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Hydrodynamic Analysis of Remedial Alternatives

Centredale Manor Restoration Project Superfund Site

November 16, 2007

Prepared for

EMHART INDUSTRIES, INC.
701 East Joppa Road
Towson, MD 21286

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Montvale, NJ 07645

Job No. EMHcen:131

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Abbreviations and Acronyms

CD	Compact Disc
CDF	Confined Disposal Facility
cfs	Cubic Feet Per Second
CMRPSS	Centredale Manor Restoration Project Superfund site
EFDC	Environmental Fluid Dynamics Code
LEA	Loureiro Engineering Associates, Inc.
NGVD29	National Geodetic Vertical Datum 1929
PCBs	Polychlorinated Biphenyls
QEA	Quantitative Environmental Analysis, LLC
RI/FS	Remedial Investigation/Feasibility Study
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

This study was performed by Quantitative Environmental Analysis, LLC (QEA) on behalf of Emhart Industries, Inc., pursuant to an Administrative Settlement Agreement and Order on Consent entered into with the United States Environmental Protection Agency (U.S. EPA) (U.S. EPA Region I, CERCLA Docket No. 01-2007-0163). QEA performed a hydrodynamic analysis of four remedial alternatives under consideration by U.S. EPA in the feasibility study for the Centredale Manor Restoration Project Superfund Site CMRPSS. The analysis was performed to evaluate the hydrodynamics of the Woonasquatucket River, including water flow and flooding potential that might result from implementation of each of the four remedial alternatives. The results of the analysis are provided in this report.

The four remedial alternatives considered in this analysis were:

- Alternative 1 – Removal of both Allendale Dam and Lyman Mill Dam, thereby returning this segment of the Woonasquatucket River to pre-impoundment flow conditions. Impacted sediment that lies within the area of the proposed river channel would be excavated. The excavated material would be placed adjacent to the channel and covered with a two-foot cap. The remainder of the area within the footprint of the existing ponds would be covered in place with a two-foot cap.

- Alternative 2 - Replacement of Allendale and Lyman Mill Dams with a weir structure, which would restrict flow and create new pond areas, but allow water to flow freely between the ponds at all times. Excavated sediment would be placed in near-shore confined disposal facilities (CDFs). All sediment within the footprints of the existing ponds not located under the CDFs would be excavated and capped within the CDFs.

- Alternative 3 – An alternative similar to Alternative 2, but with a slightly different river and pond configuration. Under this alternative, impacted sediment within the proposed area of the river and ponds would be excavated and placed adjacent to the river/ponds. The excavated material would be covered with a two-foot cap, and, unlike Alternative 2, the remainder of the area within the footprint of the existing ponds would be capped in place with a two-foot cap.

- Alternative 4 – Under this alternative, both Allendale and Lyman Mill Dams would remain in place such that the river maintains the mill pond characteristics. Impacted sediment would be excavated and placed in near-shore CDFs.

The primary objective of the study was to assess whether implementation of these alternatives would be feasible from a hydrodynamic standpoint. QEA sought to fulfill the study's objective by undertaking the following analyses:

- Evaluate various channel designs in the Allendale and Lyman Mill Ponds.
- Investigate the hydrodynamics and extent of inundation in the floodplain areas of Allendale and Lyman Mill Ponds.
- Analyze the effects of the ~~various~~ remedial alternatives on the hydrodynamics and flood plain inundation in Manton Pond.
- Evaluate the impacts of the ~~various~~ remedial alternatives on stage height and floodplain inundation during high-flow events in the region from Manton Dam to the confluence of the Woonasquatucket and Moshassuck Rivers.

In performing the quantitative analysis, a two-dimensional, vertically-averaged hydrodynamic model was applied to the study area, which extended about 2.3 miles along the Woonasquatucket River, from the gauging station at Centredale Manor to Manton Dam. The model was used to predict future hydrodynamics for the four alternatives for four flow conditions: (i) the seven-day, consecutive low flow with a ten year return frequency (7Q10); (ii) average flow; (iii) 2-year flood; and (iv) 100-year flood. For each flow condition, lower- and upper-bound simulations were conducted, resulting in eight simulations for a particular channel/pond configuration. Model output was processed to generate figures illustrating the extent of channel and floodplain inundation, water depth and surface water elevation, current velocity, bed shear stress, and stable bed particle size.

Based on an evaluation of the model results, the following conclusions were reached:

- All four alternatives result in reasonable predicted ranges of current velocities and current speeds. Accordingly, any of the alternatives can be engineered to minimize erosion.
- All four alternatives result in predicted flood inundation that has no appreciable effect beyond that for existing conditions for the areas adjacent to Allendale and Lyman Mill Ponds, even for 100-year flood events.

- All four alternatives would have a negligible effect on flood stage height and floodplain inundation during high-flow events (100 yr-flood) in the region downstream of Manton Dam.

In light of the modeling results, each of the four alternatives evaluated in this study are viable remedial options for the CMRPSS from a hydrodynamic standpoint.

SECTION 1
INTRODUCTION

1.1 BACKGROUND

The Centredale Manor Restoration Project Superfund site (CMRPSS) is located in North Providence, RI. Chemicals, including dioxins, polychlorinated biphenyls (PCBs), volatile organic compounds, polycyclic aromatic hydrocarbons (PAHs), pesticides, and heavy metals, have been detected in the sediment bed and/or biota of the Woonasquatucket River (river) within the CMRPSS. In March 2000, the site was added to the National Priorities List.

Various technical studies have been conducted during the Remedial Investigation/Feasibility Study (RI/FS) process. These projects have included field studies to collect site-specific data and modeling studies to investigate sediment stability during high-flow events. The results of these past studies have been used to gain an improved understanding of chemical concentrations in sediment and biota within the study area, as well as hydrodynamic and sediment transport processes. This information is being used to evaluate a range of remedial alternatives.

Several of the remedial alternatives being considered by U.S. EPA in its feasibility study include removal of the Allendale and Lyman Mill Dams. Removal of these dams, and subsequent changes to the river channel, may impact the river hydrodynamics. This study evaluates the effect of the dam removal remedial alternatives on the hydrodynamic behavior of the river, both within the CMRPSS and in the region downstream of the site. In addition, this study analyzes the hydrodynamic behavior of the river that may result from a remedial alternative in which the existing dams remain in place. Quantitative Environmental Analysis, LLC (QEA) performed the study on behalf of Emhart Industries, Inc. pursuant to an Administrative Settlement Agreement and Order on Consent entered into with the United States Environmental Protection Agency (U.S. EPA) (U.S. EPA Region I, CERCLA Docket No. 01-2007-0163).

The flow of the river is controlled by several dams. The river flow can be as low as 8 cubic feet per second (cfs) for the 7Q10 flow, defined as the "seven-day, consecutive low flow with a ten-year return frequency; [or] the lowest stream flow for seven consecutive days that would be expected to occur once in ten years," (USEPA 1997), and can reach 2,300 cfs during the 100-year flood. Two of the dams, Allendale and Lyman Mill Dams, are located within the CMRPSS. The sediments at the upstream ponds of each of these two dams are impacted by site-related compounds. Three of the remedial alternatives currently being considered in the feasibility study include removing the two dams and excavating and capping impacted sediments presently located within the streambed and in the ponds. These dam removal alternatives may modify the hydrodynamic pattern of the river. Accordingly, this study focuses on the potential impacts of the dam removal remedial alternatives on water depths, flood plain inundation, and shear stresses that may cause higher erosions during both low and high flow conditions. Moreover, because the potential impacts of the dam removal alternatives may extend beyond the areas in the vicinity of the dams, the study also evaluates the downstream reach and, as applicable, parts of the upstream reach as well.

As discussed below, three dam removal alternatives are analyzed with different excavated areas, and are compared to the current condition, with the dams in place. Also, one sediment excavation and capping alternative that does not require the removal of the existing dams is evaluated.

1.2 STUDY OBJECTIVES

The study goal is to evaluate the hydrodynamic effects of three dam removal remedial alternatives within the CMRPSS, and to evaluate the hydrodynamic effects of one remedial alternative with the dams remaining in place. The primary objective is to assess whether implementation of any of the four remedial alternatives would be feasible from a hydrodynamic standpoint. To fulfill that objective, the following tasks were undertaken through the application of a hydrodynamic model to the reach of the Woonasquatucket River that extends from the U.S. Geological Survey (USGS) Centredale gauging station at the upstream limit to Manton Dam at the downstream limit:

- Evaluate various channel designs in the Allendale and Lyman Mill Ponds.
- Investigate the hydrodynamics and extent of inundation in the floodplain areas of Allendale and Lyman Mill Ponds.
- Analyze the effects of the remedial alternatives on the hydrodynamics and flood plain inundation in Manton Pond.
- Evaluate the impacts of the remedial alternatives on stage height and floodplain inundation during high-flow events in the region from Manton Dam to the confluence of the Woonasquatucket and Moshassuck Rivers.

1.3 DESCRIPTION OF STUDY AREA

The study area extends over approximately 2.3 miles of the Woonasquatucket River, from the USGS gauging station at Centredale to Manton Dam. This area contains Allendale and Lyman Mill Dams, as shown on Figure 1-1. Allendale Pond Dam was reconstructed in Spring 2002, after a breach occurred in 1991. The bathymetry and geometry of the Allendale, Lyman Mill, and Manton Ponds for present conditions are shown on Figures 1-2, 1-3 and 1-4, respectively. Each pond may be divided into two distinct regions: 1) pond area created by the dam backwater; and 2) free-flowing river channel upstream of the pond. The area upstream of each pond is typified by a narrow and shallow river channel with an adjacent floodplain area.

1.4 REPORT ORGANIZATION

This report presents an overview and general description of the modeling framework and technical approach, as well as the results of the modeling analysis. It is organized into six sections:

- Section 1: Introduction;
- Section 2: Hydrodynamic Model Description and Development;
- Section 3: Remedial Alternative Design Considerations;
- Section 4: Evaluation of Remedial Alternatives;
- Section 5: Summary and Conclusions; and
- Section 6: References.

SECTION 2
HYDRODYNAMIC MODEL DESCRIPTION AND DEVELOPMENT

2.1 GENERAL DESCRIPTION OF HYDRODYNAMIC MODEL

Hydrodynamic simulations for the remedial alternatives addressed in this report were conducted using a QEA-modified version of the Environmental Fluid Dynamics Code (EFDC). EFDC was originally developed by Dr. John Hamrick (Hamrick 1992) and is supported by the U.S. Environmental Protection Agency (USEPA). EFDC is a general purpose three-dimensional, time-variable hydrodynamic model capable of simulating flow in rivers, lakes, reservoirs, estuaries, and coastal oceans. This model solves the conservation of mass and momentum equations, which are the fundamental equations governing the movement of water in a river. EFDC has the capability to simulate the flooding and drying of floodplain areas, which is of importance when evaluating over-bank flow conditions during a high-flow event. A complete description of the model is given in Hamrick (1992). QEA has used EFDC previously to conduct a sediment stability analysis of Allendale and Lyman Mill Ponds (QEA 2005).

EFDC was applied in a two-dimensional, vertically-averaged mode for this study, which is an appropriate approximation of the shallow, non-stratified flow conditions that exist in the study area during all flow conditions. Vertically-averaged mode means that the model predicts the vertically-averaged value of the current velocity. In addition, the model predicts water surface elevation and water depth.

2.2 NUMERICAL GRID

The model domain is approximately 2.3 miles long and extends from an upstream boundary at the USGS gauging station at Centredale to a downstream boundary at Manton Dam. The floodplain areas in the model were delineated using aerial photographs of the study area. A total of 119,149 square grid cells were used to delineate the study area, including floodplain areas (Figure 2-1). In this study, each grid cell was 2-meters square to provide adequate resolution and sufficient flexibility to evaluate a wide range of channel designs for post-dam

conditions. Electronic versions (i.e., AutoCAD files) of the bathymetry and floodplain topography data were provided by Loureiro Engineering Associates, Inc. (LEA) personnel. The bathymetry and floodplain topography data were projected onto the numerical grid for use as a primary input to the hydrodynamic model.

2.3 BOUNDARY CONDITIONS

The hydrodynamic model requires specification of two boundary conditions: 1) incoming flow rate at the upstream boundary; and 2) water surface elevation (i.e., stage height) at the dam located at the downstream boundary. Historical data collected at the USGS Centredale gauging station (station number 01114500) were used to specify the flow rates corresponding to four flow conditions considered during this modeling study: 1) low flow (e.g., 7Q10 discharge); 2) average flow, defined as the average of daily-average flow values for the period from 1941 through 1996; 3) 2-year flood; and 4) 100-year flood. A flood frequency analysis was previously conducted by U.S. Army Corps of Engineers (USACE) personnel (Corcoran 2006) and the results of that analysis were used to specify the 2-year and 100-year flood discharges in this study. Values of flow rates for the four flow conditions are presented in Table 2-1.

Table 2-1. Flow rates for hydrodynamic simulations.

Flow Condition	Flow Rate (cfs)
Low-flow (7Q10)	8
Average flow	73
2-year flood	570
100-year flood	2,300

Stage height (i.e., water surface elevation) as a function of flow rate was specified for each of the three dams (Allendale, Lyman Mill, and Manton). Since no historical stage height data were available, a broad-crested weir formulation was used to estimate the stage height at each dam (Roberson et al. 1998):

$$\eta = (Q / 3.3\ L)^{0.67} \qquad (2\text{-}1)$$

where η is water height over the dam crest (ft.), Q is flow rate (cfs), and L is length of the dam crest (ft.). A crest length of 106 ft was used for each dam. Dam crest heights were 93.5, 77 and

64.3 ft. for Allendale, Lyman Mill and Manton Dams, respectively. The dam crest heights are referenced to National Geodetic Vertical Datum 1929 (NGVD29). Application of Equation 2-1 results in a stage height range of about 3.5 ft. between the 7Q10 and 100-year flood flow rates.

2.4 MINIMIZING UNCERTAINTY USING BOUNDING SIMULATIONS

The hydrodynamic model developed for the sediment stability study was calibrated using current velocity data collected in Allendale and Lyman Mill Ponds (QEA 2005). The calibration parameter adjusted to achieve optimum agreement between observed and predicted current velocity values was the effective bed roughness height (Z_0), which affects the amount of friction (i.e., drag) exerted on the moving water in the river by the sediment bed. A value of 0.1 cm for Z_0 was determined during the model calibration process. This relatively small value for Z_0 is consistent with the general type of sediment bed in Allendale and Lyman Mill Ponds; the primarily muddy bed in the two ponds is relatively smooth, at least with respect to the hydrodynamics.

In the present study, the hydrodynamic model was used to predict future conditions in the study river after the dams are removed and the channel reconfigured. Thus, use of the model as a prognostic tool precludes calibration, which results in uncertainty in the predictive simulations. This uncertainty was minimized through the use of bounding calculations based on a realistic range of Z_0 values. The lower-bound value of Z_0 was set at 0.1 cm (i.e., calibration value for present conditions in the ponds) because it is highly likely that removing the dams will not produce a smoother bed than presently exists in the study area. The upper-bound value of Z_0 was set at 5 cm, which corresponds to a relatively rough bed that is primarily composed of sand and gravel. This type of bed is likely to be the roughest composition to exist in the various channel configurations considered in this study. Predictive model simulations were conducted using this range of bed roughness heights, which produced lower- and upper-bound results for each flow regime. The level of uncertainty in the predictions was reflected in these bounding simulations, with the "real" answer somewhere between the lower- and upper-bound of Z_0 values.

SECTION 3
REMEDIAL ALTERNATIVE DESIGN CONSIDERATIONS

Three dam removal remedial alternatives were analyzed using the hydrodynamic model. These alternatives represent various river/pond configurations that result from the removal of Allendale and Lyman Mill Dams, excavating impacted sediment, and capping the impacted sediments within the footprint of the existing ponds. A fourth remedial alternative with the dams remaining in place also was analyzed using the hydrodynamic model. This evaluation was undertaken in addition to the hydrodynamic modeling of the dam removal alternatives, based on the belief that excavating impacted sediments and capping the impacted sediments within the footprint of the existing ponds with the dams remaining in place would have minimal impact on the hydrodynamic behavior of the river, including floodplain inundation. A description of this dam-in-place alternative is provided below, together with descriptions of the three dam removal alternatives.

3.1 ALTERNATIVE 1: PARTIAL EXCAVATION – CHANNEL

Alternative 1 contemplates the removal of Allendale and Lyman Mill Dams, thereby returning this segment of the Woonasquatucket River to pre-impoundment flow conditions. The numerical grid showing the bathymetry and topography in Allendale and Lyman Mill Ponds for this alternative is presented in Figures 3-1, 3-2, 3-3, and 3-4. Impacted sediment that lies within the area of the proposed river channel inside the footprint of the existing ponds would be excavated. The excavated material would be placed adjacent to the channel and covered with a two-foot cap. The remainder of the area within the footprint of the ponds would be covered in place with a two-foot cap. A suitable substrate would be placed within the area of the proposed river channel to establish the necessary grade for the channel bed.

3.2 ALTERNATIVE 2: TOTAL EXCAVATION – CHANNEL/PONDS

Alternative 2 also contemplates the removal of Allendale and Lyman Mill Dams, and the placement of excavated sediment within near-shore confined disposal facilities (CDFs). The numerical grid showing the bathymetry and topography in Allendale and Lyman Mill Ponds for this alternative is presented in Figures 3-5, 3-6, 3-7, and 3-8. Impacted sediment within the footprint of Allendale Pond (excluding the area of the nearshore CDF) would be excavated to an average depth of 2.15 feet. Impacted sediment within the footprint of Lyman Mill Pond (excluding the areas of the CDFs) would be excavated to an average depth of 2.65 feet. The excavated sediment would be placed within the footprint of the nearshore CDFs and covered with a two-foot cap. Once all of the impacted sediment is relocated into the CDFs, the sediment within the remainder of the footprint of each pond would be graded to maximize the size and depth of the surface water area. To maximize this area, armoring and/or timberwalls may be used along the embankments. Also, to maximize the wetted area, a weir would be placed at the locations of the removed dams.

3.3 ALTERNATIVE 3: PARTIAL EXCAVATION – CHANNEL/PONDS

Under Alternative 3, Allendale and Lyman Mill Dams would be removed and impacted sediments would be excavated to create a constructed river channel/pond environment. Impacted sediment within the footprints of constructed river channel/ponds would be excavated and placed adjacent to the channel/ponds. The excavated material would be covered with a two-foot cap. The remainder of the area within the footprint of the ponds would be capped in place with a two-foot cap. A suitable substrate would be placed within the area of the proposed river channel to establish the necessary grade of the channel bed. To maximize the area and depth of the surface water under this alternative, armoring and/or timber walls may be used along the embankments. Also, to maximize the wetted area, a weir would be placed at the locations of the removed dams. The numerical grid showing the bathymetry and topography in Allendale and Lyman Mill Ponds for Alternative 3 is presented in Figures 3-9, 3-10, 3-11, and 3-12.

3.4 ALTERNATIVE 4: NEARSHORE CDF WITH DAMS IN PLACE

Under Alternative 4, both Allendale and Lyman Mill dams would remain in place so the river maintains the mill pond characteristics. Impacted sediment would be excavated and placed in near-shore CDFs. The numerical grid showing the bathymetry and topography in Allendale and Lyman Mill Ponds for Alternative 4 is presented in Figures 3-13, 3-14, 3-15, and 3-16. Impacted sediment within the footprint of Allendale Pond (excluding the area of the near-shore CDF) would be excavated to an average depth of 2.15 feet. Impacted sediment within the footprint of Lyman Mill Pond (excluding the area of the near-shore CDFs) would be excavated to an average depth of 2.65 feet. The excavated sediment placed within the near-shore CDFs would be covered with a two-foot cap. The remainder of the area within the footprint of the ponds would be covered with six inches of clean fill.

SECTION 4
EVALUATION OF REMEDIAL ALTERNATIVES

The effects of the four remedial alternative designs on river circulation within the study area were evaluated using the hydrodynamic model. Flow in the river was simulated for each alternative design for four flow conditions: 1) 7Q10 flow; 2) average flow; 3) 2-year flood; and 4) 100-year flood (see Table 2-1). As discussed in Section 2.4, uncertainty in the prognostic simulations was minimized through use of bounding simulations (i.e., simulations using lower- and upper-bound values of effective bed roughness). For comparative purposes, present-condition simulations, with Allendale and Lyman Mill Dams in place, were conducted. Thus, a total of 40 hydrodynamic simulations for the entire study area were performed.

For each simulation, model output was processed to generate figures depicting spatial distributions of: extent of channel and floodplain inundation; water depth and water surface elevation; current velocity (i.e., vector plot); current velocity speed; bed shear stress; and stable bed particle size (see Section 4.1). Hence, a voluminous set of figures (i.e., nearly 800 figures) were generated that depict the model results for the various remedial design alternatives. It is not practical or necessary to include all of these figures in this report. Rather, a sub-set of the model results that show the salient aspects of the design alternatives have been included in the report. Model results presented in the report cover the limits of the flow range (i.e., 7Q10 flow and 100-year flood) and correspond to the upper-bound limit of effective bed roughness. In addition, spatial distributions of predicted current speed and water depth are presented. All of the model results have been forwarded to Loureiro Engineering Associates, Inc. (LEA) personnel for design purposes. The entire set of figures showing model results are available in electronic format on a compact disc (CD) for use by USEPA and other stakeholders.

4.1 STABLE BED TYPE DURING FLOOD CONDITIONS

Designing a new channel after dam removal involves a number of design considerations, including bed and channel stability during rare floods. During channel design, it is useful to know the necessary sediment particle diameter for a stable bed during a rare high-flow event, such as the 100-year flood. An approach for estimating the stable bed type during a 100-year

flood is described in this sub-section. This analysis was applied to the four alternative designs and the results provided to LEA personnel for use during the channel design process.

This study uses the modified Shields equation, which was the approach applied to other impacted sediment sites for armor cap design (QEA 2004). The technical analysis was derived using guidance from sources including Hydraulic Design of Flood Control Channels (USACE 1991) and ARCS Guidance (USEPA 1998). The modified Shields equation is used as follows. The stable median particle diameter ($D_{50,stable}$) as a function of bed shear stress is given by:

$$D_{50,stable} = 80\ \tau / (\gamma_s - \gamma_w) \qquad (4\text{-}1)$$

where τ is bed shear stress; γ_s is specific weight of sediment particles; and γ_w is specific weight of water.

For each of the design alternatives, bed shear stresses calculated during the 100-year flood were used in Equation 4-1 to calculate the spatial distribution of $D_{50,stable}$. For convenient presentation of the stable bed/channel results, the $D_{50,stable}$ values were separated into the four general bed type categories listed in Table 4-1.

Table 4-1. Bed type categories for stable bed during 100-year flood.

Stable D_{50} (µm)	Stable Bed Type
< 62	Silt/Clay
62 – 500	Fine/Medium Sand
500 – 2000	Coarse Sand
> 2000	Gravel

4.2 FLOOD HYDROGRAPHS AT MANTON DAM WITH AND WITHOUT DAMS

One of the primary objectives of this study was to evaluate the impacts of dam removal on stage height and floodplain inundation during high-flow events in the region downstream from Manton Dam to the confluence of the Woonasquatucket and Moshassuck Rivers. This objective was accomplished by comparing the predicted hydrographs for the 100-year flood,

with and without dams, at Manton Dam. The comparison provides an estimate of the potential effect of dam removal on flood flows in the river downstream of Manton Dam.

The first step in this analysis was to specify the shape of the flood hydrograph (i.e., time-variable flow during the rising and falling limbs of the flood) at the upstream inflow boundary. The hydrograph for the 100-year flood event was selected from the historical daily-average flow record collected at the USGS Centredale gauging station between 1942 and 2004. A peak flow rate of 1,250 cfs occurred during a 6-day period in March 1968. This flood has a return period of 10 to 25 years. For the 100-year flood event simulations, the March 1968 hydrograph was linearly adjusted such that the peak flow rate was 2,300 cfs (Table 2-1).

The 100-year flood was simulated, using the inflow hydrograph discussed above, for the present condition (with dams) and the three design alternatives without dams (i.e., Alternatives 1, 2, and 3). Potential effects of removing Allendale and Lyman Mill Dams on flood response in the river downstream of Manton Dam were evaluated by comparing the predicted flood hydrograph at Manton Dam for the present condition to the predicted hydrographs without dams. Figures 4-1, 4-2, and 4-3 show comparisons of the predicted 100-year flood hydrographs at Manton Dam for Alternatives 1, 2, and 3, respectively. These comparisons indicate that dam removal will have a negligible effect on stage height and floodplain inundation during high-flow events in the region downstream from Manton Dam. This result is not surprising because Allendale and Lyman Mill Dams are not designed as flood control dams and have minimal flood storage capacity.

4.3 PRESENT CONDITIONS WITH DAMS IN PLACE

The hydrodynamic model was used to simulate flow in Allendale, Lyman Mill and Manton Ponds with the dams in place. Allendale and Lyman Mill Ponds are each separated into two regions (i.e., upstream and pond regions) with distinct hydrodynamic characteristics.

Predicted water depths and current speeds in Allendale Pond for 7Q10 flow and 100-year flood conditions are shown on Figures 4-4 through 4-7. In the upstream region of Allendale Pond, average current speeds range from 7 cm/s (0.23 ft/s) during 7Q10 flow conditions to 60

cm/s (2.0 ft/s) during the 100-year flood. Statistical analysis indicates that there are relatively small differences between the lower- and upper-bound effective bed roughness simulations. During the 100-year flood, current speeds can reach as high as 380 cm/s (12 ft/s) in the upstream region. Average water depths in the narrow channel entering the pond range from 1.5 ft. during low flow to 3 ft. during the 100-year flood. Water depths are lower during the 100-year flood than during the 2-year flood. This result is caused by over-bank flow, where the inundation area quadruples between the 2- and the 100-year floods, going from less than one acre to four acres. Within Allendale Pond, average current speeds are lower due to the larger cross-sectional area of the pond, ranging from less than 1 cm/s (0.03 ft/s) during 7Q10 flow to 27 cm/s (0.9 ft/s) during the 100-year flood. The inundation area increases by only about 25% for the 100-year flood, as compared to 7Q10 flow, demonstrating the influence of the dam and that the floodplain area is relatively small in this region. Average water depths range from 3.9 ft. during 7Q10 flow to 6.7 ft. during the 100-year flood.

Predicted water depths and current speeds in Lyman Mill Pond for 7Q10 flow and 100-year flood conditions are shown on Figures 4-8 through 4-11. In the upstream region of Lyman Mill Pond, average current velocities range from 3 cm/s (0.1 ft/s) during 7Q10 flow to 25 cm/s (0.8 ft/s) during the 100-yr flood. Again, there are relatively small differences, in general, between lower- and upper-bound Z_0 simulations. This region contains a relatively large floodplain area. The inundated floodplain nearly triples in size between low and high flow conditions, going from about 4 acres during 7Q10 flow to nearly 11 acres during the 100-year flood. In reality, much of the "floodplain" area in this region can be considered to be permanently wet and has marsh characteristics. Average water depths range from about 0.4 ft. during 7Q10 flow to 2.7 ft. during the 100-year flood. Within Lyman Mill Pond, the inundation area in this region changes only by about 35%, going from about 13 acres during 7Q10 flow to about 17 acres during the 100-year flood. Average water depths range from 3 ft. during 7Q10 flow to 6 ft. during the 100-year flood. Average current speeds are similar to the values observed within Allendale Pond.

