroachment and berming. Degradation is clearly the dominant process occurring in this final section of the watershed, as severe incision and widening is observed throughout. Further discussion of this reach is found in the “STD” section as well as the “project” section at the end of this document.

Reaches M02 & M03

Throughout the Centennial Woods Natural Area, reaches M02 and M03 have very good riparian buffer and corridor conditions, allowing for extensive floodplain access for these low-gradient reaches with E-type channels. In addition, this low-gradient zone of the watershed experiences intermittent beaver activity from Grove Street up the main stem to Interstate 89. This area of beaver activity resulted in low RGA and RHA scores. Beaver ponds may actually be providing some mitigation of upstream stormflows from urban runoff. Although the effect of urban runoff in this zone of the watershed is difficult to assess, the channel incision observed in areas where there are no active beaver ponds suggests that the current flow regime may be causing degradation in areas where fine sediment had accumulated from past beaver ponding. Throughout much of reach M03, the older, undisturbed hemlock forest has many dying trees which fall directly into the stream channel. This causes many debris jams and channel widening which also makes the assessment of upstream urban impacts difficult.

Reaches M04 & M05

Above Centennial Woods and Interstate 89, the channel remains low gradient with influence from beaver ponding throughout, although not as extensive as in reaches M02 and M03. The channel chosen as the main stem for assessment is that which stems from the east, originating at the airport. However, the other tributary (T2) stemming from the southeast which originates in the Williston Road area appears to be more impacted by urban runoff from the southern section of the watershed. Although this tributary was not assessed, it may actually carry greater streamflows during stormwater runoff events, as observed by the larger channel when compared to the main stem at the confluence below Interstate 89. Unlike the Centennial Woods area, protection of the river corridor is not as permanent or extensive throughout this zone of the watershed (reaches M04 & M05). Steep valley walls and wide floodplains with abundant wetlands makes development in the corridor unlikely, but in the upland areas urban land cover dominates the watershed. Protection of this section of the stream corridor is discussed in greater detail in “projects" section. One notable channel feature found in M04 is a natural channel avulsion found in the area adjacent to the old limestone quarry (where Quarry Ridge Condominiums are located). Above and below this avulsion, the channel is a low gradient E-type channel. However, it appears that an old beaver dam forced the channel from its original location where it once cascaded down a limestone bedrock terrace through a high-gradient channel. The current location of the stream is through an underground channel which loses approximately 40 feet of elevation over a distance of about 150 feet. The current channel re-enters the abandoned channel at the valley toe just upstream from the discharge of the Quarry Ridge Condominium stormwater pond.

Tributary Reaches

The only tributary assessed during summer 2005 was T1, the tributary which confluences with the main stem at the M02/M03 reach break. This tributary begins to the south of Centennial Woods and receives large amounts of stormwater runoff from the Staples plaza to the south and from the UVM/Fletcher Allen campus to the west. With the exception of the buffering provided by immediate natural stream corridor around this tributary, the watershed is almost completely urbanized. This has resulted in a channel which has incised and widened, much of which is in stage III of channel evolution. The upper segment (A) of this reach is higher-gradient channel with extensive bank erosion and a significant mass failure immediately below the outlet of the stormwater pond to the south. This recently installed stormwater pond may mitigate impacts of urban runoff into the future, but adjustments in this reach will likely continue for years to come. In segment B, a change in channel bedform has been noted from riffle-pool to plane bed. Significant widening and aggradation from eroded material originating from upstream segment B has eliminated much of the pool habitat in this gravel-bottomed segment. One additional stormwater pond which collects runoff from Centennial Field and the Fletcher Allen Facility also discharges into segment A near the confluence with the main stem.

Stream Type Departures (STD):

Stream Type Departure (STD) have been noted for the following reaches for **bedform only**:

M01 – The “sub-reach” section of the DMS (in step 2) has been checked to indicate that this reach was likely a cobble-bottomed step-pool channel in reference condition (even though it is not a subreach of a larger reach). There is significant incision occurring in the upper sections of the reach, however it is controlled in many areas by bedrock. Significant widening and aggradation, likely due to bank erosion from within the reach and reaches above, has filled in many of the pools resulting in more of a plane-bed system. D50 substrate is now gravel due to high percentage of fine sediments. One very large mass failure is also leading to widening and aggradation in the lower section of the reach. In addition, historic and current encroachment on the floodplain (berming) is likely contributing to increased stream power (and thus incision) during the higher streamflow events.

T1.01-A – This segment is experiencing incision as well as aggradation due to bank erosion within the reach and in upstream segment B. Although there are sections of the reach with riffle-pool bedform**,** a majority of the segment has plane bedform. The segment has remained classified as a C-type channel. Relatively good connection to floodplain throughout the lower section of the segment may be ameliorating some of the impacts of frequent high flows from urban runoff in the upstream watershed.

Project Identification:

<u>Corridor Protection:</u>

The Centennial Woods Natural Area provides excellent stream corridor protection to reaches M02, M03, and Tributary T1. Other reaches outside of the natural area represent zones where historic and current encroachment threatens the floodplain and channel integrity:

In **M01** in particular, historic and current encroachment has increased stream power and is resulting in extreme incision in the upper section of the reach. This incision begins just below the Grove St. culvert where the channel is constricted by both the culvert itself and the berming associated with the S.D. Ireland facility, and the adjacent parking lot associated with Schimanska Park. Ongoing encroachment in the floodplain in this section of the reach has been observed where materials continue to be dumped down the valley wall from the S.D. Ireland facility. Protecting this corridor from further encroachment should be a key, cost-effective measure taken to reduce further incision, mass wasting, and sediment conveyance to the Winooski river a short distance downstream.

In upstream reaches **M04** and **M05,** further encroachment near the stream corridor is still a possibility, as this area is not protected like it is in Centennial Woods. Further encroachment within M05 (headwaters reach) is unlikely in most areas because most property adjacent the corridor is already developed in medium-density residential neighborhoods. In M04, however, recent development along the corridor has resulted in observable impacts to channel stability. Below the stormwater pond associated with Quarry Ridge Condominiums, there is a severely eroded outlet channel which is contributing sediment to the Centennial Brook channel at the receiving point. With this example in mind, any additional development along the stream corridor should consider the inherent sensitivity of the E-type channels in this reach. Although there is currently good floodplain access and riparian buffer throughout this upper reach, additional stressors on the hydrologic regime could result in further incision and bank erosion in this sandy-bottomed channel.

