Fitzgerald Environmental Associates, LLC.

Applied Watershed Science & Ecology

Johnnie Brook Watershed Report: Phase 1 and 2 Stream Geomorphic Assessment Summary

August 24, 2007

Introduction:

Johnnie Brook was identified for assessment during 2005 as part of a joint UVM-ANR research project to assess the impacts of stormwater runoff on geomorphic stability in small watersheds in Chittenden County (Fitzgerald, 2007). Due to its rural setting and an established UVM water research site within the basin, Johnnie Brook reaches were chosen as reference sites for reaches in stormwater impaired watersheds in the Burlington area. The assessments for the Johnnie Brook watershed, which included a total of 11 Phase 1 reaches and Phase 2 reaches/segments, were carried out by Evan Fitzgerald and the UVM field crew in August 2005. Fitzgerald Environmental Associates, LLC. was retained by the ANR River Management Program in 2007 to organize and review the data and produce a summary report of the Phase 1 and 2 assessments.

The following is a documentation of the key geomorphic processes and adjustments occurring in the Johnnie Brook watershed at the reach scale. The intent of this documentation is twofold: 1) concisely summarize Johnnie 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 1 and 2 data in the DMS, and the SGA watershed mapping, this documentation also provides explanation for questions that may arise concerning discrepancies in the data. At the end of each reach or watershed zone 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 notes and other relevant information for the Phase 1 and 2 databases. Plots for each channel cross-section measured during the Phase 2 analysis are provided in Appendix 2. Reach summary statistics and maps are found respectively in Appendices 3 and 4.

Johnnie Brook Watershed Setting:

Johnnie Brook is drained by a south to north flowing watershed which spans the towns of Hinesburg and Richmond. The overall slope of the channel network from headwaters to outlet at the Winooski River is 3.1%, reflecting the high gradient nature of many of the reaches. The surficial geology of the basin is diverse. Like many of the small basins in Chittenden County which were historically affected by Lake Vermont and the Champlain Sea (Wright, 2003), the parent material in the Johnnie Brook basin is composed of a mixture of alluvial, till, and lacustrine substrates. In addition to the alluvial valley associated with the Winooski River floodplain, one wide alluvial valley with depositional channels is found along the channel network around the crossing of the Richmond-Hinesburg Road. Above this alluvial valley, a series of sediment transport channels are found within confined valley settings. These zones are characterized by steep valley side slopes composed of glacial till and occasionally bedrock substrate. Above these confined valley settings, another area of alluvial parent material (Segments M08-B and M09) is found before a final steepening of the channel where the headwaters are found. The drainage area of the basin is approximately 6.5 square miles, and land cover is predominately second-growth forest and agriculture with some areas of low density residential development.

During the Phase II field assessments of the Johnnie Brook watershed, six distinct zones were observed with respect to natural topographic and geologic characteristics, as well as human impacts and the presence of beaver activity. Below is a summary of the reaches assessed for Phase II data during summer 2005 within each of these watershed zones. Stream type departure (STD) information is found within each reach summary, and a project identification discussion is included for those reaches which STD was observed.

Winooski Valley Zone (M01):

Reach M01 is found within the historic Winooski River floodplain which is characterized by alluvial soils and frequent flooding. This reach has been impacted by historic agricultural land use, include historic channel straightening and disturbances to the buffer and bank vegetation from the M01-M02 reach break down to the outlet. The current channel conditions remain in an incised state as the channel begins to redevelop sinuosity. It is important to note that the Phase 1 analysis of this reach did not extend to the Winooski River, but stopped approximately 1,700 feet short of the confluence. However the Phase 2 field assessment of this reach did extend to the confluence. This discrepancy has been noted in the DMS and any future analysis of the Johnnie Brook watershed should consider the difference in watershed size and channel length for this reach.

Reach Description:

Reach M01 is found from the outlet at the Winooski River up approximately 3,443 feet to a change in valley confinement as the channel enters a heavily wooded area. This reach has E-type geometry (Rosgen, 1994) with gravel substrate, riffle-pool bedform (Montgomery and Buffington, 1997) and a channel slope of 0.6 %. Today's channel conditions have resulted from an evolution of channel planform and slope, and much of the reach is now in the beginning stages of adjustment and stabilization (stage III of channel evolution). Significant bank erosion was observed in the lower part of the reach near the outlet (Figure 1) where the channel is influenced by the backwater effect of the Winooski River. In this area the channel is cutting through the historically aggraded floodplain of the Winooski River. One constricting bridge (VAST trail) found mid-reach just upstream of the cross-section station is causing significant scour and planform change above and below (Figure 2).

Figure 1. M01 bank erosion near outlet

Figure 2. Bridge constriction in M01

Preliminary Project Identification:

Efforts to actively reestablish the depositional floodplain areas associated with the reference conditions of reach M01 are not recommended because of the advancing stage of channel evolution in this reach. Reestablishment of native vegetation on the northern side of the channel in the lower reach would help moderate summer stream temperatures and should be considered. The VAST bridge has severely constricted channel and floodplain width and has created to a large scour pool below the bridge, as well degraded habitat conditions for approximately 200 feet downstream of the constriction. Above it, moderate aggradation of coarse gravel is occurring which is also degrading the habitat conditions. Although the reconfiguration of this bridge in the short term may not be feasible, long-term restoration planning for lower Johnnie Brook should include the removal or redesign of this structure to improve geomorphic stability and habitat conditions.

Foothills Zone (M02 to M04):

A sharp change in slope is found at the M01-M02 reach break at the edge of the alluvial Winooski Valley. From this point west up to a second alluvial valley at Reach M05, the Johnnie Brook channel is found in undulating topography which includes a diversity of valley and channel forms. B and C-type channels are found in confined and unconfined settings, and geomorphic and habitat conditions are good and reference in the absence of significant human impacts. Channel slopes range from 2 to as high as 7% in areas where multiple cascades are found. Stream buffer and corridor conditions in this zone are excellent and provide shading and organic inputs for the rich macroinvertebrate community found in these reaches. Due to the reference conditions observed in this watershed zone, no project identification summaries have been included.

Reach Descriptions:

Reach M02 is found from the break in slope up to a change in buffer conditions from forested to herbaceous and shrub-sapling. This reach has a length of 1447 feet with an overall channel slope of 3.6% which supports a stable step-pool system with cobble substrate (Figure 3). Four natural grade controls (Figure 4) were noted within this reach. Macroinvertebrates sampled as part of an on-going UVM research project indicate a rich community of sensitive species (e.g., high EPT index; Parker, 2007).


Figure 3. M02 cross section


Figure 4. Grade control mid-reach in M02

Reach M03 is found from the change in buffer conditions up to a 20 foot waterfall found upstream in Reach M04. M03 has an overall channel slope of 1.5%, but has been divided into two segments to reflect changes in confinement and bedform. Segment A has a channel length of approximately 1100 feet with C-type geometry and riffle pool bedform (Figure 5). Buffer conditions on the right bank have been impacted by historically used hay fields, however no evidence of active cutting was observed during August 2005. Segment B has a length of 2030 feet with B-type channel geometry and plane bedform (Figure 6). No significant corridor encroachments or buffer impacts were observed in this segment, and there are no natural grade controls. Good and reference conditions were noted for geomorphic stability and habitat in this reach, and channel evolution was assessed as stage I.


Figure 5. Riffle-pool bedform in Segment M03-A


Figure 6. Plane bedform in Segment M03-B

Reach M04 is found from a 20 foot waterfall up to a sharp break in slope south of a 90 degree bend in Kenyon Road where the channel enters a wide alluvial valley to the west (Reach M05). Reach M04 has a channel length of approximately 1790 feet and includes a wide diversity of channel forms due to changes in topography. Although the channel has an overall channel slope of 7%, approximately 90% of the vertical drop is found along four short cascades equally spaced along the reach. The largest of the four cascades is found approximately 200 feet east of Kenyon road and has a vertical drop of 50 feet (Figure 7). In between the cascades, the channel is found in an unconfined setting with slopes ranging from 1.5 to 2%. The resulting form is a C-type channel with plane bedform and some riffle-pool forms where the slopes are mild (Figure 8). With the exception of the upper extreme of M04, the corridor and buffer conditions of this reach are excellent and no historic impacts to the channel boundary conditions were observed. Reference geomorphic stability and habitat conditions are found in this reach.


Figure 7. Large cascade in upper M04


Figure 8. Dominant plane bedform in Reach M04

Fays Corner Valley (M05):

A sharp change in slope occurs at the reach break between M04 and M05, and the valley widens significantly in reach M05 northeast of Fays Corners. M05 is found from the Kenyon Road bend up to approximately 1300 feet upstream of the Richmond-Hinesburg Road crossing and has a channel length of approximately 4000 feet. In M05 the valley slope lessens to approximately 1.5%, with the alluvial setting and wide valley having supported a channel with meandering planform and riffle-pool bedform under reference conditions. However, historic straightening (~60% of reach) has caused a STD for bedform to planebed features. A single cross section measurement was taken for this reach above the road crossing, and the geometry at this site suggests a G-type channel (Figure 9). However much of the middle and lower parts of the reach have redeveloped C-type geometry with a reduced


Figure 9. Cross section in M05


Figure 10. Cross section in M06

floodplain area. Future assessment or restoration work in the watershed should note the need for additional cross-section measurements for this reach. One ten foot waterfall, found 400 feet above the road crossing, acts as a grade control for any adjustments occurring downstream.

Preliminary Project Identification:

In this depositional zone of the watershed the primary issue of concern should be (in the absence of current encroachment on the corridor) the protection of the corridor from future encroachment. Although the straightened channel through this alluvial valley is currently stable, the valley characteristics below the Hinesburg Road crossing (valley slope ~1%) make it susceptible to sediment deposition and planform adjustment if a large event were to occur. Currently there is no encroachment on the stream corridor, despite suitable land for development (e.g., flat with suitable soils for septic). Corridor protection efforts for this half-mile stretch of Johnnie Brook should define an adequate width for the stream corridor and ensure that no development is permitted within this zone.