Predicted water depths and current speeds in Manton Pond for 7Q10 flow and 100-year flood conditions are shown on Figures 4-12 through 4-15. In Manton Pond, average water depths range from 1.7 ft. during 7Q10 flow to 5 ft. during high flows. The inundation area

ranges from 3.2 acres during 7Q10 flow to 10 acres during the 100-year flood. Average current speeds are higher than those observed in Allendale and Lyman Mill Ponds, due to the nature of the channel. Average current speeds range from 3 cm/s (0.1 ft/s) during 7Q10 flow to 57 cm/s (1.9 ft/s) during the 100-year flood.

4.4 ALTERNATIVE 1: PARTIAL EXCAVATION – CHANNEL

A detailed description of the Alternative 1 design is provided in Section 3.1. Predicted water depths and current speeds in the Allendale Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-16 through 4-19. The main characteristic of this design, in both the Allendale and Lyman Mill Ponds' regions, is that the river flow is primarily restricted to a relatively narrow channel which results in minimal ponding. In Allendale Pond, during 7Q10 flow conditions, because the channel has been designed to be relatively narrow and water depths are shallow (about 2 ft.), average current speeds are higher (up to 15 cm/s [0.5 ft/s])) than those predicted during present conditions. During a 100-year flood, average current speeds exceed 100 cm/s (3.3 ft/s) throughout the channel in the Allendale Pond region. A relatively small area of the floodplain in the Allendale Pond region would be inundated by over-bank flow during a flood event.

Predicted water depths and current speeds in the Lyman Mill Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-20 through 4-23. In the Lyman Mill Pond region, a larger area is inundated in the floodplain area adjacent to the channel between the removed Allendale and Lyman Mill Dams. During 7Q10 flow conditions, average current speeds are higher than present conditions, reaching 4 cm/s (0.13 ft/s) in various locations within the Alternative 1 channel. During the 100-year flood event, average current speeds exceed 80 cm/s (2.6 ft/s) throughout the channel.

In the Manton Pond region, differences in water depth and current speed between present conditions and the Alternative 1 design are limited to within about 300 ft. downstream of the Lyman Mill Dam. Within that limited area, current speeds are higher and water depths are lower after the dams are removed. In the region downstream of this limited area, there are negligible

differences in predicted water depths and current speeds between the Alternative 1 design and present conditions.

4.5 ALTERNATIVE 2: TOTAL EXCAVATION – CHANNEL/PONDS

A detailed description of the Alternative 2 design is provided in Section 3.2. Predicted water depths and current speeds in the Allendale Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-24 through 4-27. The primary difference between Alternatives 1 and 2, in both the Allendale and Lyman Mill Ponds' regions, is that the Alternative 2 channel is wider than the Alternative 1 channel, which results in a larger cross-sectional area in the main channel. In the Allendale Pond region during 7Q10 flow conditions, average water depths are between 3 and 4 ft. Current speeds within the pond region are similar to present conditions, averaging less than 3 cm/s (0.1 ft/s) during 7Q10 flow. Floodplain inundation has also been reduced in the middle of the pond. During the 100-year flood, maximum water depths range from 11 ft in the main channel to less than 2 ft in the floodplain area. Maximum current speeds range from 80 cm/s (2.6 ft/s) in the main channel to 40 cm/s (1.3 ft/s) in the shallower floodplain area during this rare flood.

For the Alternative 2 design, predicted water depths and current speeds in the Lyman Mill Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-28 through 4-31. During 7Q10 flow conditions, average water depths of 3 to 4 ft are predicted in the Lyman Mill Pond region, and current speeds are less than 10 cm/s (0.3 ft/s) throughout this region. During the 100-year flood, the extent of floodplain inundation is generally similar to present conditions. However, river flow during floods is confined to the Alternative 2 channel within about 500 ft upstream of the Lyman Mill Pond after dam removal. Maximum water depths and current speeds are about 13 ft and 60 cm/s (2.0 ft/s), respectively, during a 100-year flood, which is similar to that predicted for present conditions.

Similar to the results for the Alternative 1 design, the effects of dam removal on water depths and current speeds in the Manton Pond region are limited to a relatively short distance (about 300 ft) downstream of Lyman Mill Dam.

4.6 ALTERNATIVE 3: PARTIAL EXCAVATION – CHANNEL/PONDS

A detailed description of the Alternative 3 design is provided in Section 3.3. Predicted water depths and current speeds in the Allendale Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-32 through 4-35. A characteristic of this alternative design is larger ponds, compared to Alternatives 1 and 2, during low-flow conditions. In the Allendale Pond region during 7Q10 flow conditions, maximum water depths are about 2 to 3 ft. and current speeds are less than 10 cm/s (0.3 ft/s). During the 100-year flood, maximum water depths are about 10 ft. in this region, with maximum current speeds of about 80 cm/s (2.6 ft/s). The area of floodplain inundation is similar to present conditions.

Predicted water depths and current speeds in the Lyman Mill Pond region for 7Q10 flow and 100-year flood conditions are shown on Figures 4-36 through 4-39. In the Lyman Mill Pond region, two ponds exist during low-flow conditions, with these areas connected by a relatively narrow channel. During 7Q10 flow conditions, maximum water depths in the upstream area range from 2 to 3 ft and in the downstream area water depths are about 4 to 5 ft in the lower pond. Current speeds are less than 10 cm/s (0.3 ft/s) during these low-flow conditions. During the 100-year flood, the area of floodplain inundation is similar to present conditions. Maximum water depths in the ponded areas are about 10 ft., while water depths in the floodplain areas are less than 2 ft. Current speeds of about 140 cm/s (4.6 ft/s) are predicted in the channel between the two ponded areas.

Similar to the results for the Alternative 1 and 2 designs, the effects of dam removal on water depths and current speeds in the Manton Pond region are limited to a relatively short distance (about 300 ft.) downstream of Lyman Mill Dam.

4.7 ALTERNATIVE 4: NEAR-SHORE CDF WITH DAMS REMAINING IN PLACE

A detailed description of the Alternative 4 design is provided in Section 3.4. For this alternative, the dams are not removed and the geometries of Allendale and Lyman Mill Ponds are modified to accommodate near-shore CDFs. Predicted water depths and current speeds in Allendale Pond, with the CDF, for 7Q10 flow and 100-year flood conditions are shown on

Figures 4-40 through 4-43. In Allendale Pond during 7Q10 flow conditions, maximum water depths and current speeds are 7 ft. and less than 10 cm/s (0.3 ft/s), respectively. During the 100-year flood, maximum current speeds are about 80 cm/s (2.6 ft/s) in the pond area, which is about a factor of two-greater than predicted for present conditions.

Predicted water depths and current speeds in Lyman Mill Pond, with the CDF, for 7Q10 flow and 100-year flood conditions are shown on Figures 4-44 through 4-47. In Lyman Mill Pond during 7Q10 flow conditions, maximum water depths are about 10 ft and current speeds in the pond are less than 10 cm/s (0.3 ft/s). During the 100-year flood, current speeds of about 60 cm/s (2.0 ft/s) or less are predicted throughout most of the pond.

4.8 COMPARISONS OF REMEDIAL ALTERNATIVE DESIGNS AND PRESENT CONDITIONS

The previous subsections presented model results for the four remedial alternative designs, as well as present conditions with the dams in place. As noted at the beginning of this section, a total of 40 simulations were conducted which evaluated the effects of river flow (i.e., 7Q10 to 100-year flood conditions) and effective bed roughness for the four alternative designs and present conditions. The analyses presented in this subsection provide comparisons of large-scale metrics between the alternative designs and present conditions so that an improved understanding of the impacts of each remedial alternative on hydrodynamics in the study area can be gained. These analyses focused on three regions within the study area: Allendale Pond, Lyman Mill Pond, and Manton Pond. The metrics used for the comparative analyses were: spatially-averaged current speed, spatially-averaged water depth, and total inundation area. These metrics provide a useful method for understanding basic differences between the four remedial alternatives.

Average current speed, average water depth and inundation area, as a function of flow rate, for the Allendale Pond region are presented on Figures 4-48, 4-49 and 4-50, respectively. A summary of these predicted results is provided in Table 4-2. Alternative 1 has the highest average current speed, lowest average water depth, and lowest inundation area because river flow is confined to a relatively narrow channel. Generally, Alternatives 2 and 3 yield similar

results for these three metrics. Model results indicate that these two alternatives lie between Alternative 1 and Alternative 4/present conditions, with respect to average current speed/water depth and inundation area. Alternative 4 has the lowest average current speed, highest average water depth, and highest inundation area. Inundation areas for all alternatives are less than the predicted values for present conditions. Moreover, there is no appreciable increase in floodplain inundation for the four remedial alternatives relative to the predicted values for present conditions. The effects of effective bed roughness on model results are greatest for Alternative 1, moderate for Alternatives 2 and 3, and minimal for Alternative 4 and present conditions.

Table 4-2. Summary Comparison of Current Conditions and Alternatives 1 through 4 - Allendale Pond.

Metric	Alternative ID	Modeled Flow Condition (lower-bound)				Modeled Flow Condition (upper-bound)			
		7Q10	Average	2-yr flood	100-year flood	7Q10	Average	2-yr flood	100-year flood
Configuration Includes Ponds	Current Conditions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 1	No	No	No	No	No	No	No	No
	Alternative 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hydrodynamic Impact Downstream of Manton Dam	Current Conditions	NA	NA	NA	NA	NA	NA	NA	NA
	Alternative 1	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 2	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 3	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 4	NA	NA	NA	NA	NA	NA	NA	NA
Increased Area of Floodplain Inundation	Current Conditions	NA	NA	NA	NA	NA	NA	NA	NA
	Alternative 1	No	No	No	No	No	No	No	No
	Alternative 2	No	No	No	No	No	No	No	No
	Alternative 3	No	No	No	No	No	No	No	No
	Alternative 4	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Total Inundation Area (acres)	Current Conditions	6.8	7.1	7.9	8.6	6.8	7.1	7.9	8.6
	Alternative 1	0.6	0.8	1.2	3.3	0.6	0.9	1.3	4.8
	Alternative 2	2.1	2.2	4.7	5.3	2.1	2.2	4.2	5.6
	Alternative 3	2.1	2.8	3.4	7.3	2.1	2.9	3.7	7.5
	Alternative 4	5.8	6.0	6.2	6.7	5.8	6.0	6.3	6.7
Average Predicted Water Depth (ft)	Current Conditions	3.9	4.1	4.8	6.6	3.9	4.1	4.8	6.7
	Alternative 1	0.6	1.2	2.9	3.2	0.7	1.6	3.4	3.2
	Alternative 2	3.2	3.7	3.1	4.7	3.2	3.9	3.7	5.0
	Alternative 3	1.7	2.1	3.9	4.2	1.7	2.3	4.0	4.5
	Alternative 4	4.7	4.9	5.8	7.8	4.7	4.9	5.8	7.9
Maximum Predicted Water Depth (ft)	Current Conditions	7.6	7.9	8.9	11.0	7.6	7.9	8.9	11.0
	Alternative 1	1.5	2.4	4.5	8.1	1.5	2.5	5.4	9.3
	Alternative 2	4.6	5.3	7.5	11.0	4.5	5.6	7.9	11.0
	Alternative 3	2.5	3.3	5.6	9.0	2.5	3.6	5.9	9.3
	Alternative 4	8.6	8.9	9.9	12.0	8.6	8.9	9.9	12.0
Average Predicted Current Speed (ft/sec)	Current Conditions	0.3	0.3	0.4	0.9	0.3	0.3	0.4	0.9
	Alternative 1	0.5	1.8	3.8	3.6	0.4	1.1	2.8	2.3
	Alternative 2	0.3	0.5	0.8	1.8	0.3	0.3	0.8	1.5
	Alternative 3	0.3	0.3	1.0	1.4	0.3	0.3	0.8	1.2
	Alternative 4	0.3	0.3	0.4	1.0	0.3	0.3	0.4	1.0
Maximum Predicted Current Speed (ft/sec)	Current Conditions	0.3	1.2	6.4	8.9	0.3	1.1	5.5	7.6
	Alternative 1	2.5	4.6	10.0	13.0	2.0	2.8	8.5	12.0
	Alternative 2	3.1	6.1	8.1	9.9	1.9	4.1	7.0	9.3
	Alternative 3	2.7	6.1	8.3	9.9	1.8	4.0	7.3	9.3
	Alternative 4	0.3	1.2	6.7	8.5	0.3	1.2	6.3	7.4

Average current speed, average water depth and inundation area, as a function of flow rate, for the Lyman Mill Pond region are presented on Figures 4-51, 4-52 and 4-53. A summary of these predicted results is provided in Table 4-3. Similar to the Allendale Pond region, Alternative 1 has the highest average current speed, lowest average water depth, and lowest inundation area because of the relatively narrow channel. However, Alternatives 2 and 3 produce average current speeds and water depths in the Lyman Mill Pond Region which have larger differences than in the Allendale Pond region. Alternative 3 has higher average current speed and lower average water depth than Alternative 2 (and Alternative 1). Average current speeds for Alternatives 2 and 4 are similar to present conditions; average water depths for these two alternatives are greater than present conditions. Inundation areas for all four remedial alternatives are less than or equal to the predicted values for present conditions. Moreover, there is no appreciable increase in floodplain inundation for the four remedial alternatives relative to the predicted values for present conditions. Similar to the Allendale Pond region, the effects of effective bed roughness on model results are greatest for Alternative 1 and minimal to moderate for Alternatives 2, 3, 4 and present conditions.

Average current speed, average water depth and inundation area, as a function of flow rate, for the Manton Pond region are presented on Figures 4-54, 4-55, and 4-56. Overall, there is minimal difference between the four remedial alternatives and present conditions. This result is consistent with the results presented in previous subsections which noted that the effects of the remedial alternatives were limited to a relatively short distance downstream of Lyman Mill Dam.

Table 4-3. Summary Comparison of Current Conditions and Alternatives 1 through 4 - Lyman Mill Pond.

Metric	Alternative ID	Modeled Flow Condition (lower-bound)				Modeled Flow Condition (upper-bound)			
		7Q10	Average	2-yr flood	100-year flood	7Q10	Average	2-yr flood	100-year flood
Configuration Includes Ponds	Current Conditions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 1	No	No	No	No	No	No	No	No
	Alternative 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Alternative 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hydrodynamic Impact Downstream of Manton Dam	Current Conditions	NA	NA	NA	NA	NA	NA	NA	NA
	Alternative 1	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 2	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 3	NA	NA	NA	Negligible	NA	NA	NA	NA
	Alternative 4	NA	NA	NA	NA	NA	NA	NA	NA
Increased Area of Floodplain Inundation	Current Conditions	NA	NA	NA	NA	NA	NA	NA	NA
	Alternative 1	No	No	No	No	No	No	No	No
	Alternative 2	No	No	No	No	No	No	No	No
	Alternative 3	No	No	No	No	No	No	No	No
	Alternative 4	No	No	No	No	No	No	No	No
Total Inundation Area (acres)	Current Conditions	13.0	14.0	15.0	17.0	13.0	14.0	15.0	17.0
	Alternative 1	3.4	4.4	6.3	10.0	3.5	4.9	7.8	15.0
	Alternative 2	7.1	7.1	11.0	15.0	7.0	8.0	11.0	15.0
	Alternative 3	7.6	7.8	9.5	17.0	7.5	7.9	11.0	18.0
	Alternative 4	10.0	10.0	11.0	13.0	9.8	10.0	11.0	13.0
Average Predicted Water Depth (ft)	Current Conditions	3.0	3.1	3.9	5.7	3.0	3.1	4.0	5.9
	Alternative 1	0.9	1.0	1.5	2.3	0.9	1.1	1.8	3.1
	Alternative 2	3.1	4.1	4.7	6.1	3.3	3.9	5.0	6.4
	Alternative 3	1.5	2.0	3.2	3.7	1.6	2.2	3.4	4.5
	Alternative 4	4.2	4.4	5.1	6.7	4.3	4.4	5.1	6.9
Maximum Predicted Water Depth (ft)	Current Conditions	3.0	3.1	3.9	5.7	3.0	3.1	4.0	5.9
	Alternative 1	0.9	1.0	1.5	2.3	0.9	1.1	1.8	3.1
	Alternative 2	3.1	4.1	4.7	6.1	3.3	3.9	5.0	6.4
	Alternative 3	1.5	2.0	3.2	3.7	1.6	2.2	3.4	4.5
	Alternative 4	4.2	4.4	5.1	6.7	4.3	4.4	5.1	6.9
Average Predicted Current Speed (ft/sec)	Current Conditions	0.3	0.3	0.4	0.8	0.3	0.3	0.4	0.8
	Alternative 1	0.3	0.6	1.8	2.7	0.3	0.4	1.1	1.4
	Alternative 2	0.3	0.3	0.4	0.8	0.3	0.3	0.4	0.8
	Alternative 3	0.3	0.3	0.9	1.3	0.3	0.3	0.6	0.9
	Alternative 4	0.3	0.3	0.3	0.8	0.3	0.3	0.3	0.8
Maximum Predicted Current Speed (ft/sec)	Current Conditions	1.3	1.2	2.0	6.8	0.9	1.5	2.4	6.8
	Alternative 1	2.8	6.0	10.0	15.0	2.2	3.0	7.0	12.0
	Alternative 2	3.0	8.3	12.0	16.0	2.9	5.0	9.7	15.0
	Alternative 3	2.2	6.8	12.0	16.0	2.1	4.4	9.1	14.0
	Alternative 4	2.3	2.8	1.9	5.1	1.2	1.4	1.9	5.4

SECTION 5
SUMMARY

The primary objective of the study was to assess whether implementation of any of the four identified remedial alternatives would be feasible from a hydrodynamic standpoint. To fulfill this objective, hydrodynamic modeling was undertaken, as discussed, to:

- Evaluate various channel designs in the Allendale and Lyman Mill Ponds.
- Investigate the hydrodynamics and extent of inundation in the floodplain areas of Allendale and Lyman Mill Ponds.
- Analyze the effects of dam removal on the hydrodynamics and flood plain inundation in Manton Pond.
- Evaluate the impacts of the various remedial alternatives on stage height and floodplain inundation during high-flow events in the region from Manton Dam to the confluence of the Woonasquatucket and Moshassuck Rivers.

A two-dimensional, vertically-averaged hydrodynamic model (i.e., EFDC) was applied to the study area, which extended about 2.3 miles along the Woonasquatucket River, from the USGS gauging station at Centredale to Manton Dam. A high-resolution numerical grid was used so that geometry and bathymetry for the various remedial alternative designs could be represented adequately in the model; the grid was composed of about 120,000 2-meter grid cells.

The hydrodynamic model was used to predict future conditions in the river under various channel/pond configurations associated with each of the three dam removal alternatives and the one remedial alternative with the dams remaining in place. Thus, use of the model as a prognostic tool precludes calibration, which results in uncertainty in the predictive simulations. However, this uncertainty was minimized through the use of bounding calculations based on a realistic range of effective bed roughness values (i.e., 0.1 to 5 cm). Predictive model simulations were conducted using this range of bed roughness heights, which produced lower- and upper-bound results for each flow regime. The level of uncertainty in the predictions was reflected in these bounding simulations, with the "real" answer lying somewhere between the lower- and upper-bound of effective bed roughness values.

Four remedial alternative designs were evaluated during this study:

- Alternative 1 – partial excavation with channel with dams removed
- Alternative 2 – total excavation with channel and ponds with dams removed
- Alternative 3 – partial excavation with channel and ponds with dams removed
- Alternative 4 – near-shore CDF with dams in place

Detailed descriptions of these four alternative designs are presented in Section 3. The model was used to simulate the hydrodynamics (i.e., current speed, water depth, extent of inundation) in the study area for the four design alternatives and to present the resulting conditions for four flow scenarios: 1) 7Q10 flow; 2) average flow; 3) 2-year flood; and 4) 100-year flood. River discharge ranges were identified from 8 cfs for 7Q10 flow to 2,300 cfs for 100-year flood conditions.

A total of 40 hydrodynamic simulations were executed for the study area. For each simulation, model output was processed to generate figures depicting spatial distributions of: extent of channel and floodplain inundation; water depth and water surface elevation; current velocity (i.e., vector plot); current velocity speed; bed shear stress; and stable bed particle size. Hence, a voluminous set of figures (i.e., nearly 800 figures) were generated that depict the model results for the various remedial design alternatives. A sub-set of the model results that show the salient aspects of the design alternatives (i.e., spatial distributions of current speed and water depth) have been included in the report. All of the model results have been forwarded to LEA personnel for design purposes. The entire set of figures showing model results are available in electronic format on a CD for use by USEPA and other stakeholders.

Comparisons of large-scale metrics between the alternative designs and present conditions were made to gain an improved understanding of the impacts of each remedial alternative on hydrodynamics in the study area. These analyses focused on three regions within the study area: Allendale Pond, Lyman Mill Pond, and Manton Pond. The metrics used for the comparative analyses were: spatially-averaged current speed, spatially-averaged water depth, and total inundation area. These metrics provide a useful method for understanding basic differences between the four remedial alternatives.

Within Allendale Pond, Alternative 1 has the highest average current speed, lowest average water depth, and lowest inundation area because river flow is confined to a relatively narrow channel. Generally, Alternatives 2 and 3 yield similar results for these three metrics. Model results indicate that these two alternatives lie between Alternative 1 and Alternative 4/present conditions, with respect to average current speed/, water depth and inundation area. Alternative 4 has the lowest average current speed, highest average water depth, and highest inundation area of the four alternatives. Inundation areas for all four remedial alternatives are less than the predicted values for present conditions. Moreover, there is no appreciable increase in floodplain inundation for the four remedial alternatives relative to the predicted values for present conditions. The effects of effective bed roughness on model results are greatest for Alternative 1, moderate for Alternatives 2 and 3, and minimal for Alternative 4 and present conditions.

Similar to the Allendale Pond region, Alternative 1 has the highest average current speed, lowest average water depth, and lowest inundation area in the Lyman Mill Pond region because of the relatively narrow channel. However, Alternatives 2 and 3 produce average current speeds and water depths in the Lyman Mill Pond region which have larger differences than in the Allendale Pond region. Alternative 3 has higher average current speed and lower average water depth than Alternative 2 and Alternative 1. Average current speeds for Alternatives 2 and 4 are similar to present conditions; average water depths for these two alternatives are greater than present conditions. Inundation areas for all four remedial alternatives are less than or equal to the predicted values for present conditions. Moreover, there is no appreciable increase in floodplain inundation for the four remedial alternatives relative to the predicted values for present conditions. Similar to the Allendale Pond region, the effects of effective bed roughness on model results are greatest in the Lyman Mill Pond region for Alternative 1 and minimal to moderate for Alternatives 2, 3, 4 and present conditions.

Overall, there is minimal difference between the four remedial alternatives and present conditions within the Manton Pond region. This result is consistent with the results presented in prior subsections, which noted that the effects of the remedial alternatives were limited to a relatively short distance downstream of Lyman Mill Dam.

Based on an evaluation of the model results, the following conclusions were reached:

- All four alternatives result in reasonable predicted ranges of current velocities and current speeds. Accordingly, any of the alternatives can be engineered to minimize erosion.
- All four alternatives result in predicted flood inundation that has no appreciable effect beyond that for existing conditions for the areas adjacent to Allendale and Lyman Mill Ponds, even for 100-year flood events.
- All four alternatives would have a negligible effect on flood stage height and floodplain inundation during high-flow events (100 yr-flood) in the region downstream of Manton Dam.

In light of the modeling results, each of the four alternatives evaluated in this study are viable remedial options for the CMRPSS from a hydrodynamic standpoint.

SECTION 6
REFERENCES

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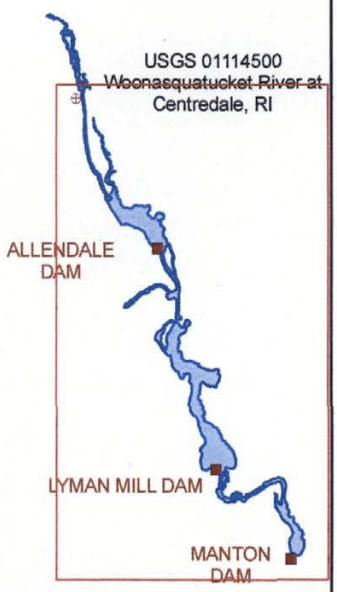

GRAPHIC SCALE

0 750 1,500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

CENTREDALE MANOR STUDY AREA

Figure 1-1.
Map of entire study area.

QEA
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EMHcen:120 November 2007

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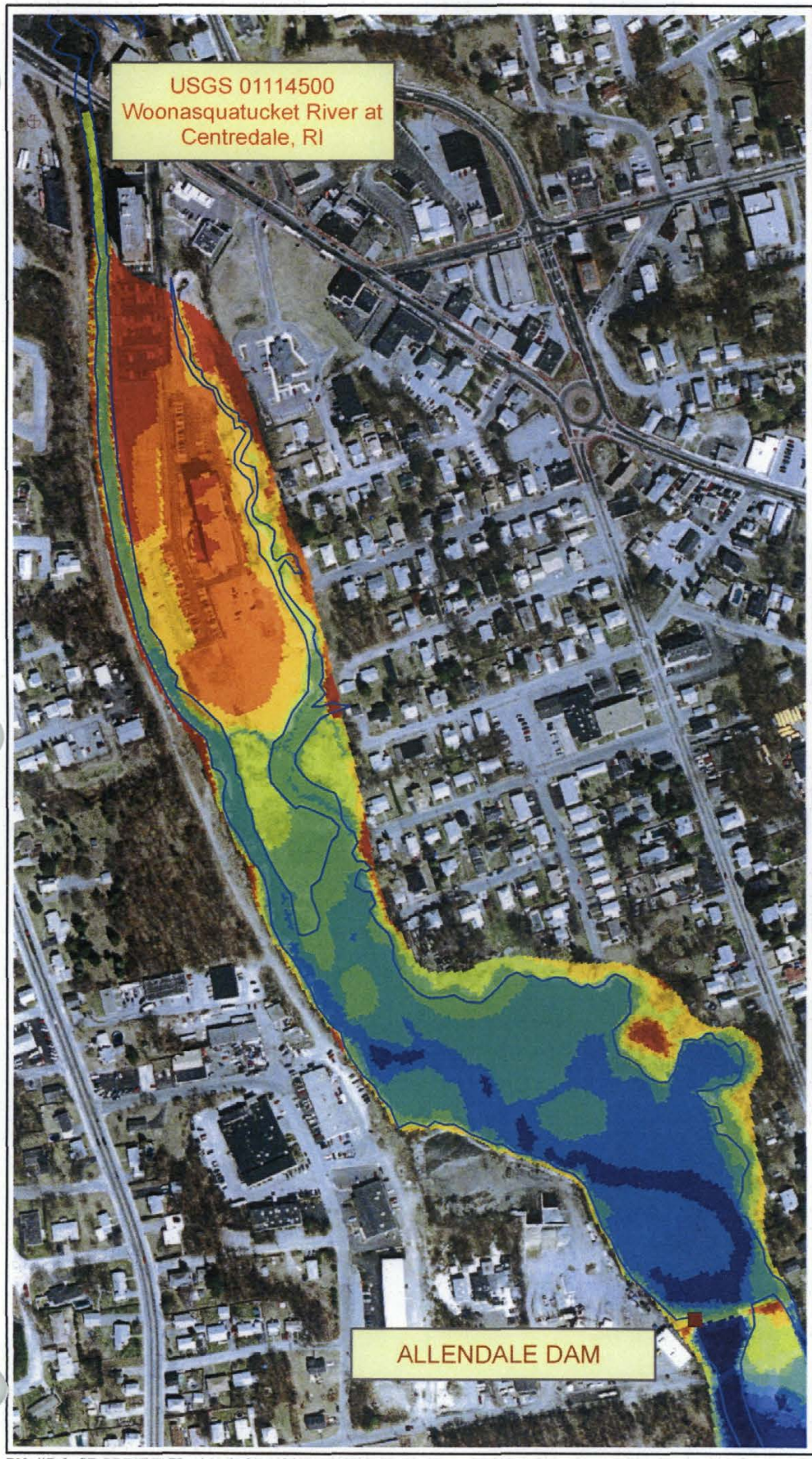

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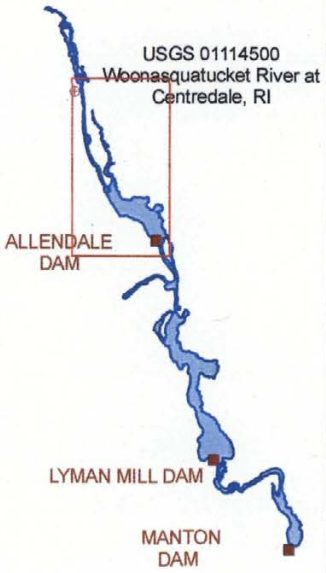

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 85
- 85 - 87
- 87 - 89
- 89 - 91
- 91 - 93
- 93 - 95
- 95 - 97
- 97 - 99
- > 99

CENTREDALE MANOR STUDY AREA

Figure 1-2. Current bathymetry and topography in Allendale Pond.

