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Sunderland Brook Phase II Documentation and QA/QC Notes
September 13, 2006

Introduction:

The following is a documentation of the key geomorphic processes and adjustments occurring in the Sunderland Brook watershed at the reach scale. The intent of this documentation is twofold: 1) concisely summarize Sunderland 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 Map, 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. Plots for each channel cross-section measured during the Phase II analysis are provided in Appendix 2. Reach summary statistics and maps are found respectively in Appendices 3 and 4.

Sunderland Brook Summary:

Sunderland Brook is drained by an elongated, west to east flowing watershed which spans the towns of Essex Junction and Colchester. The overall slope of the channel network from headwaters to outlet at the Winooski River is only 0.4%, reflecting the low gradient nature of many of the reaches. The drainage area of the basin is approximately 5.5 square miles, and land use patterns vary significantly along the channel network. In the headwaters reaches above Fort Ethan Allen on VT Route 15, urbanization is high and physical impacts to the stream channel are quantifiable. However, in the middle and lower sections of the watershed, natural and agricultural land use patterns dominate the landscape.

During the Phase II field assessments of the Sunderland Brook watershed, three distinct zones were observed with respect to natural topographic and geologic characteristics, as well as human impacts. In the lower zone of the watershed near the brook's outlet to the Winooski River, historic agricultural encroachment and channelization has had profound and lasting impacts on the geomorphic stability of the channel. Straightening and dredging in these lower reaches have perpetuated sediment delivery processes to the Winooski, and limited buffer vegetation results in additional high impacts to the channel. Above Malletts Bay Avenue in the middle zone of the watershed, surrounding drainage areas are largely forested around Camp Johnson, and the physical channel condition is generally good to fair. Through this middle zone of the watershed up to Fort Ethan Allen, long stretches of the channel are impacted by beaver activity. Above Fort Ethan Allen and along the Rt. 15 corridor, the impacts of surrounding urban land use are more clearly observed. Beaver activity is also abundant in this upper zone of the watershed, making the assessment of urban impacts difficult in some reaches.

Below is a summary of reaches assessed for Phase II data during summer 2005. Stream type departure information is found within each reach summary, and a project identification discussion follows the summaries.

Lower Watershed Zone (M01 & M02)

Reach Descriptions:

Reaches M01 and M02 are both significantly impacted by historic agricultural impacts. These impacts include channel straightening and dredging, as well as disturbance to the buffer and bank vegetation from Malletts Bay Avenue down to the outlet. It appears that the degree of straightening in reach M02 may have been so severe (historically) that the current location of the stream channel does not follow the natural topography of the landscape (see mapping in Appendix 4). Both reaches M01 and M02 have low gradient channel morphology with E-type geometry. Analysis of the slope and valley characteristics suggest that this lower watershed zone had E-type channel morphology with sand substrate in reference conditions. Due to the straightening of the planform of M01, a stream type departure has been noted for both segments from dune-ripple to plane bedform. Channel geometry has been maintained in reference conditions, however incision in M01 is very high (incision ratio: 1.9) and this reach will likely become further entrenched with time due to its capacity to accommodate excess stream power in the enlarged channel (see figure 1). Widening has begun to occur in sections of these reaches, however the cohesive silty-clay lower bank material prevents significant sloughing and bank erosion. Reach M02 has also undergone significant changes in planform due to straightening, but the geometry and substrate observations of this reach (see figure 3) suggest that aggradation is the dominant process occurring at present.

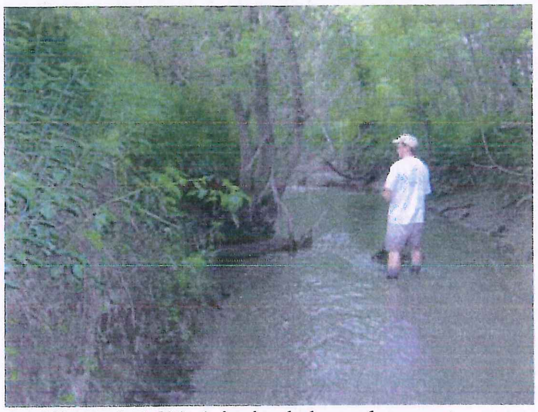


Figure 1. M01-A incised channel geometry


Figure 2. M01-B Cross Section

Low RGA scores have been noted for both reaches in this watershed zone, reflecting the ongoing and pervasive channel adjustments observed throughout. Habitat assessment scores (RHA) are also very low because of the degraded substrate habitat resulting from the straightening and the limited buffer vegetation and shading. One other notable feature is a tributary confluence in the upper section of segment M01-A. At the segment break noted on the watershed map (Appendix 4), a tributary enters from the east and review of the aerial photography shows this surface water originating in the vicinity of the quarry along I-89. During the Phase II assessment on June 29, 2005, significant amounts of fine sediment were observed entering from this eastern tributary (see figure 4). Due to the limited amount of sediment storage capacity in the downstream reach, this fine sediment was being delivered directly to the Winooski River.


Figure 3. M02 cross section


Figure 4. Tributary confluence in upper M01-A

Project Identification:

The farmland surrounding the stream corridor of Sunderland Brook in this lower watershed zone has been established in the Winooski floodplain for many decades. Efforts to reestablish the depositional floodplain areas associated with the reference conditions of Sunderland Brook would likely be met with strong resistance from landowners. In addition, the linear distance of channel below Malletts Bay Avenue that would need protection and restoration is approximately 1.5 miles. Given these obstacles, it may be difficult to argue that the benefits achieved from protecting the entire stream corridor of the brook in this zone outweigh the costs.

Nevertheless, there are some important pieces of information that can be gleaned from the coarse Phase II data in this part of the watershed. Degradation and sediment transport are clearly observed as the dominant processes in M01, while aggradation may be starting to occur in reach M02 as part of the channel evolution process. This data could suggest that protecting the corridor in reach M02, rather than M01, may be a more practical option in the near future for creating sediment storage areas for the lower watershed. In the absence of complete acquisition of the (property associated with) historic stream corridors in M01 and M02 for protection purposes, *and* the reshaping of the channel to promote equilibrium conditions, the channel of both reaches will continue to adjust and deliver significant amounts of fine sediment to the Winooski River for many years to come.

Finally, there should be further observation of the sediment delivered from the eastern tributary in M01-A. Although the impacts associated with this fine sediment may not be significant with respect to the geomorphic adjustments in this reach, the water quality and habitat impacts are notable and could propagate downstream into the Winooski River.

Middle Watershed Zone (M03 through M07):

Reach Descriptions

From Malletts Bay Avenue up through the forested areas associated with Camp Johnson, the physical condition of Sunderland Brook is unaffected by substantial direct urban and agricultural impacts. The only exception to this are some areas in reach M03 which have been historically straightened and are in a state of readjustment (through incision). The low gradient valley topography found through this middle zone of the watershed creates conditions for slow-winding, sand-bottomed channels. All of the channel geometries recorded for reaches M03 through M07 were E-type in fair to good conditions (see Appendix 3), with one notable exception: M05B. This short, high-gradient segment is a bedrock cascade approximately 350 feet long, and has been given classification of an A-type channel due to its gradient. Channel geometry measurements were approximated for this segment, and RGA and RHA scores were not evaluated due to the segment's relatively short length.