<u>Disequilibrium Remediation:</u>

M01 – As discussed in the stream type departure section of this document, this lowest reach of Centennial Brook is experiencing extreme incision, widening, and bedform departure. Active restoration of stream channel geometry is likely not be feasible until the mitigation of the hydrologic regime of the entire watershed is addressed. This strategy, adopted by ANR, is consistent with research from other parts of the U.S. (Booth et al, 2002; Booth, 2005). Although restoration of channel geometry may not be desirable in this reach, the instability in the lower section of the reach where significant widening is occurring could be addressed with other means. First, there are large amounts of metal and concrete debris which cause debris jams and could be contributing to this widening. Manual removal of this unnatural debris out of the floodplain may reduce the severity of this widening. In addition, a mass failure on the left bank approximately half way down the reach contributes significant amounts of sediment to the channel and downstream receiving waters. Stabilization of this failure, either through re-vegetation or other non-mechanical means, could also slow the widening process in this section of the reach and could reduce fine sediment conveyance to the Winooski River and thus Lake Champlain.

References:

Booth, D. B. (2005). Challenges and prospects for restoring urban streams: A perspective from the pacific northwest of north america. *Journal of the North American Benthological Society, 24*(3), 724-737.

Booth, D. B., Hartley, D., & Jackson, R. (2002). Forest cover, impervious-surface area, and the mitigation of stormwater impacts. *Journal of the American Water Resources Association, 38*(3), 835-845.

Appendix 1

Phase II Notes and Updates to Phase I Data:
General updates are reviewed below for each DMS Phase II step to which noteworthy revisions were made, after the initial QA from DEC staff. Common parameter themes across reaches are summarized with **reach names in bold text**. References to Phase I data are summarized and discussed in red text.

- *Step 1 - Valley and Floodplain Corridor:*
  - Adjacent Terrace or Hillside (1.4)
    - Phase II side-slopes have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct valley side-slope data.
  - Valley Features (1.5)
    - Where better estimated or measured values were taken for valley width in Phase II surveys, Phase I data has been updated. Otherwise, Phase I valley width has been used and entered in Phase II database.
    - All human caused changes in valley width reflect significantly altered valleys due to berming, adjacent roadways, etc. Structures that are in the floodplain that might significantly alter the floodplain hydraulics are also considered as human caused changes. Reaches with human-caused changes to valley width include: **M01 & T1.01-B**
  - Grade Controls (1.6)
    - Phase II grade controls have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct grade control data.
    - Despite the abundance of beaver dams in many reaches and their ability to control stream grade on a short-term basis, these features have been removed as grade controls in the database.
- *Step 2 - Stream Channel:*
  - Stream Channel (2.1 – 2.9)
    - Efforts were made to get a minimum of 2 cross-sections per reach, especially for the longer reaches. Sometimes representative cross-sections selected for DMS data entry disagrees with stream type or adjustment type, or suggests a higher/lower degradation adjustment than that observed.
      1. Reaches with more than one cross-section that have average incision ratios **lower** than the one reported incision ratio include: **M03**
      2. Reaches with more than one cross-section that have average incision ratios **higher** than the one reported incision ratio include: **M01 & M04**
  - Riffle Data (2.10 – 2.11)
    - Riffle data has not been collected for “dune-ripple” bedforms. All observed riffle/pool spacings have been included for “riffle-pool” and “step-pool” bedforms.
  - Substrate Data (2.12 – 2.13)
    - Percent Detritus has been estimated and tends to be higher on lower gradient reaches (E-types). Note that this data is more qualitative than quantitative.
    - For “Dune-Ripple” bedforms, average largest particles on both the bed and bar are sand, which often appear as “0” values in the DMS.
  - Stream Type (2.14)
    - In heterogeneous reaches, dominant bedform has been selected even though reach may contain multiple bedforms throughout (e.g., B3 step-pool may also have significant portions of plane bedform). Those reaches with altered bedform from reference conditions are listed below:
      1. Plane bed reaches that were likely step-pool include: **M01**

2. Plane bed reaches that were likely riffle-pool include: **T1.01-A**

- Determination of stream type may be based on data from more than one cross-section measurement. Please refer to all cross section data to confirm chosen stream type.
- Reference condition stream types have been updated in the Phase I database where a type different from Phase I estimate was observed in the field. This included many reaches that were thought to be C riffle-pool streams during Phase I assessment but were observed as E dune-ripple during Phase II assessments.

- *Step 3 - Riparian Banks, Buffers, and Corridors:*
  - Stream Banks (3.1)
    - Bank textures observations during Phase II assessments focused more on material type more than cohesiveness. Therefore, "cohesive" versus "non-cohesive" values have been updated during the QA process and are now considered accurate.
    - Observed bank erosion values in many cases represent best possible estimations of length for each bank. For reaches with higher percentages in particular, estimated values are likely more qualitative than quantitative.
    - Phase II bank erosion data have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data.
  - Stream Buffer (3.2)
    - Phase II buffer width and vegetation data have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data.
  - Stream Corridor (3.3)
    - Phase II corridor land use data have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data.
- *Step 4 – Flow and Flow Modifiers:*
  - Springs, Seeps, & Tributaries (4.1)
    - In addition to seeps and springs, tributaries of any size were considered to provide water storage capacity at the reach scale during the Phase II assessments. GIS mapping using orthophotography and VHD layers were also used to determine the abundance of tributaries for each reach.
  - Adjacent Wetlands/GW Inputs; Impoundments/Flow Regs; Constrictions (4.2, 4.5, 4.7, 4.8)
    - Phase II inputs for above-described data have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data.
  - Flow Regulating Impoundments (4.5 & 4.7)
    - In the Centennial Brook watershed there are 2 in-stream impoundments that affect the hydrologic and sediment regimes for some distance downstream. For each of these structures, the gradient of the channel network downstream of the impoundment has been analyzed to determine how far down the structure is likely to be impacting the watershed. Reaches affected by these impoundments include: **M05-A, M05-B, T1.01-A & T1.01-B**
  - Stormwater Inputs (4.6)
    - Stormwater inputs include those outfalls discharging directly to the channel, as well as those ditches and other features conveying concentrated runoff directly to channel. Man-made drainage mapping was used in field during Phase II assessments to locate potential stormwater inputs not found directly on the channel.
    - User of data should also consult with Pioneer's mapping and documentation of stormwater inputs directly to the channel for confirmation of this dataset.
  - Beaver Dams (4.9)
    - Active beaver dams causing significant ponding and were documented. The length of the channel affected by the ponding was measured using mapping in the field and/or GIS.