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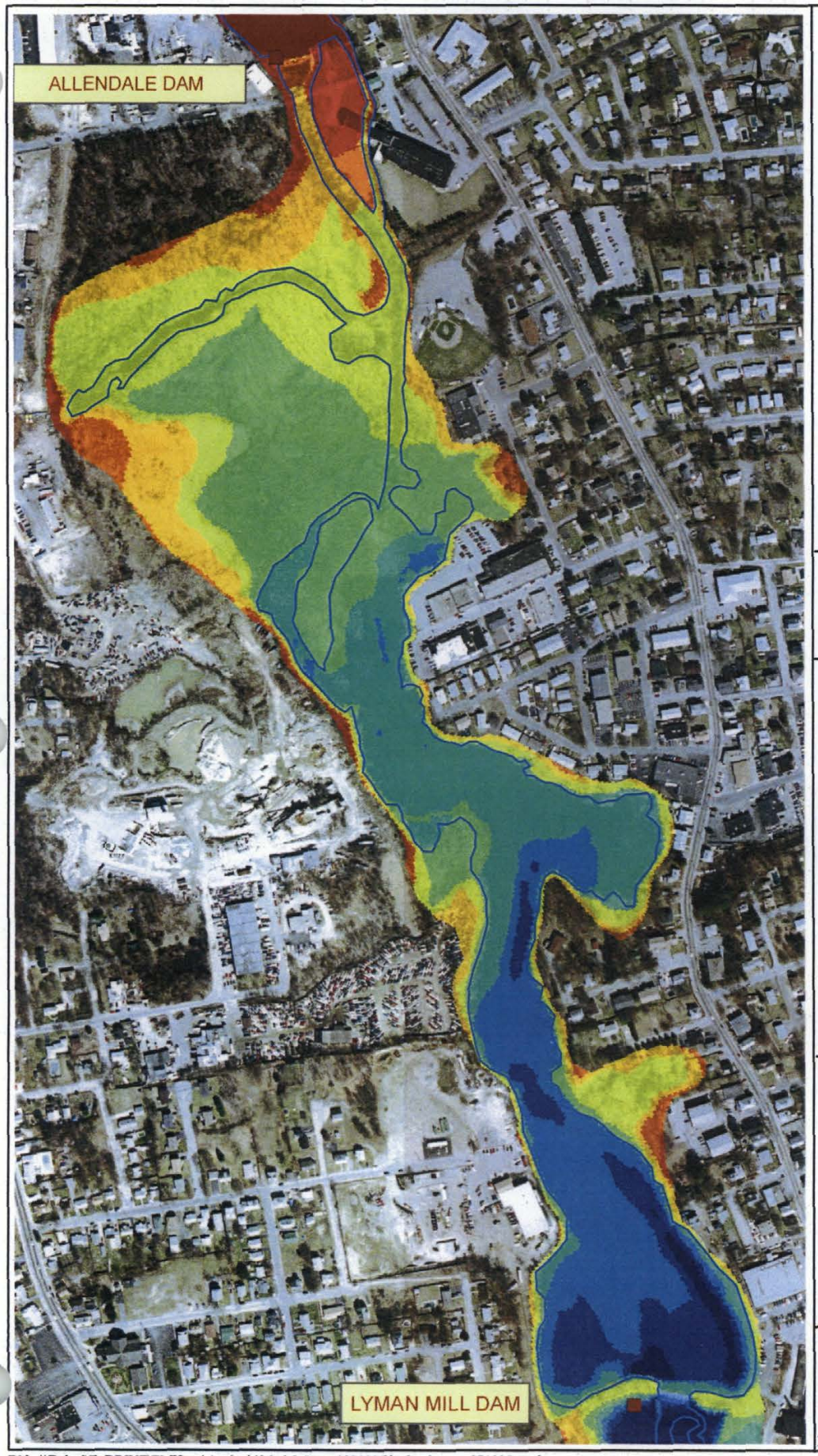

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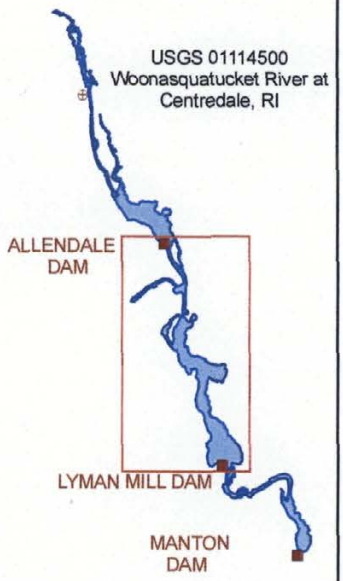

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 70
- 70 - 72
- 72 - 74
- 74 - 76
- 76 - 78
- 78 - 80
- 80 - 82
- 82 - 84
- > 84

CENTREDALE MANOR STUDY AREA

Figure 1-3. Current bathymetry and topography in Lyman Mill Pond.

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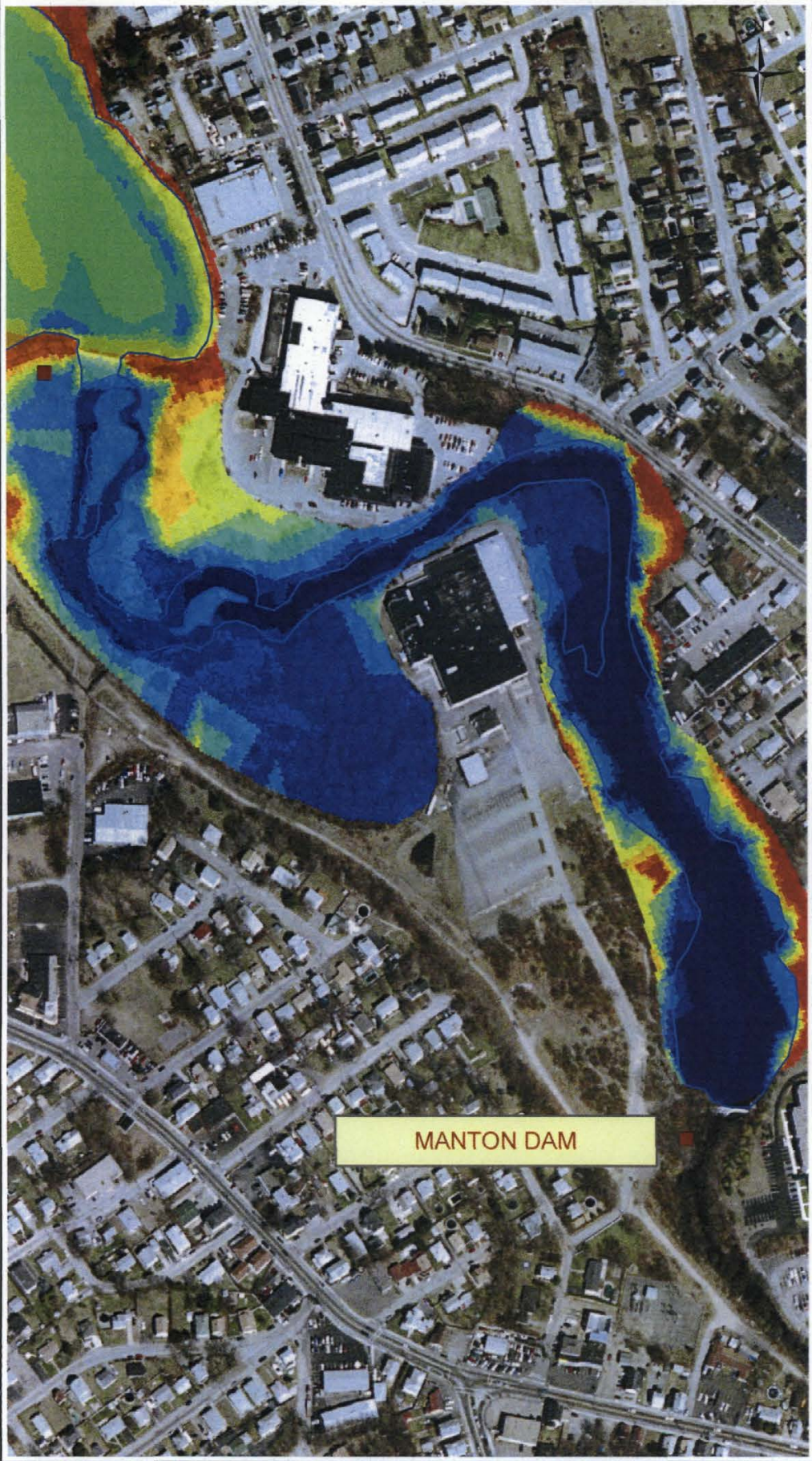

LOCATOR MAP

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 65
- 65 - 67
- 67 - 69
- 69 - 71
- 71 - 73
- 73 - 75
- 75 - 77
- 77 - 79
- > 79

CENTREDALE MANOR STUDY AREA

Figure 1-4. Current bathymetry and topography in Manton Pond.

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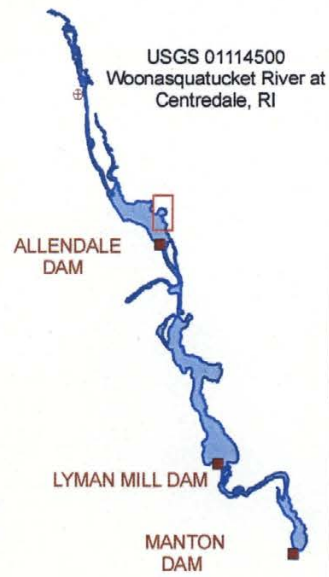
LOCATOR MAP



GRAPHIC SCALE

Feet

0 50 100

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Model Grid

- River Channel
- Floodplain

CENTREDALE MANOR STUDY AREA

Figure 2-1.
Numerical grid showing floodplain areas and main channel.

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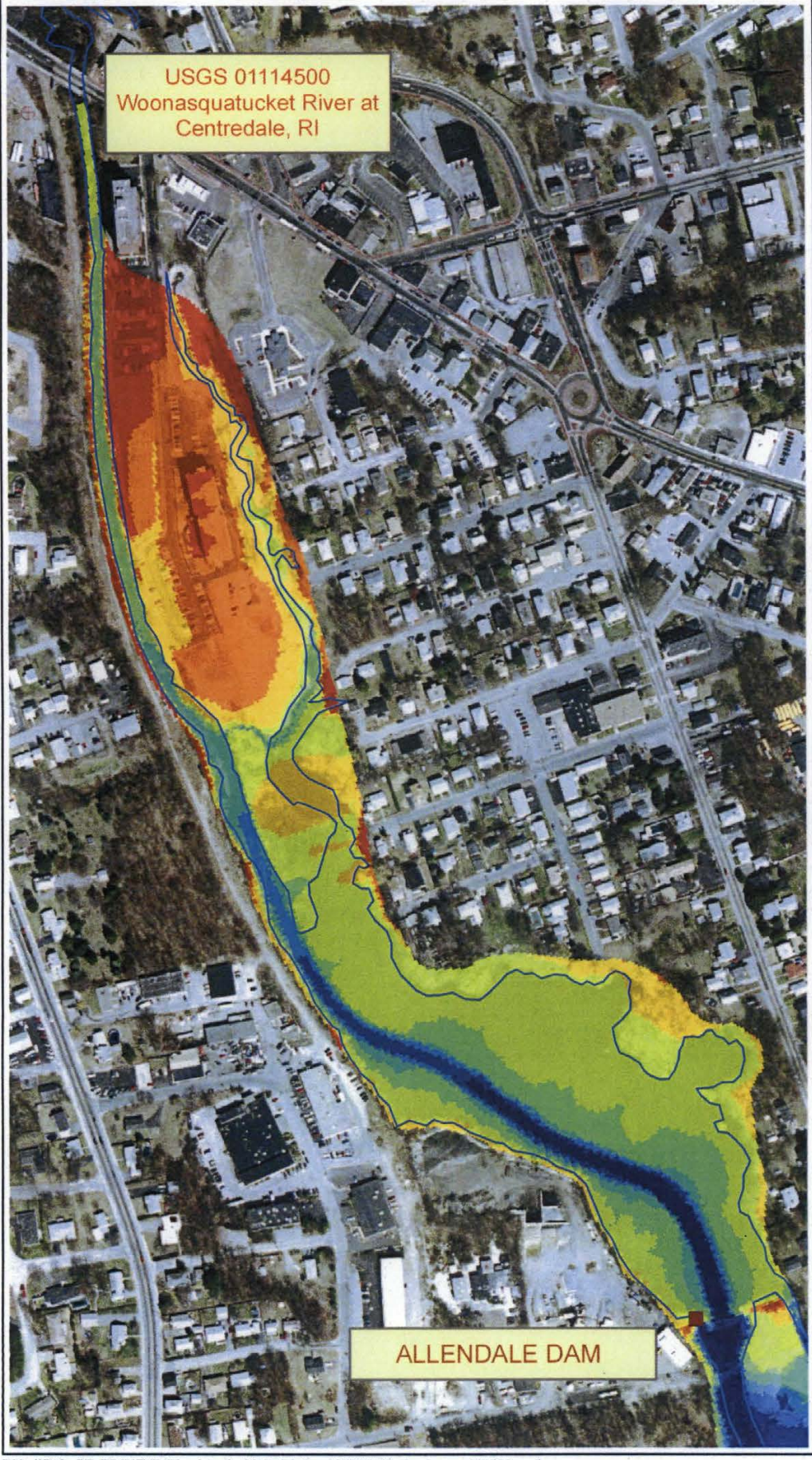

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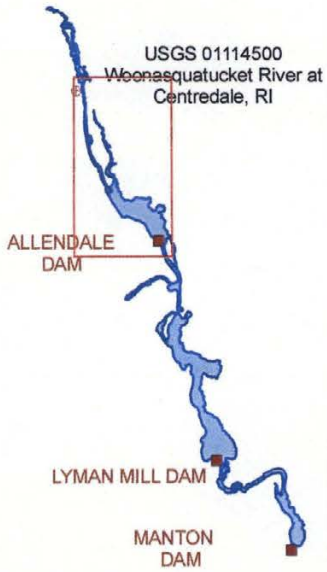

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 85
- 85 - 87
- 87 - 89
- 89 - 91
- 91 - 93
- 93 - 95
- 95 - 97
- 97 - 99
- > 99

CENTREDALE MANOR STUDY AREA

Figure 3-1. Numerical grid showing bathymetry and topography in Allendale Pond for Alternative 1: partial excavation - channel.

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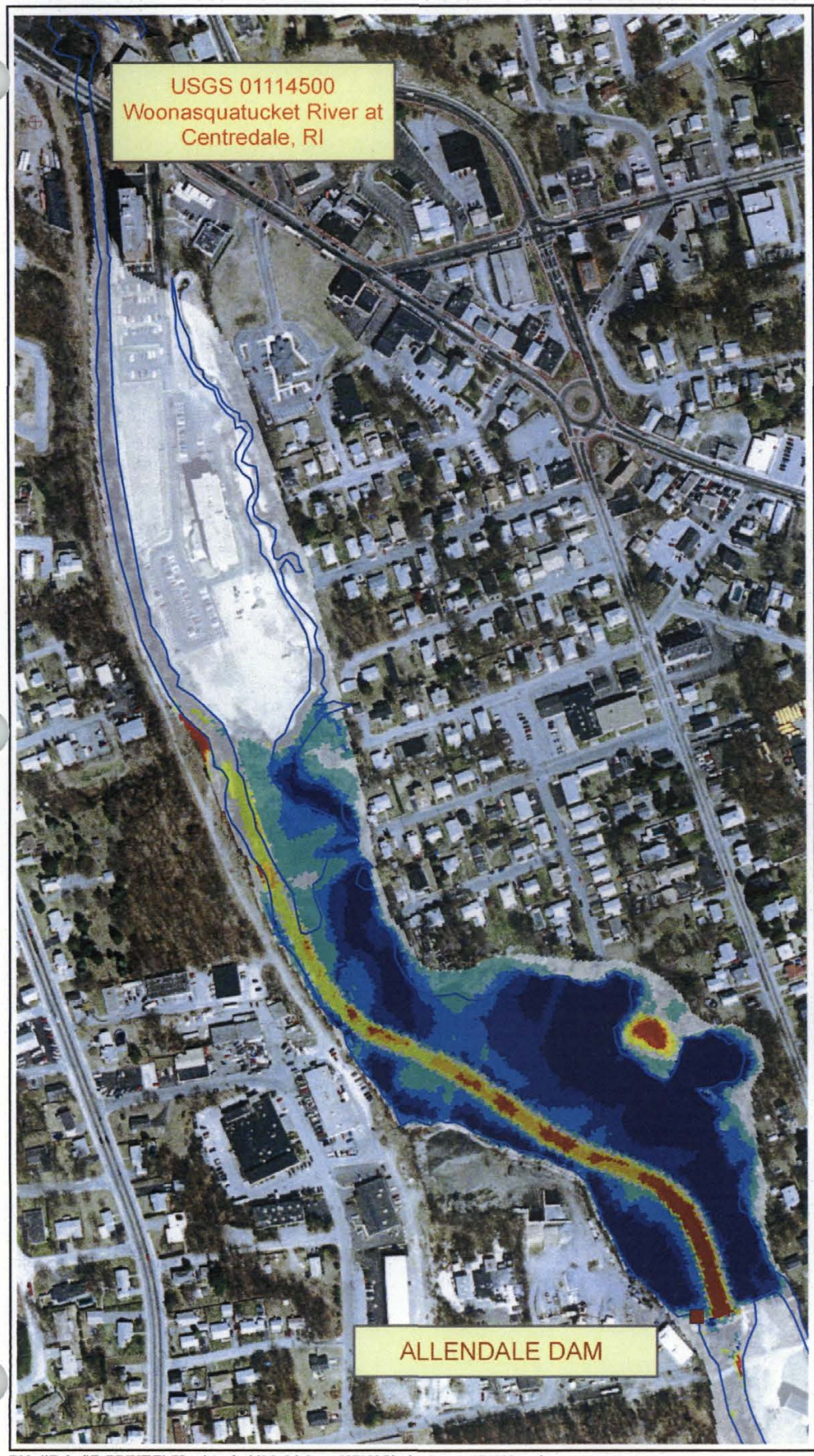

LOCATOR MAP

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

CENTREDALE MANOR STUDY AREA

Figure 3-2.
Numerical grid showing bathymetry and topography differences in Allendale Pond for Alternative 1: partial excavation - channel.

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Quantitative Environmental Analysis, LLC

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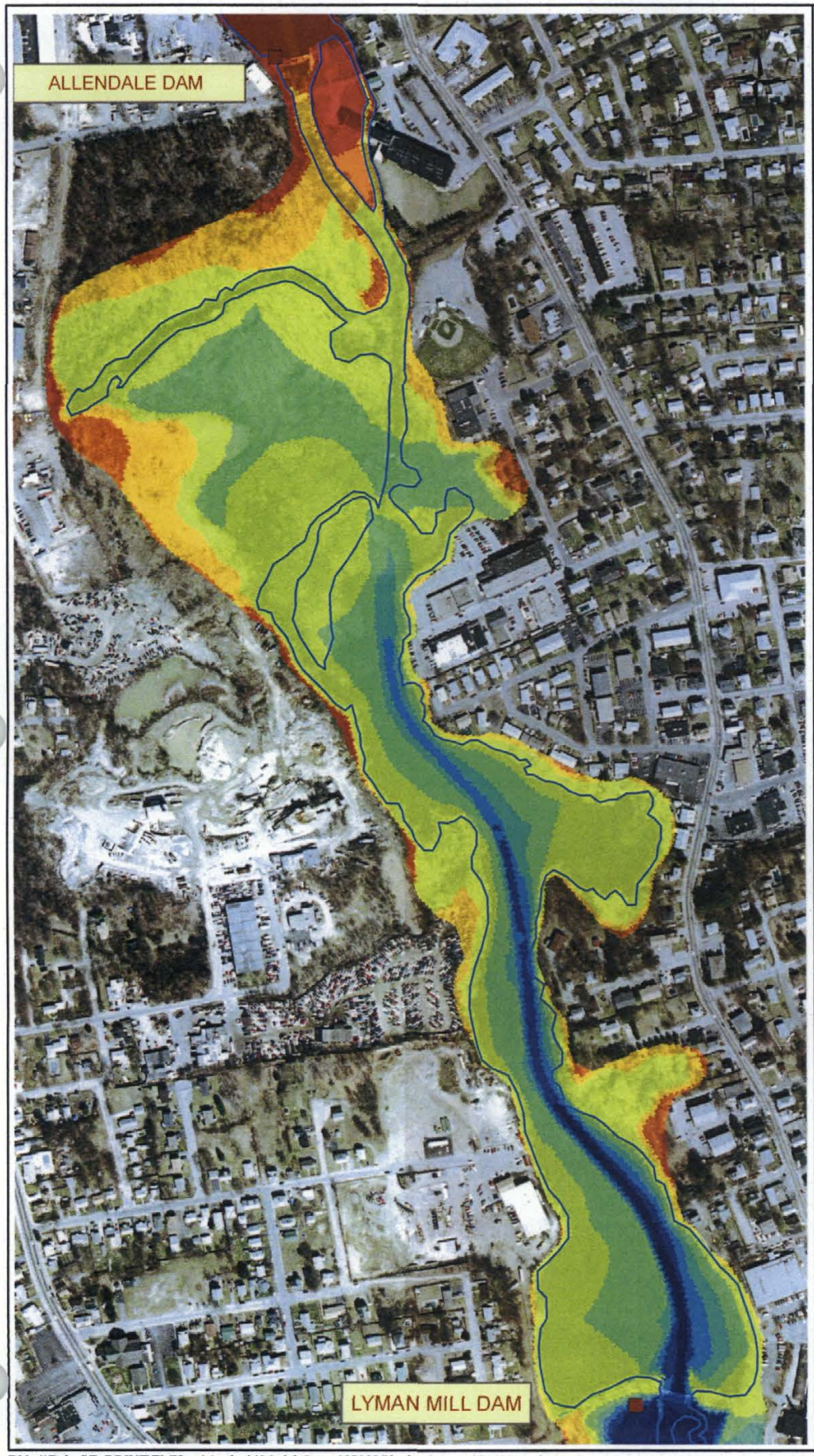

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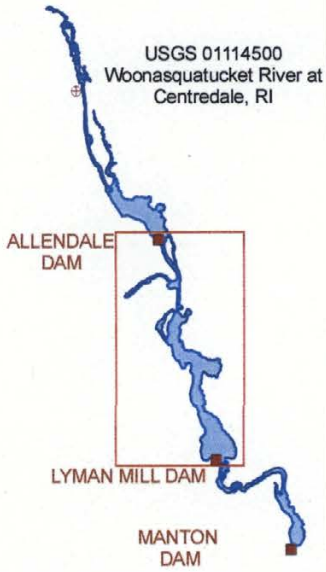

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 70
- 70 - 72
- 72 - 74
- 74 - 76
- 76 - 78
- 78 - 80
- 80 - 82
- 82 - 84
- > 84

CENTREDALE MANOR STUDY AREA

Figure 3-3. Numerical grid showing bathymetry and topography in Lyman Mill Pond for Alternative 1: partial excavation - channel.

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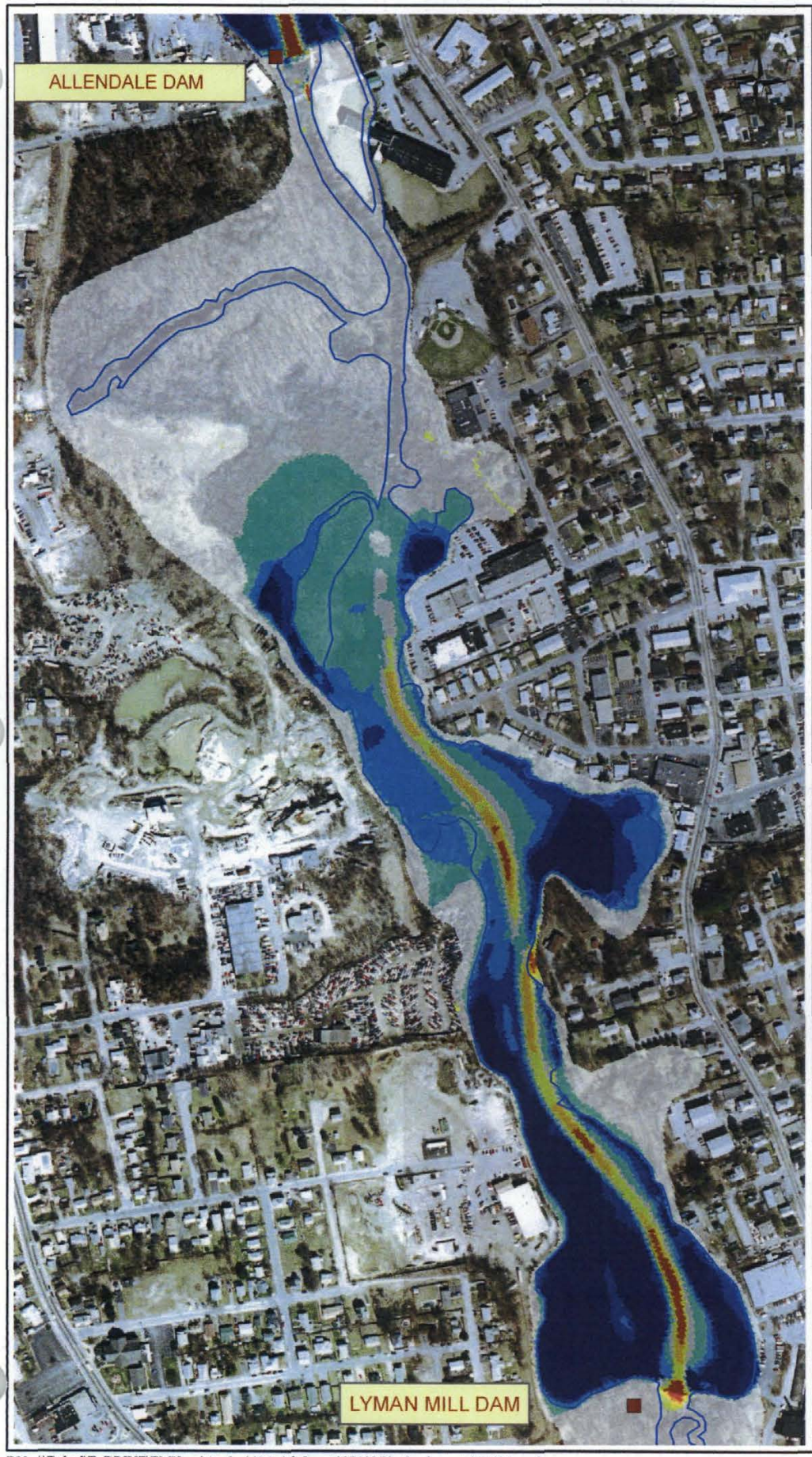

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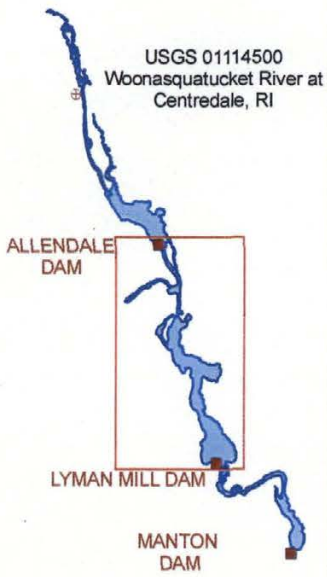

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

CENTREDALE MANOR STUDY AREA

Figure 3-4.
Numerical grid showing bathymetry and topography differences in Lyman Mill Pond for Alternative 1: partial excavation - channel.