Beaver activity was observed very frequently throughout this watershed zone, and in reach M07 the extensive ponding precluded geomorphic assessment. Beavers are a common natural inhabitant of slow-winding, sand-bottomed channels throughout Chittenden County. The low slope of the brook's valley combined with a narrow valley bottom (~100 feet) creates ideal conditions for beavers to flood the entire valley with a single dam. This kind of beaver activity makes the assessment of geomorphic conditions difficult. Indeed, the effects intense of beaver activity on geomorphic condition can make the detection of human impacts nearly impossible. As in other watershed assessments carried out by the UVM team in summer 2005, care was taken to document, to the degree possible, the differences between human and beaver impacts on the stream channel. Notes in Appendix 1 (Step 5) provide specific documentation to this end.

Project Identification:

For reaches M04 up through M07, both the local (reach-scale) watersheds and the stream corridors are protected and minimally disturbed. Unless there are significant land use changes proposed for Camp Johnson, there is little need to consider potential restoration projects for these reaches.

Reach M03, on the other hand, should be considered due to the historic (and perhaps ongoing) agricultural impacts recorded for the lower section of the reach. Since the stability of this reach is closely connected to the ongoing adjustments in downstream reaches M02 and M01, any proposed restoration measures in these reaches should consider the stability of M03. Phase II observations in M03 noted some incision along the straightened section of the reach (along the irrigation pond). It is possible that this adjustment represents a source of fine sediment, both for the lower section of M03 and downstream reach M02. Since aggradation was noted in M02, any restoration efforts to restore the floodplain and sediment storage capacity in this reach should carefully consider the condition of M03. Further, more detailed measurements of incision along the channel network of M03 would be helpful in determining the relative size of the sediment source for downstream reaches.

Upper Watershed Zone (M08 through M10):

Reach Descriptions:

In the upper zone of the watershed, the effect of urban impacts on the physical condition of the stream channel becomes more apparent. However, there is significant beaver activity within reaches M08 and M09 up until the crossing at Susie Wilson Road, making the assessment of stormwater impacts still difficult. The Sunderland Brook valley maintains its low gradient character up through reaches M08 and M09, and stream geometry measurements resulted in E-type classification with sand substrate. In segment M08-A, the stream condition was noted as fair below the beaver ponding (in M08-B), with reference conditions for dune-ripple bedform.

Above the ponding in segment M08-B and lower M09, a departure from reference was noted for bedform from dune-ripple to plane bed. In this area above Susie Wilson Road the channel size is much reduced (see figure 5), yet the impacts associated with urban runoff are easily noted. There is a significant amount of sediment aggrading, apparently due to upslope bank erosion as well as exogenous sediment delivery to the channel. The channel planform is dynamic, with many flood chutes and cutoffs observed. Poor habitat conditions were noted in upstream headwaters reach M10, where there has also been a departure from reference conditions due to extensive stormwater inputs and bed and bank scour. The slightly higher slope of this reach suggests it is naturally gravelbottomed, however large amounts of fine sediment have accumulated and covered the coarse substrate (as seen in figure 6).

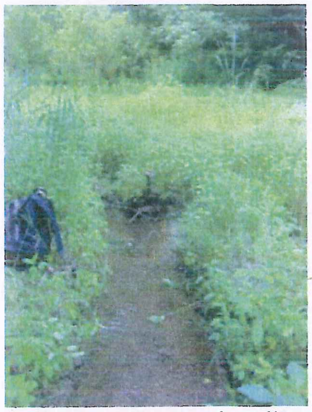


Figure 5. M09 above Susie Wilson Rd.

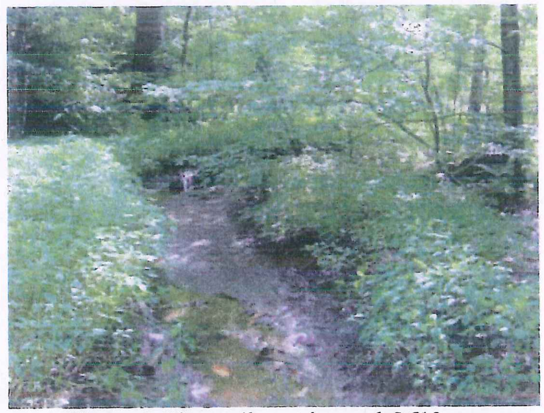


Figure 6. Fine sediment in reach M10

Upper Tributary Reaches:

In addition to the main stem reaches assessed in the upper watershed zone, two additional tributary reaches were assessed in summer 2005. These tributaries both stem from the main channel into highly urbanized areas of the watershed, and were therefore considered important in the assessment of stormwater impacts. Tributary M08.T1 extends from the reach break at M08 and M09 to the northeast into the dense urban areas along Susie Wilson and Kellogg roads. A sand-bottomed, E-type channel was noted for this reach, with plane bedform. Geomorphic stability and habitat conditions were noted as fair. Multiple channel bar features were observed along this reach, yet bank erosion was not as severe as in mainstem reach M09. Upper tributary M09.T1 stems from the reach break at M09 and M10, extending to the northeast into residential neighborhoods along Edgewood Drive. Similar stream type and channel conditions were noted for this tributary, with fair conditions and a relatively low degree of bank failure.

Project Identification:

Disequilibrium stream conditions were noted in the upper watershed zone of Sunderland Brook. In this highly urbanized area, the channel is experiencing aggradation and widening, and bedform departure. Active restoration of stream channel geometry will likely not be feasible until the mitigation of the hydrologic regime of this watershed zone is addressed. This strategy, adopted by ANR, is consistent with research from other parts of the U.S. (Booth et al, 2002; Booth, 2005). Continued geomorphic assessment of the effect of urban runoff in future years will highlight adjustment processes and channel evolution stage throughout these reaches. Although mass failures and a high degree of bank erosion were noted in these reaches, stabilization of these exposed soils will also be unfeasible until the mitigation of the hydrologic regime is addressed. If future assessments note any significant changes in slope resulting from urbanization (such as nickpoints and headcuts), however, possible active restoration strategies should be considered to address these channel adjustments.

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 to the Sunderland Brook dataset, after the initial QA/QC 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-A & M10**
  - 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 some 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 1 to 2 cross-sections per reach; 2 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.
  - Riffle Data (2.10 – 2.11)
    - Riffle data has not been collected for "dune-ripple" or "plane" 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 riffle-pool include: **M10**
      2. Plane bed reaches that were likely dune-ripple include: **M01-A, M01-B & M09**
    - Determination of stream type may be based on data from more than one cross-section measurement.
    - Please refer to all cross section data (see appendix 4) 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.
- *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)
    - Aside from beaver ponding, there were no on-stream impoundments noted for Sunderland Brook.
  - 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.
- *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 in the Sunderland Bk. watershed are caused primarily by: 1) urban runoff, 2) historic agricultural impacts, and 3) 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 when both are present in a reach or segment. Noteworthy planform changes relative to each impact are listed below:
      1. Reaches where significant alterations to planform have resulted from **historic agricultural impacts** include the following reaches: **M01-A & M01-B**
      2. Reaches where extreme alterations to planform have clearly resulted from **urban runoff** and/or **floodplain encroachment** include: **M09 & M10**
      3. Reaches where alterations to planform have resulted from **beaver activity** include: **M03, M04, M05-A, M06, & M08**
  - 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.