Hinesburg Road Zone (M06 to M08-A):

Beginning just upstream of the waterfall in Reach M05 the valley walls begin to tighten and the channel enters a more confined setting along Hinesburg Road. From this point south along the road, the channel slope steepens (slopes range from 1.5 to 3.0%) and numerous sediment transport zones are found. B and C-type channel geometry with a wide range of bedforms were observed during the field assessments. Many areas of the stream corridor in this zone have been encroached upon by the road, its berms, and low-density housing stemming from the road. Significant impacts from agricultural land use in the corridor were noted in the upper segment of Reach M07 where the channel flows directly through a dairy farm.

Reach Descriptions:

Reach M06 is found from approximately 800 feet upstream of the waterfall in M05 to the confluence with a tributary entering from the east. This reach has been studied extensively by a separate UVM research team (RAN program) due to its rural setting, coarse substrate and stable geomorphic conditions. The channel slope in this reach is 2.1% and the reach exhibits B-type geometry with a mixture of riffle-pool and plane bed morphology (Figure 10). Both the Phase 1 and the Phase 2 assessments revealed that extensive historic straightening had occurred in this reach, especially in the lower section. The channel has since recovered and has redeveloped a narrow floodplain at a lower elevation (stage V of channel evolution). Currently, there is significant development along and within the corridor on the left side, however there remains a vegetated buffer that provides adequate shading and organic inputs. Macroinvertebrates sampled as part of the RAN research indicate a healthy biotic community. RGA and RHA scores were in the good range for this reach.

Figure 11. Cross section in lower M07-A

Figure 12. Cross section in lower M07-B

Reach M07 is found from the tributary confluence up to a sharp bend upstream of both farms found to the east of Hinesburg Road. This reach has a channel slope of 2.8%, but the gradient and resulting bedform vary along the reach. The reach has been divided into two segments to account for this variability and the change in buffer conditions above the Hinesburg Road crossings.

Segment A is found from the M06 break up to the road crossing, and has a channel length of approximately 3200 feet. The slope of this segment is slightly greater than the average reach slope, and B-type channel geometry with step-pool bedform was observed (Figure 11). Approximately 20% of the reach length is affected by road encroachment on the left bank, which has resulted in areas of bank failure nearby. Two small grade controls (ledges) were observed in the lower part of the reach. Good conditions were noted for geomorphic stability and habitat, and channel evolution was assessed as stage I.

Segment B is found from the downstream road crossing up to the previously described sharp bend. The lower section of this segment is significantly impacted by two stressors: 1) the encroachment and armoring associated with Hinesburg Road; 2) the lack of buffer and grazing cattle impacts where the channel passes through a dairy farm. Despite these impacts the channel is redeveloping stability (stage IV of channel evolution) and maintains C-type channel geometry (Figure 12). However the impacts from channel straightening have led to

Figure 13. Cross section in lower M08-A

Figure 14. Bank erosion in upper M06

a STD from riffle-pool to plane bedform. Geomorphic stability and habitat conditions were assessed as fair for Segment B.

Segment M08-A is a high-gradient reach found downstream of an area of beaver ponding immediately above Old Farm Road. This reach has a length of approximately 1590 feet with a channel slope of 1.5%. The upper part of this segment has been affected by beaver activity in the past as evidenced by aggradation and a large broken dam immediately below the Old Farm Road crossing. The middle and lower parts of this segment have been impacted by historic straightening and bank armoring, and the channel is now in a state of recovery of equilibrium conditions (stage V of channel evolution). Current channel conditions support a riffle-pool morphology (Figure 13) with good geomorphic stability and physical habitat.

Preliminary Project Identification:

Due to the presence of housing in the corridor of Reach M06, an area of severe bank failure should be monitored in the future to avoid additional property losses. The area of bank failure is found approximately 350 feet upstream of the cross section location on the left bank (Figure 14). Quasi-equilibrium conditions have become established in this reach and it is unlikely that drastic adjustments to planform will occur in the future. However, during heavy rainstorms in July 2005 it was observed that this area of Johnnie Brook has high energy and sediment transport capacity; the continued erosion of this bank and terrace could jeopardize the shared driveway in this neighborhood and increase sediment loading to downstream reaches.

Immediately upstream of the second Hinesburg Road crossing the channel is impacted by cattle from a large dairy farm. Along this farm there is no fencing to keep the cattle away from the channel, which has increased bank erosion and likely been a source of nutrient and bacterial inputs to Johnnie Brook. This is the only area of Johnnie Brook that is significantly impacted by grazing cattle and it is recommended that it be considered a priority for fencing the animals away from the channel.

Swamp Road Zone (M08-B & M09)

A second, upland alluvial valley occupies a small portion of the upper Johnnie Brook basin. This area, found from Old Farm Road up to the Magee Road crossing, is characterized by a wide valley (1000 feet wide in some areas) made up of mixture of coarse alluvial substrate and glacial till. The channel slopes in this watershed zone are all below 1.0%, with reference channel conditions supporting C and E-type geometry with sand and fine gravel bed substrate. Due to the depositional nature of this valley, it is likely that the channel through this valley once had dynamic meandering planform. However agricultural impacts to the channel boundary conditions (e.g., armoring) and planform (e.g., straightening) have significantly changed the channel configuration, especially in Reach M09. Significant beaver activity resulting in impoundment of the channel was noted during the field assessments and therefore no Phase 2 data was collected for either reach.

Headwaters Zone (M10 & M11):

Above the Magee Road crossing there is a significant change in valley slope within the headwaters zone of the basin. Upstream of this slope change, reference channel conditions begin to change from depositional reaches to transport reaches in a more confined valley setting. With the exception impacts associated with the Magee Road crossing, the human impacts in this zone are limited to legacy impacts from historic forestry practices. C and B-type channel morphologies are found within this zone.

Figure 15. Cross section in Reach M10

Figure 16. Dry channel in Reach M11

Reach M10 is found from just above the Magee Road crossing up to approximately 500 feet upstream of the confluence with a tributary entering from the east. This reach has a channel length of 3466 feet and a slope of 2.7%. C-type channel geometry and riffle-pool bedform was noted in the lower reach where the valley is less confined (entrenchment ratio > 10). Four large beaver dams were noted in the upper section of this reach where the valley widens and the channel slope lessens. Stable geomorphic conditions and reference habitat conditions were observed in this reach, and no restoration project areas have been identified.

Reach M11 is a headwaters reach located above the area of beaver ponding in M10. The channel slope increases significantly in this reach (>10%), and much of the coarse-bottomed channel was dry during the field visit in August 2005. This reach was not assessed during the field effort because its small size was not suitable for scope of the research project. However, the extreme lower section of reach was walked and appeared to be in reference condition.

Conclusions:

The Johnnie Brook watershed supports many stream reaches in good to reference conditions, particularly in areas where the topography is steep enough to have limited historic impacts to the channel boundary conditions (e.g., straightening). Three of the lower reaches (M02, M03-B and M04) are characterized by steep channel slopes and narrow valley conditions at lower elevations (300 to 500 feet) that can be compared to similar stream types in the larger stormwater impaired watersheds in Chittenden County. Impacts from encroachments (e.g., houses in the corridor) are minimal and the large scale stressors of altered hydrology are nearly absent. Therefore, these reaches are recommended for comparison with high-gradient stormwater impaired reaches with drainage areas greater than five square miles.

Historic impacts to the Johnnie Brook channel conditions from agricultural land uses are still pervasive in many reaches. These impacts are severe in reach M05 and segment M07-B. Although there have been limited alterations to hydrology upslope of these areas, channel straightening has had the effect of initiating channel evolution processes that are similar to those observed in stormwater impaired reaches in the Burlington area. Incision, followed by widening and a redevelopment of sinuosity are the processes occurring in these reaches. Due to their altered conditions, these reaches are not recommended for comparison (as reference channels) with stormwater impaired reaches in Chittenden County.

Literature Cited:

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Montgomery, D. R., & Buffington, J. M., 1997, Channel-reach morphology in mountain drainage basins, *Geological Society of America Bulletin*, 109(5), 596-611.

Parker, S.P., 2007, The effect of stream geomorphic variability on macroinvertebrate communities in northwestern Vermont, UVM URECA! Poster Presentation, Burlington, Vermont

Rosgen, D. L., 1994, A classification of natural rivers, *Catena*, 22(3), 169 - 199.

Wright, S., 2003, Glacial geology of the Burlington and Colchester 7.5 minute quadrangles, Vermont Geological Survey, Waterbury, VT

Appendix 1

QA Notes For: **Johnnie Brook**
Data checked by Jared Carrano (5/29/07)

The questions raised in this Quality Assurance assessment are meant to address potential discrepancies within the data set, uncover data entry errors, or otherwise clarify and confirm those observations that might not have been expected. It is important to take into consideration how data might be viewed or interpreted by the myriad of users who are familiar with the science and protocols but may be unfamiliar with the assessed reaches. While providing notes and comments, try to anticipate the types of questions that may arise due to outliers and exceptions observed within the reach or segment. While attempting to clarify the data for those users wishing to utilize it years after collected, it's better to err on the side of making excessive comments than it is for them to be insufficient.

After reviewing the information noted, the consultant should update this document (preferably in a second color) with what steps, if any, were taken to address the comments/questions.

General:

When you update a project from "Old" status with the new FIT extension you should delete the older data so that there is only one set of data. When both old and new data exists simultaneously, an error will get generated in the QA step X.1. The easiest way to delete the old data is to hit the "Delete" button on the QA page. Please go back through for all the reaches where you noted "See new FIT data" and delete the old data.
Completed by Evan Fitzgerald (6/3/07).

Ph1 6.3 Channel Bars and 6.4 Meander Migration: These have been left blank for the entire project
Completed by Evan Fitzgerald (6/3/07).

Erosion Height and Beaver Dams: You have noted in the QC Comment report the actual heights and lengths for these fields for various reaches where the location was indexed but the associated height or length was not given. Was there a reason you did not go back and add these values into FIT? **Reaches: M01, M05 and M10**
Field sheets reviewed by Evan Fitzgerald and data added to FIT and re-uploaded (6/5/07)

Channel Evolution Model: This has been left blank for **Reaches: M02, M03, M04, M07A,**
Completed by Evan Fitzgerald (6/3/07).