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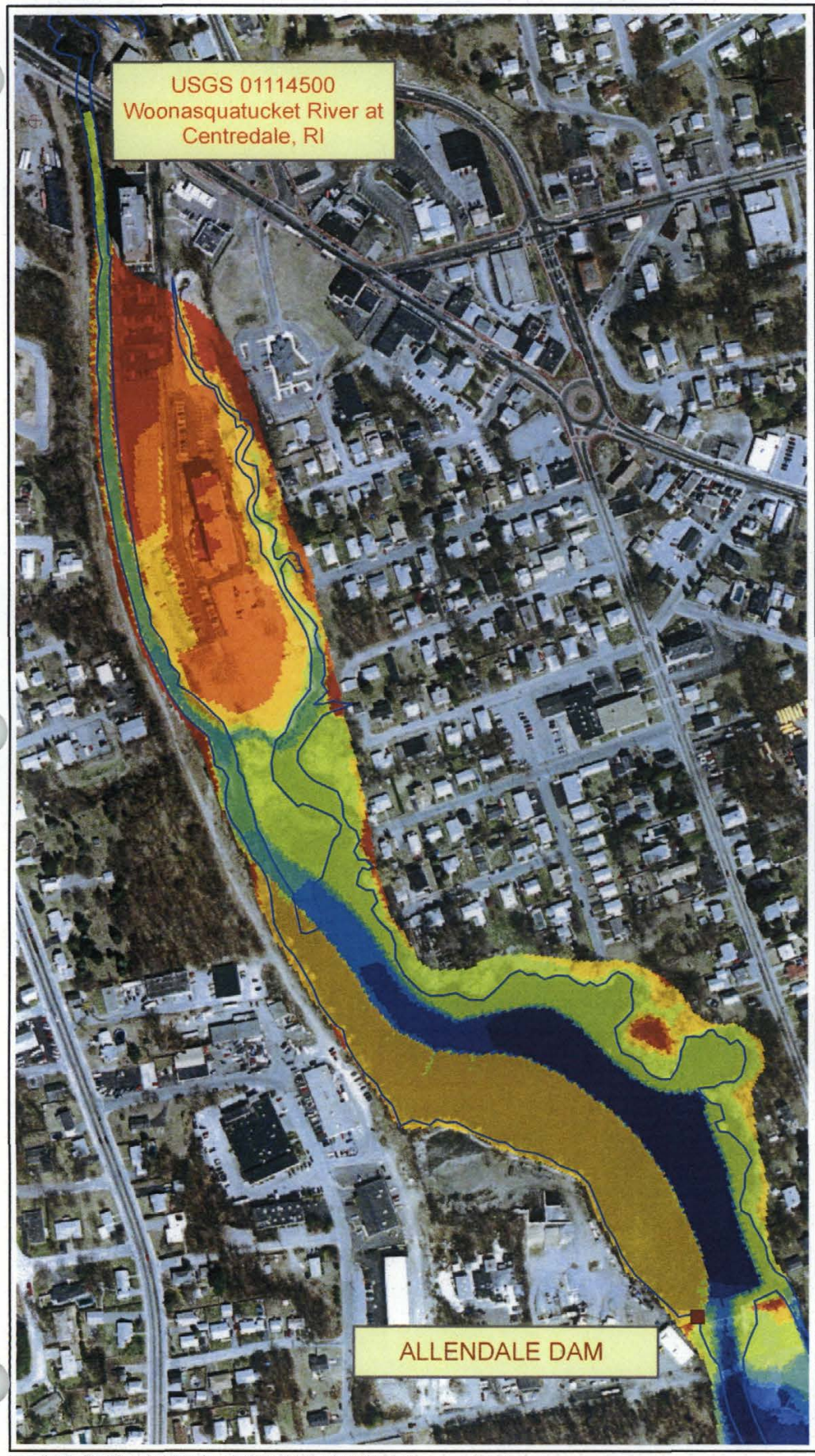

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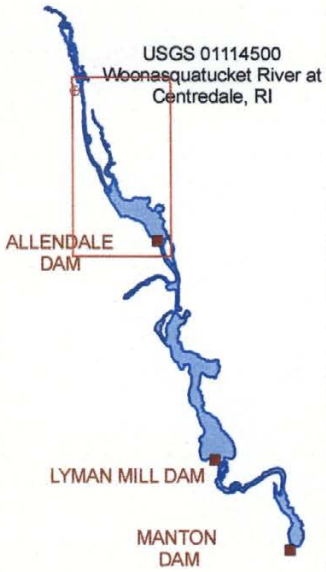

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 85
- 85 - 87
- 87 - 89
- 89 - 91
- 91 - 93
- 93 - 95
- 95 - 97
- 97 - 99
- > 99

CENTREDALE MANOR STUDY AREA

Figure 3-5. Numerical grid showing bathymetry and topography in Allendale Pond for Alternative 2: total excavation - channel/ponds.

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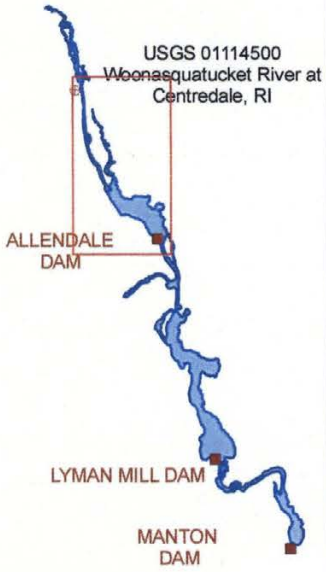
LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

CENTREDALE MANOR STUDY AREA

Figure 3-6. Numerical grid showing bathymetry and topography differences in Allendale Pond for Alternative 2: total excavation - channel/ponds.

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

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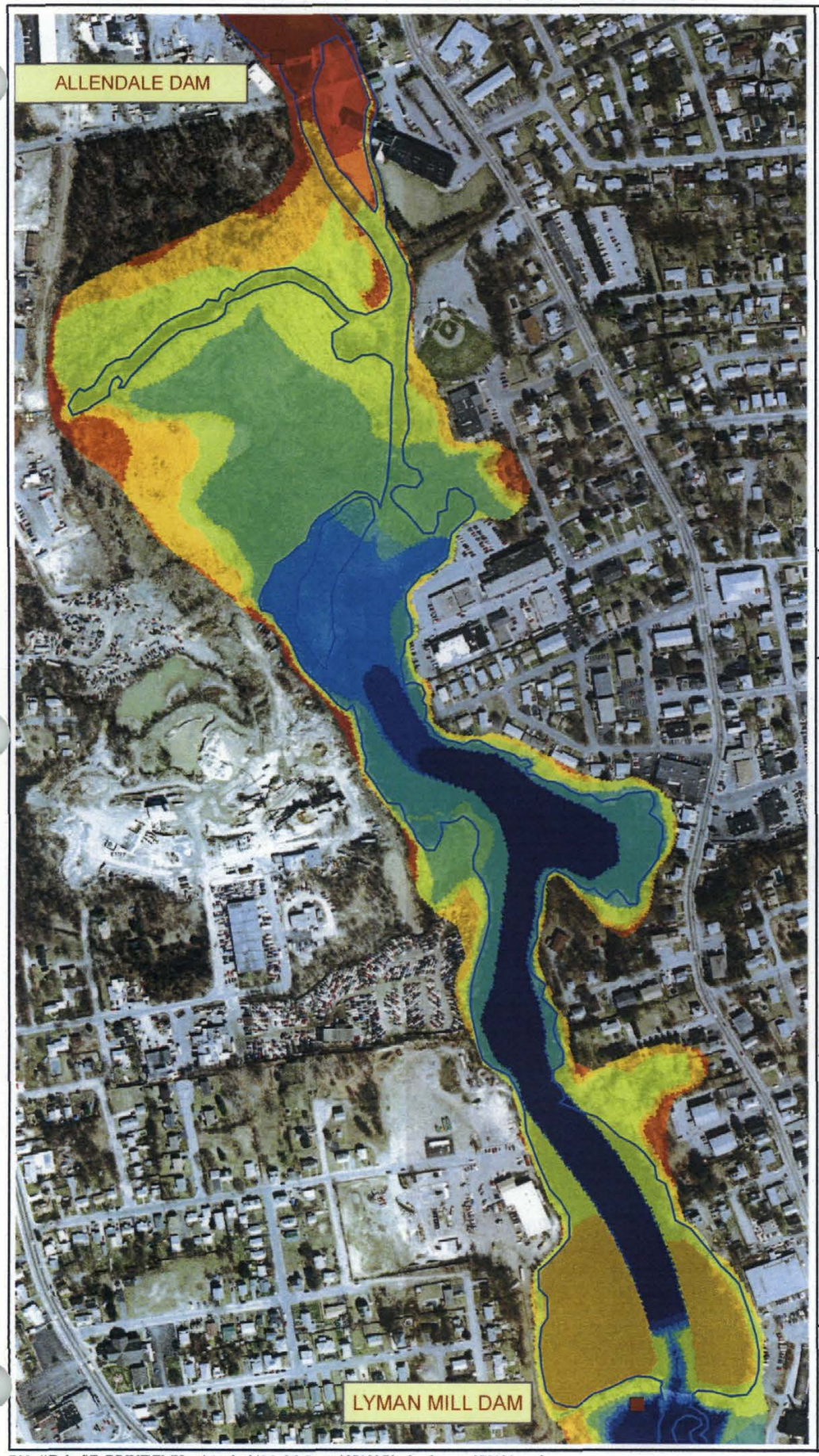

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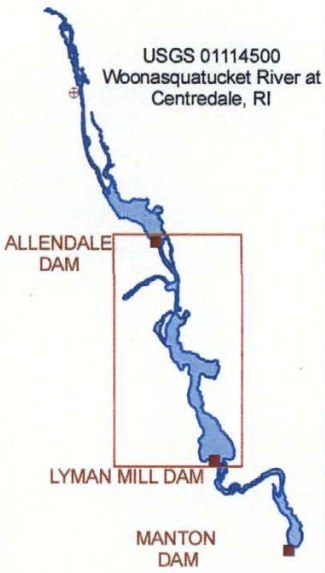

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 70
- 70 - 72
- 72 - 74
- 74 - 76
- 76 - 78
- 78 - 80
- 80 - 82
- 82 - 84
- > 84

CENTREDALE MANOR STUDY AREA

Figure 3-7. Numerical grid showing bathymetry and topography in Lyman Mill Pond for Alternative 2: total excavation - channel/ponds.

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

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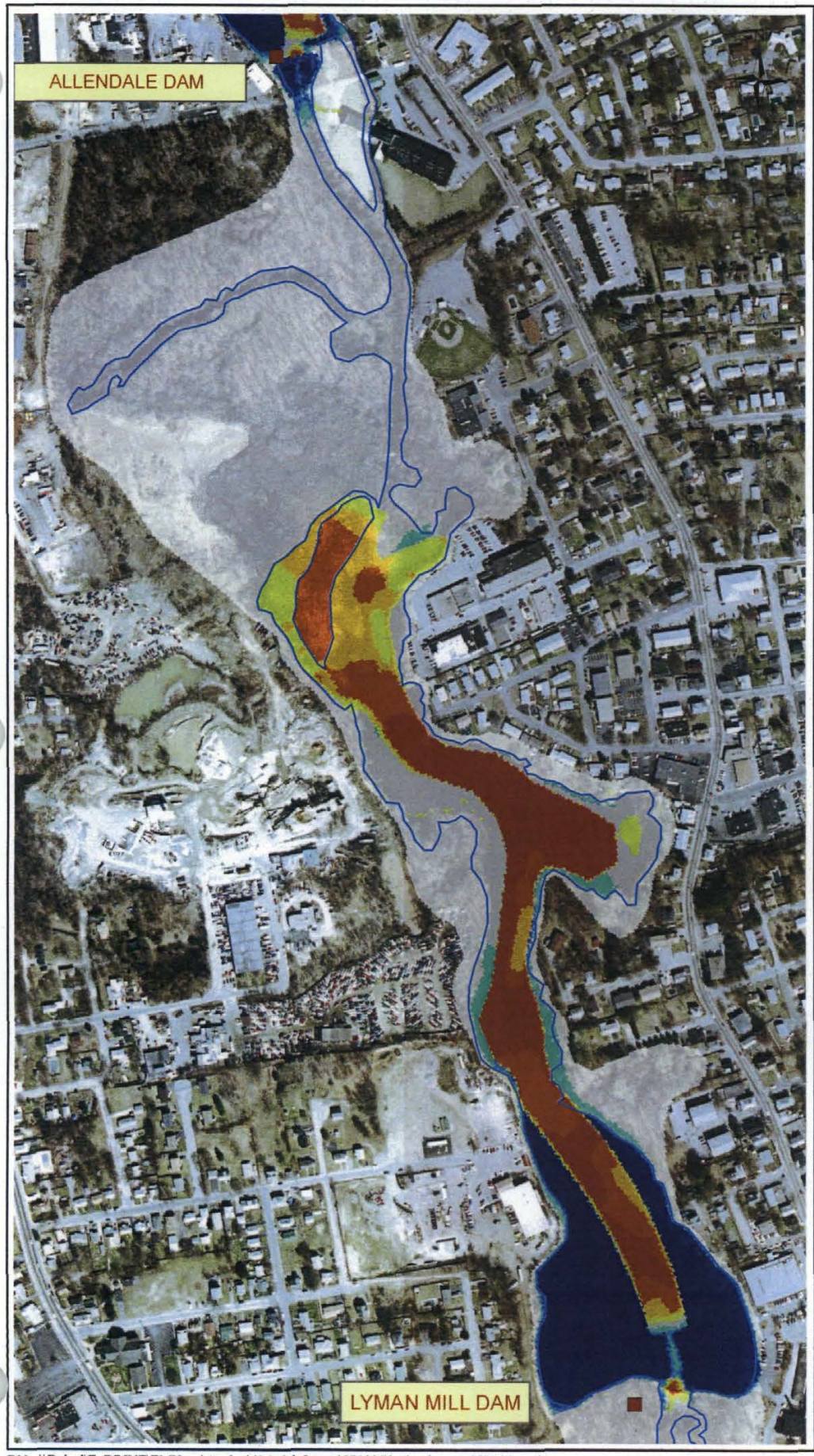

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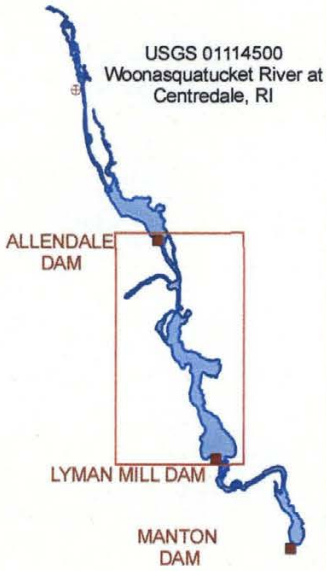

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

CENTREDALE MANOR STUDY AREA

Figure 3-8. Numerical grid showing bathymetry and topography differences in Lyman Mill Pond for Alternative 2: total excavation - channel/ponds.

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

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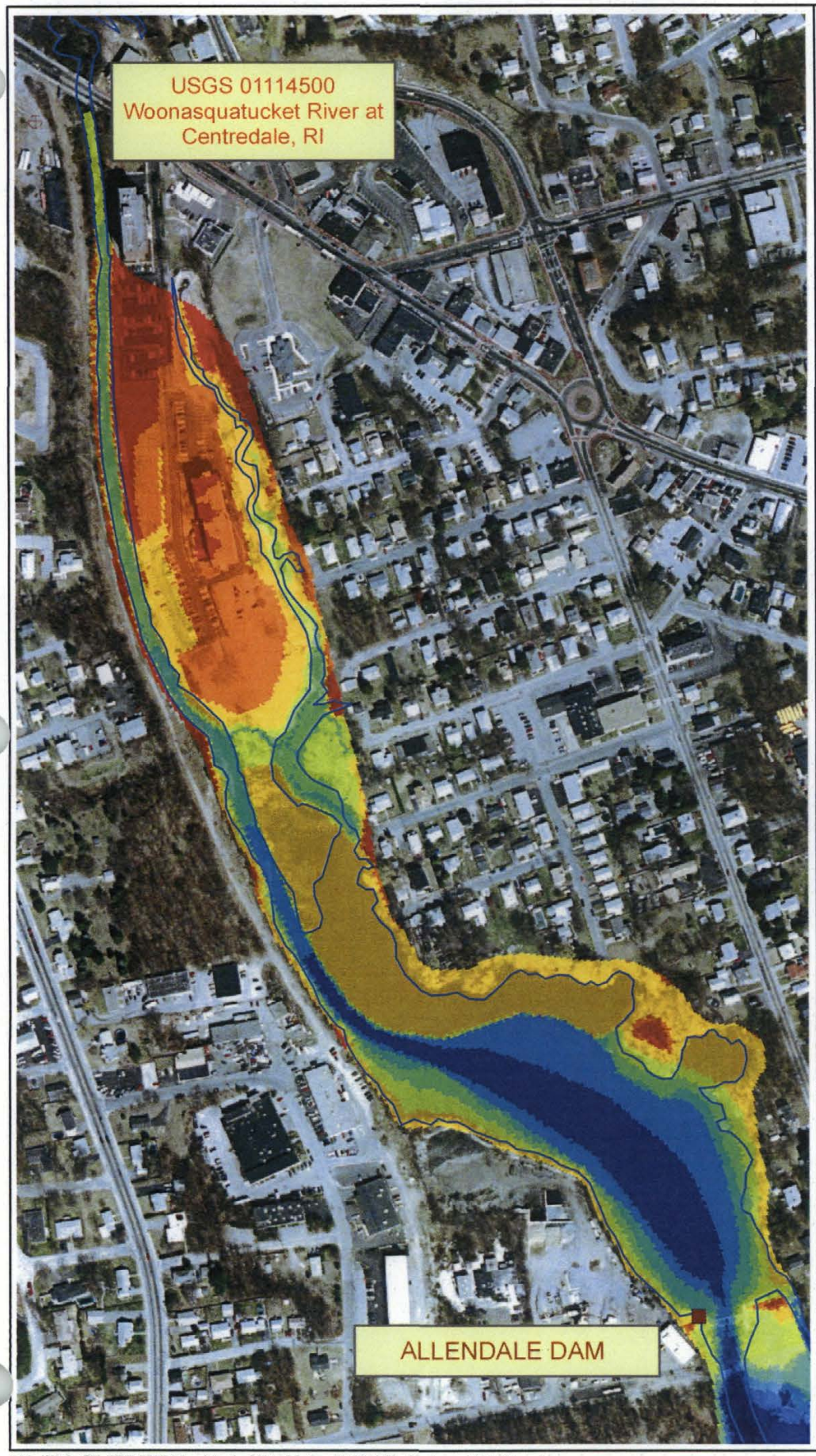

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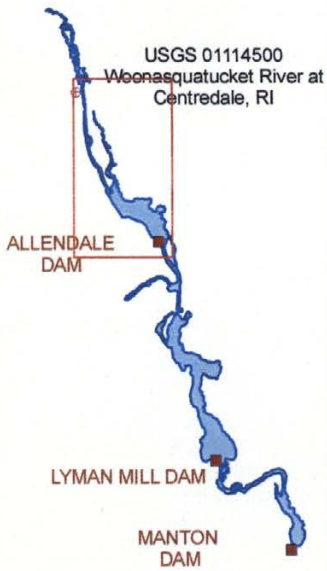


GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 85
- 85 - 87
- 87 - 89
- 89 - 91
- 91 - 93
- 93 - 95
- 95 - 97
- 97 - 99
- > 99

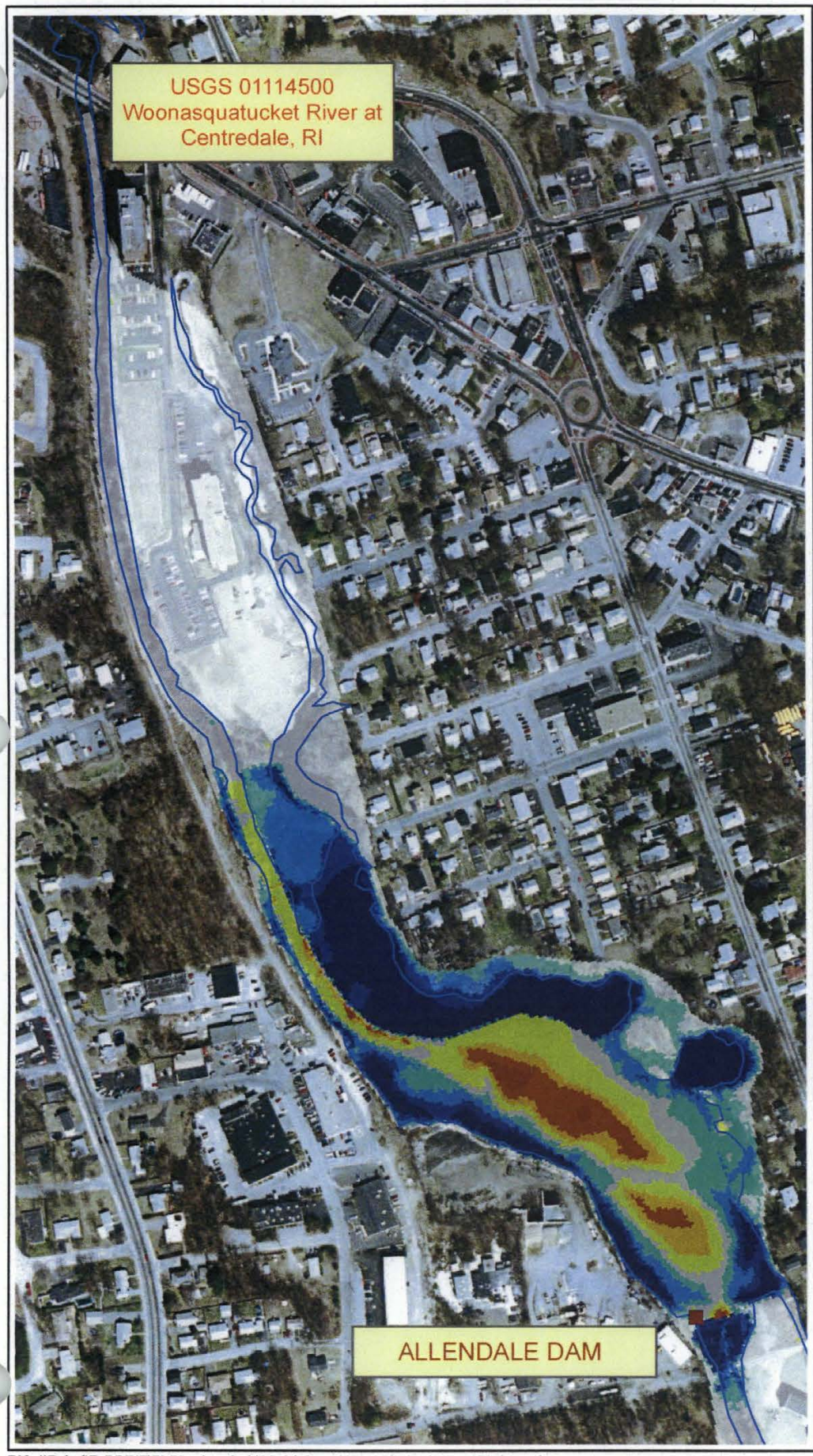
CENTREDALE MANOR STUDY AREA

Figure 3-9. Numerical grid showing bathymetry and topography in Allendale Pond for Alternative 3: partial excavation - channel/ponds.

QEA Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

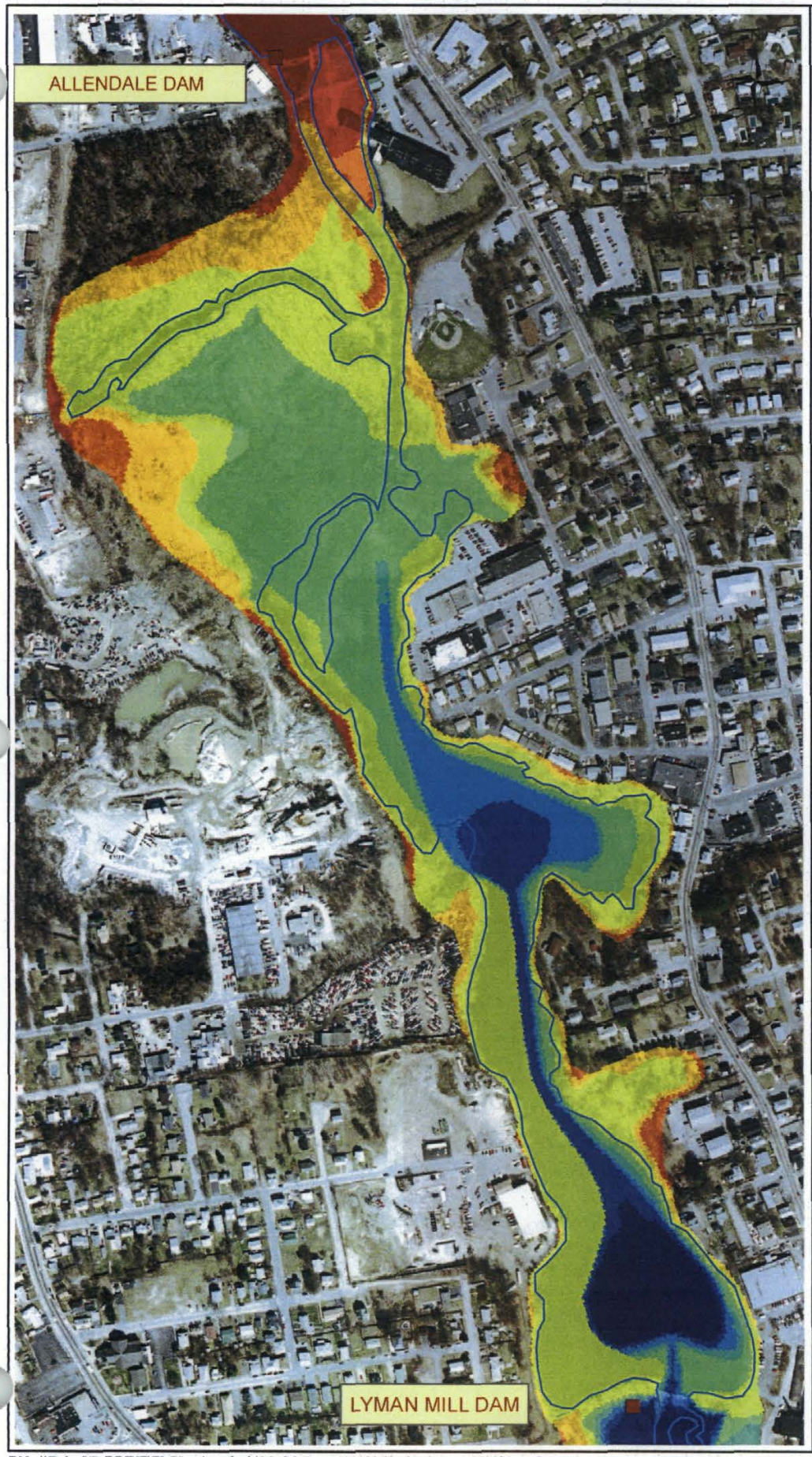
CENTREDALE MANOR STUDY AREA

Figure 3-10. Numerical grid showing bathymetry and topography differences in Allendale Pond for Alternative 3: partial excavation - channel/ponds.