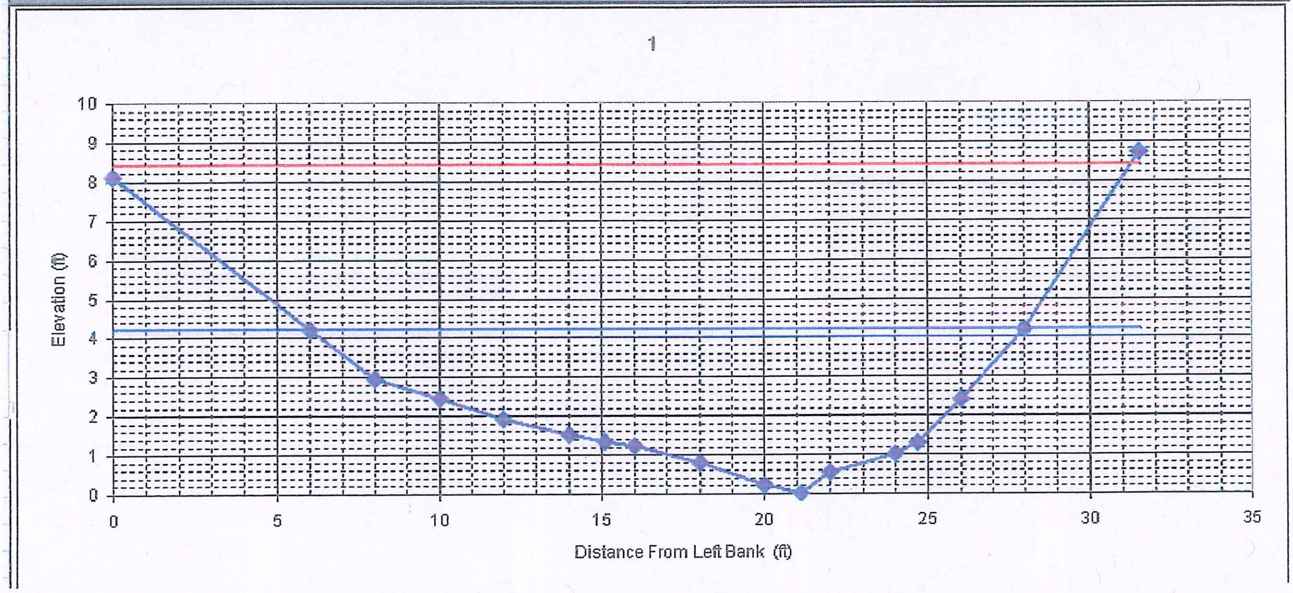
- *Step 6 – RHA:*
  - Bank Stability (6.8)
    - Bank stability measurements reflect estimated bank erosion values entered in step 3.1. In some cases RHA scores for bank stability may appear slightly higher or lower than the expected ranges/values entered in step 3.1. Best judgment was used in these cases when evaluating bank stability from a habitat perspective.
  - Overall Rating (6.11)
    - Confidence in integrity of overall RHA scores is high for Sunderland Brook.
    - Overall habitat assessment in E-type channels is difficult due to general lack of quality habitat associated with these sand-bottomed reaches.
- *Step 7 – RGA:*
  - Channel Degradation (7.1)
    - Degradation and widening are the predominant adjustment processes occurring in most reaches in Sunderland 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 and field observations 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 and/or DMS narrative in step 5.
  - Channel Widening (7.3)
    - 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 Sunderland Brook.
    - Stream Type Departure (STD) information is found in a separate section in the text of this document.

Appendix 2

Cross-sectional plots for Sunderland Brook reaches are found below. The horizontal blue line represents the bankfull width and depth, and the red line represents the field-estimated floodprone depth and width (if plotted).

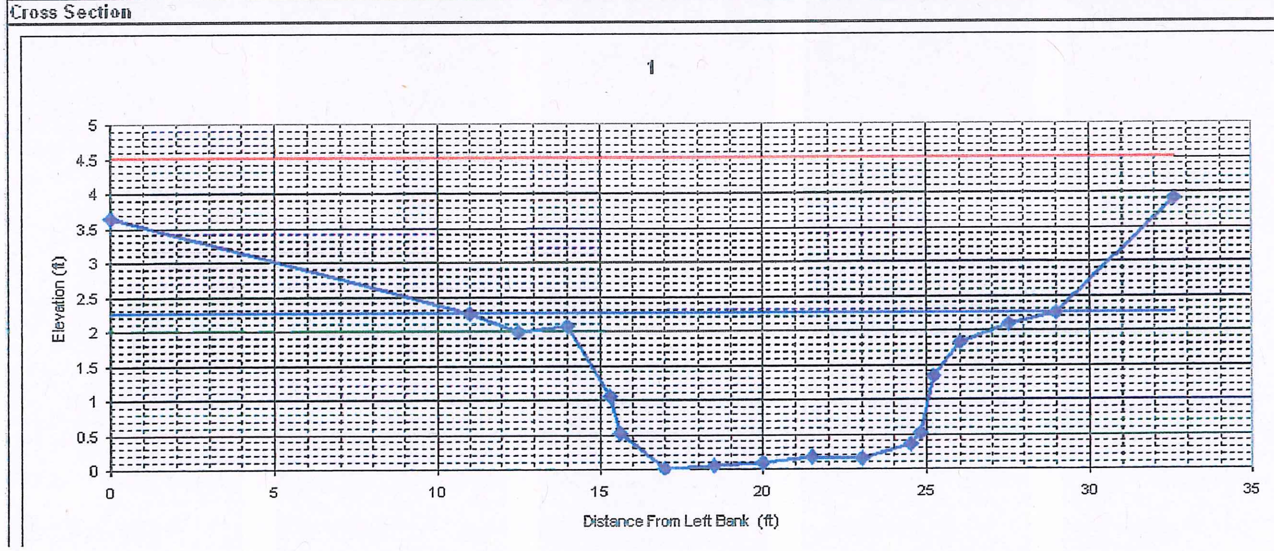
Notes: Sunderland Brook - M01 - Segment A