Four of the reaches in this project have cross-sections that suggest stream types different from what has been selected. There are comments that explain that these x-sections are not representative, but no explanation is given as to why better cross-sections couldn't be taken. At the very least, this should be identified as a future need for this project. **Reaches: M05, M07B, M08 and M10**
Completed by Evan Fitzgerald (6/5/07).

No cross-sections have been uploaded to the DMS. This used to be something that was strongly encouraged, but it is now a requirement. If you can upload these to the DMS it would be very helpful.
Cross sections for all reaches uploaded in M01 and M02 locations on DMS (6/5/07).

When a reach cannot be assessed because it is impounded (for whatever reason) the protocol still calls for those out of channel parameters to be assessed (i.e. valley setting, buffers, encroachments, etc.). **Reaches: M09 and M11**
Data entered for Steps 1, 3, 4 & 5 (6/5/07).

Steep Riffles and Head Cuts: It appears that no steep riffles or head cuts have been indexed. If this is because the spatial location is not known you will have to provide a best guess location with FIT. This is the only way we can capture this information in the DMS. In the comments space in FIT you should note that this was a best guess as well as in the Step 5 comments.
Field sheets reviewed by Evan Fitzgerald and 3 steep riffles added to FIT for reaches M06 and M07-A and re-uploaded (6/5/07)

Reach By Reach

M02	There appears to be a data entry error in your cross section as the Recently Abandoned Floodplane is only 0.20', giving an incision ratio of 0.09. **Corrected by Evan Fitzgerald (6/5/07).** Check spelling of your comment in the narrative section. **Corrected by Evan Fitzgerald (6/5/07).**
M03 A	Comments say "Segment A is split with part of segment B." Does this mean that there should really be three segments? It is okay to use the same RGA data for multiple segments when similar, but the data should be entered into unique segments each with the relative spatial data. If this can be reconciled at this point, it should be. **Corrected by Evan Fitzgerald (6/5/07).** Why is the Riffle Type "Not Applicable" if the bedform is riffle/pool? **Corrected by Evan Fitzgerald (6/5/07).**
M03 B	The channel width for this segment is significantly larger than the up and downstream reaches/segments. Please re-evaluate this cross sectional data and determine whether you are confident with it. **Reviewed and comments included in Step 5 (6/5/07).**
M05	There is a huge incision ratio (>2.0) which should automatically score 7.1 as Poor. You say that the x-section is not representative of the reach, but is the incision ratio? Is there evidence that supports a less incised stream? **Reviewed and incision ratio revised to 1.0 by Evan Fitzgerald (6/13/07).** If a reach is plane bed due to straightening than the riffle type should be "eroded". **Corrected by Evan Fitzgerald (6/5/07).**
M07 A	A B channel should not have a sub-slope of b. Should be "none". **Corrected by Evan Fitzgerald (6/5/07).**
M08	The slope is in the C range and so there shouldn't be a sub-slope of b. **Corrected by Evan Fitzgerald (6/5/07).**

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 Johnnie Brook dataset, after the automated DMS QC and the subsequent 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.
  - 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: **M05 & M07-B**

    - 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 2) 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, no on-stream impoundments were noted in the Johnnie Bk watershed.
  - 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.
- *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 Johnnie Bk. watershed are caused primarily by: 1) historic agricultural impacts, 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 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, M05, M07-B & M08-A**
2. Reaches where alterations to planform have resulted from **beaver activity** include: **M08-B, M09, & M10**

- 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 Johnnie Brook.
  - Overall habitat assessment in E-type channels is difficult due to general lack of quality habitat associated with these sand-bottomed reaches, and alterations from beaver activity.

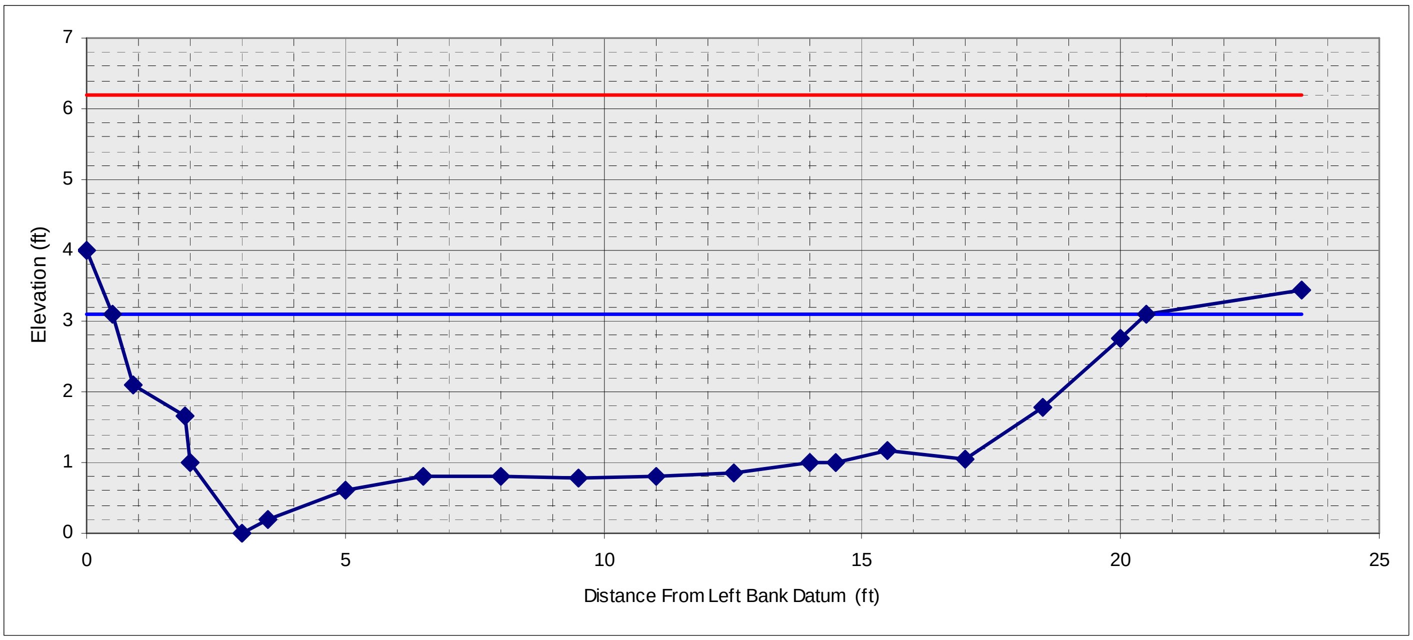
• *Step 7 – RGA:*

- Channel Degradation (7.1)
  - 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)
  - Aggradation and widening are the predominant adjustment processes occurring in the impacted reaches of Johnnie Brook. This can be explained by the historic alterations to the channel planform (e.g., straightening) and subsequent readjustment of channel width and slope as these reaches move through stages III and IV of channel evolution. Channel widths were 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 Johnnie Brook.

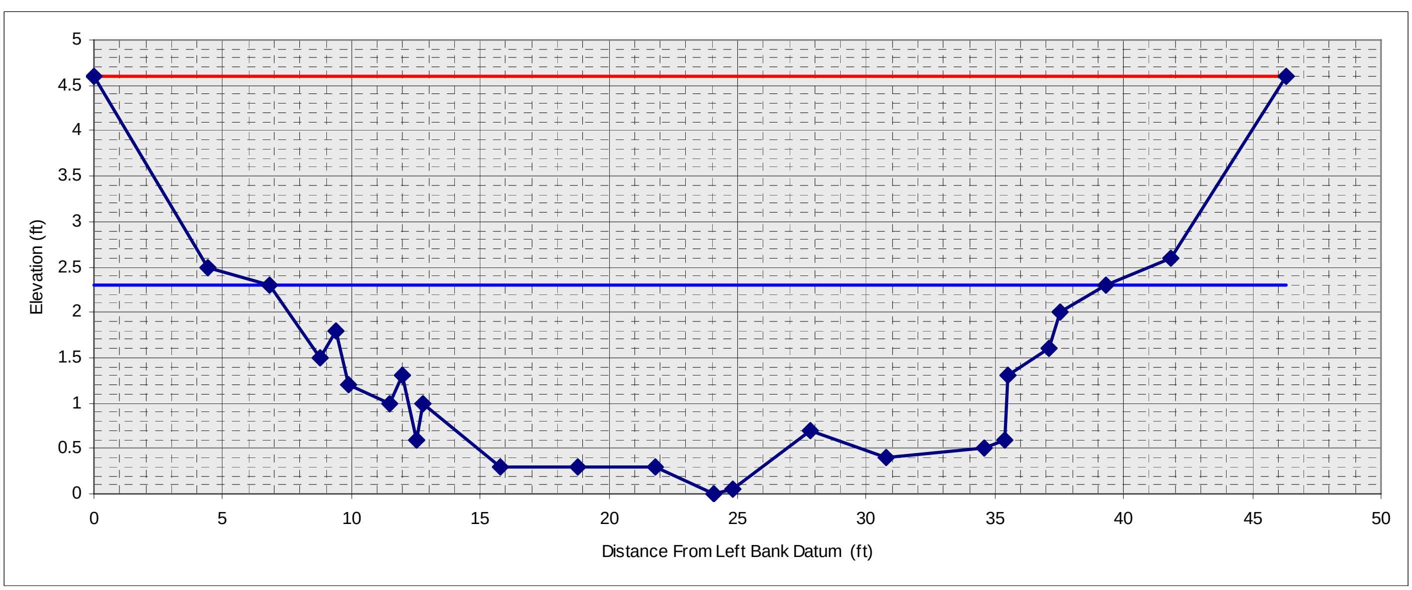
Appendix 2

Cross-sectional plots for Johnnie Brook reaches and segments 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 visible on plot). Reaches/segments with multiple cross sections are denoted by X1, X2, etc.