- *Step 5 – Channel Bed and Planform Changes:*
  - Bar Types (5.1)
    - Phase II bar type and abundance data have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data.
  - Planform Changes (5.2 – 5.3)
    - Alterations to the hydrologic and sediment regimes the in Centennial Bk. watershed are caused primarily by: 1) urban runoff, and 2) beaver modifications to channel and floodplain. It is often difficult to tease apart the relative impacts of each of these factors during Phase II assessments. Noteworthy planform changes relative to each impact are listed below:
      1. Reaches where significant alterations to planform can be associated with **beaver activity** include the following reaches: **M02 & M05-A**
      2. Reaches where significant alterations to planform appear to be resulting from **urban runoff** include the following reaches: **M03, T1.01-A & T1.01-B**
      3. Reaches where extreme alterations to planform have clearly resulted from **urban runoff** include: **M01**
  - Channel Alterations (5.5)
    - Phase II channel alteration data have been reviewed but have **NOT** been updated in the Phase I database. Therefore, database user should refer to Phase II for correct data. Channel alterations are described in further detail in the commentary section at the end of step 5.
- *Step 6 – RHA:*
  - Bank Stability (6.8)
    - Bank stability measurements reflect estimated bank erosion values entered in step 3.1. In some cases RHA scores for bank stability may appear slightly higher or lower than the expected ranges/values entered in step 3.1. Best judgment was used in these cases when evaluating bank stability from a habitat perspective.
  - Overall Rating (6.11)
    - Confidence in integrity of overall RHA scores is high for Centennial Brook.
    - Overall habitat assessment in E-type channels is difficult due to general lack of quality habitat associated with these sand-bottomed reaches. Another confounding variable which makes assessment of habitat in low-gradient E-type channels difficult is the influence of beaver activity. Reaches with lower RHA scores due to beaver influence included: **M02 & M05-A**
- *Step 7 – RGA:*
  - Channel Degradation (7.1)
    - Degradation is the predominant adjustment process occurring in most reaches in Centennial Brook. This can be explained by the alterations to the hydrologic regime that result in higher stream power. Incision values and entrenchment ratios were reviewed for ALL reach cross-section measurements in order to determine scores in 7.1 (row 2) and 7.3 (row 3). Certain reaches may appear to have RGA scores for these rows which do not agree with reported DMS cross section geometry, in which case database user should refer to additional cross-sections. Reaches with this apparent discrepancy include: **M01**
  - Channel Widening (7.3)
    - As the channel evolution stage that follows incision, channel widening is also an adjustment process occurring in some of the impacted high-gradient (B & C type channels) reaches in Centennial Brook. In the future, channel widths will be compared with hydraulic geometry curves developed for Chittenden County in order to make adjustments to scores in 7.3 (row 1). For this parameter, width to depth ratio is not always adequate at capturing the degree of widening. Also, certain reaches may appear to have RGA scores

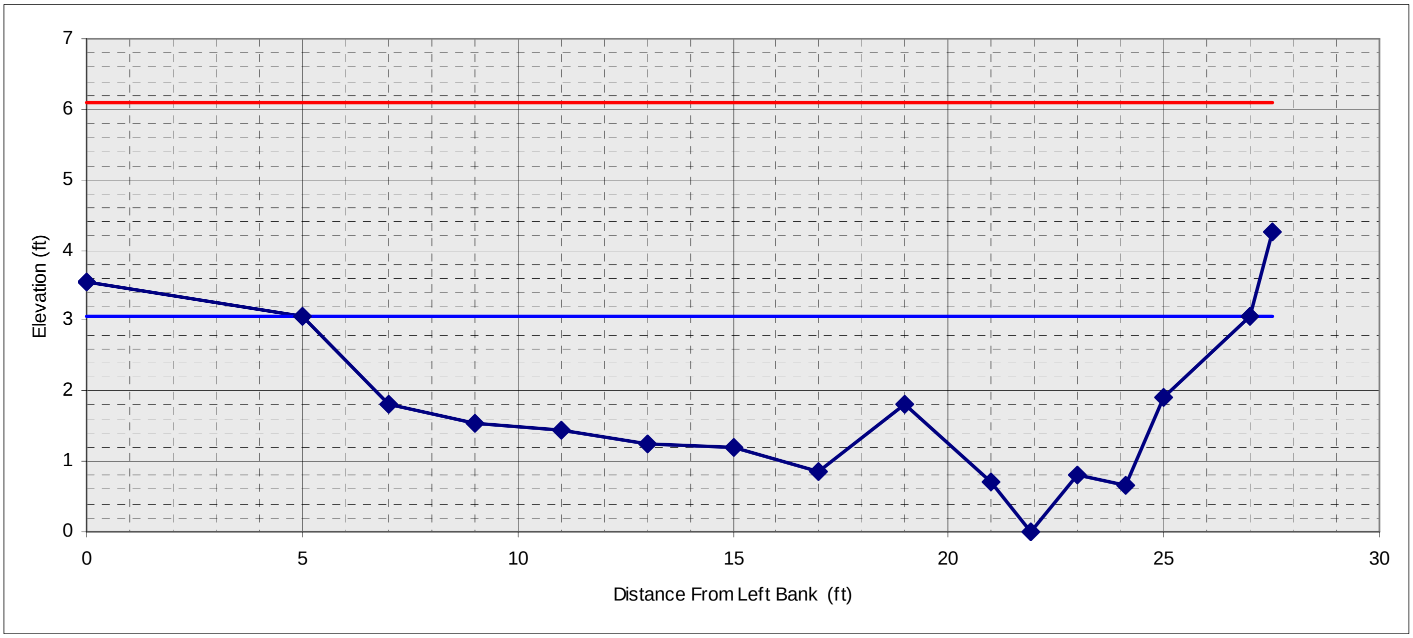
for these rows which do not agree with reported DMS cross section geometry, in which case the database user should refer to additional cross sections.

- Overall Rating (7.6)
    - Confidence in integrity of overall RGA scores is high for Centennial Brook.
    - As discussed above in the RHA section, overall geomorphic stability is often difficult to assess in low-gradient, E-type channels affected by beaver activity. Historic beaver activity in many cases has led to aggradation of fine sediments behind the historic dam in many low gradient reaches. These reaches, when observed in current-day conditions in the absence of flooding, often appear to be actively incising back down through this aggraded material. Reaches where this phenomenon has been observed include: **M02 & M05-A**