Cross Section



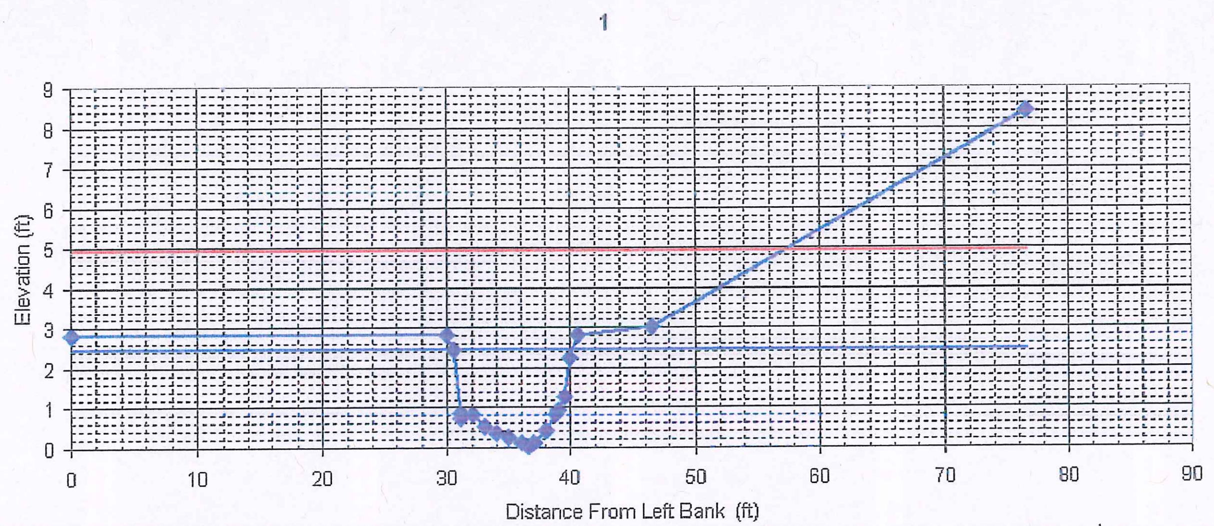
Notes: Sunderland Brook - M01 - Segment B