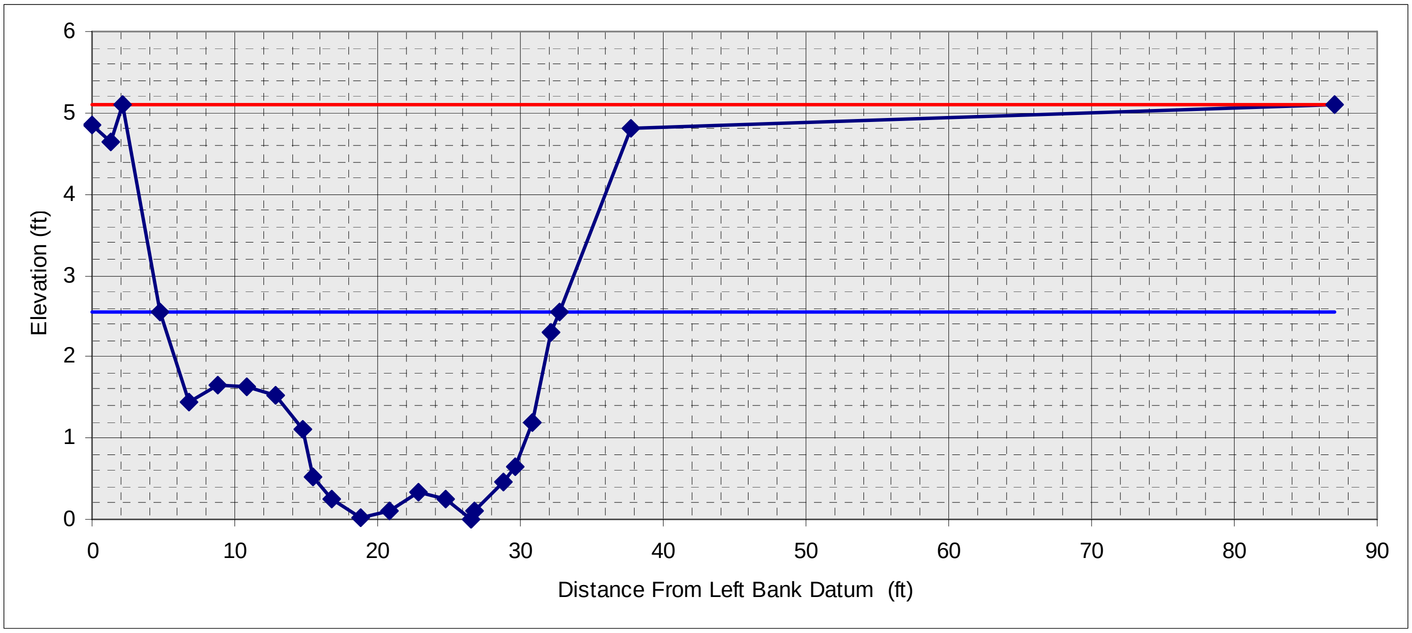
Reach M01



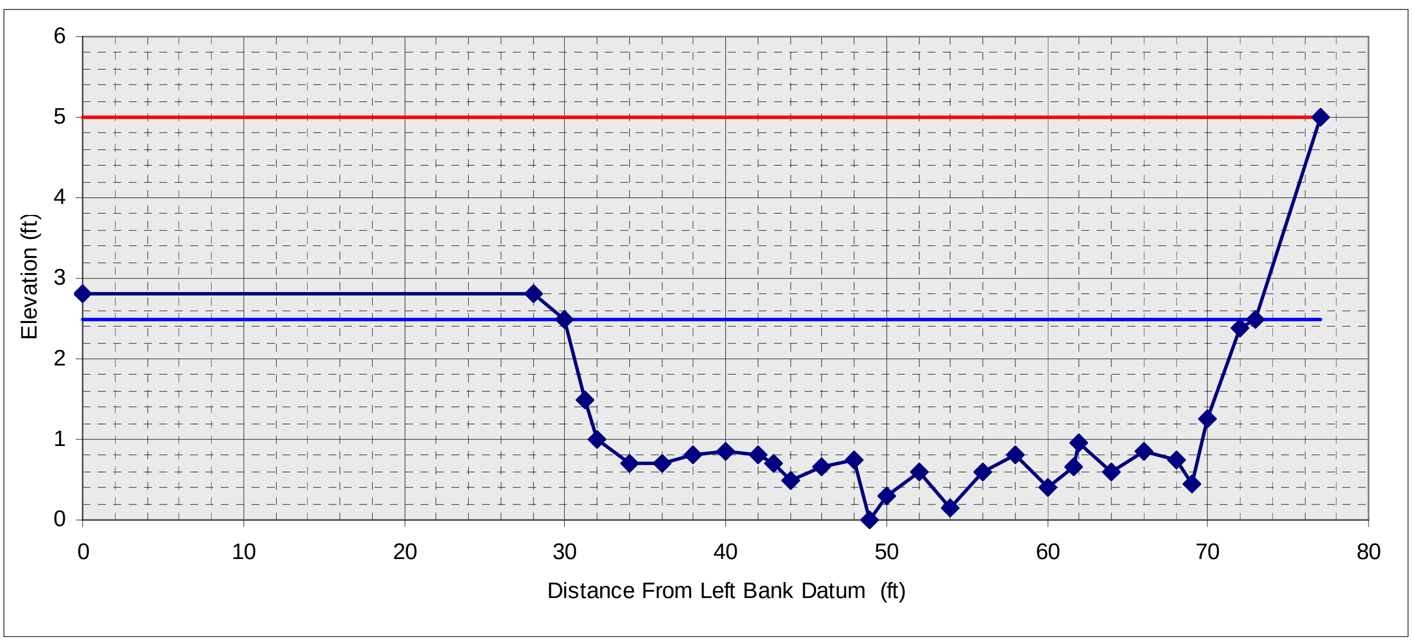
Reach M02



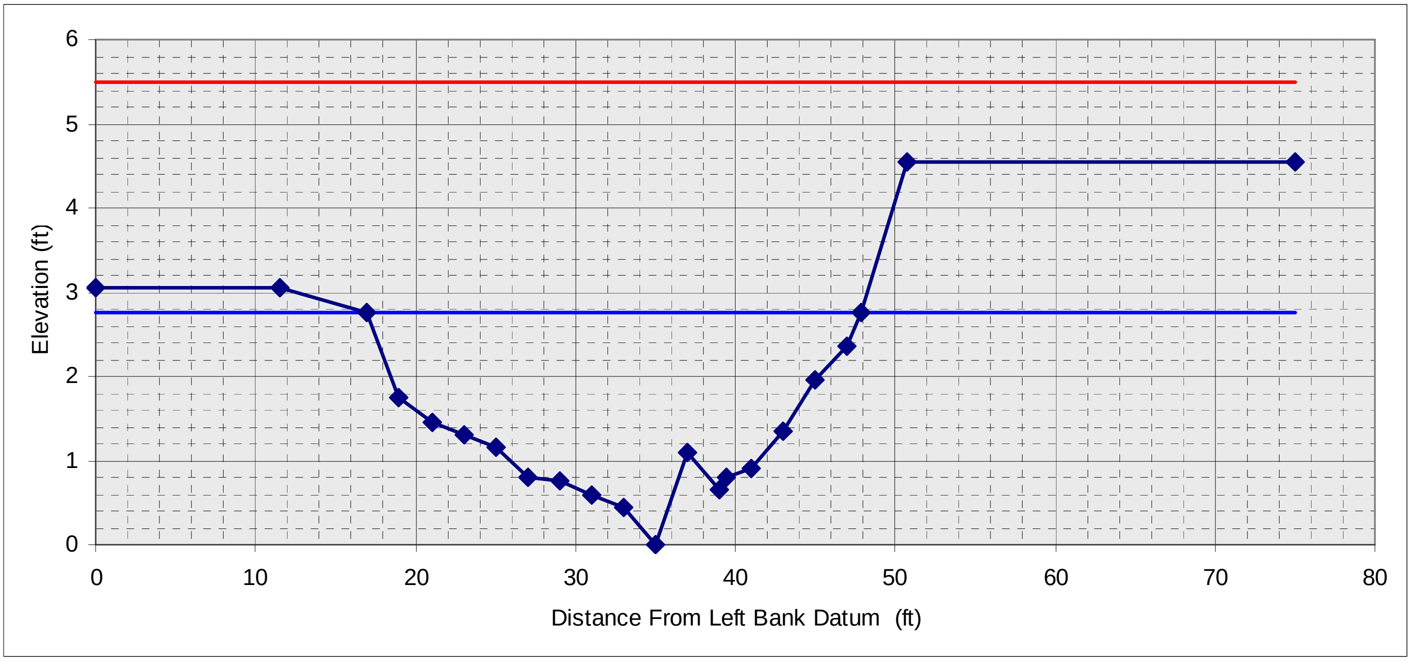
Segment M03-A



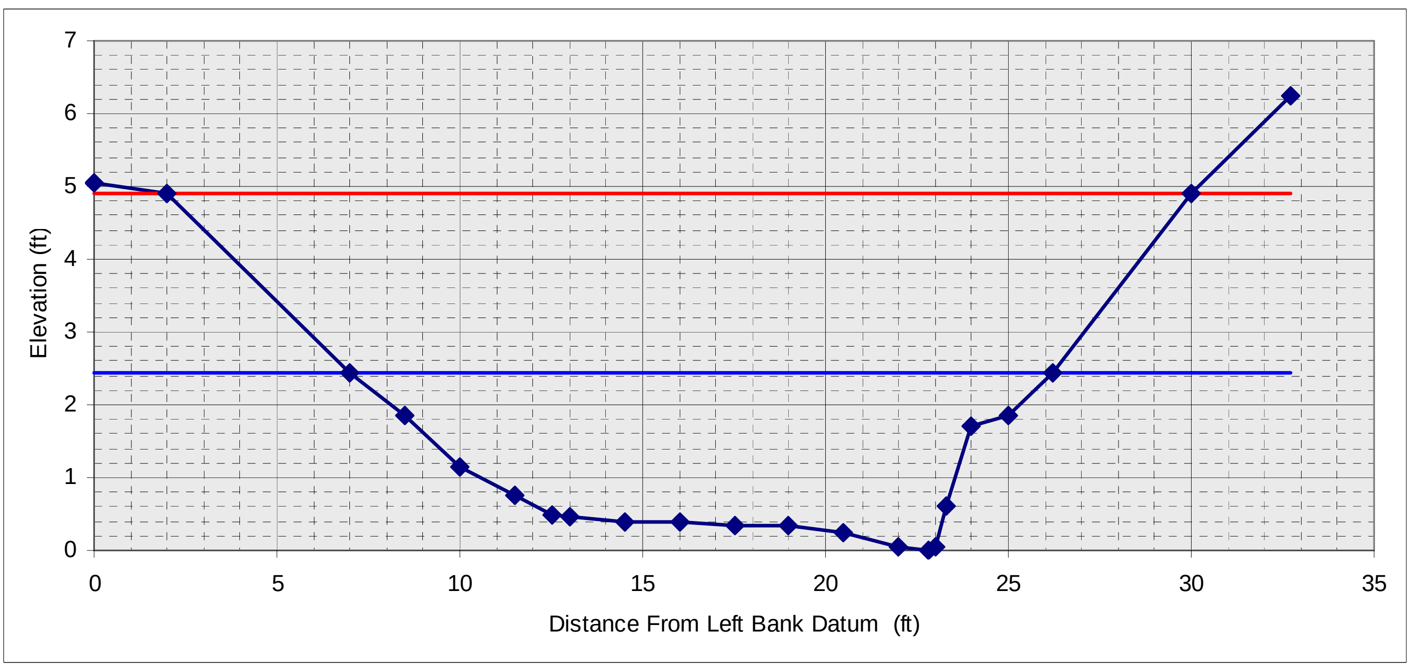
Segment M03-B



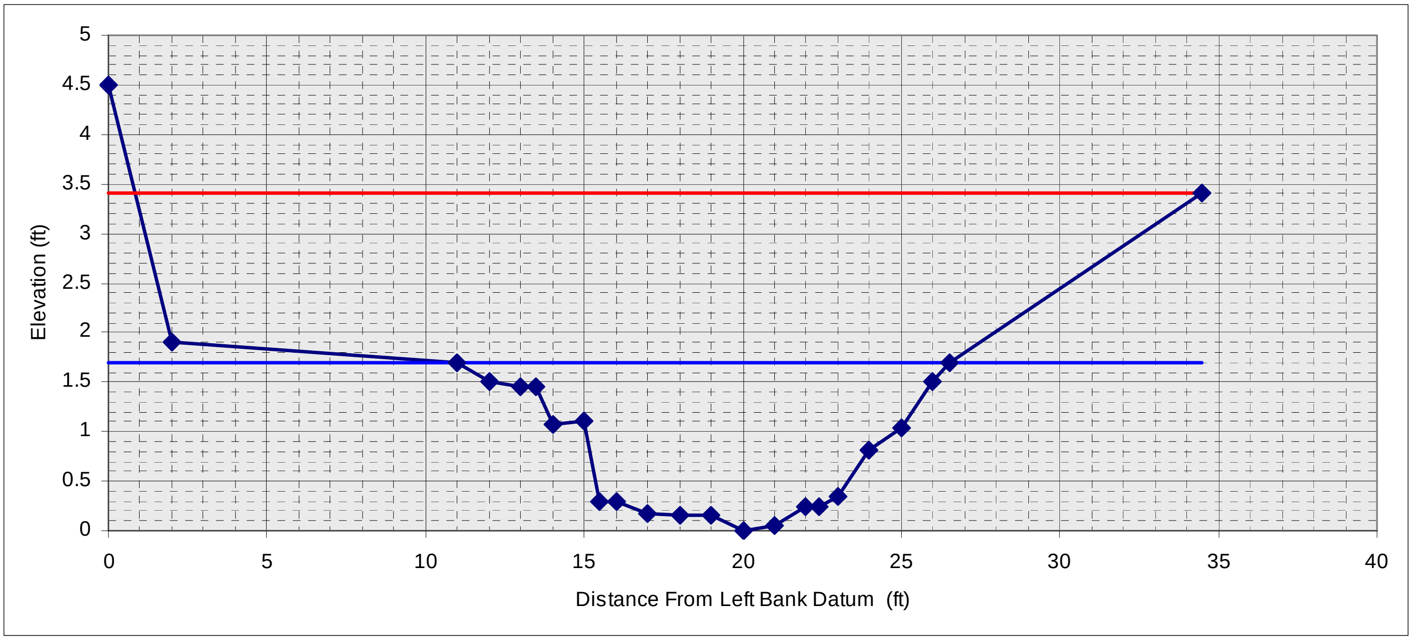
Reach M04



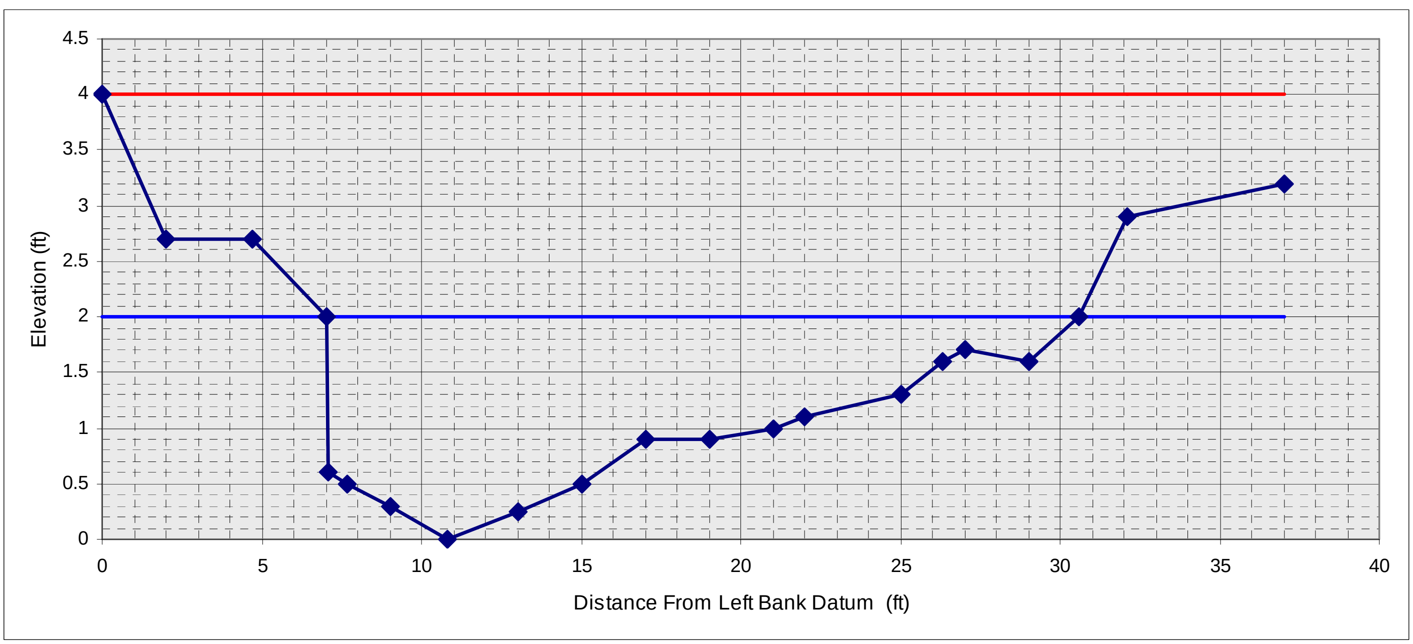
Reach M05



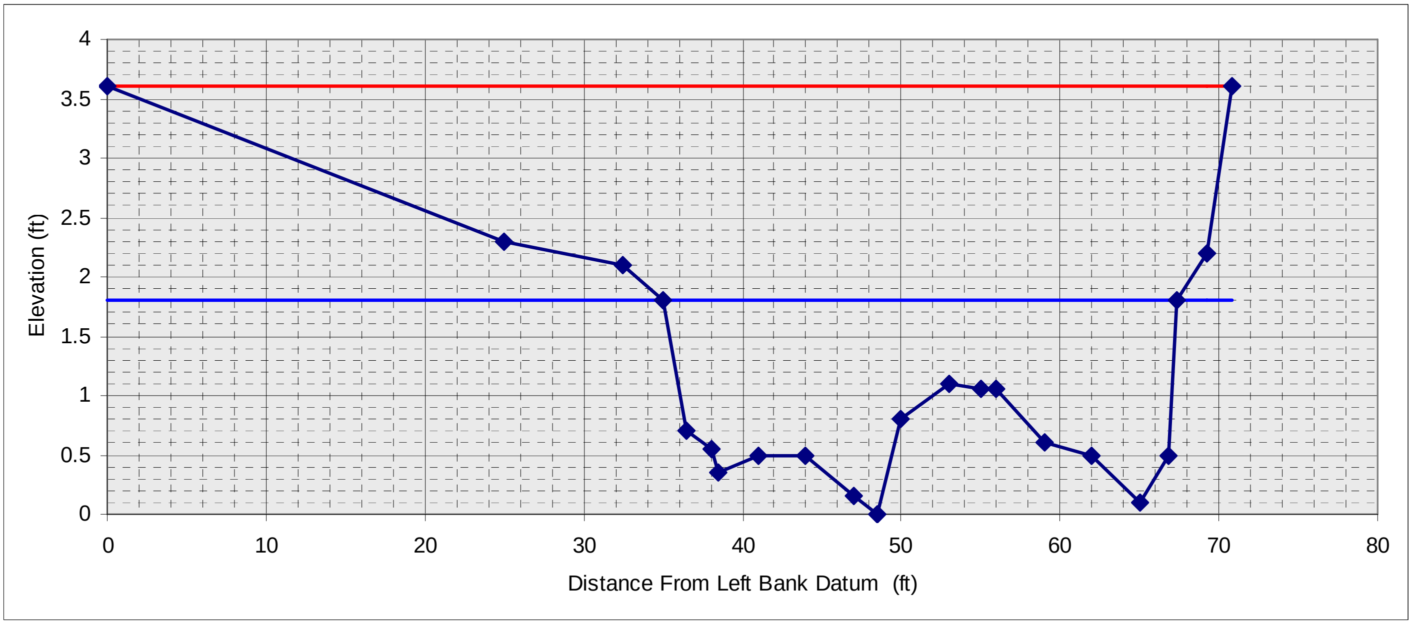
Reach M06



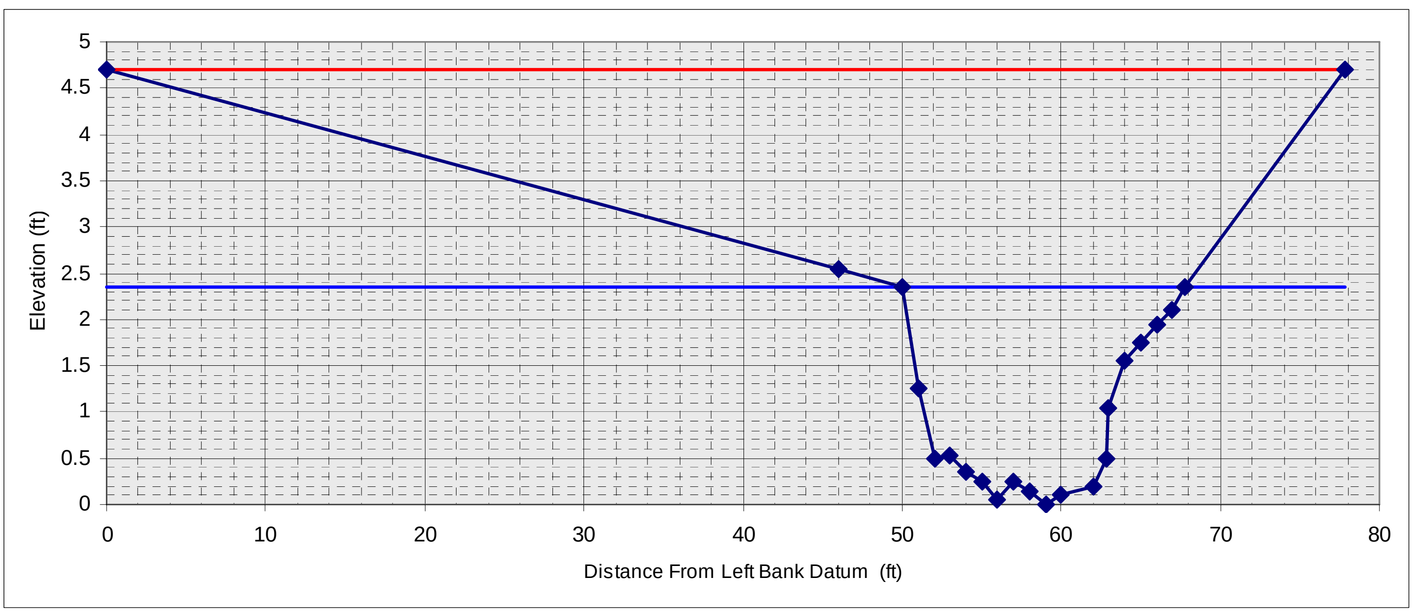
Segment M07-A X1



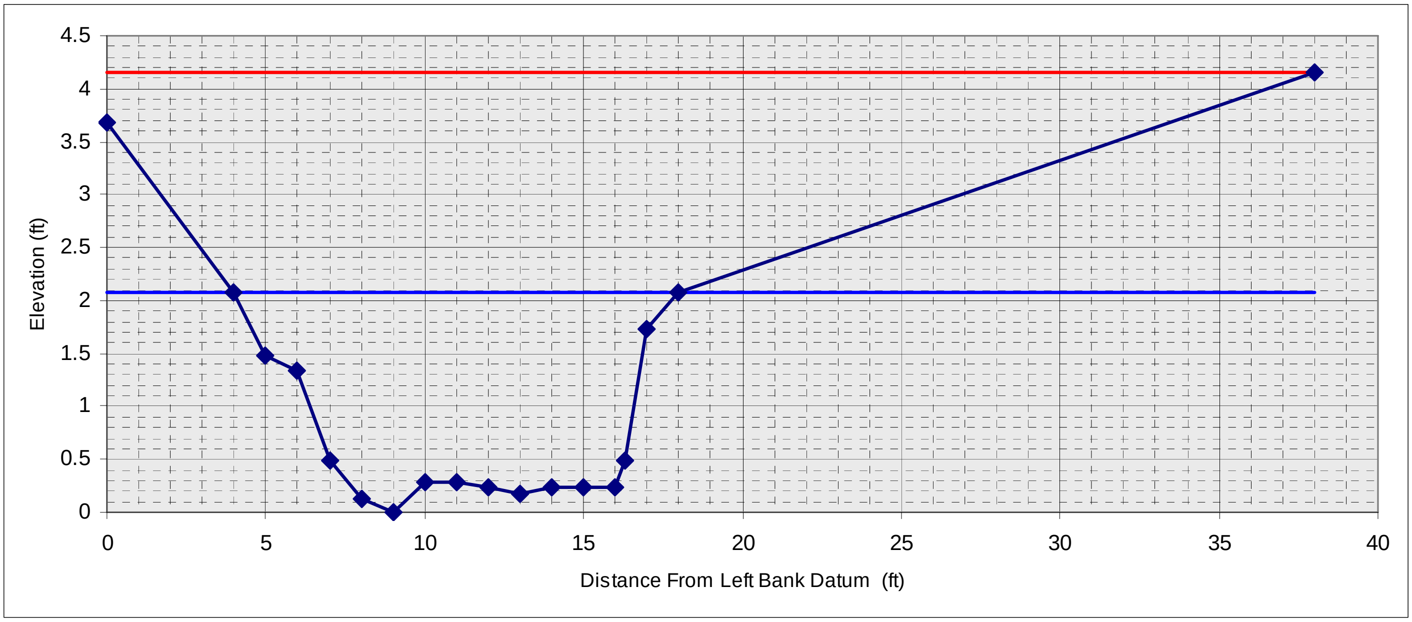
Segment M07-A X2



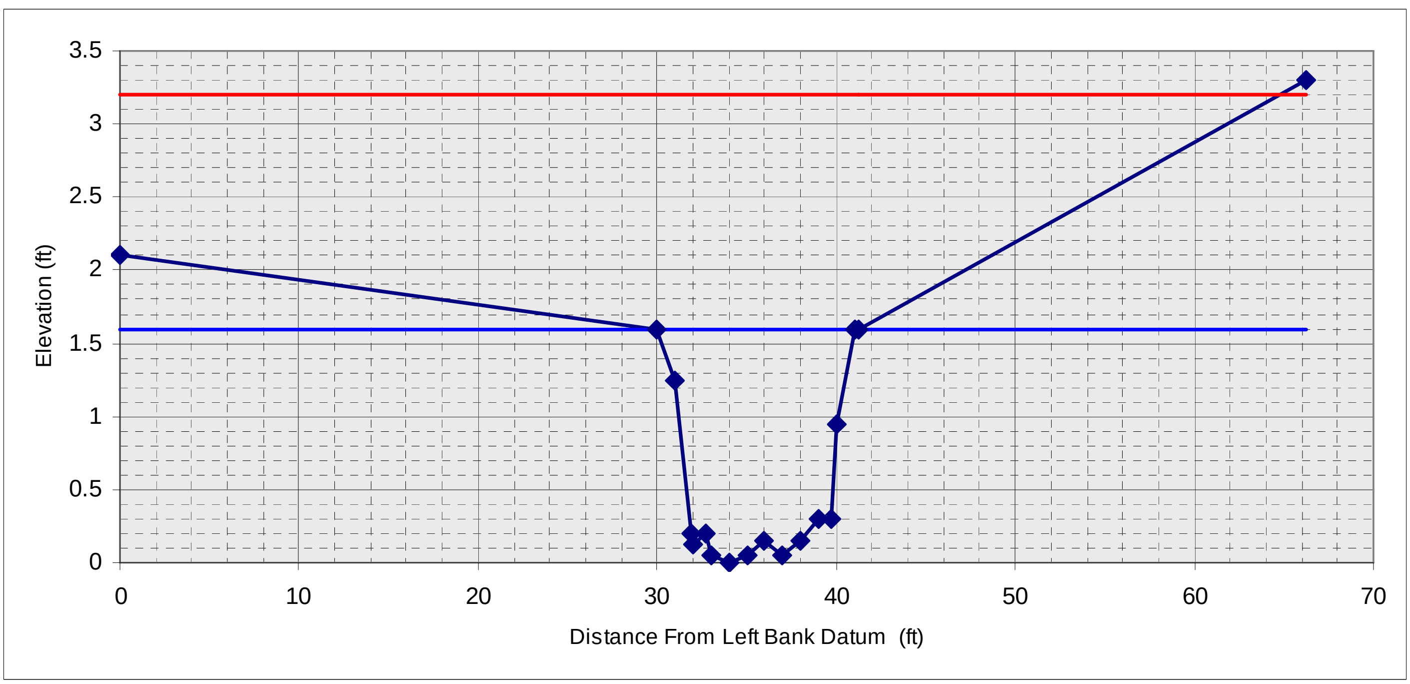
Segment M07-B



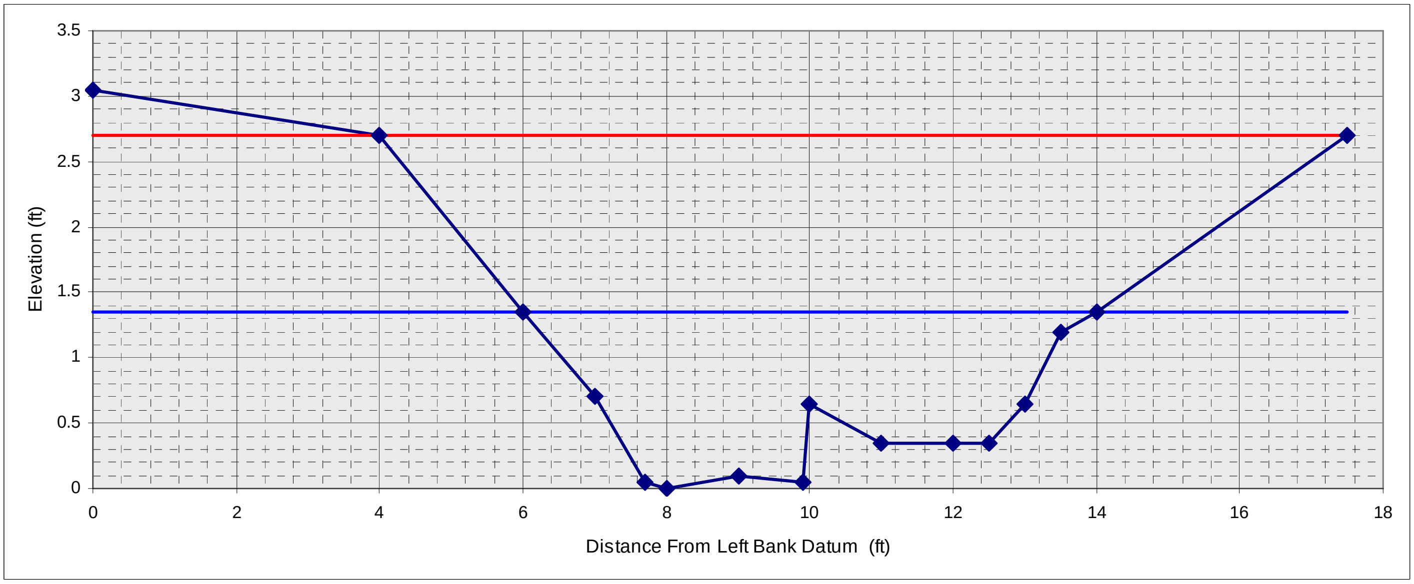
Segment M08-A



Reach M10