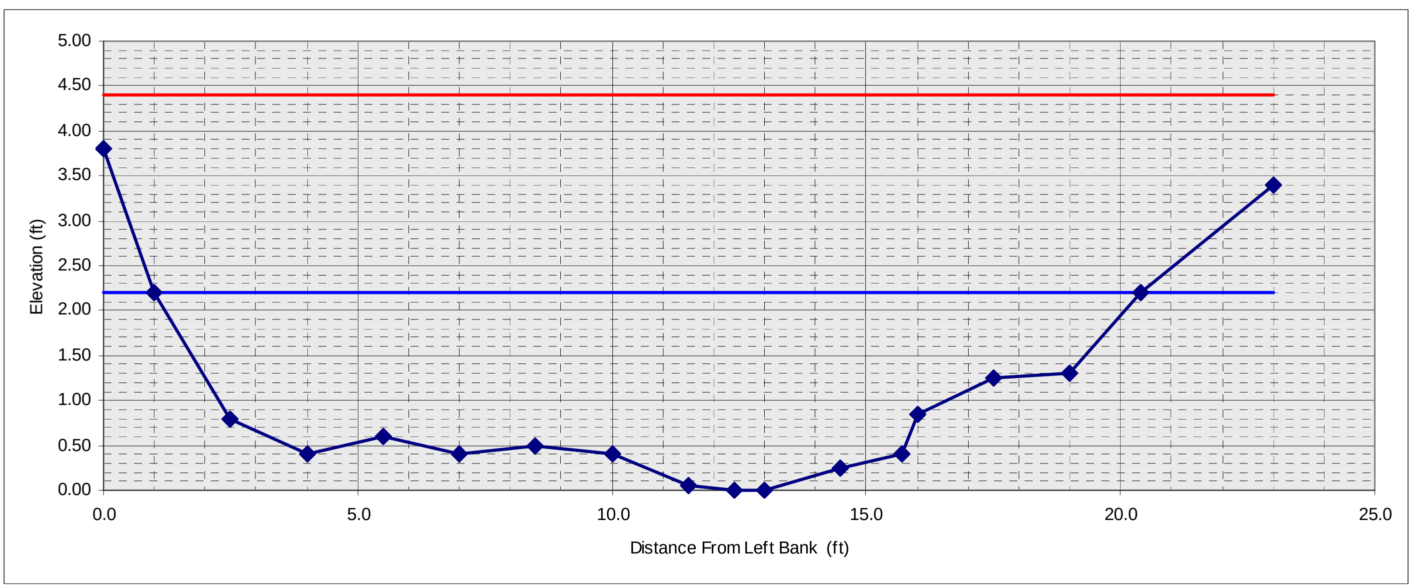
Appendix 2

Cross-sectional plots for Centennial Brook reaches and segments are found below (all units in feet). The horizontal **blue line** represents the bankfull width and depth, and the **red line** represents the field-estimated floodprone depth and width (if visible on plot). Reaches/segments with multiple cross sections are denoted by X1, X2, etc.