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 70
- 70 - 72
- 72 - 74
- 74 - 76
- 76 - 78
- 78 - 80
- 80 - 82
- 82 - 84
- > 84

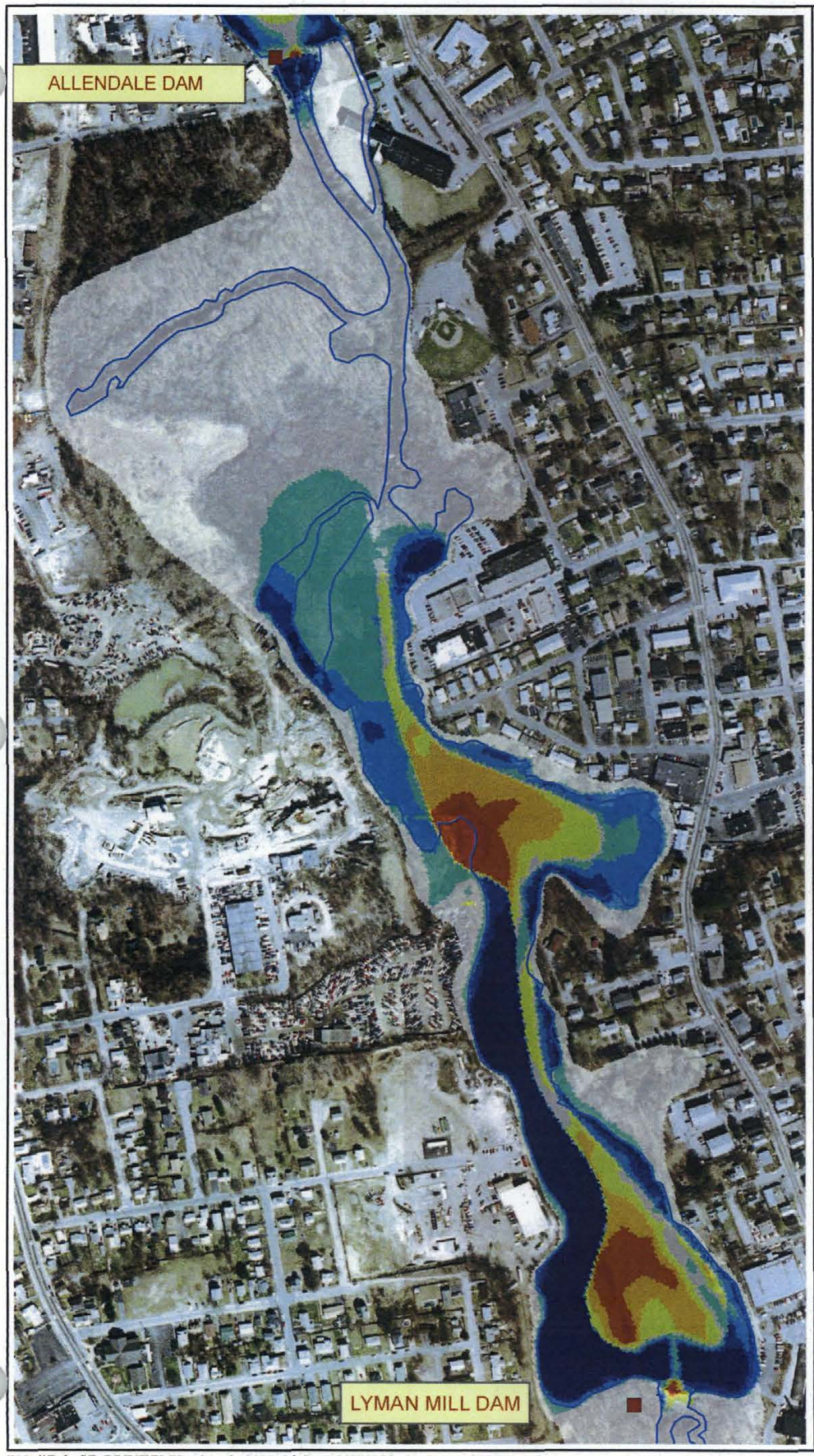
CENTREDALE MANOR STUDY AREA

Figure 3-11. Numerical grid showing bathymetry and topography in Lyman Mill Pond for Alternative 3: partial excavation - channel/ponds.

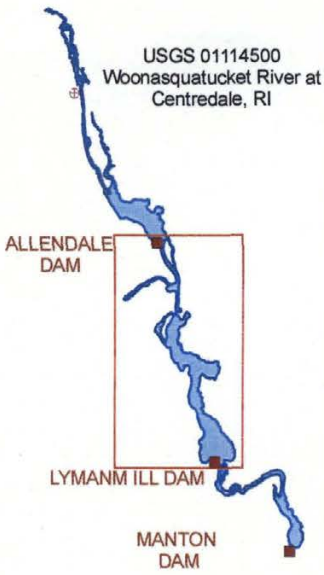
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

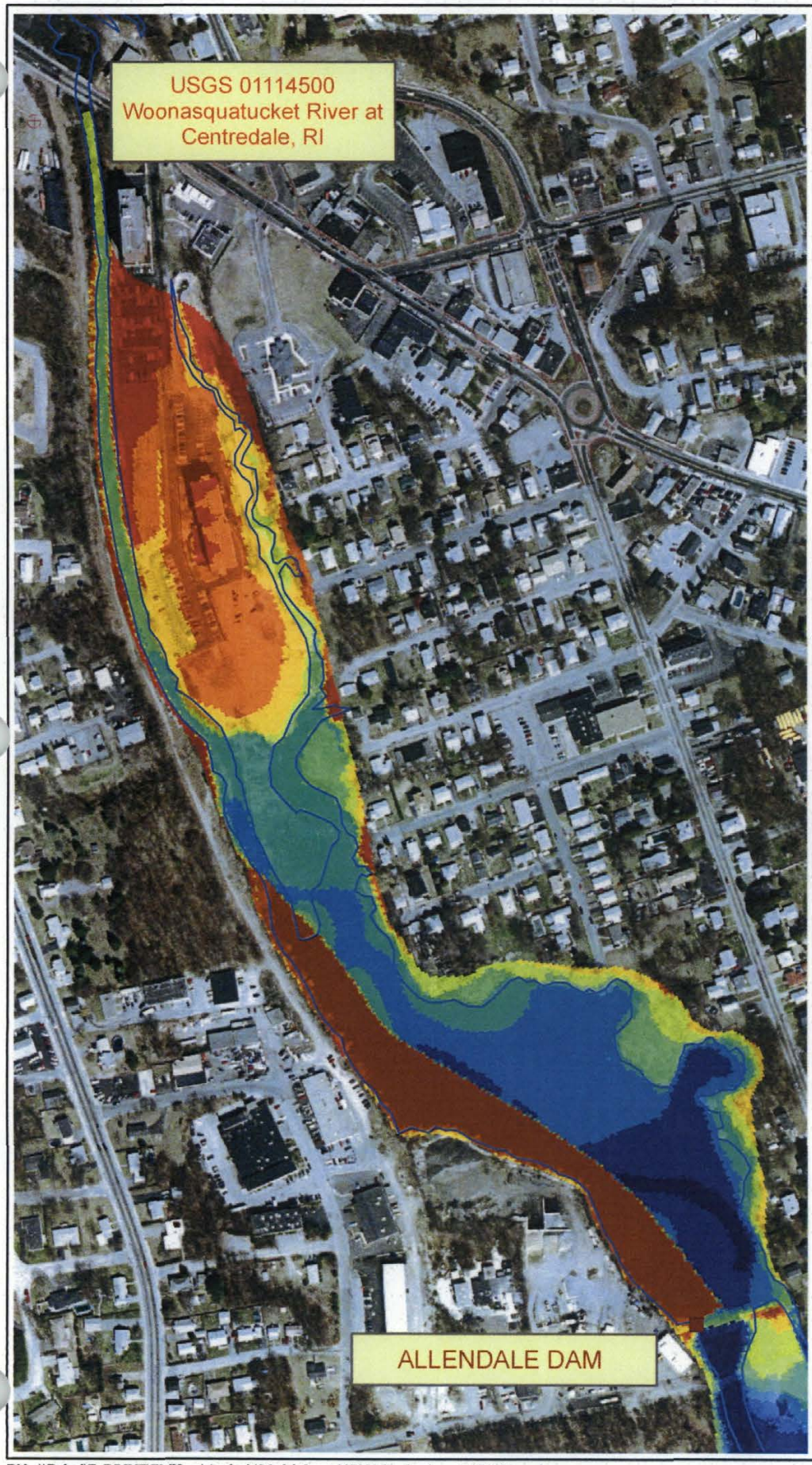
CENTREDALE MANOR STUDY AREA

Figure 3-12. Numerical grid showing bathymetry and topography differences in Lyman Mill Pond for Alternative 3: partial excavation - channel/ponds.

QEA Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 85
- 85 - 87
- 87 - 89
- 89 - 91
- 91 - 93
- 93 - 95
- 95 - 97
- 97 - 99
- > 99

CENTREDALE MANOR STUDY AREA

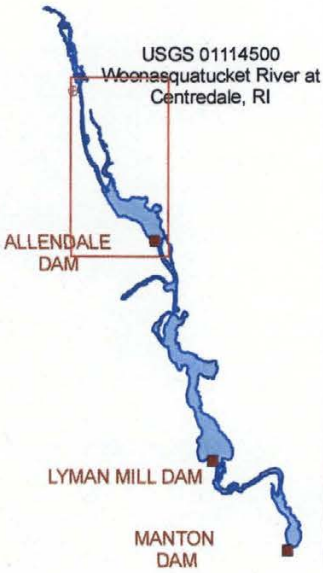
Figure 3-13. Numerical grid showing bathymetry and topography in Allendale Pond for Alternative 4: nearshore CDF with dams in place.

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd

LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

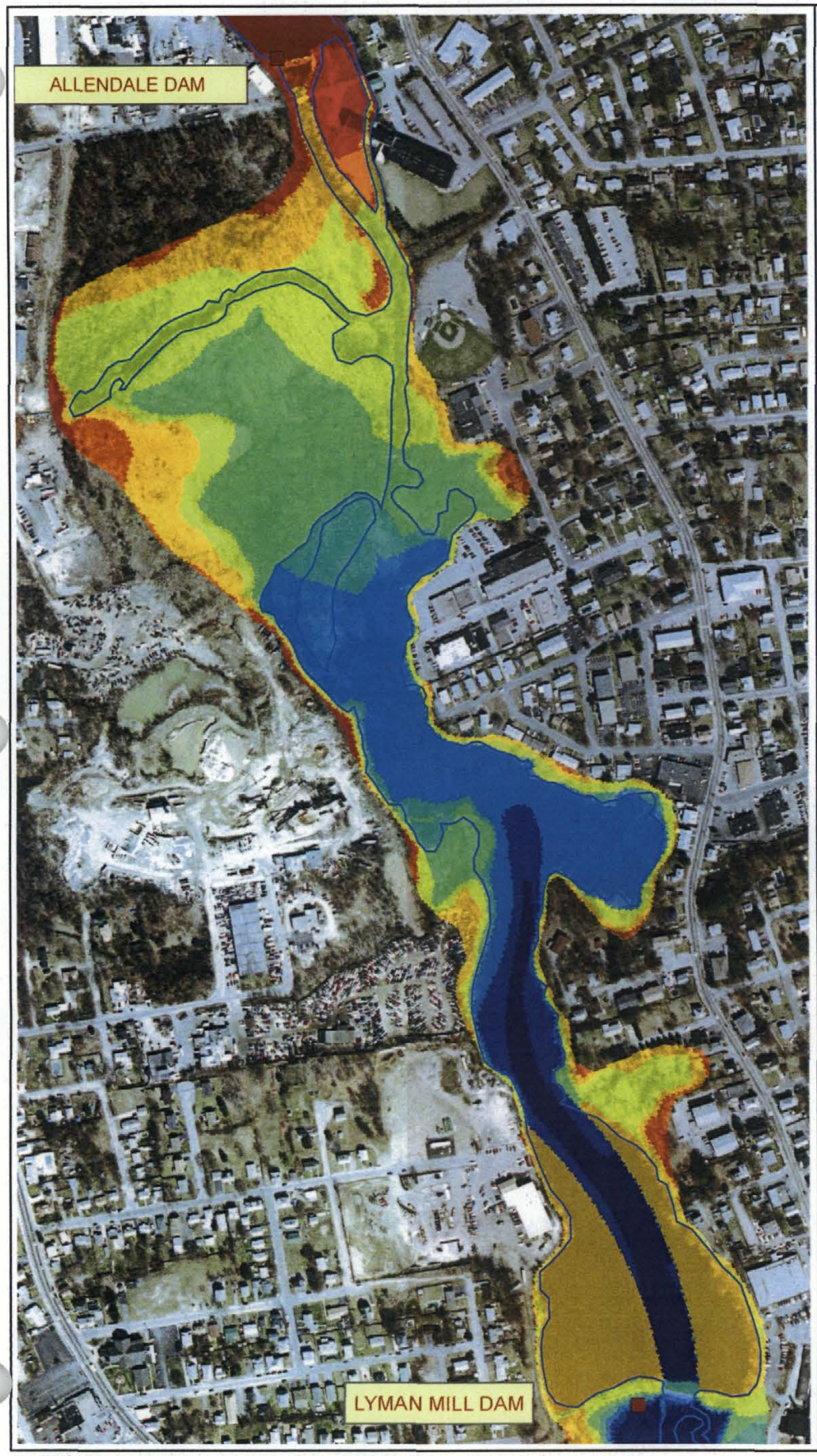
CENTREDALE MANOR STUDY AREA

Figure 3-14. Numerical grid showing bathymetry and topography differences in Allendale Pond for Alternative 4: nearshore CDF with dams in place.

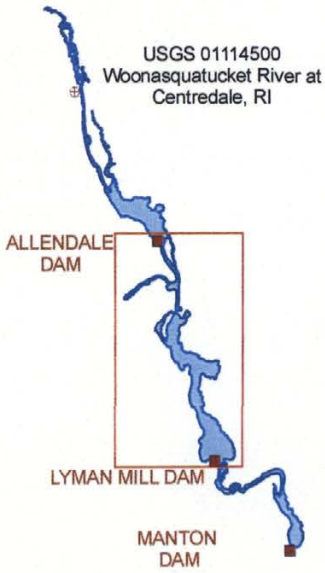
QEA Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Elevation (ft NGVD29)

- < 70
- 70 - 72
- 72 - 74
- 74 - 76
- 76 - 78
- 78 - 80
- 80 - 82
- 82 - 84
- > 84

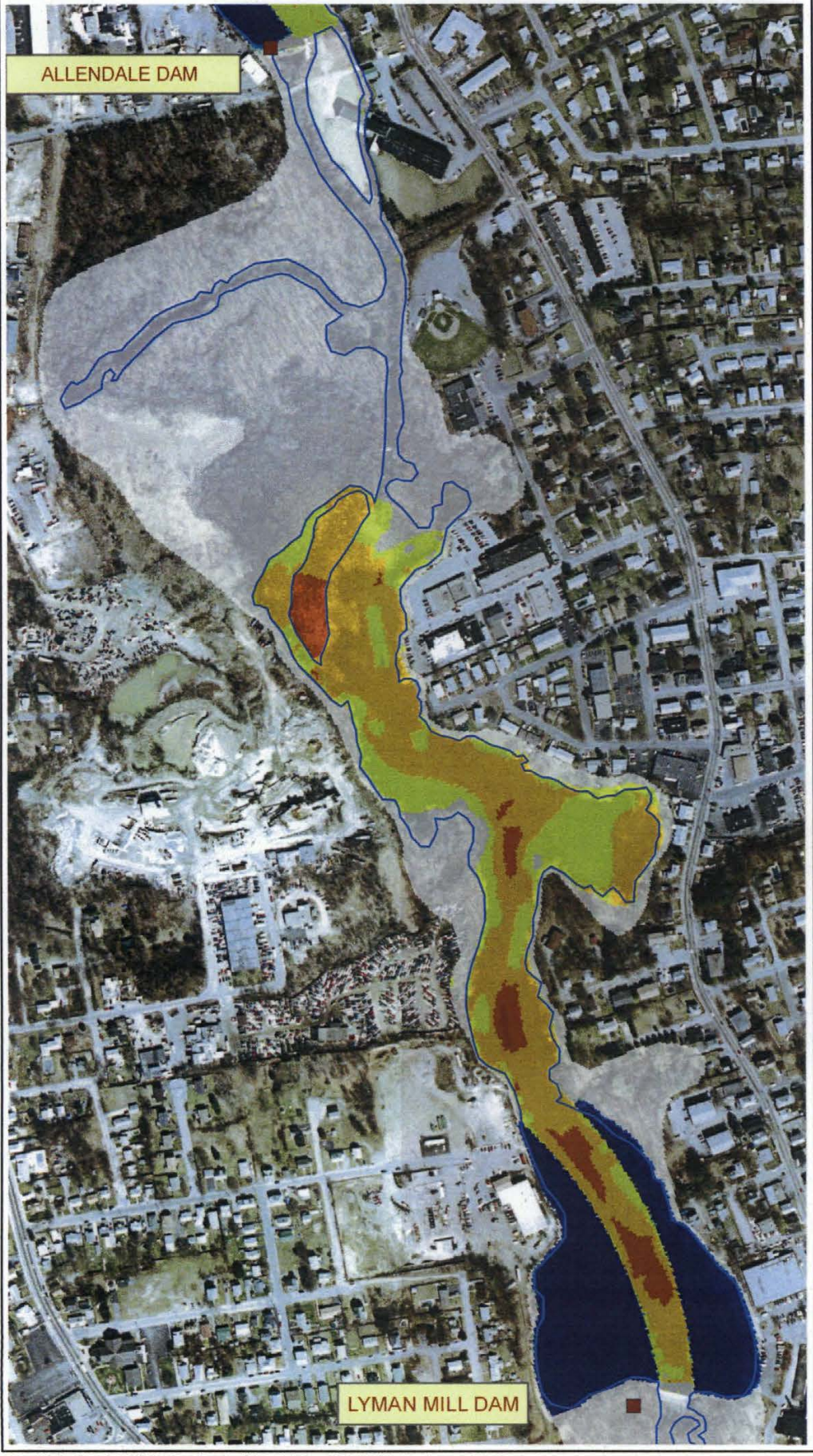
CENTREDALE MANOR STUDY AREA

Figure 3-15. Numerical grid showing bathymetry and topography in Lyman Mill Pond for Alternative 4: nearshore CDF with dams in place.

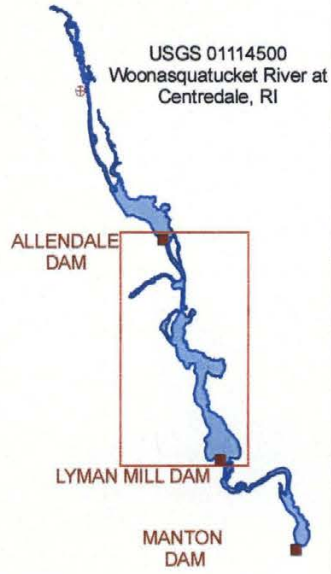
QEA Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Bed Difference (ft)

- < -4
- -4 - -3
- -3 - -2
- -2 - -0.5
- -0.5 - 0.5
- 0.5 - 2
- 2 - 3
- 3 - 4
- > 4

CENTREDALE MANOR STUDY AREA

Figure 3-16. Numerical grid showing bathymetry and topography differences in Lyman Mill Pond for Alternative 4: nearshore CDF with dams in place.

QEA Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Inputs\071005\bathy_layout_071101.mxd

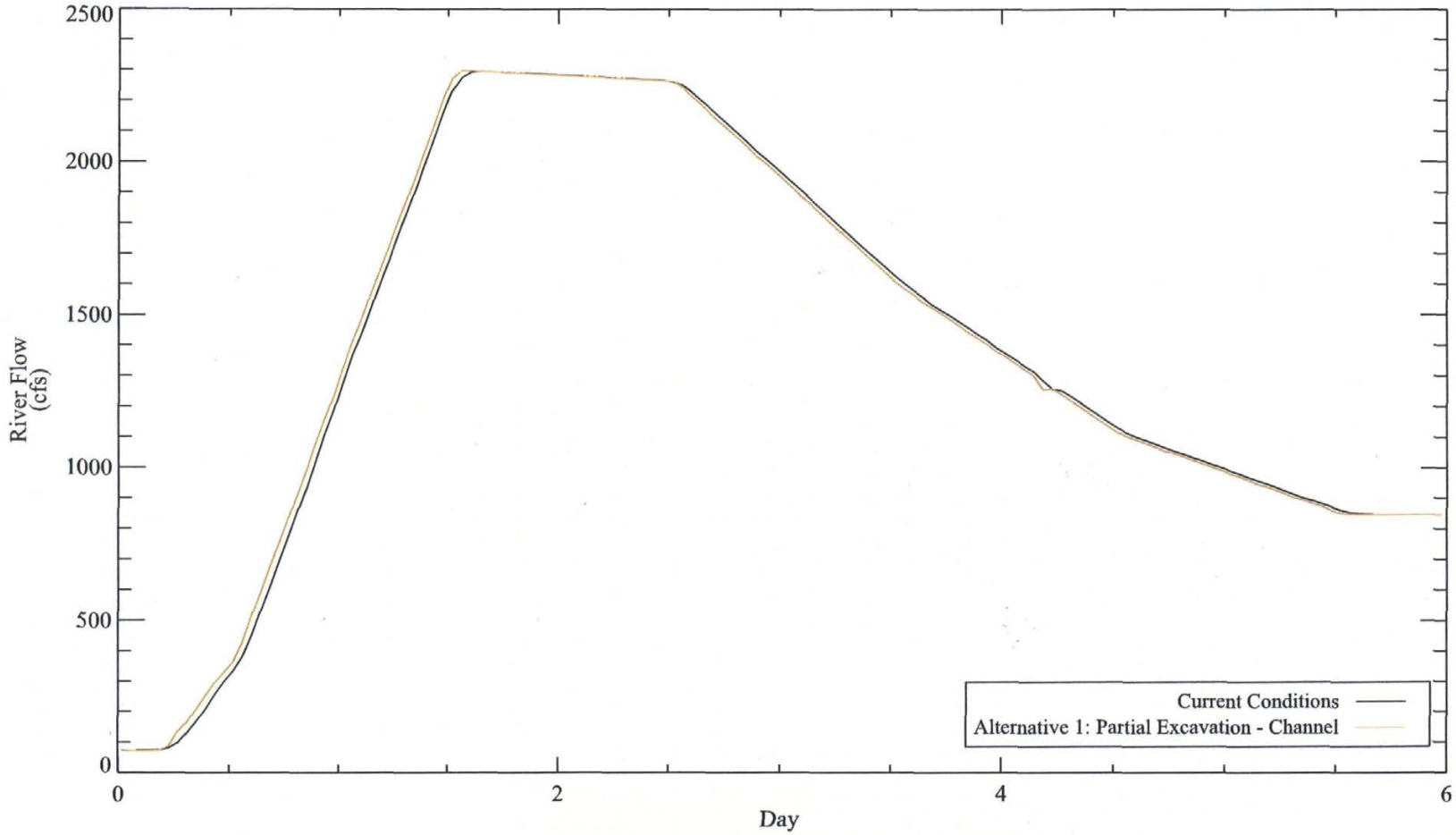


Figure 4-1. Comparison of 100-yr flood hydrograph at Manton Dam between current conditions and Alternative 1 (partial excavation - channel).

DN - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\Alt2\hydrograph_comparison_rpt.pro
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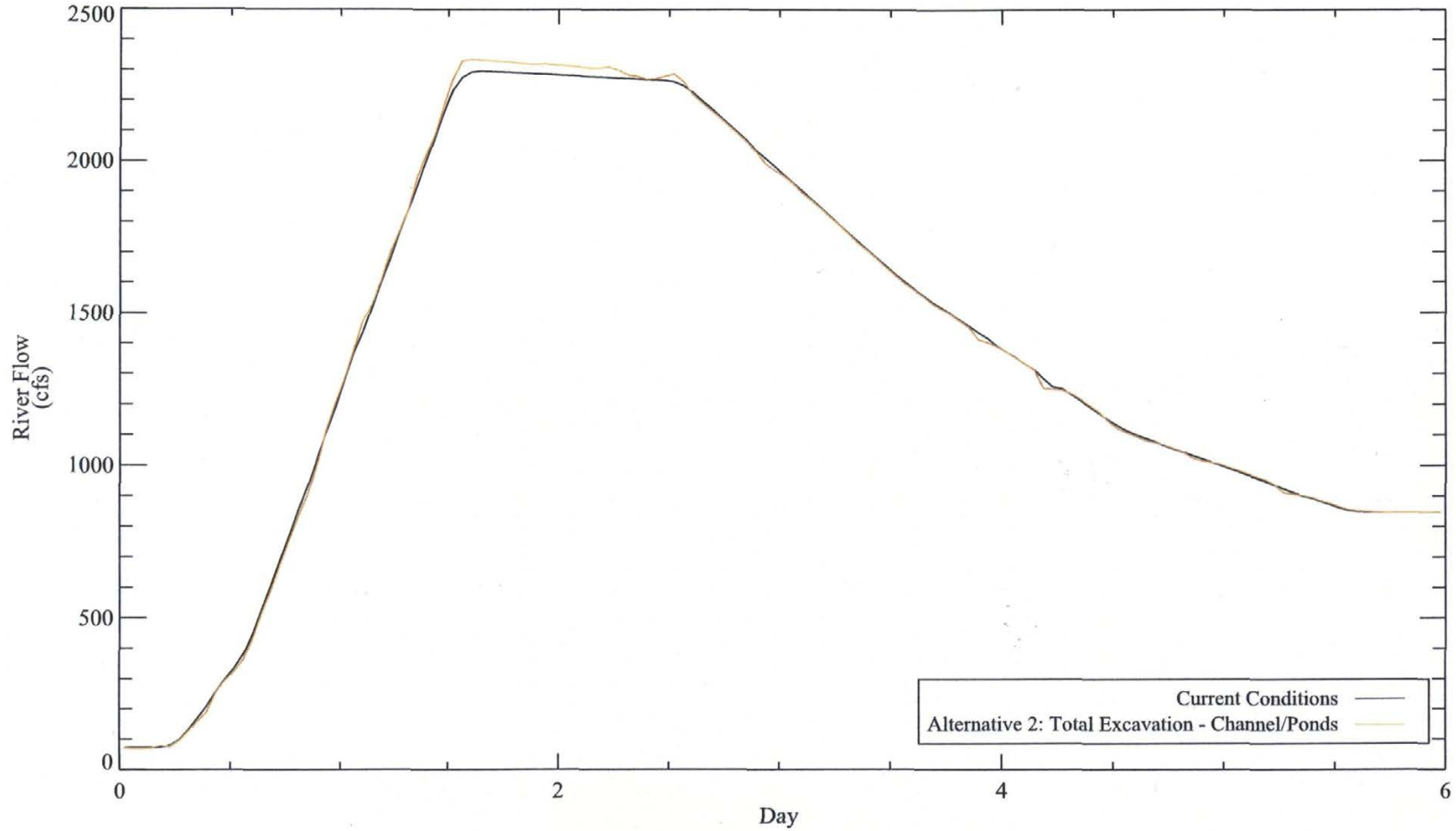

Figure 4-2. Comparison of 100-yr flood hydrograph at Manton Dam between current conditions and Alternative 2 (total excavation - channel/ponds).