Reach M11



3.5
3
2.5
2
1.5
1
0.5
0
Elevation (ft)
0
2
4
6
8
10
12
14
16
18
Distance From Left Bank Datum (ft)

Appendix 3 - Phase 2 Reach Summary Statistics														
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	CEM**	CEM** Stage
M01	E	Gravel	Riffle-Pool	No				0.56	Fair	0.64	Fair	Very High	F	III
M02	B	Cobble	Step-Pool	No				0.88	Reference	0.85	Reference	Moderate	F	I
M03-A	C	Gravel	Riffle-Pool	No				0.83	Good	0.81	Good	High	F	I
M03-B	B	Cobble	Plane Bed	No				0.94	Reference	0.89	Reference	Moderate	F	I
M04	C	Cobble	Plane Bed	No				0.89	Reference	0.86	Reference	Moderate	F	I
M05	C	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.74	Good	0.70	Good	High	F	V
M06	B	Cobble	Riffle-Pool	No				0.72	Good	0.69	Good	Moderate	F	V
M07-A	B	Cobble	Step-Pool	No				0.79	Good	0.70	Good	Moderate	F	I
M07-B	C	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.47	Fair	0.60	Fair	Very High	F	IV
M08-A	C	Gravel	Riffle-Pool	No				0.71	Good	0.76	Good	High	F	V
M08-B	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
M09	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
M10	C	Gravel	Riffle-Pool	No				0.85	Reference	0.86	Reference	High	F	I
M11	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
							Mean:	0.76		0.76				
							Max:	0.94		0.89				
							Min:	0.47		0.60				