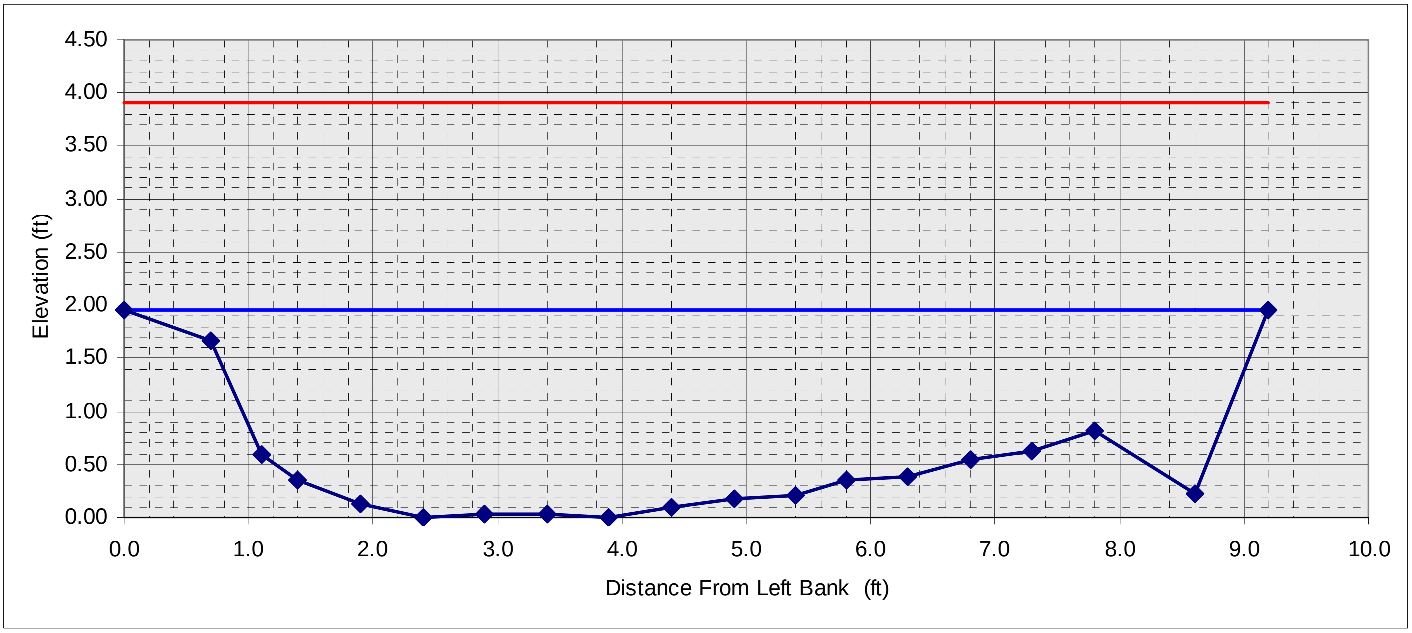
Reach M01 – X1



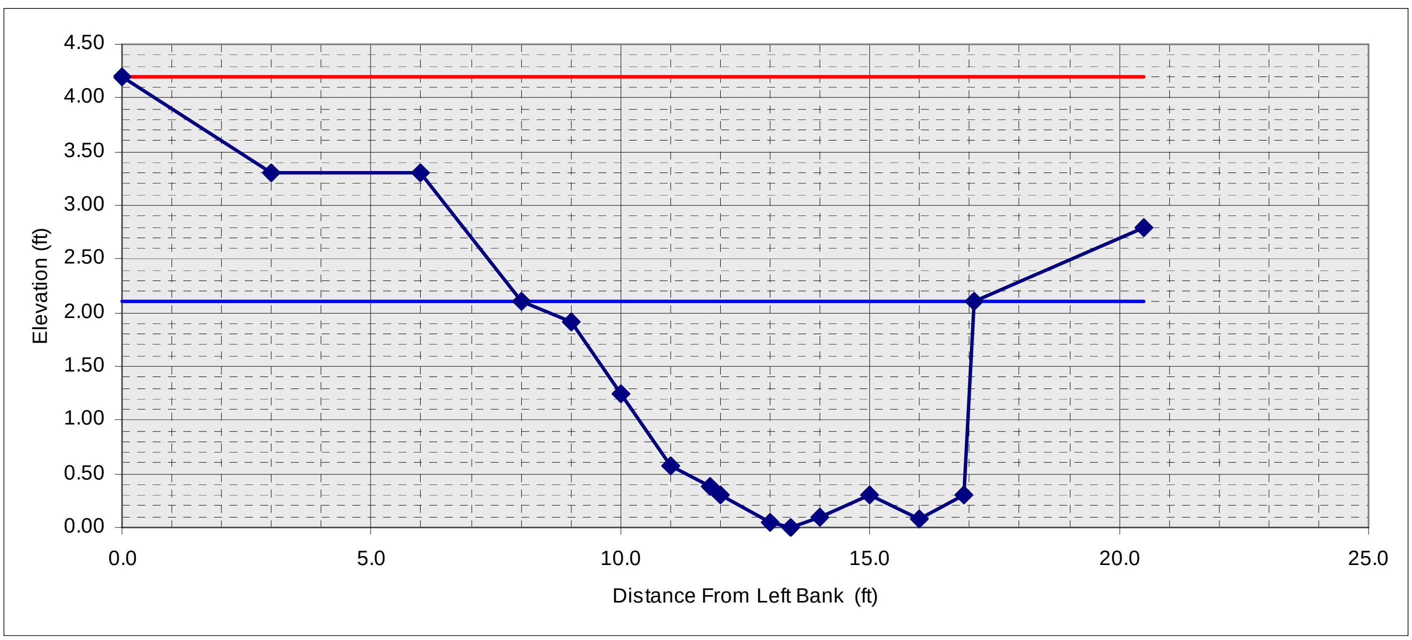
Reach M01 – X2



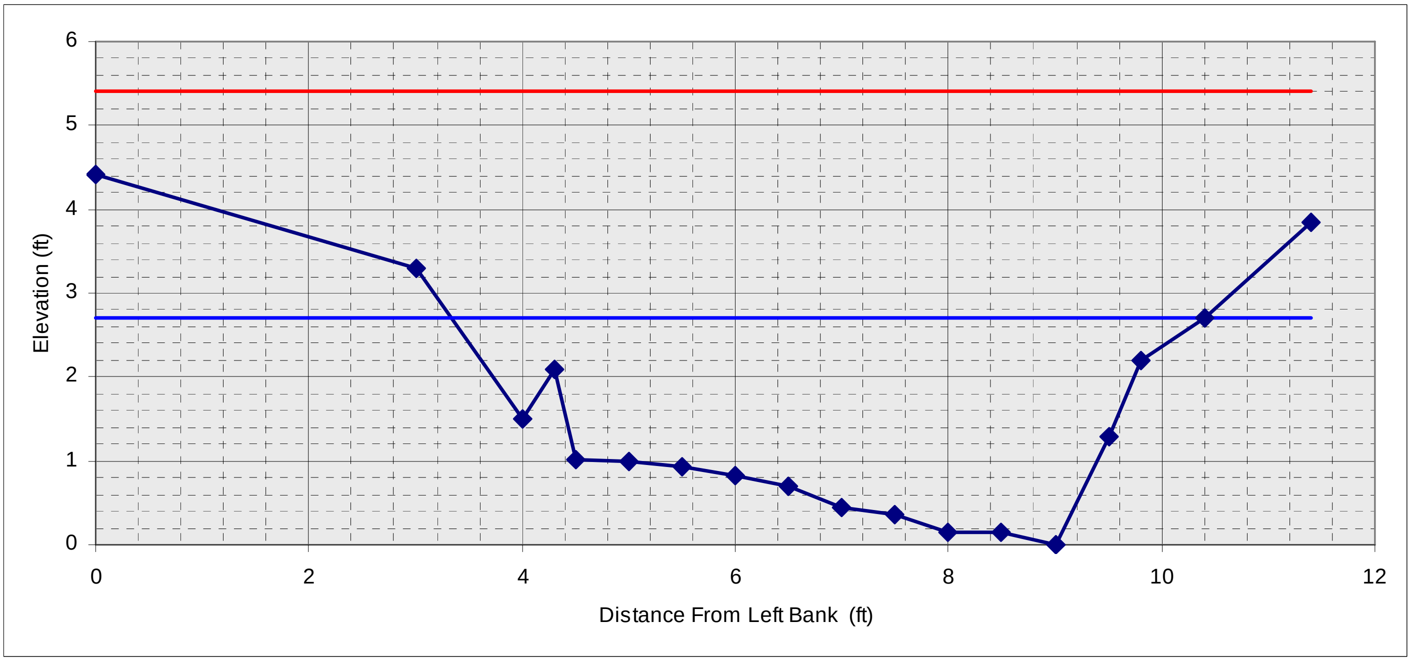
Reach M02



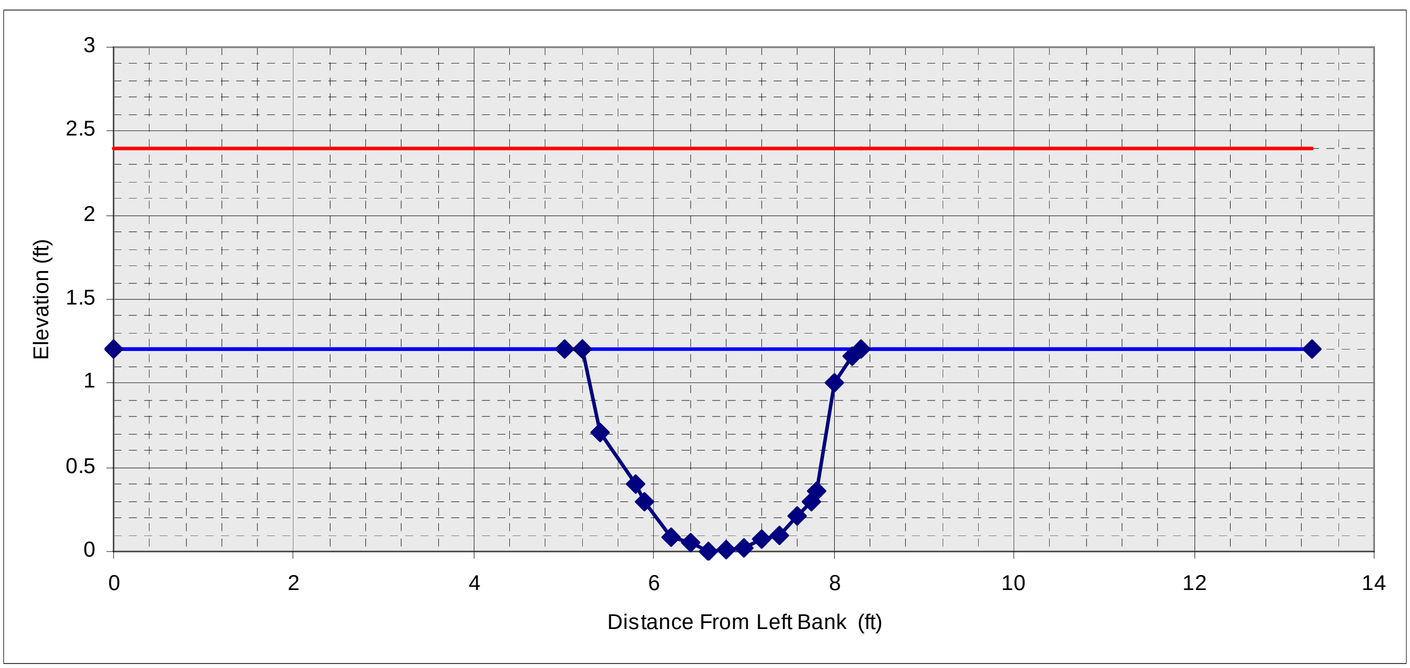
Reach M03 – X1



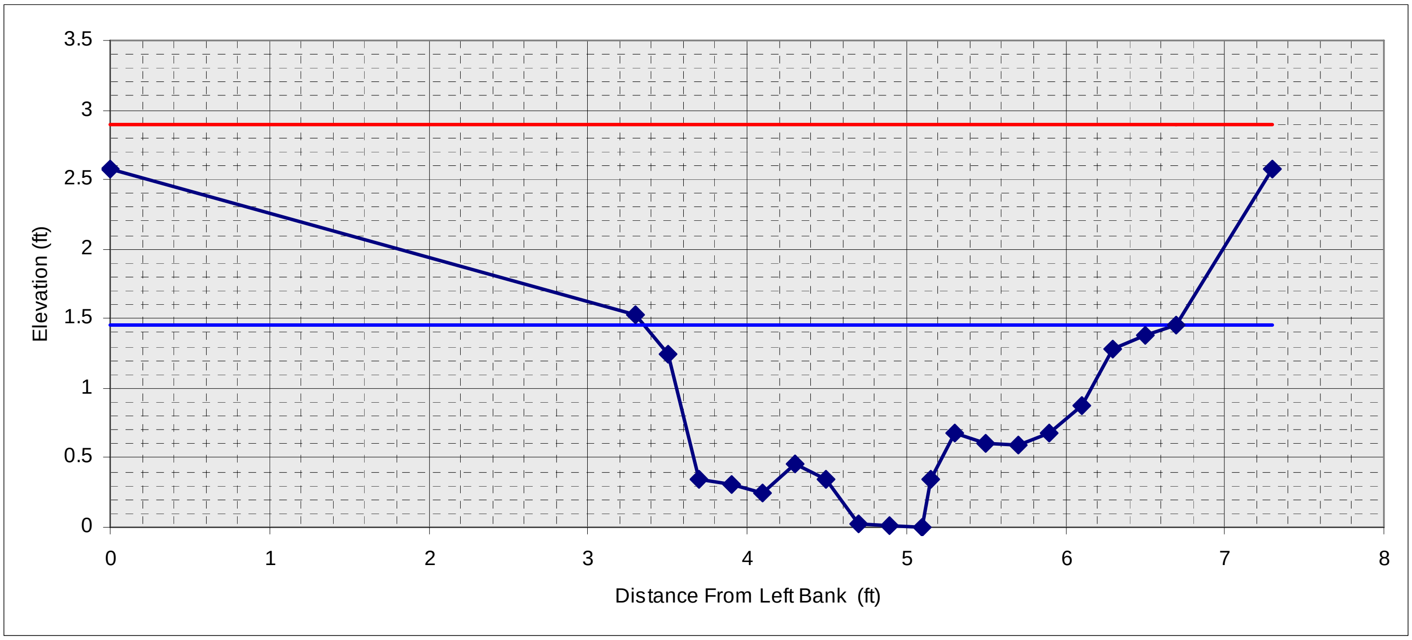
Reach M03 – X2



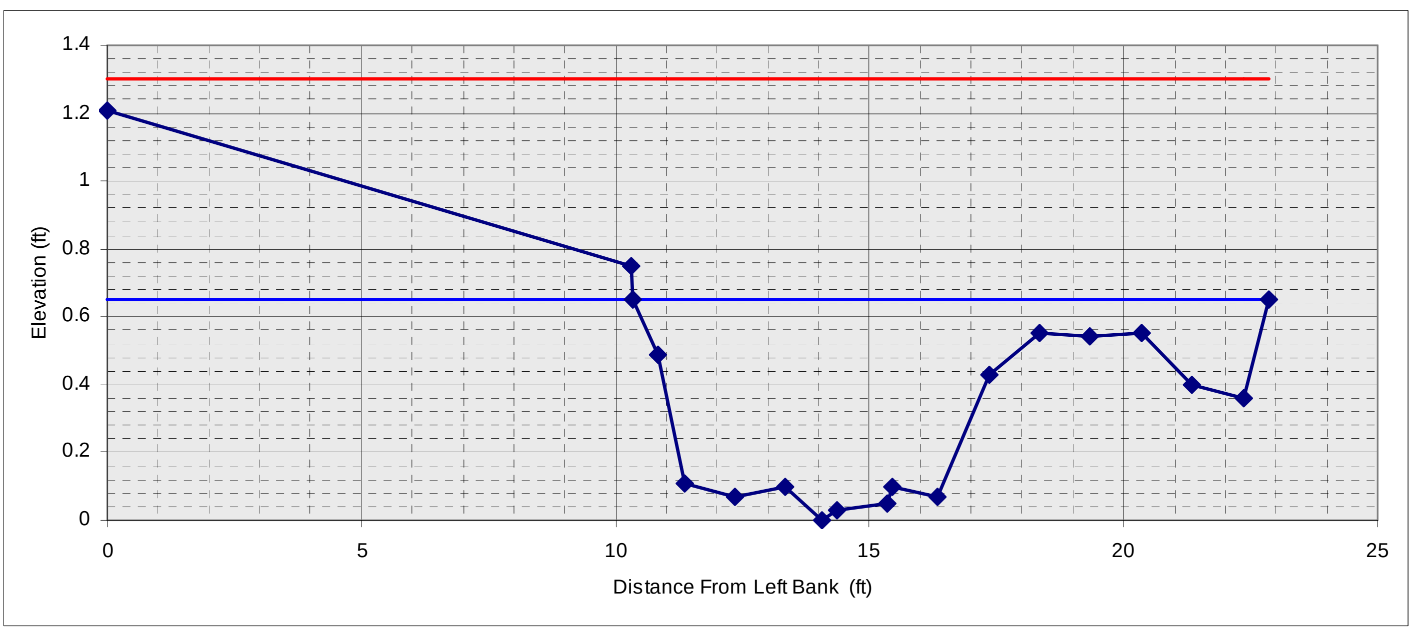
Reach M04 – X1



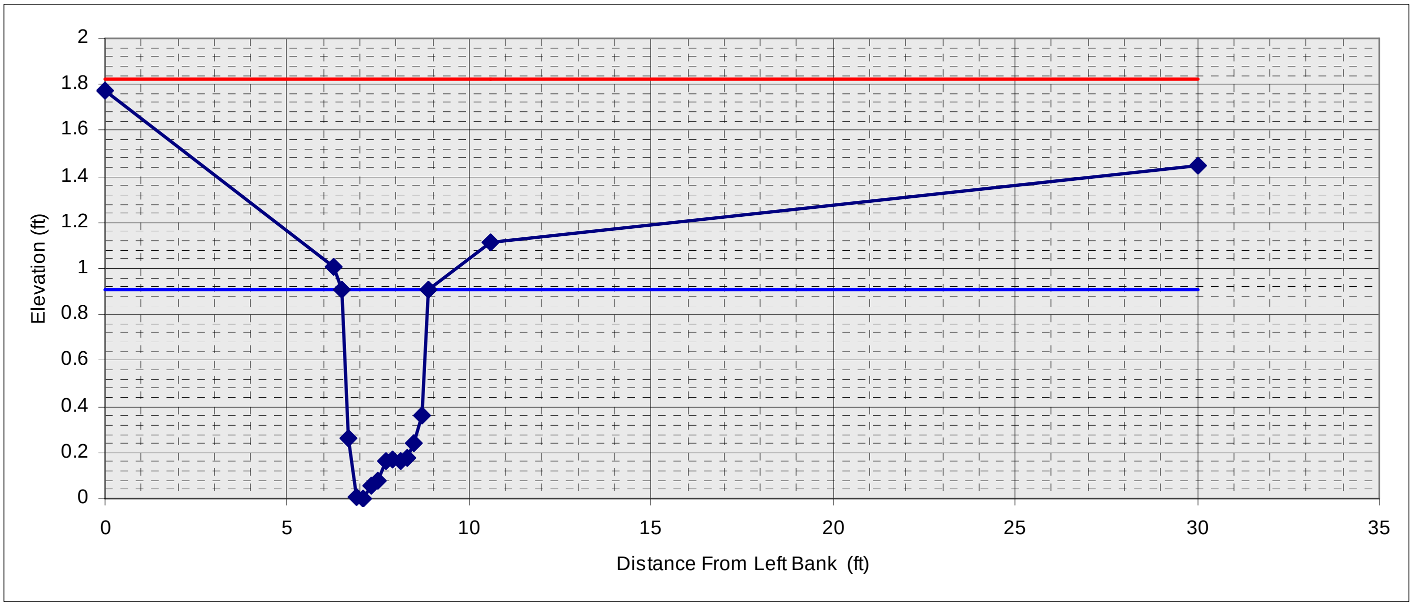
Reach M04 – X2



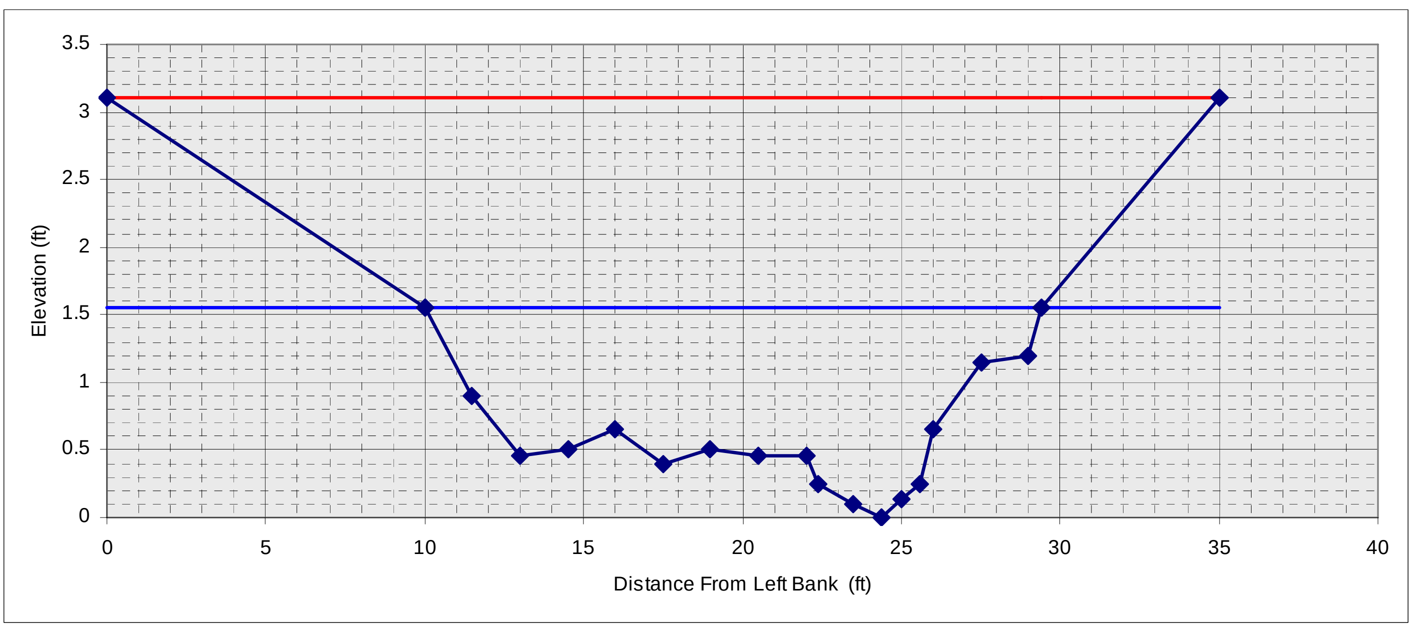