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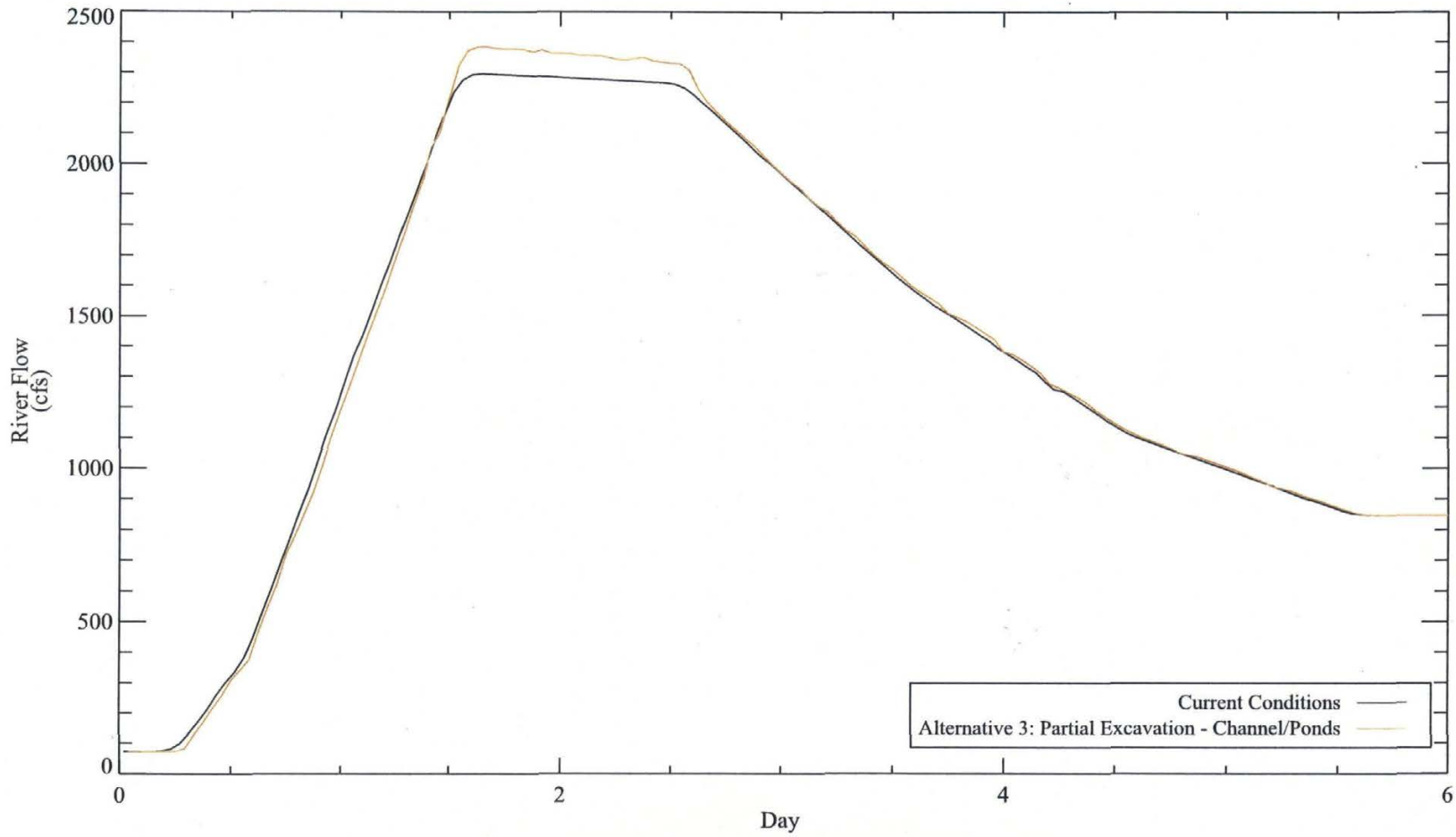

Figure 4-3. Comparison of 100-yr flood hydrograph at Manton Dam between current conditions and Alternative 3 (partial excavation - channel/ponds).

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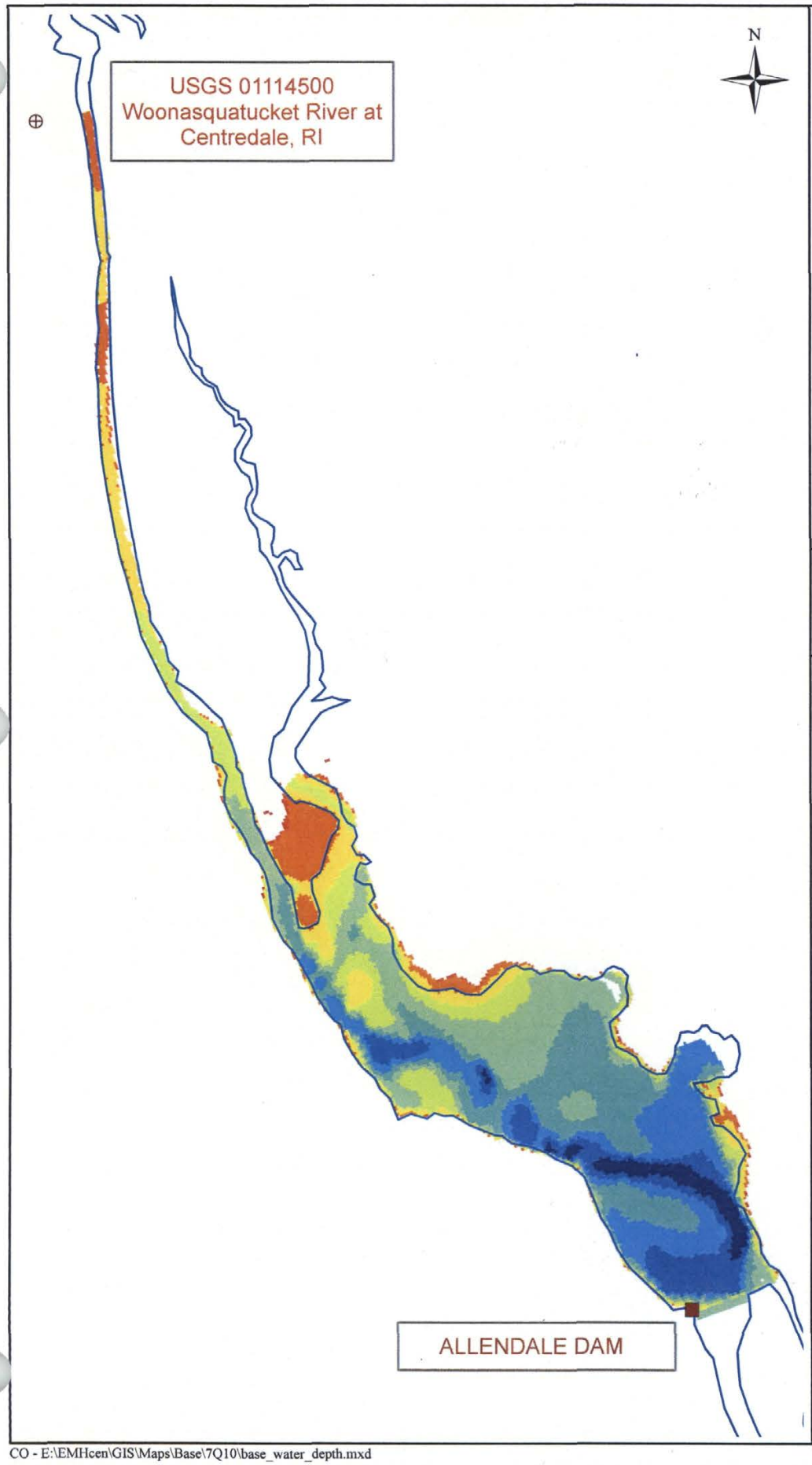
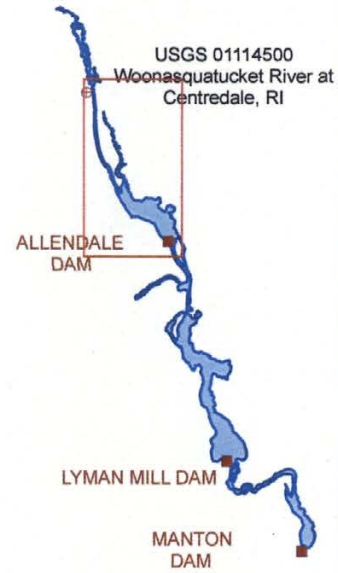


LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-4.
Predicted water depth during 7Q10 discharge.

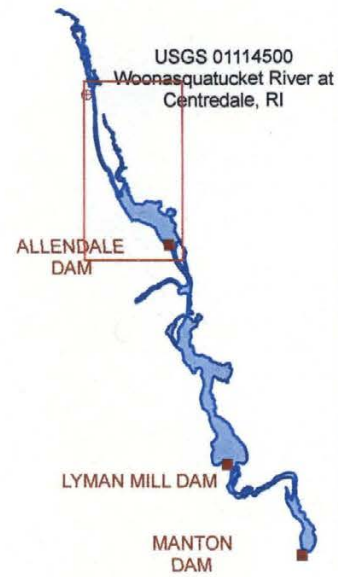
Base Case
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 October 2007

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_water_depth.mxd

LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

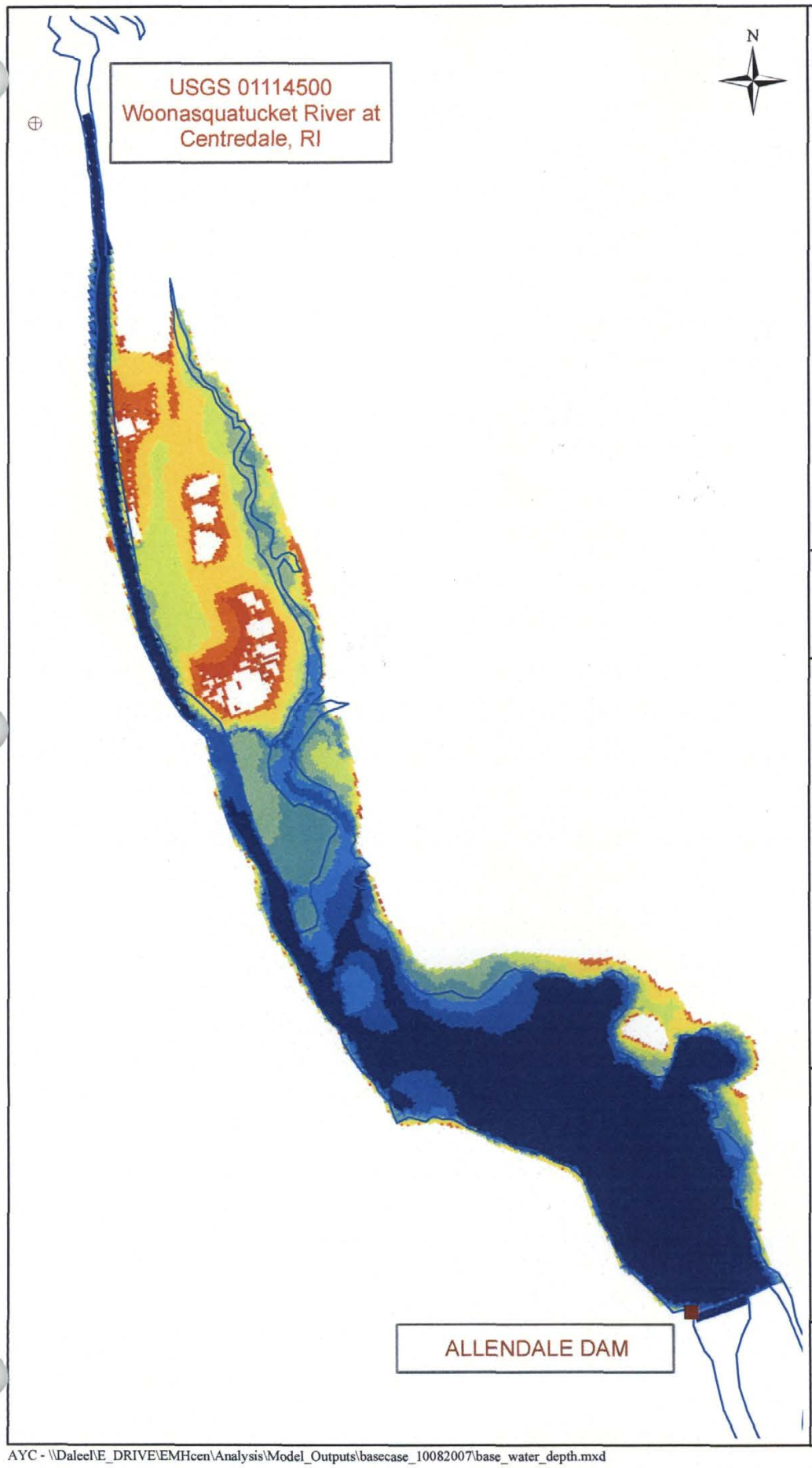
Figure 4-5.
Predicted current speed during 7Q10 discharge.

Base Case
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_current_speed.mxd



LOCATOR MAP

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-6.
Predicted water depth during 100-yr flood event.

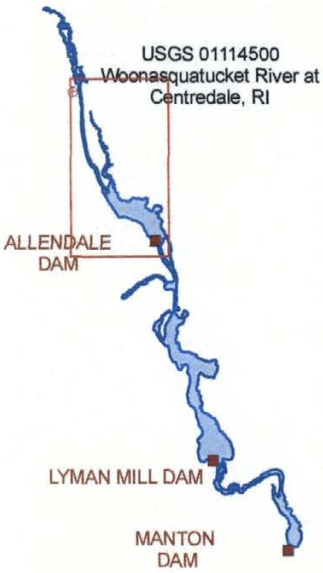
Base Case
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd

LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

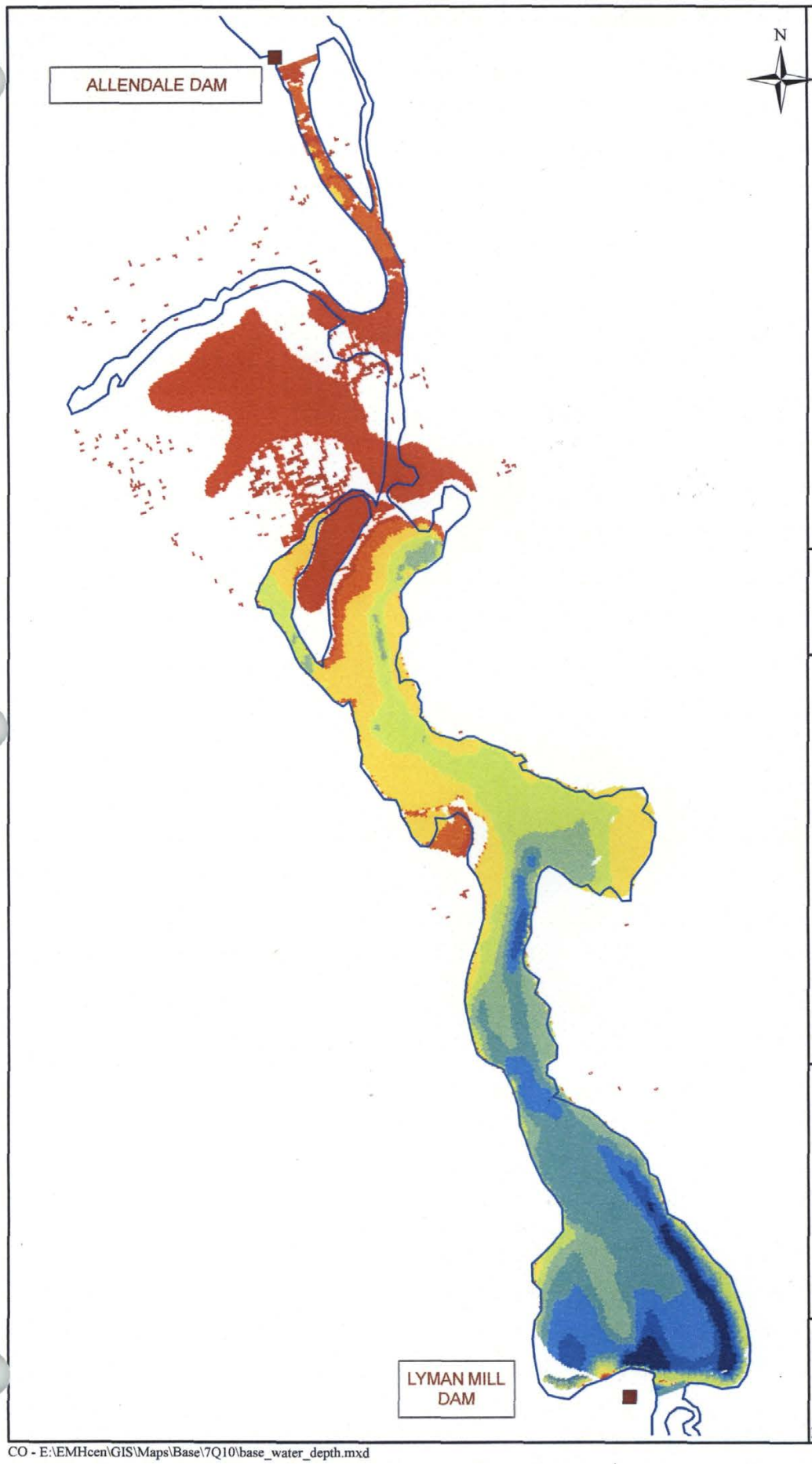
Figure 4-7.
Predicted current speed during 100-yr flood event.

Base Case
Upper-Bound Case
Allendale Pond

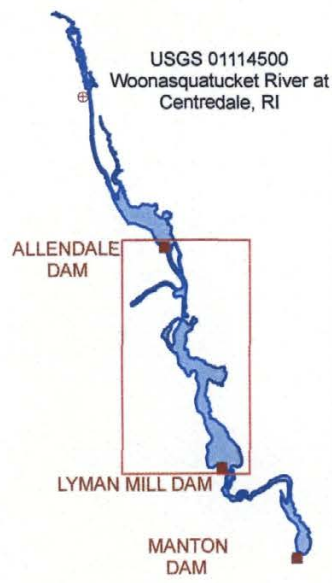
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

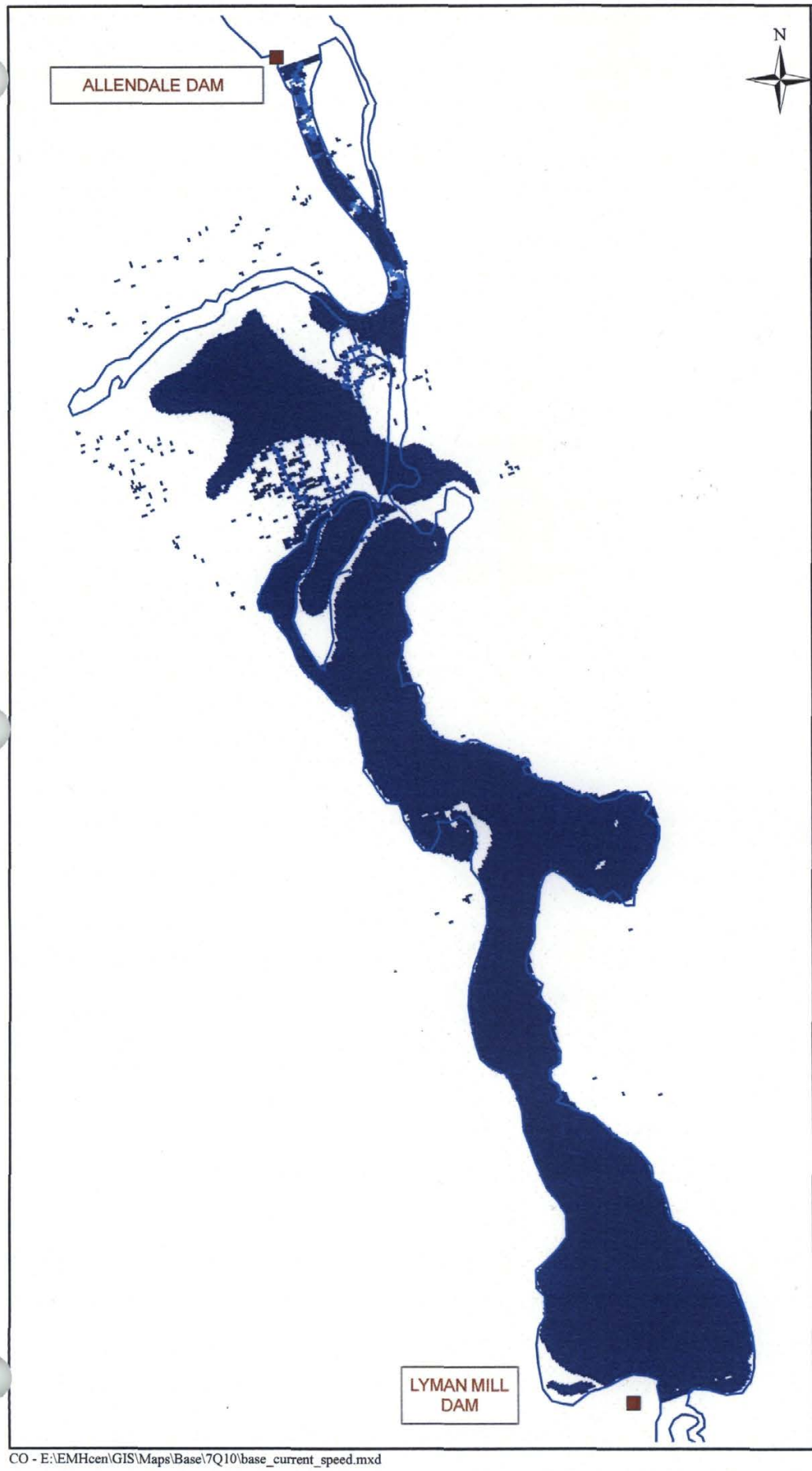
Figure 4-8.
Predicted water depth during 7Q10 discharge.

Base Case
Upper-Bound Case
Lyman Mill Pond

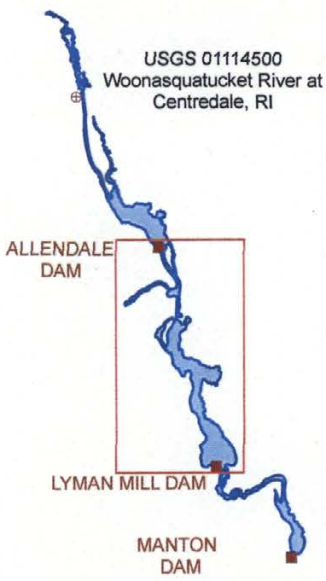
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

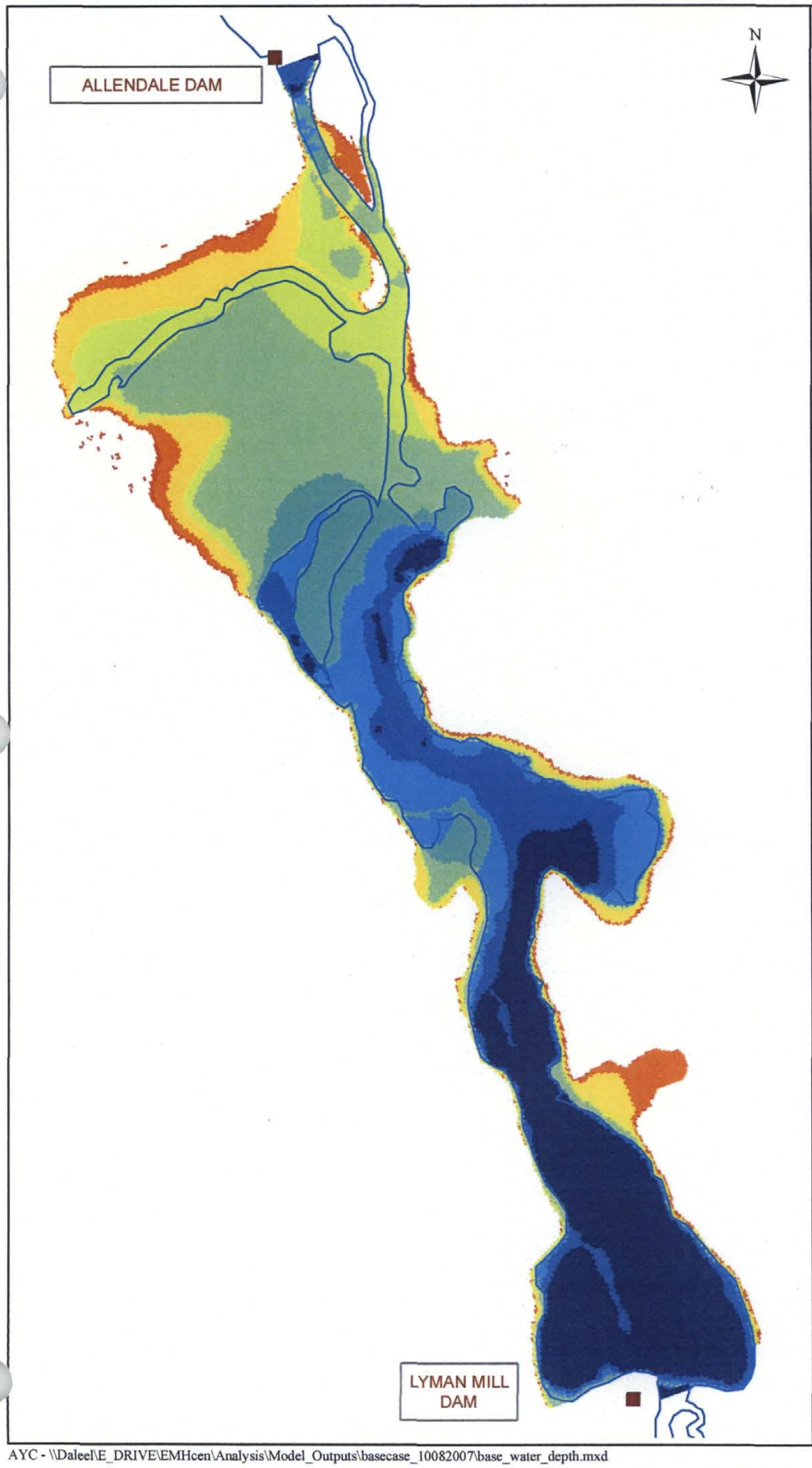
Figure 4-9.
Predicted current speed during 7Q10 discharge.