* STD = Stream Type Departure

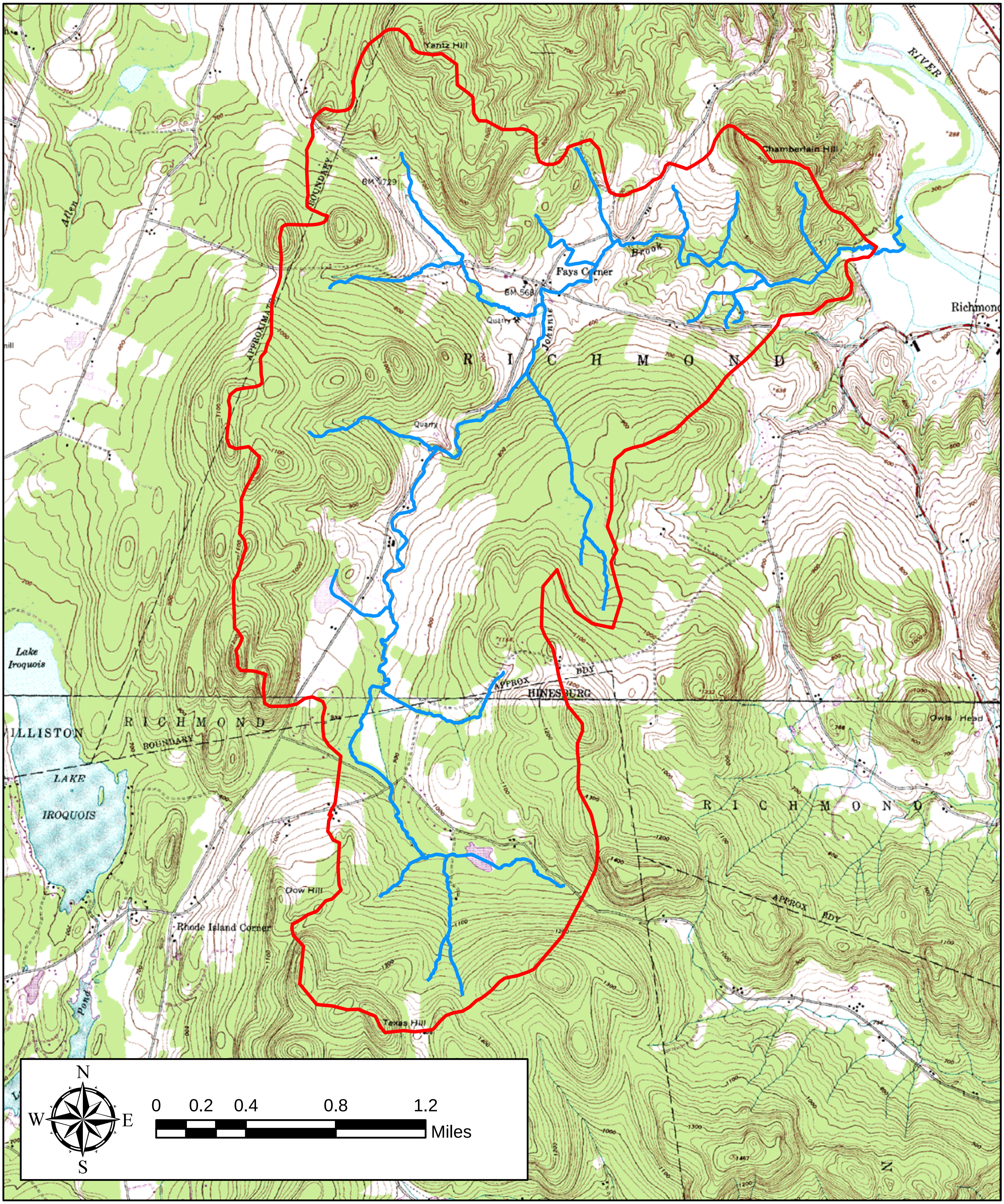
** CEM = Channel Evolution Model

† = Assessed Reference Condition Prior to Stream Type Departure

NE = Not Evaluated

Appendix 4

Watershed and Reach Maps

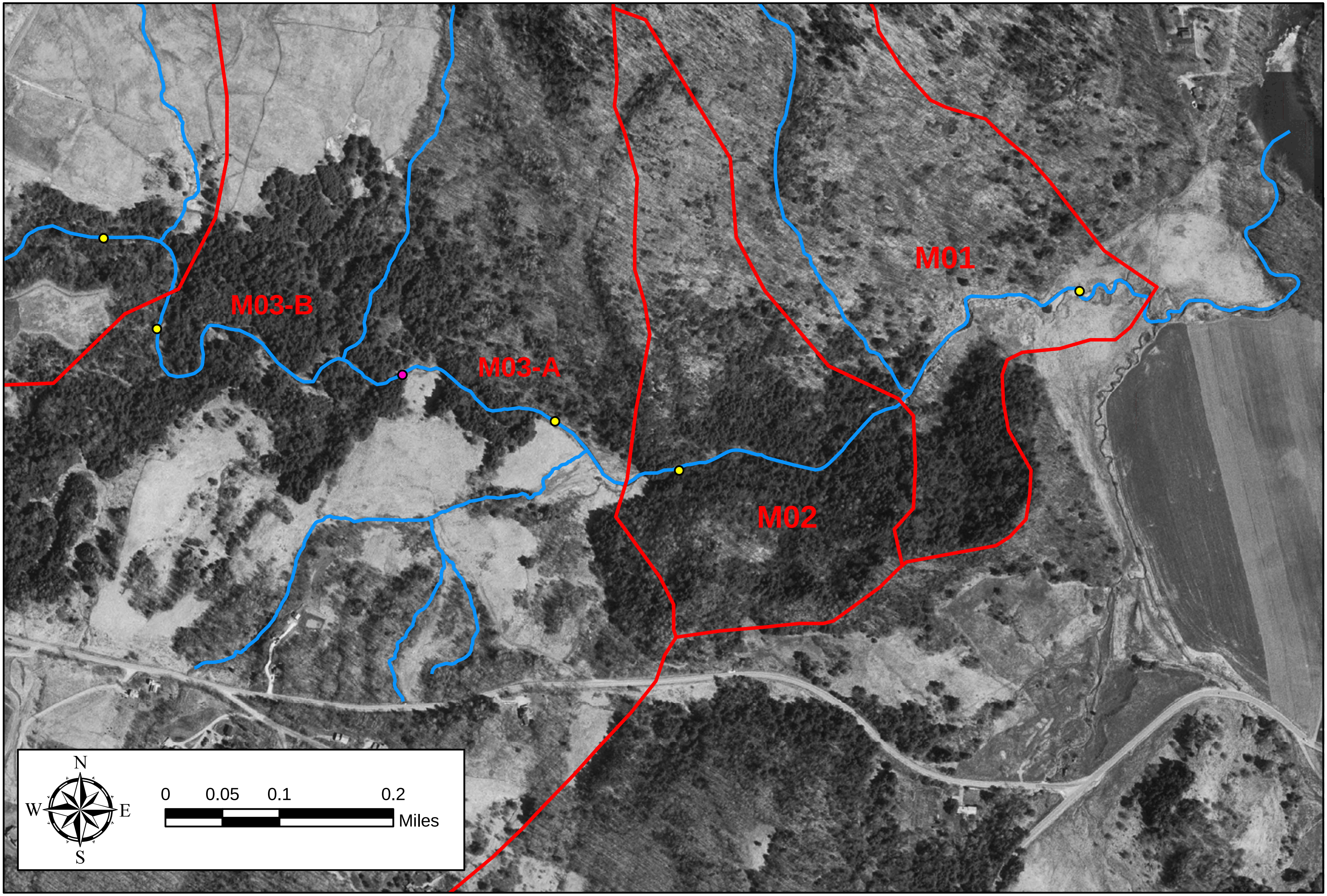


Johnnie Bk Watershed

Johnnie Bk Surface Waters

Johnnie Brook Watershed Map

Fitzgerald Environmental Associates, LLC.
316 River Road
Colchester, VT 05446
tel. 802.999.1357 fax. 802.861.7599



Johnnie Bk Surface Waters
Johnnie Bk Subwatersheds
Johnnie Bk Cross Sections
Johnnie Bk Segment Breaks

Johnnie Brook Subwatershed Map
Reaches M01 to M03-B

Fitzgerald Environmental Associates, LLC.