Cross Section



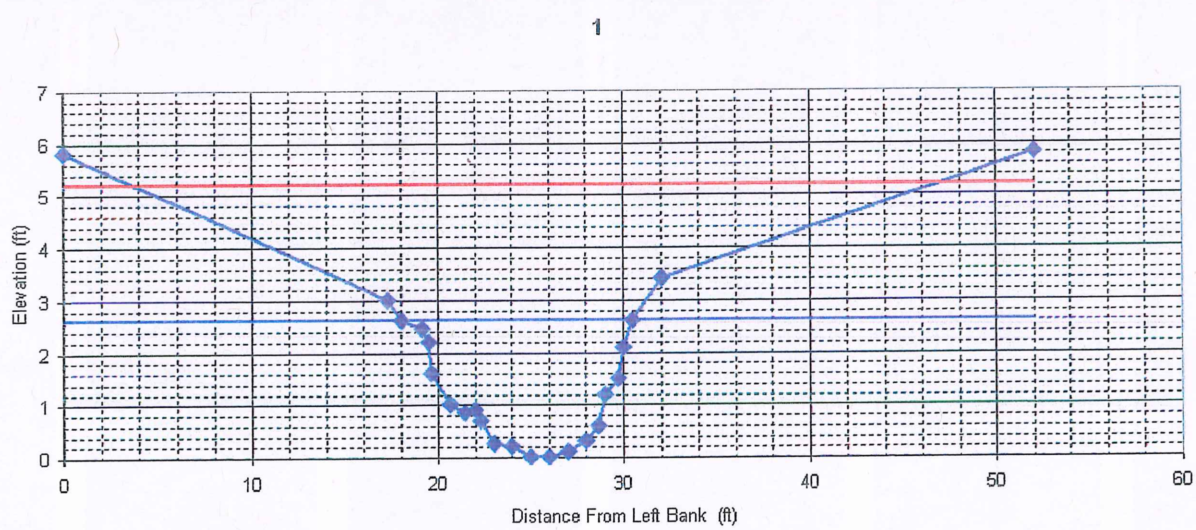
Notes: Sunderland Brook - M02

Cross Section



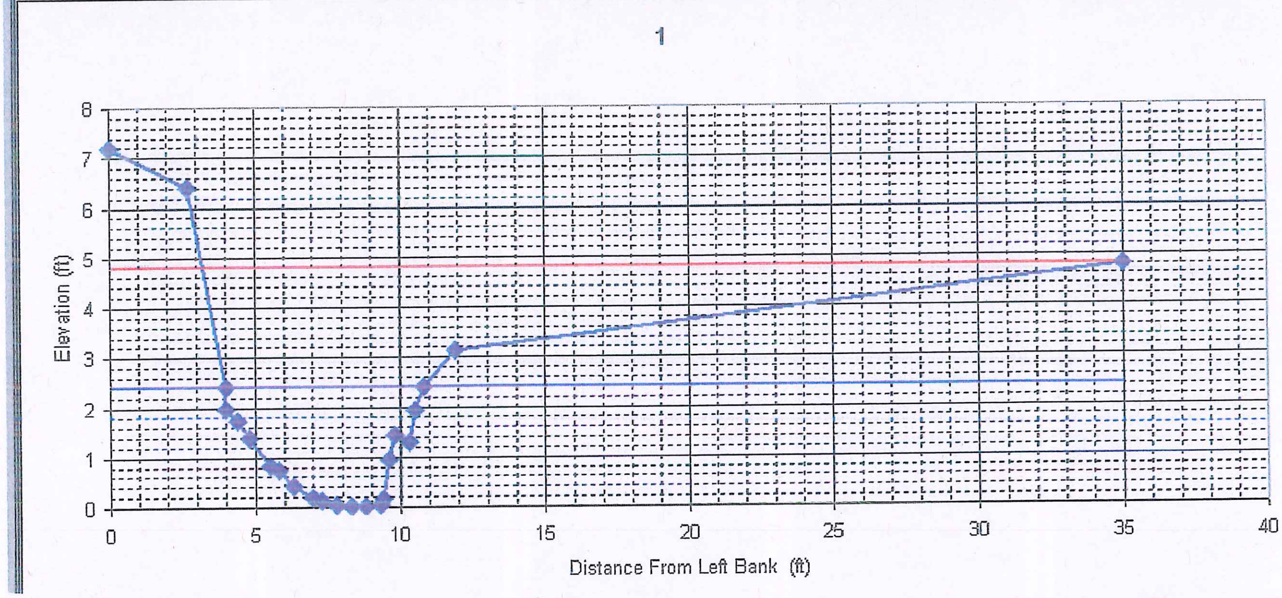
Notes: Sunderland Brook- M03

Cross Section



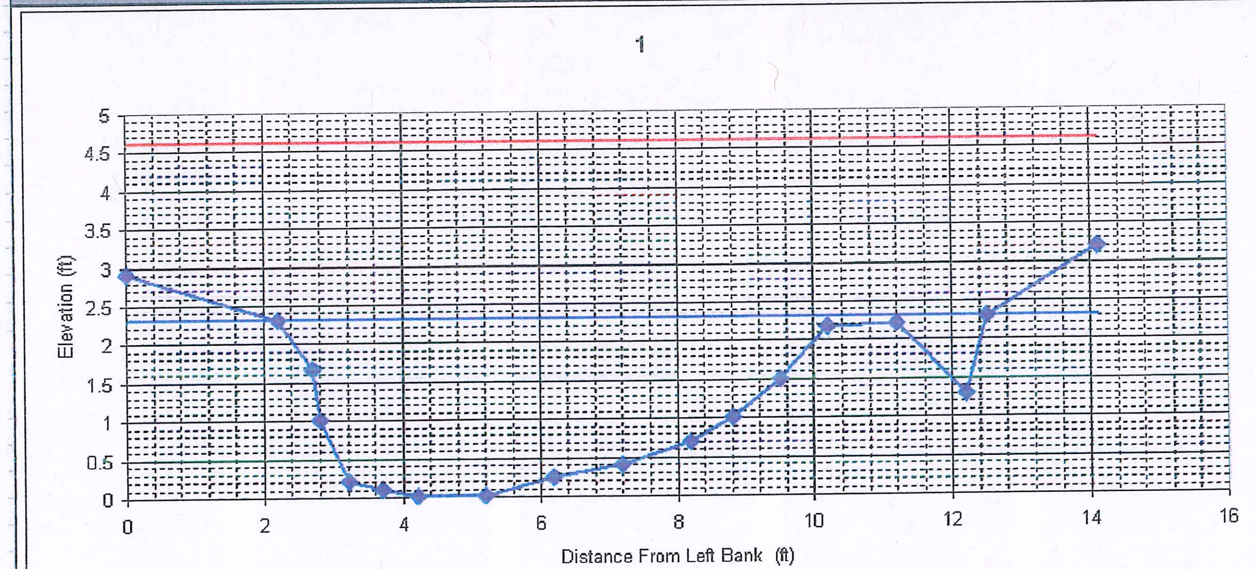
Notes: Sunderland Brook - M04

Cross Section



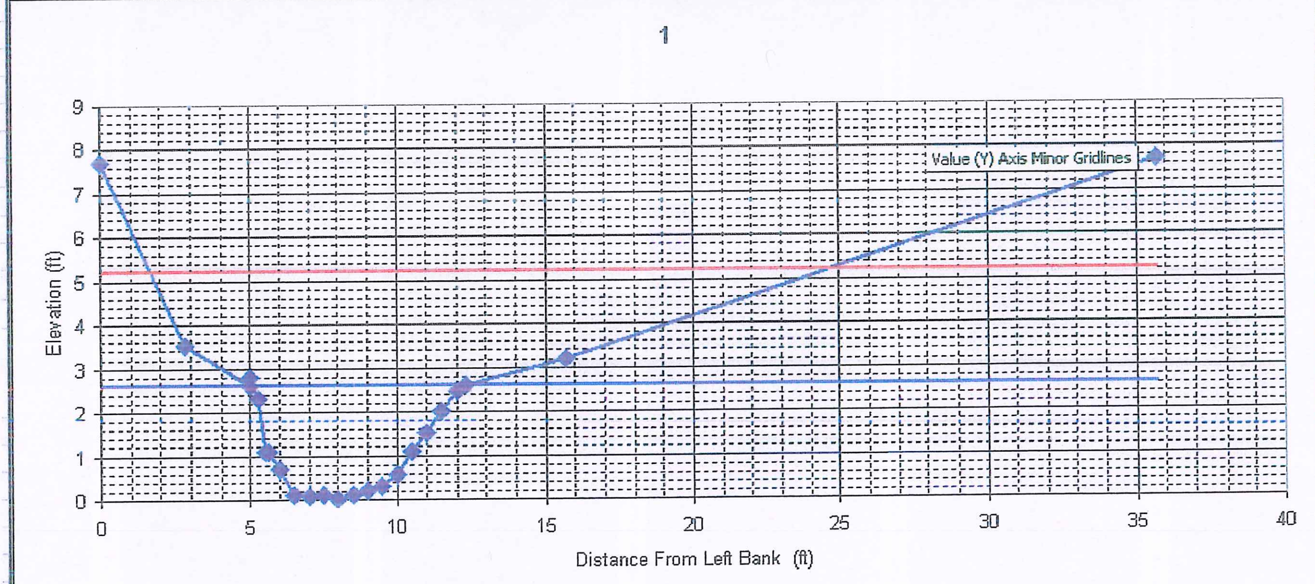
Notes: Sunderland Brook - M05

Cross Section



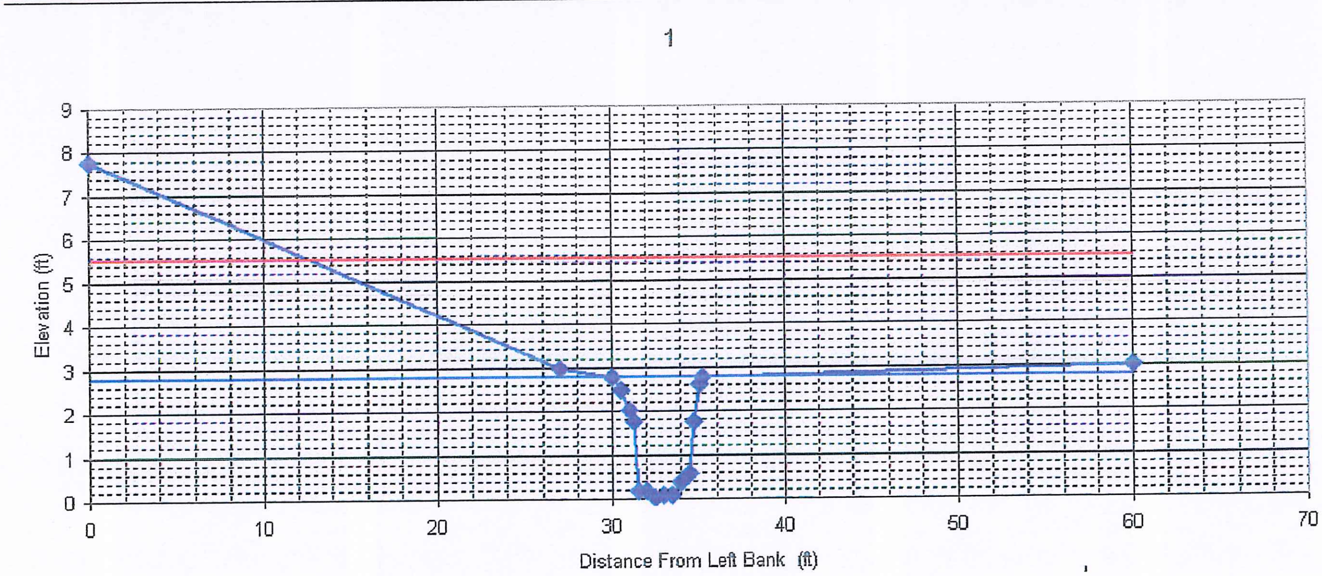
Notes: Sunderland Brook - M06

Cross Section



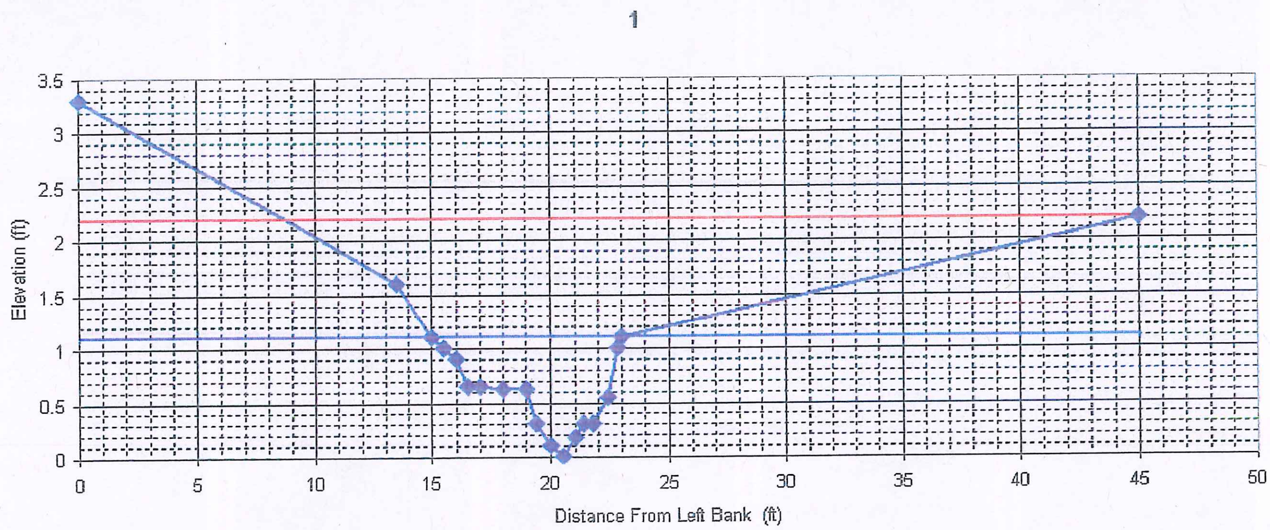
Notes: Sunderland Brook - M08

Cross Section



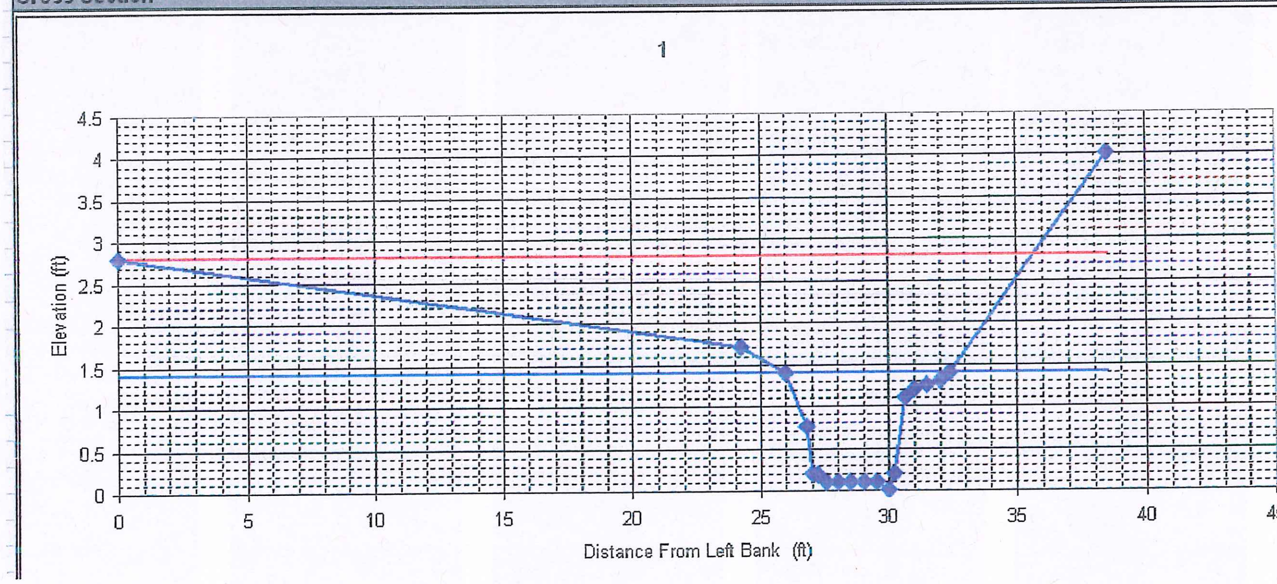