Base Case
Upper-Bound Case
Lyman Mill Pond

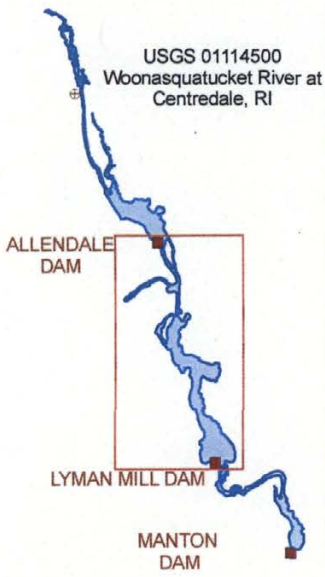
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

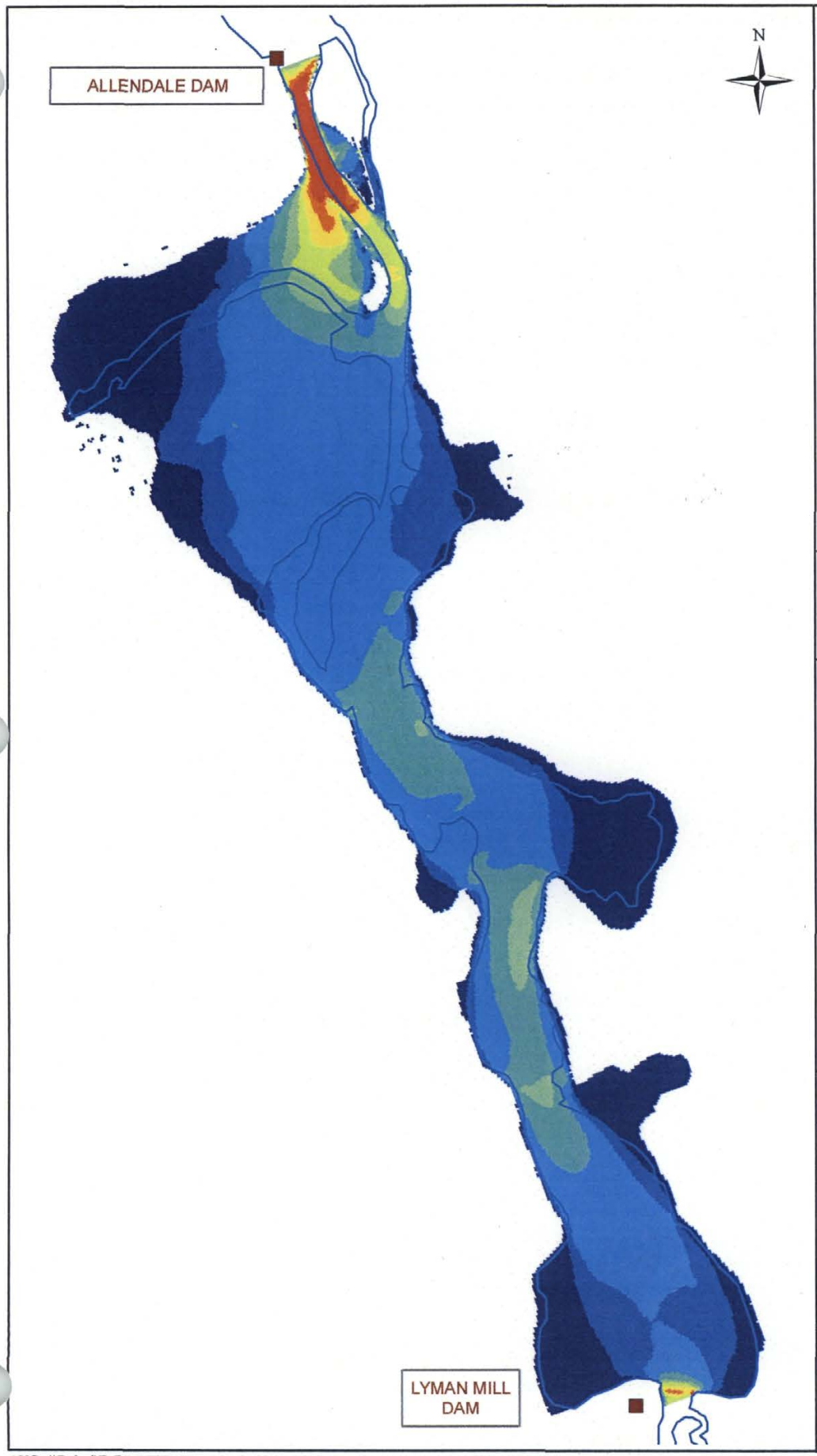
Figure 4-10.
Predicted water depth during 100-yr flood event.

Base Case
Upper-Bound Case
Lyman Mill Pond

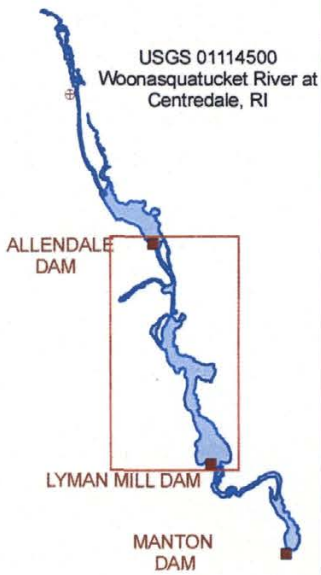
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

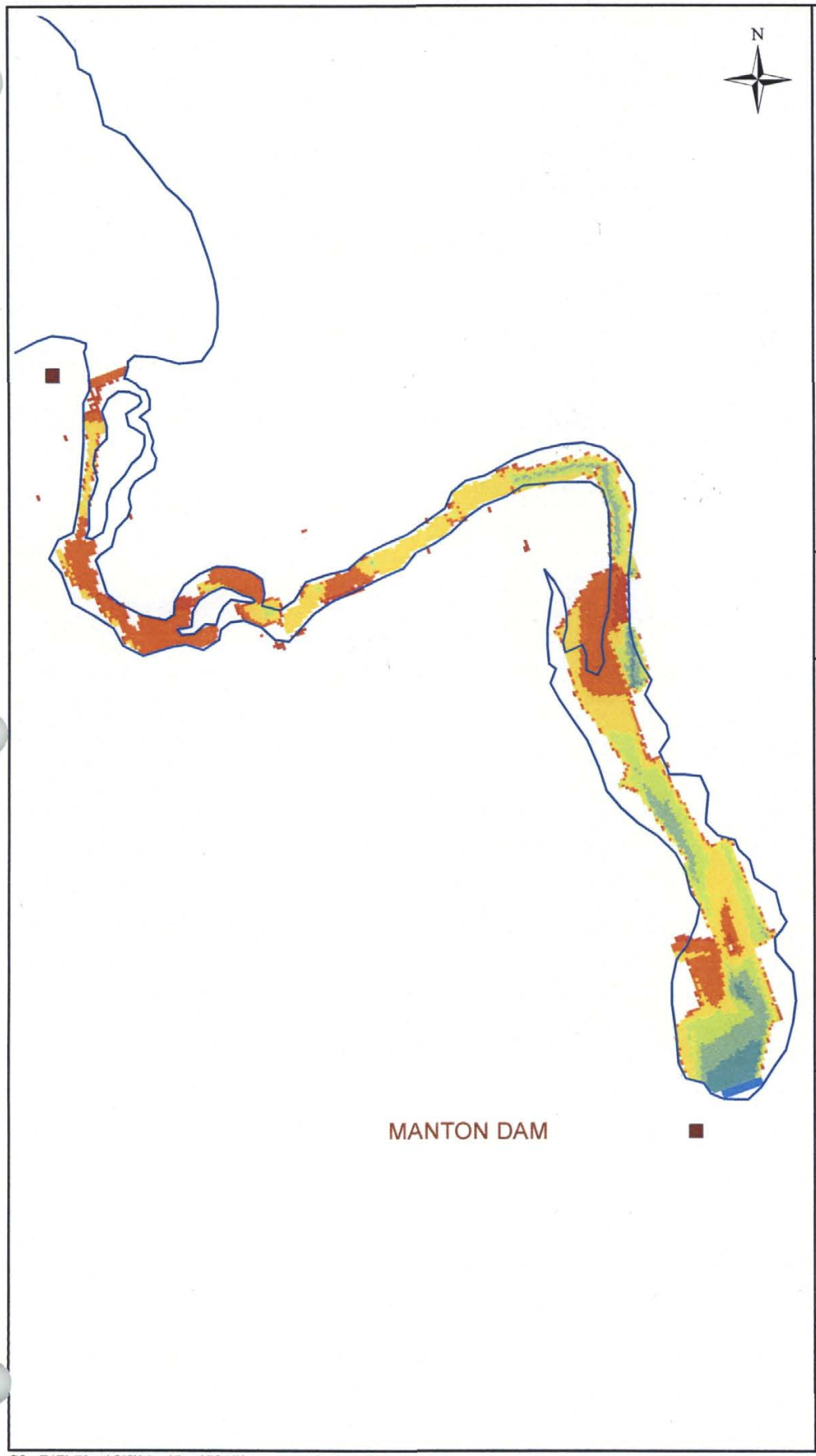
Figure 4-11.
Predicted current speed during 100-yr flood event.

Base Case
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

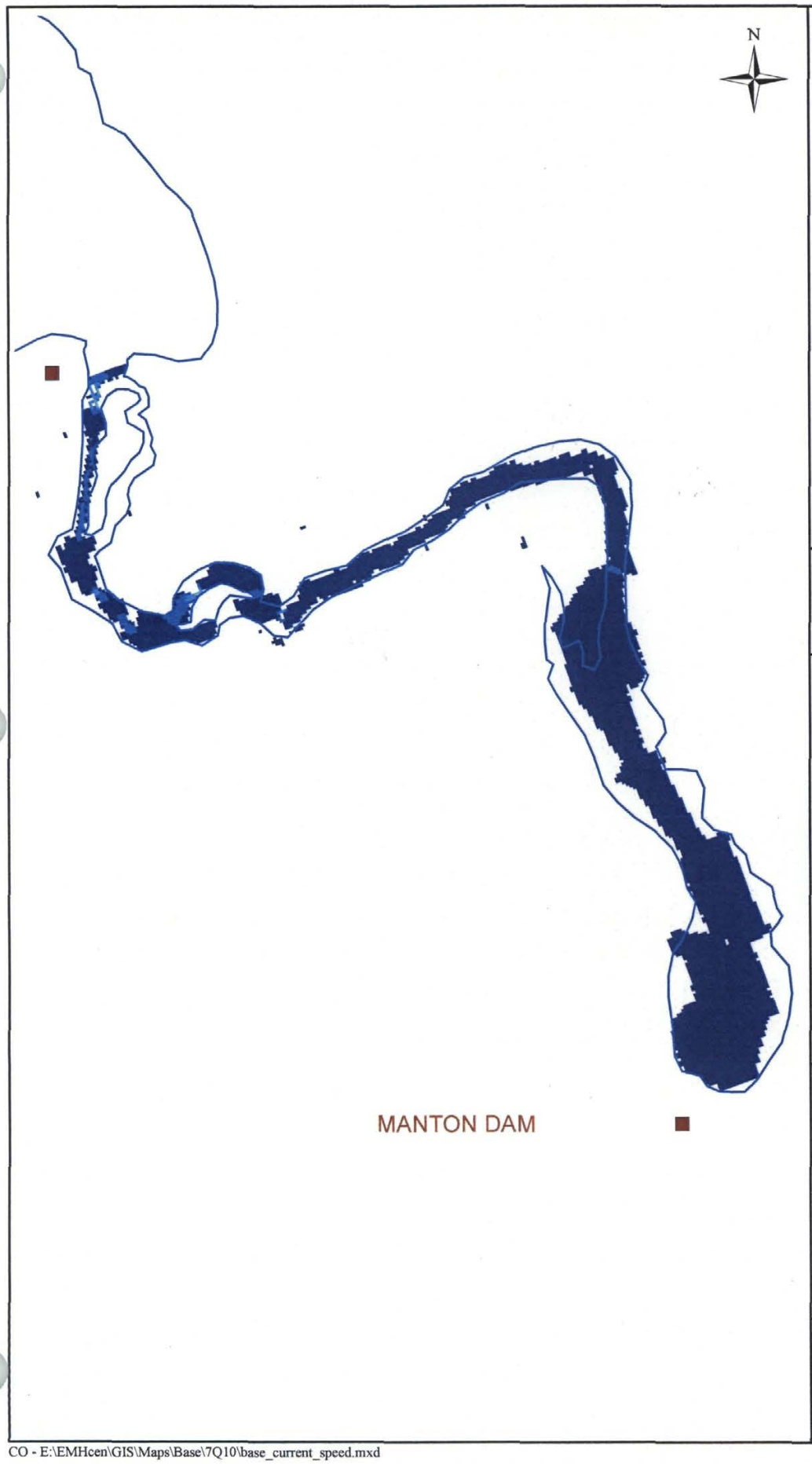
Figure 4-12.
Predicted water depth during 7Q10 discharge.

Base Case
Upper-Bound Case
Manton Pond

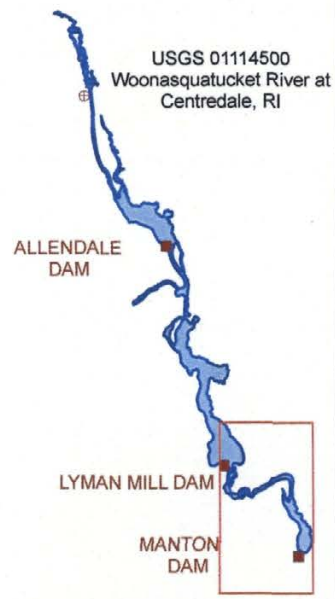
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

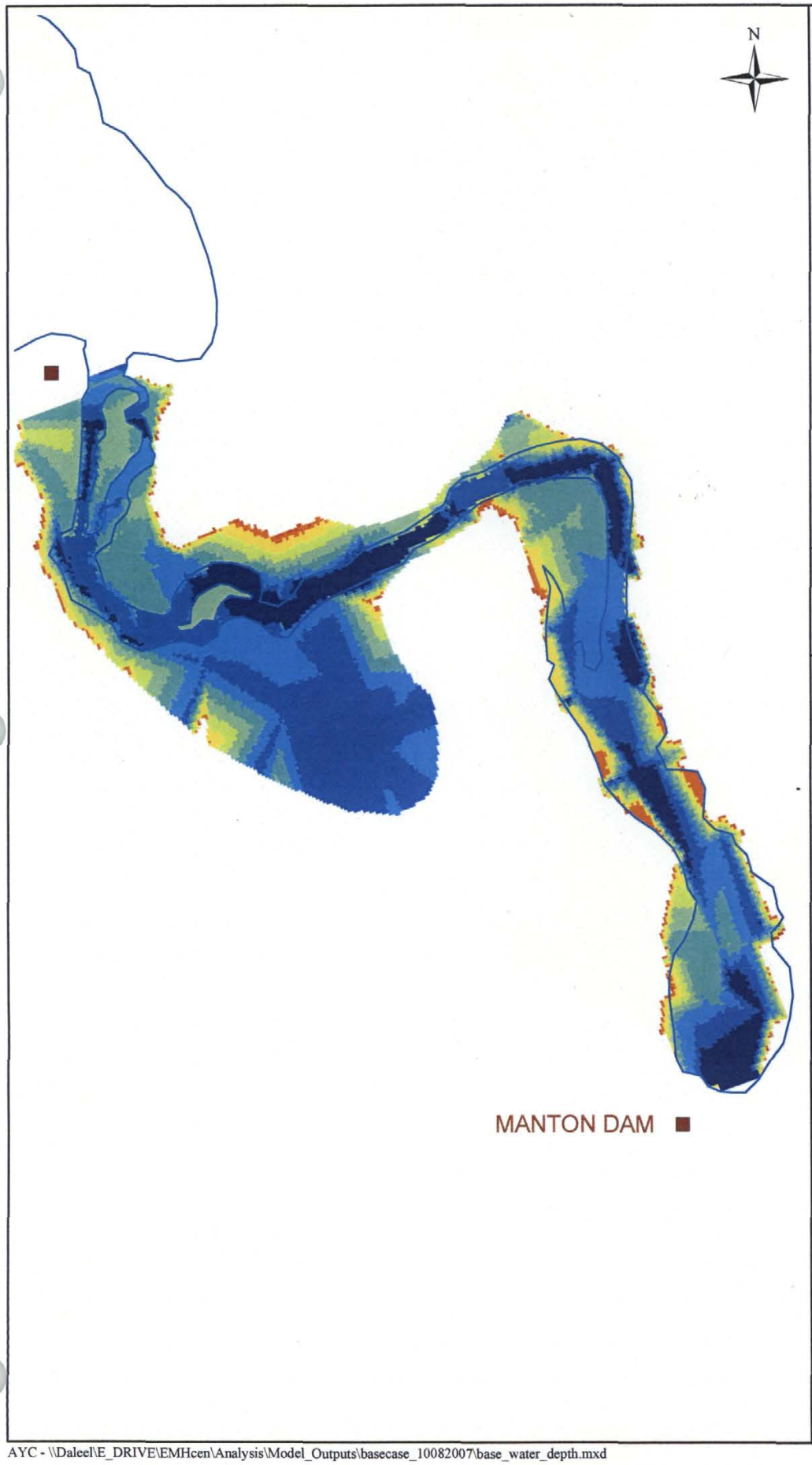
Figure 4-13.
Predicted current speed during 7Q10 discharge.

Base Case
Upper-Bound Case
Manton Pond

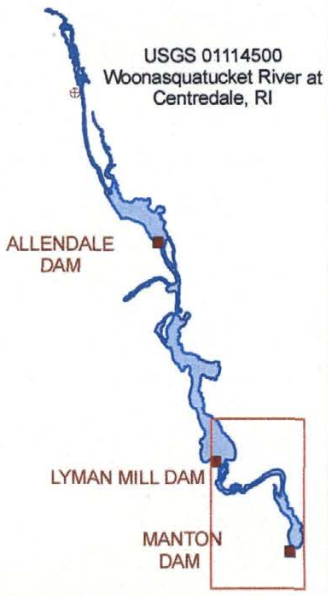
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\Base\7Q10\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

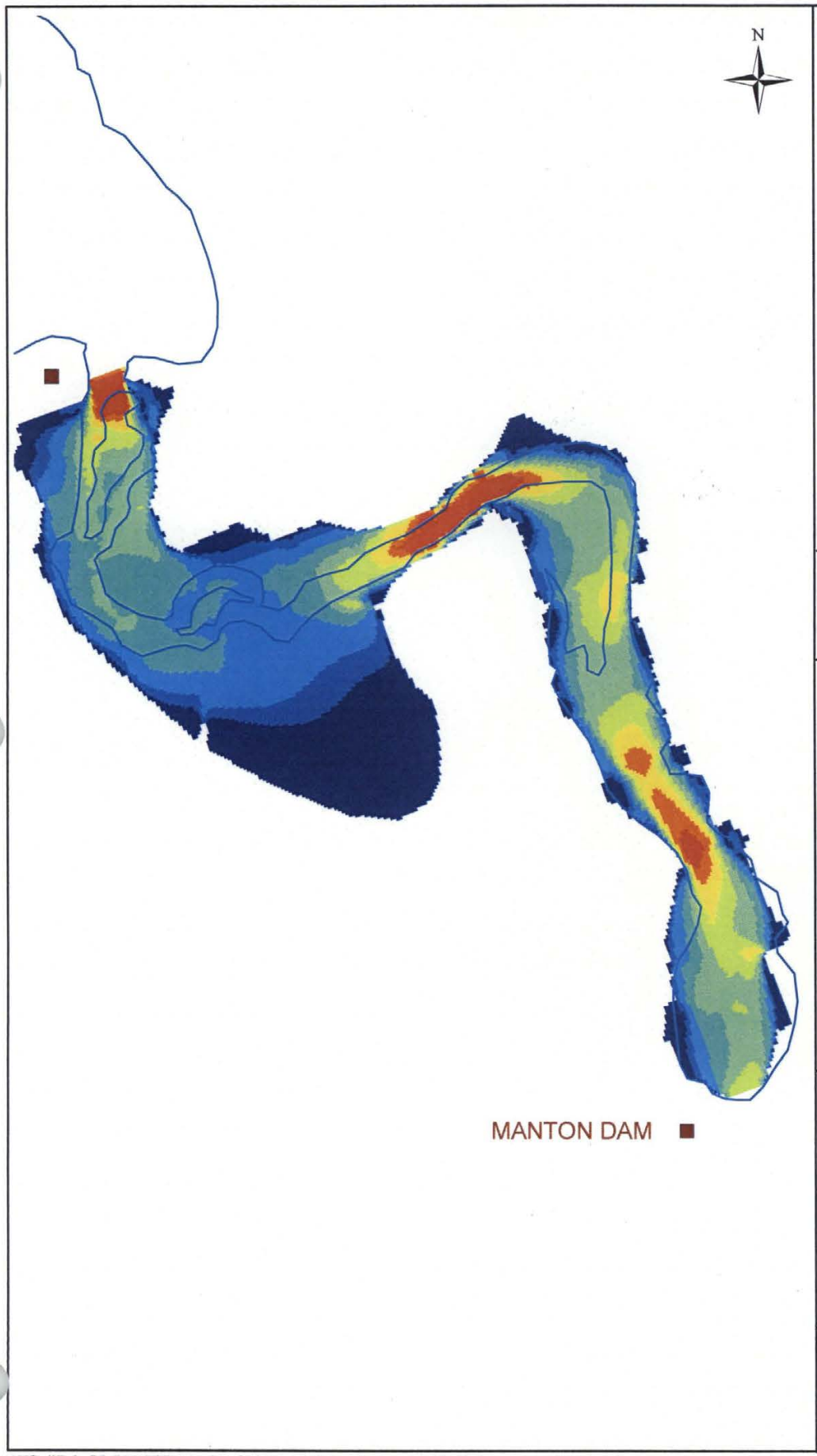
Figure 4-14.
Predicted water depth during 100-yr flood event.

Base Case
Upper-Bound Case
Manton Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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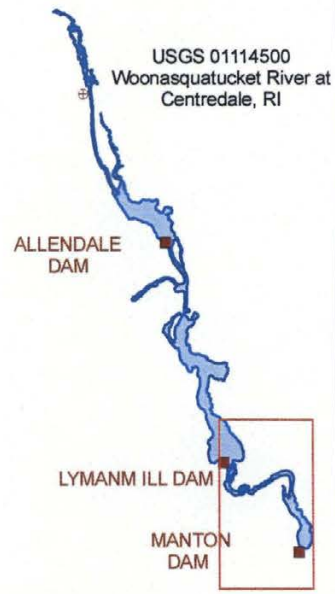


GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

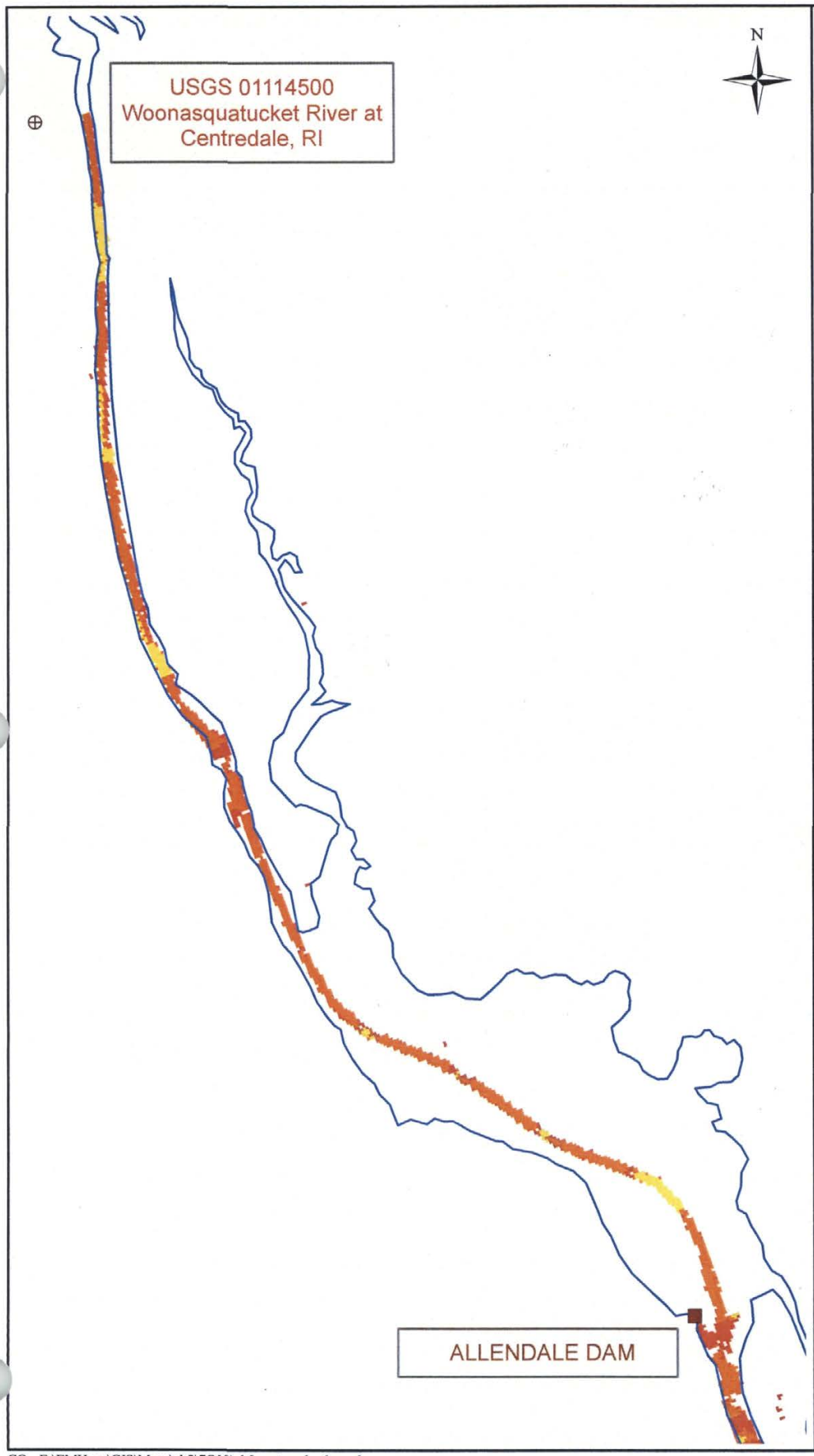
Figure 4-15.
Predicted current speed during 100-yr flood event.