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Colchester, VT 05446
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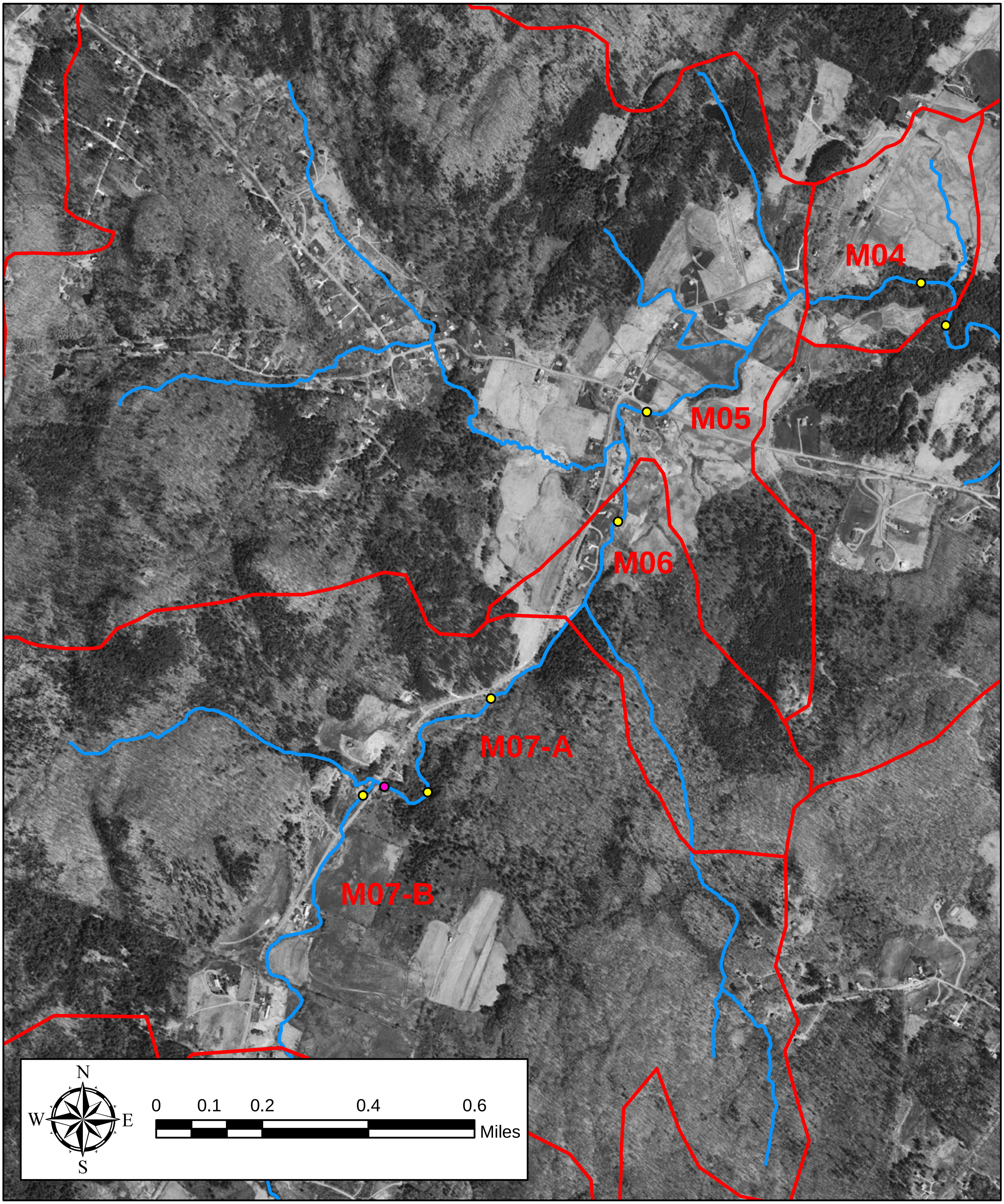

- Johnnie Bk Surface Waters
- Johnnie Bk Subwatersheds
- Johnnie Bk Cross Sections
- Johnnie Bk Segment Breaks

Johnnie Brook Subwatershed Map Reaches M04 to M07-B

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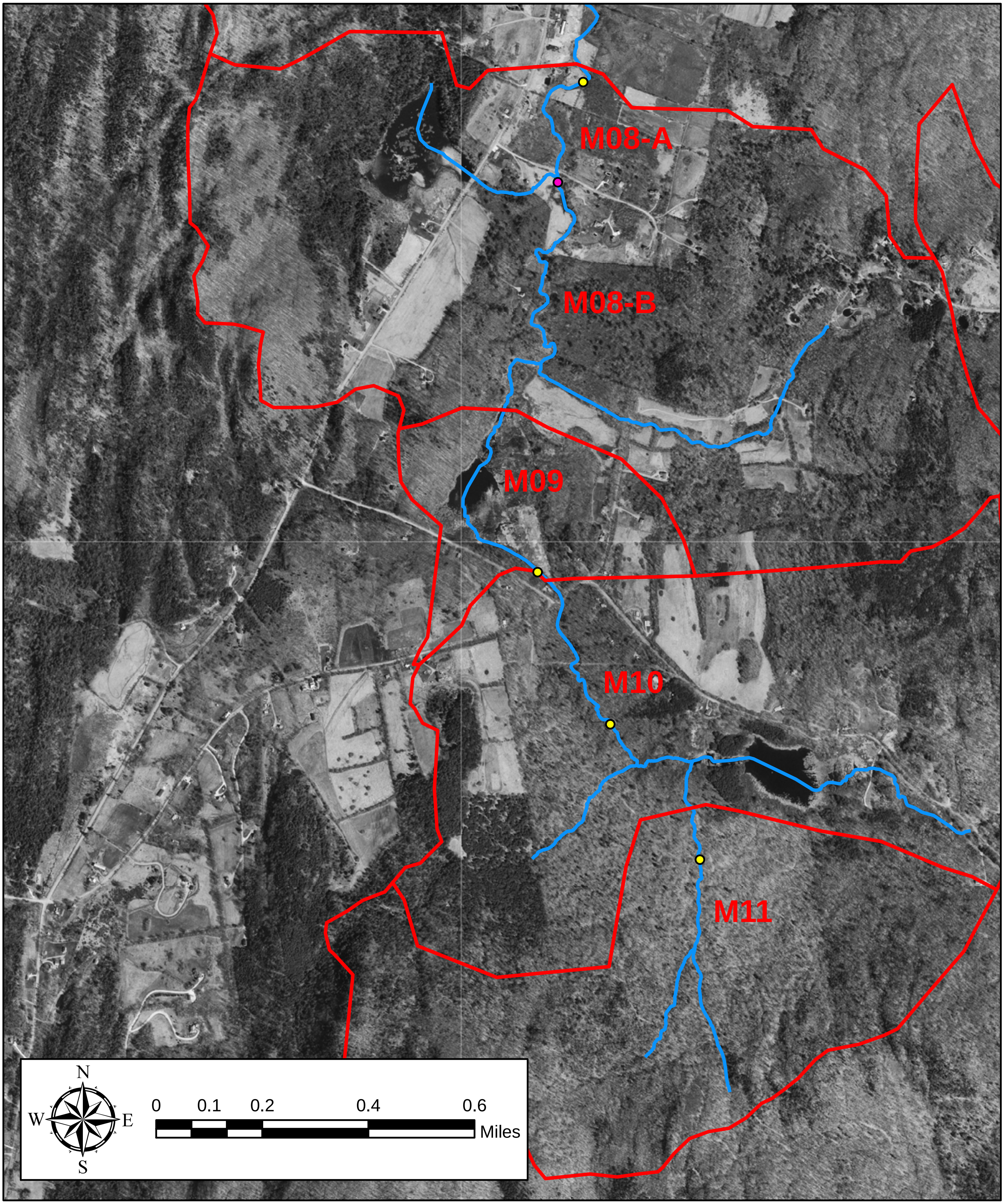

Johnnie Bk Surface Waters
Johnnie Bk Subwatersheds
Johnnie Bk Cross Sections
Johnnie Bk Segment Breaks

Johnnie Brook Subwatershed Map Reaches M08-A to M11

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