Segment M05-A – X1



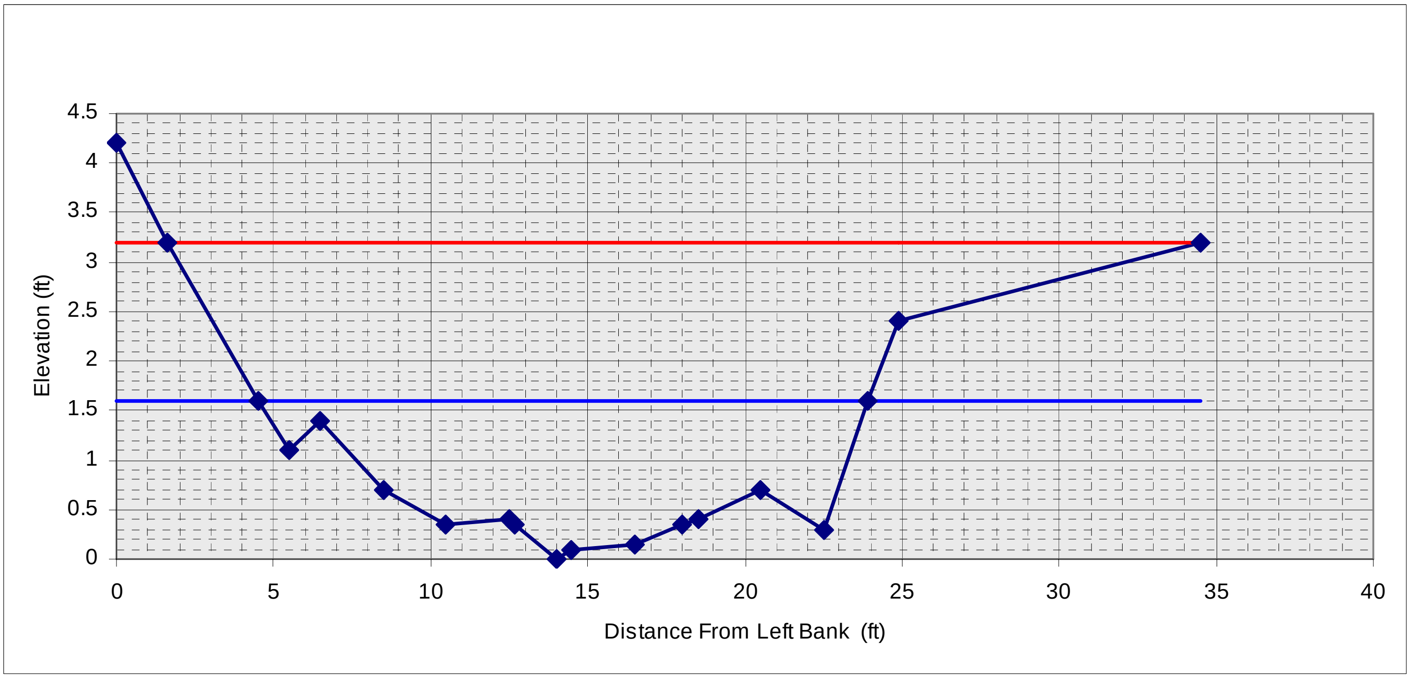
Segment M05-A – X2



Segment T.1-A



Segment T.1-B

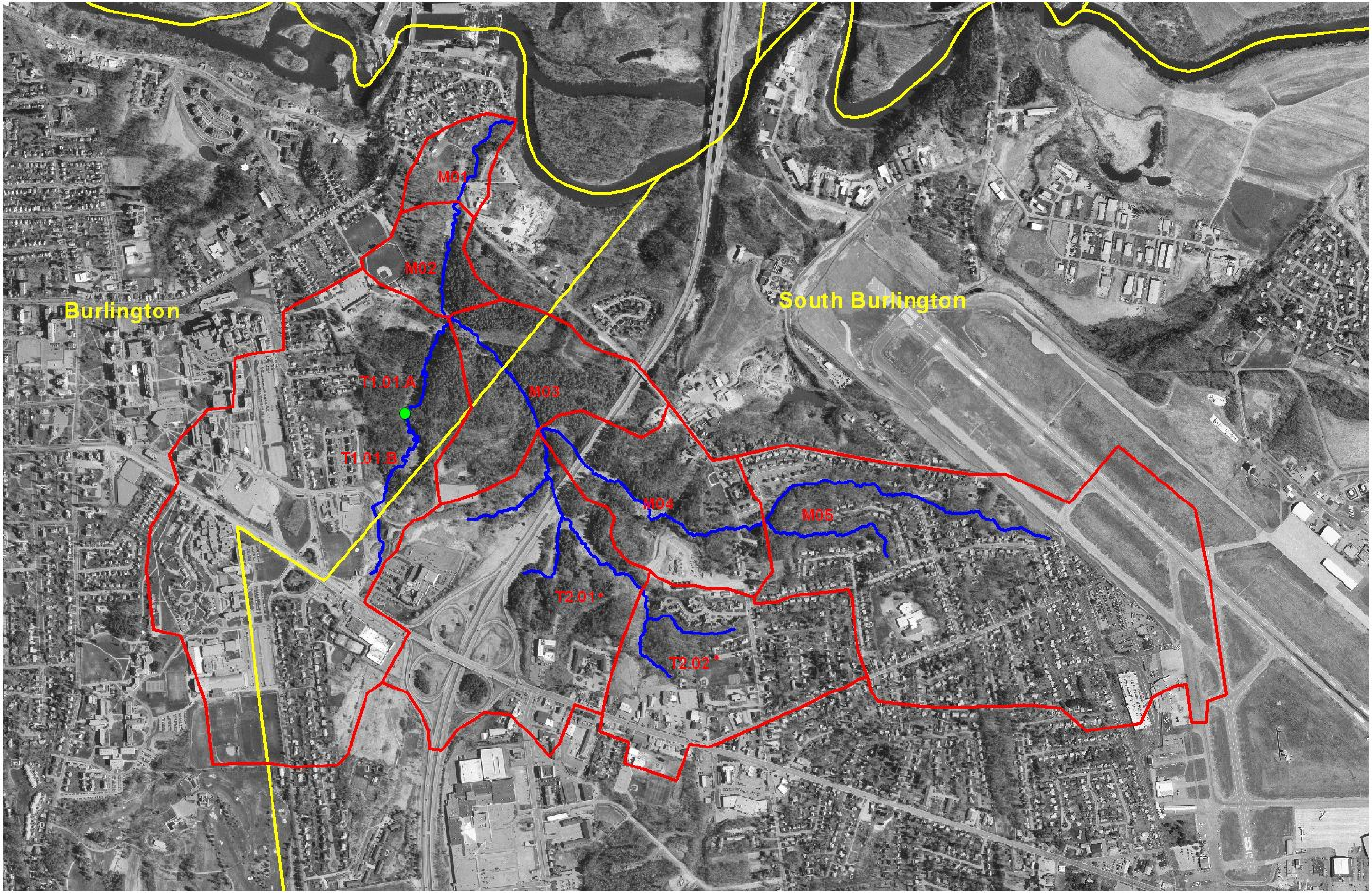


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Elevation (ft)
0
5
10
15
20
25
30
35
40
Distance From Left Bank (ft)

Centennial Brook Reach Summary Table
Evan P. Fitzgerald
03/03/06

Reach	Segment	Stream Type	Dominant Bed Material	Bedform	STD*	Reference Stream Type†	Reference Bed Material†	Reference