Notes: Sunderland Brook - M08 - T1

Cross Section



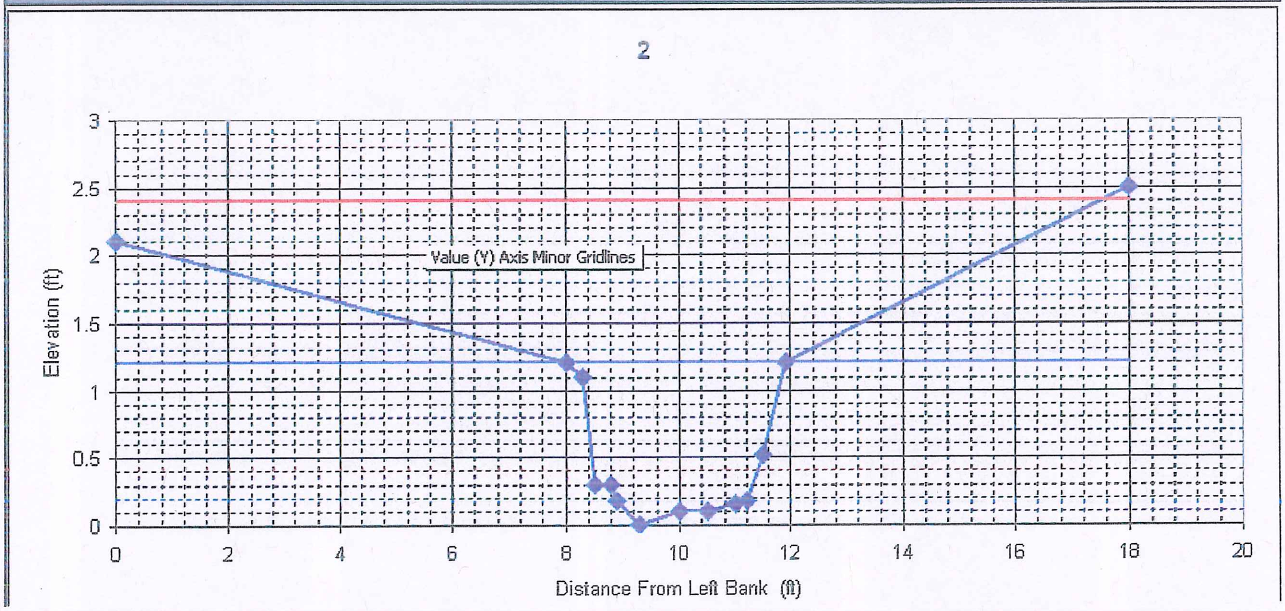
Notes: Sunderland Brook - M09 - X1

Cross Section



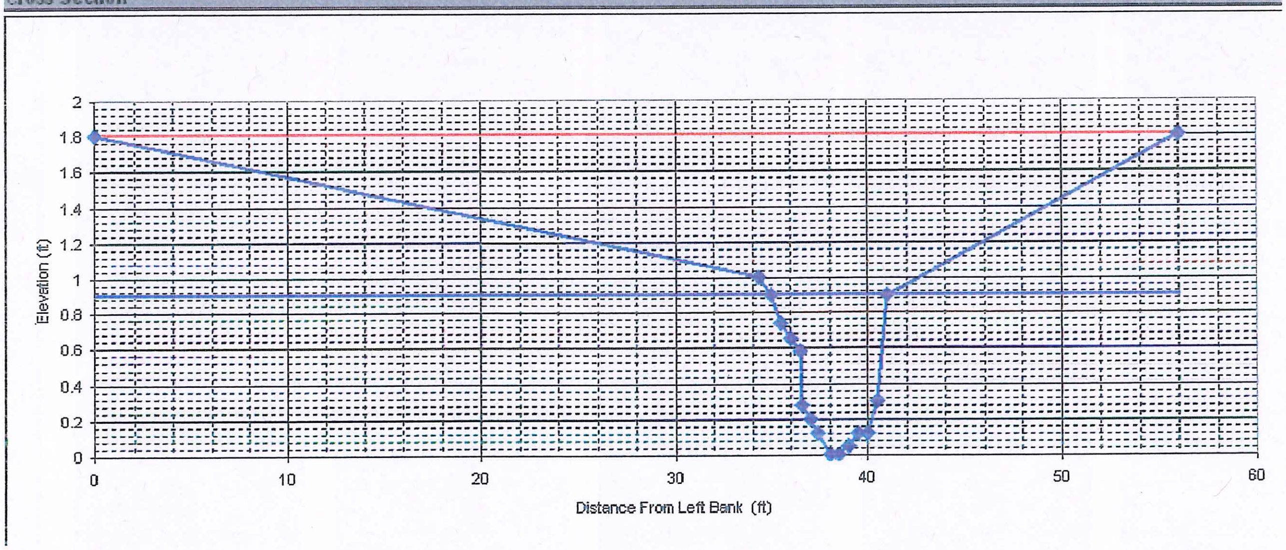
Notes: Sunderland Brook - M09 - X2

Cross Section



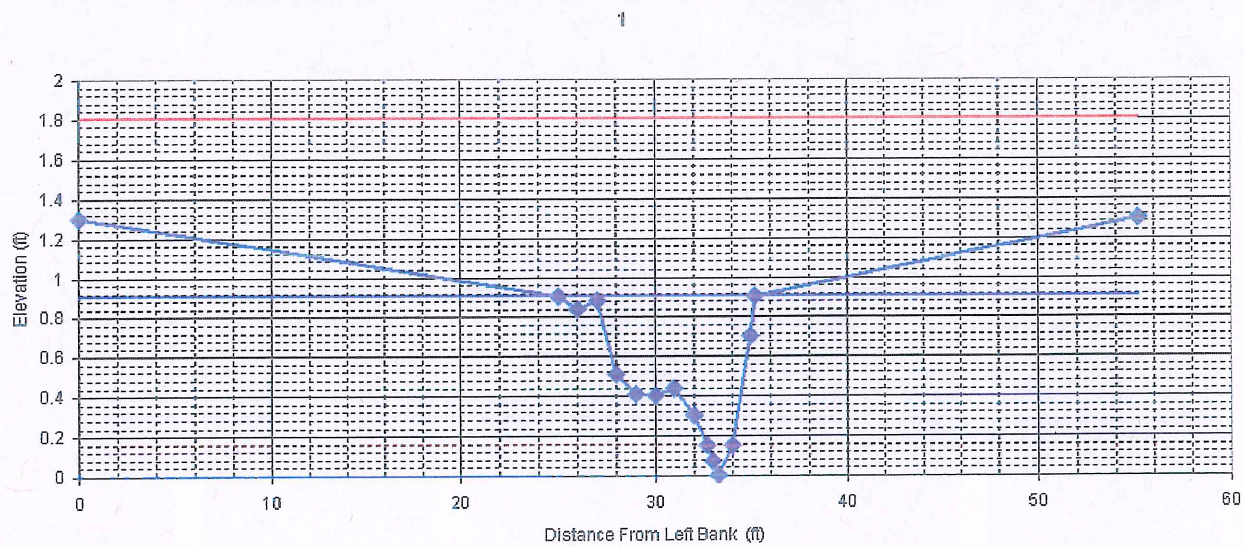
Notes: Sunderland Brook - M09 - T1

Cross Section



Notes: Sunderland Brook - M10

Cross Section



Appendix 3 - Reach Summary Statistics

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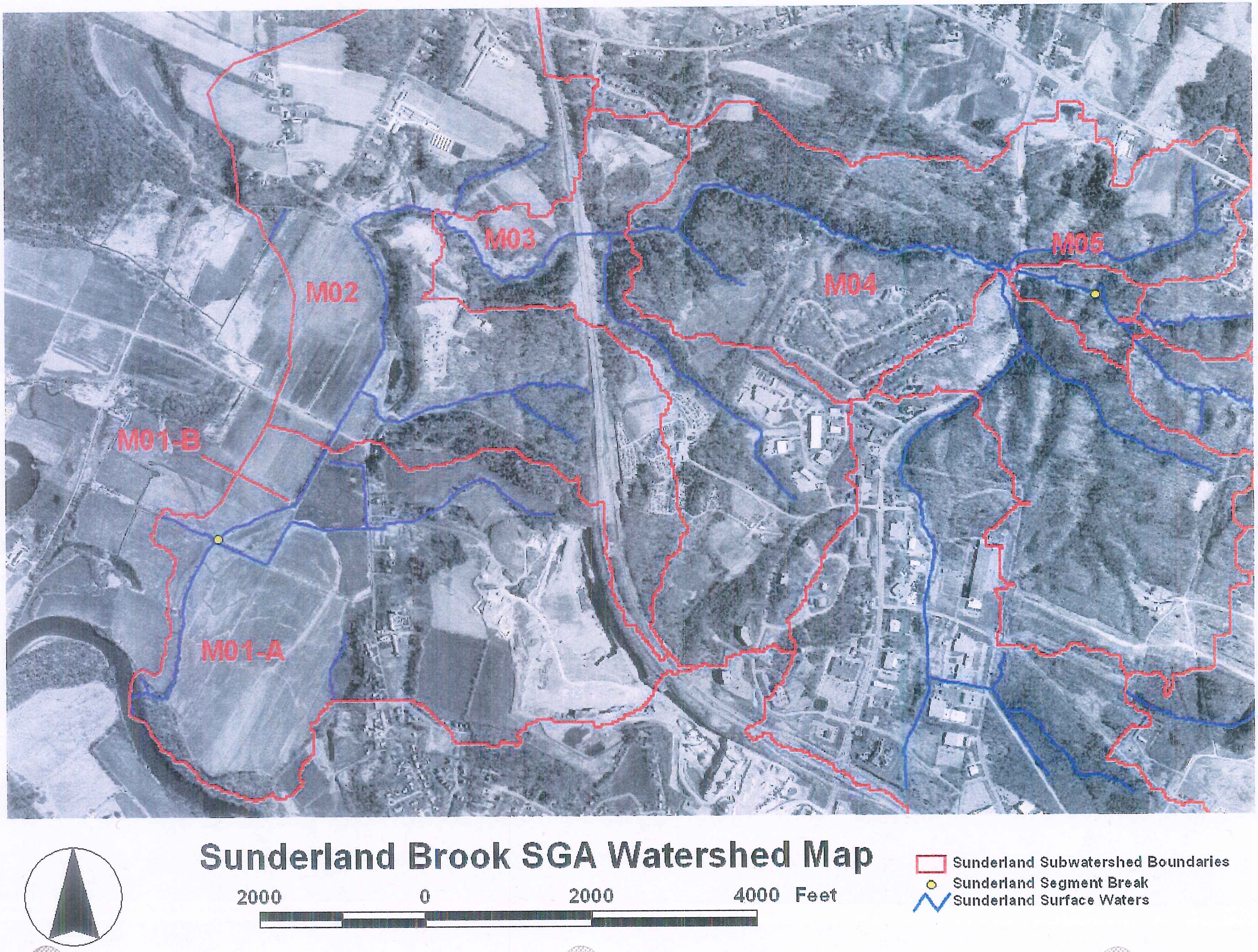
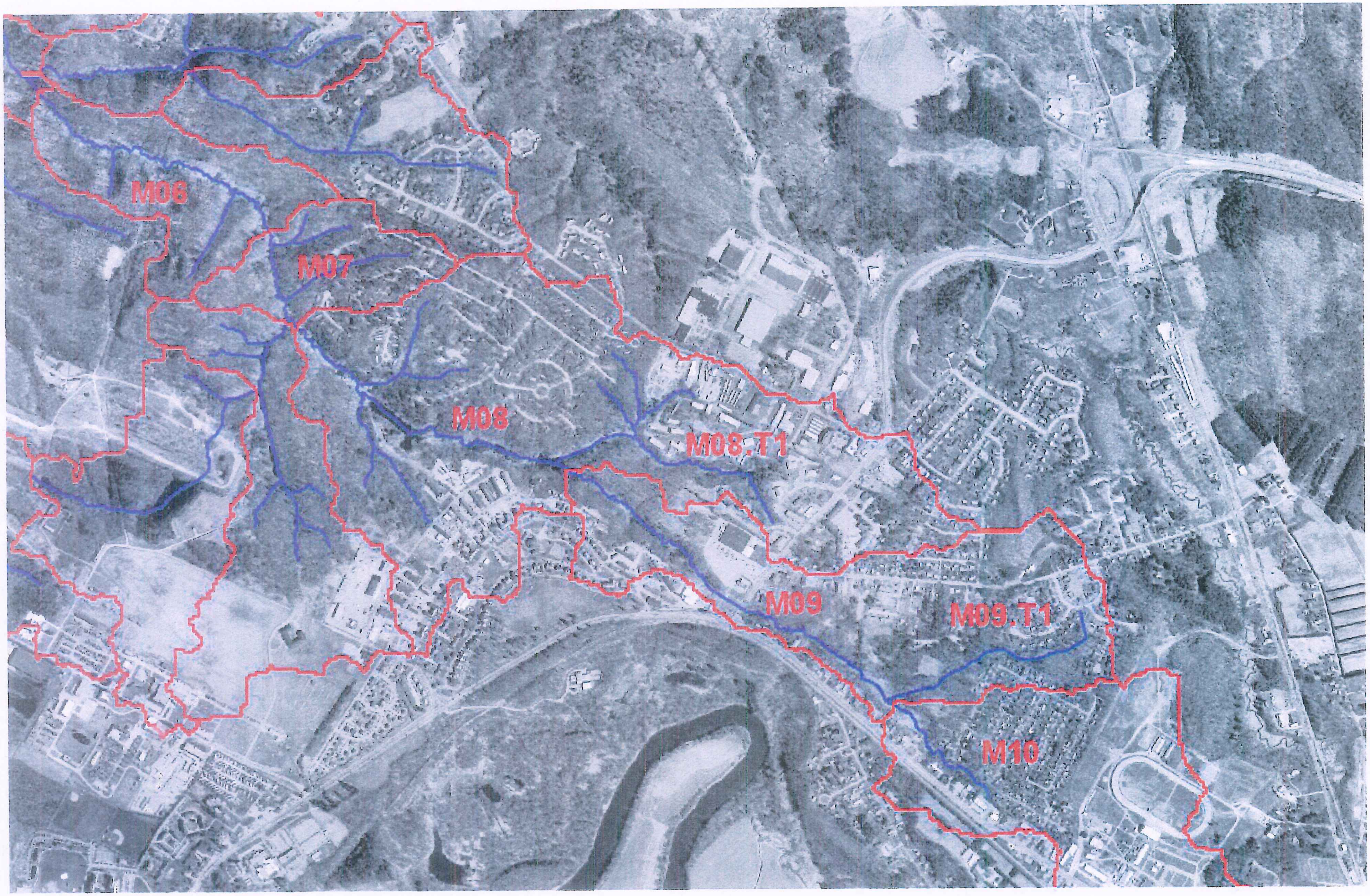
09/11/06