Bedform†	RHA Score	RHA Condition	RGA Score	RGA Condition	Reach Sensitivity
M01		B	Gravel	Plane Bed	Yes	B	Cobble	Step-Pool	0.59	Fair	0.53	Fair	High
M02		E	Sand	Dune-Ripple	No				0.45	Fair	0.56	Fair	Very High
M03		E	Sand	Dune-Ripple	No				0.57	Fair	0.59	Fair	Very High
M04		E	Sand	Dune-Ripple	No				0.78	Good	0.75	Good	High
M05	A	E	Sand	Dune-Ripple	No				0.48	Fair	0.61	Fair	Very High
T1.01	A	C	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.64	Fair	0.63	Fair	High
T1.01	B	C	Gravel	Riffle-Pool	No				0.56	Fair	0.51	Fair	Very High
								Mean:	0.58		0.60		
								Max:	0.78		0.75		
								Min:	0.45		0.51		

* Stream Type Departure (Rosgen Type or Bedform)
† Assessed Reference Condition Prior to Stream Type Departure



Centennial Brook SGA Watershed Map

1500 0 1500 3000 4500 Feet

- Segment Break
- Centennial Bk Phase I & II Subwatersheds
- City Boundaries
- Surface Waters
- * Segment Not Assessed for Phase II