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	A	E	Sand	Plane-Bed	Yes	E	Sand	Dune-Ripple	0.25	poor	0.35	Fair	Very High
M01	B	E	Sand	Plane-Bed	Yes	E	Sand	Dune-Ripple	0.47	fair	0.49	Fair	Very High
M02		E	Sand	Dune-Ripple					0.30	poor	0.39	Fair	Very High
M03		E	Sand	Dune-Ripple					0.50	fair	0.56	Fair	Very High
M04		E	Sand	Dune-Ripple					0.60	fair	0.51	Fair	Very High
M05	A	E	Sand	Dune-Ripple					0.62	fair	0.66	Good	High
M05	B	A	Bedrock	Cascade					NE	NE	NE	NE	NE
M06		E	Sand	Plane-Bed					0.73	good	0.64	Fair	Very High
M07		NE	NE	NE					NE	NE	NE	NE	NE
M08	A	E	Sand	Dune-Ripple					0.60	fair	0.63	Fair	Very High
M08	B	NE	NE	NE					NE	NE	NE	NE	NE
M09		E	Sand	Plane Bed	Yes	E	Sand	Dune-Ripple	0.41	fair	0.50	Fair	Very High
M10		C	Sand	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.32	poor	0.35	Fair	Very High
								Mean:	0.48		0.51		
								Max:	0.73		0.66		
								Min:	0.25		0.35		

* STD = Stream Type Departure
† = Assessed Reference Condition Prior to Stream Type Departure
NE = Not Evaluated


M01-A
M01-B
M02
M03
M04
M05
Sunderland Brook SGA Watershed Map
2000
0
2000
4000 Feet
Sunderland Subwatershed Boundaries
Sunderland Segment Break
Sunderland Surface Waters



Sunderland Brook SGA Watershed Map