Base Case
Upper-Bound Case
Manton Pond

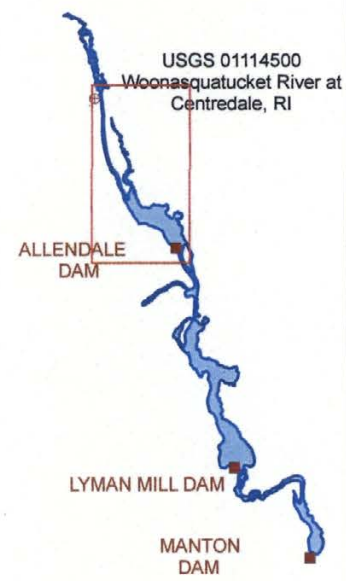
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

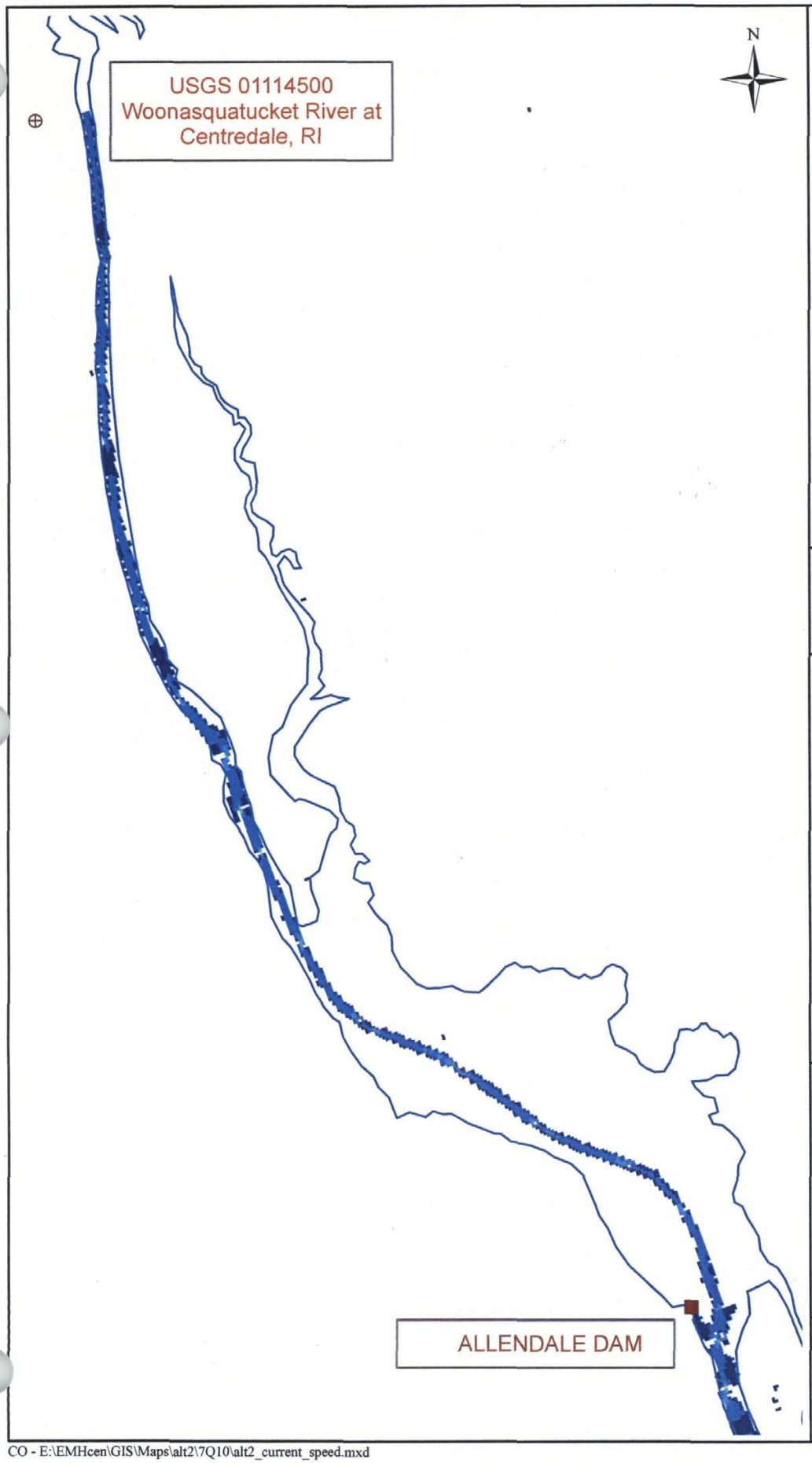
Figure 4-16.
Predicted water depth during 7Q10 discharge.

Alternative 1: Partial Excavation - Channel Upper-Bound Case Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\alt2\7Q10\alt2_water_depth.mxd



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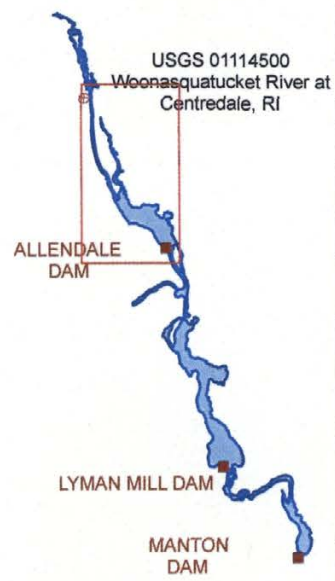


GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

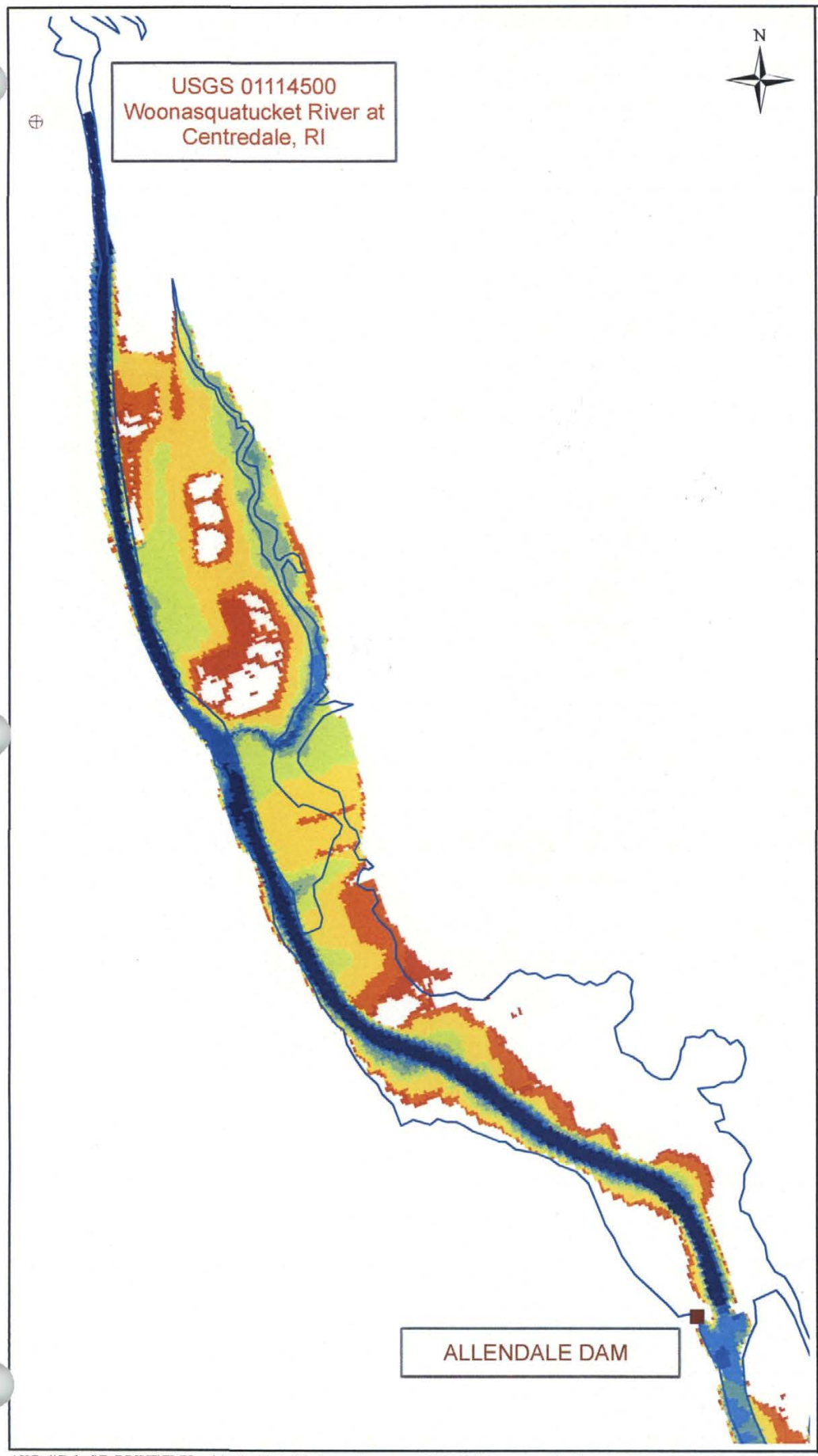
Figure 4-17.
Predicted current speed during 7Q10 discharge.

Alternative 1: Partial Excavation - Channel Upper-Bound Case Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\alt2\7Q10\alt2_current_speed.mxd



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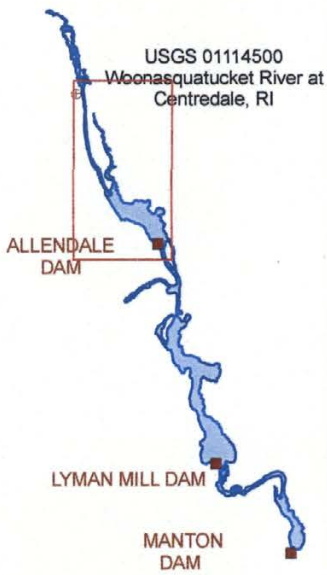


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

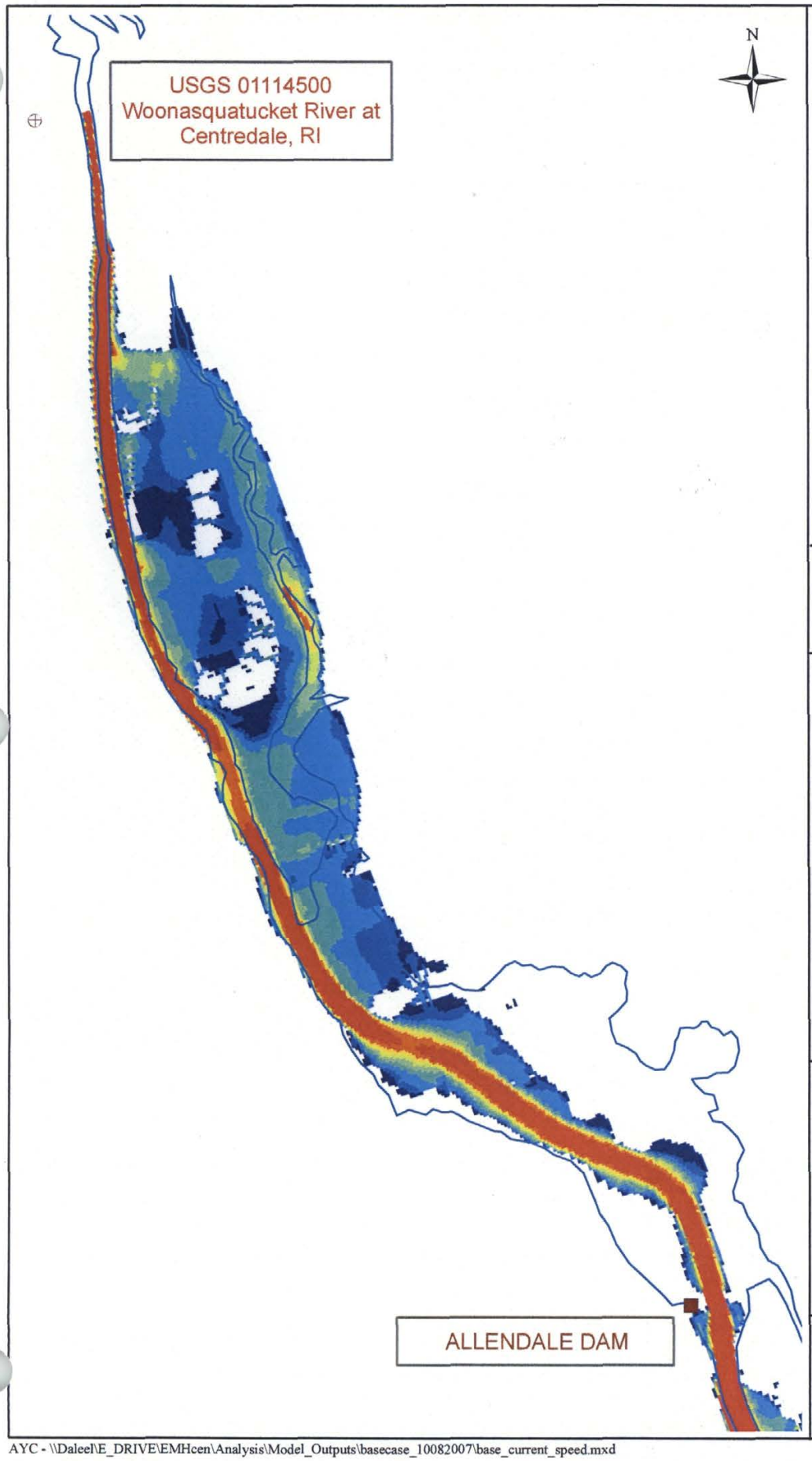
Figure 4-18.
Predicted water depth during 100-yr flood event.

Alternative 1: Partial Excavation - Channel.
Upper-Bound Case
Allendale Pond

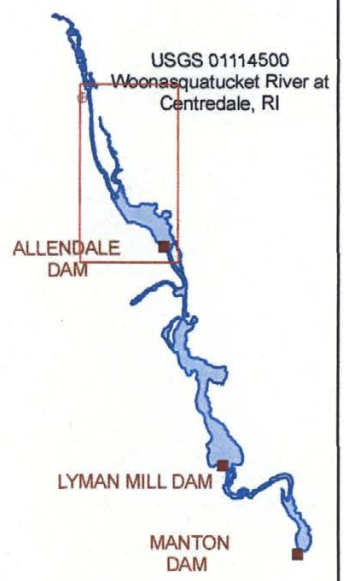
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

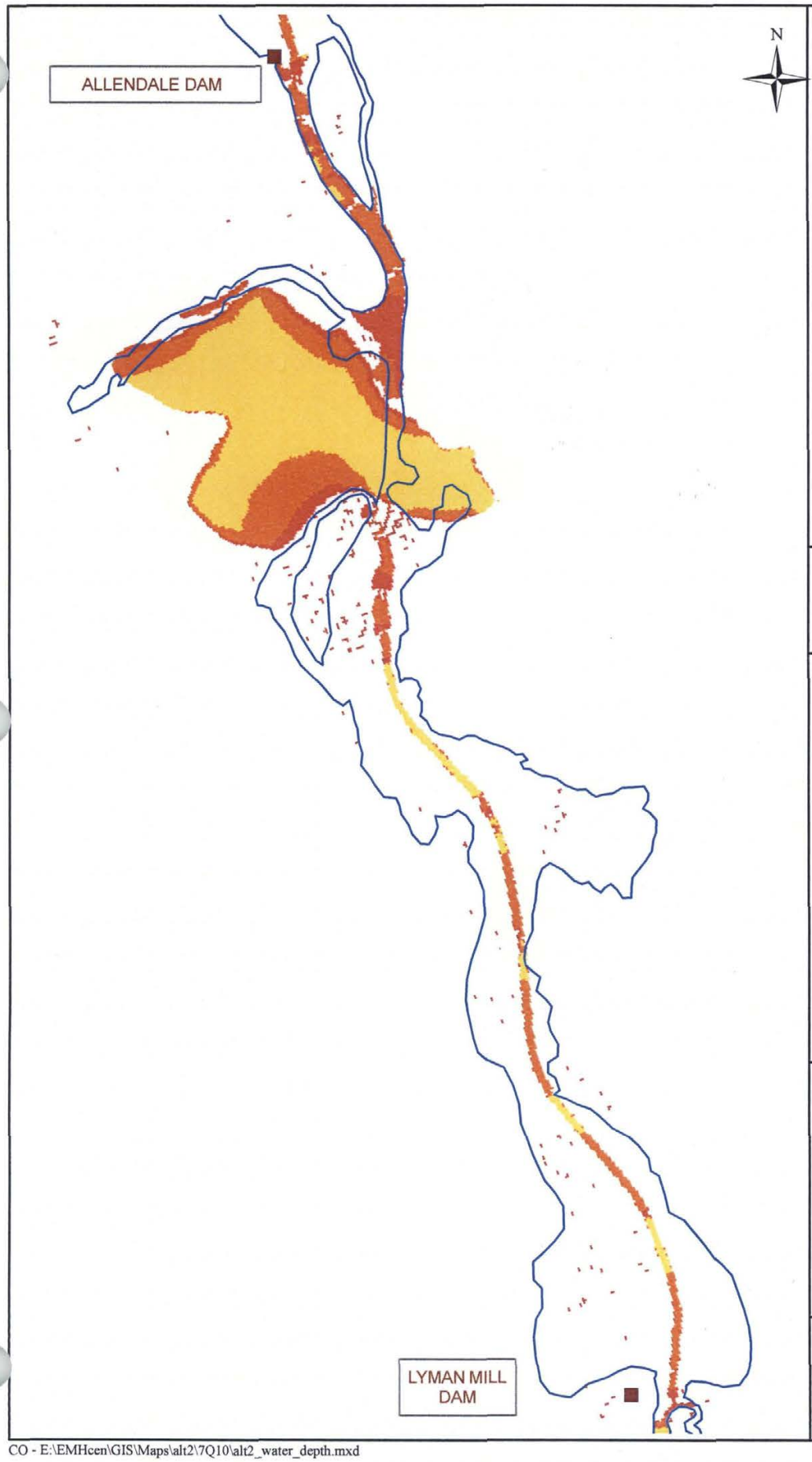
Figure 4-19.
Predicted current speed during 100-yr flood event.

Alternative 1: Partial Excavation - Channel.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



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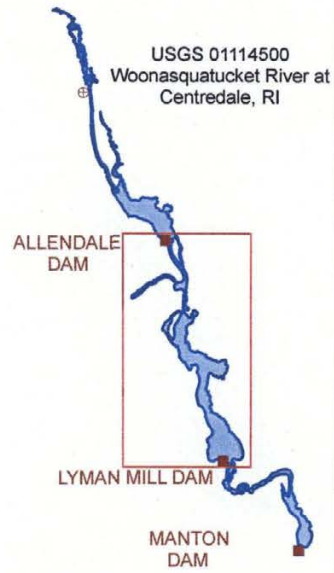


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

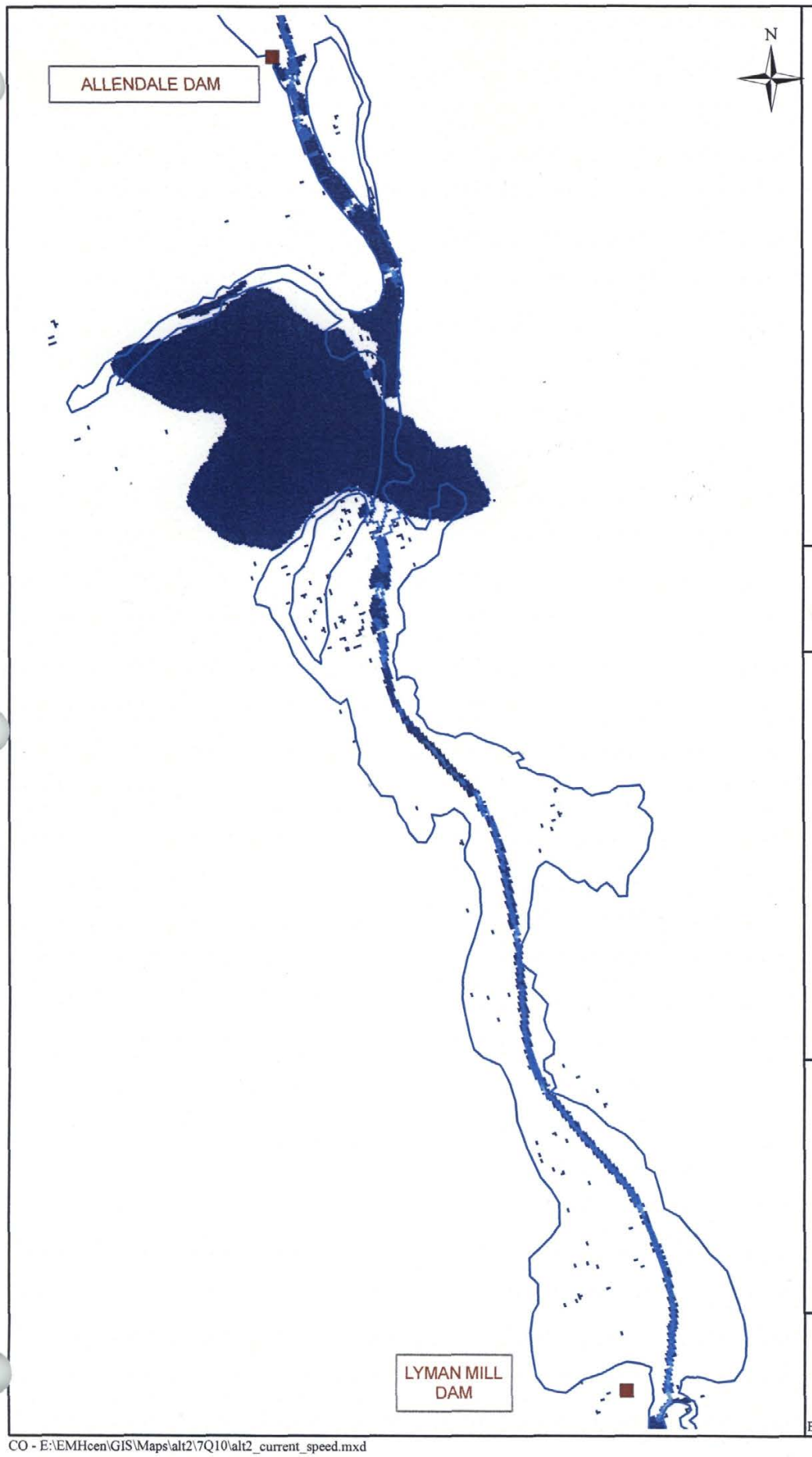
Figure 4-20.
Predicted water depth during 7Q10 discharge.

Alternative 1: Partial Excavation - Channel Upper-Bound Case Lyman Mill Pond

QEA Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\alt2\7Q10\alt2_water_depth.mxd



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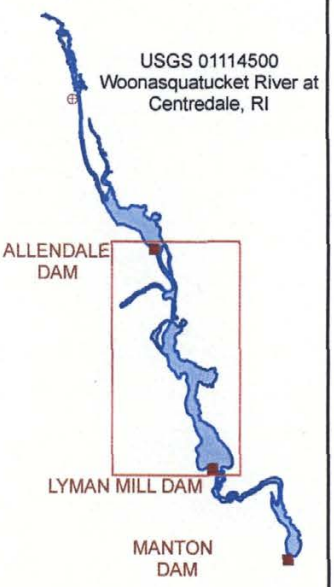


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

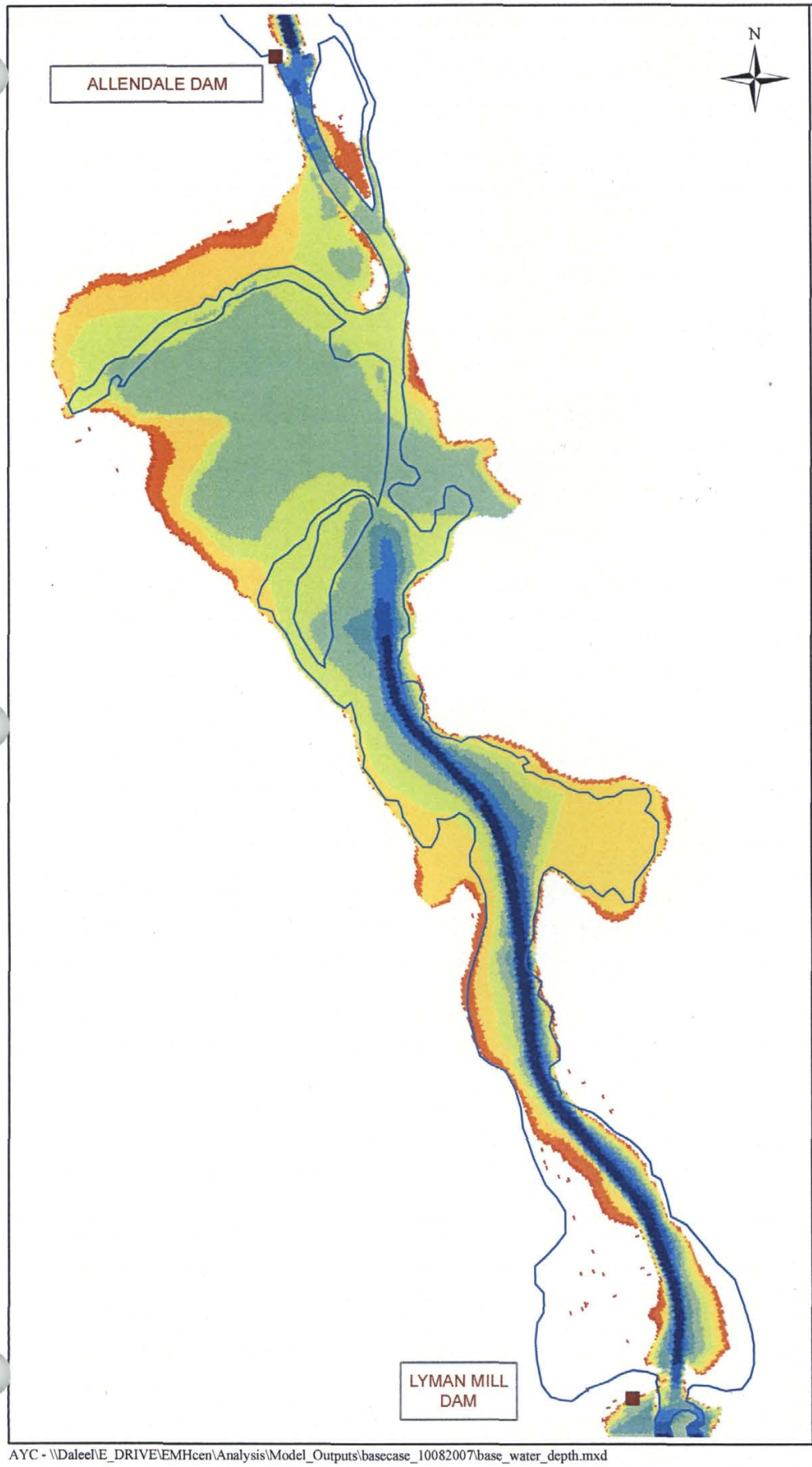
Figure 4-21.
Predicted current speed during 7Q10 discharge.

Alternative 1: Partial Excavation - Channel Upper-Bound Case Lyman Mill Pond

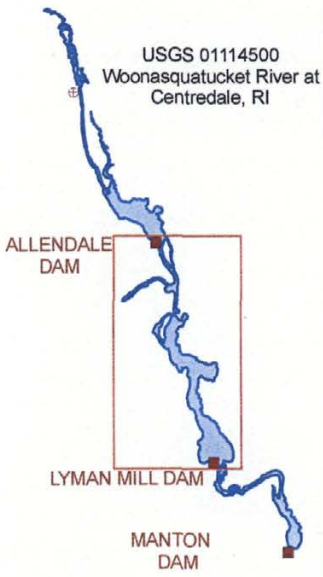
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\alt2\7Q10\alt2_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

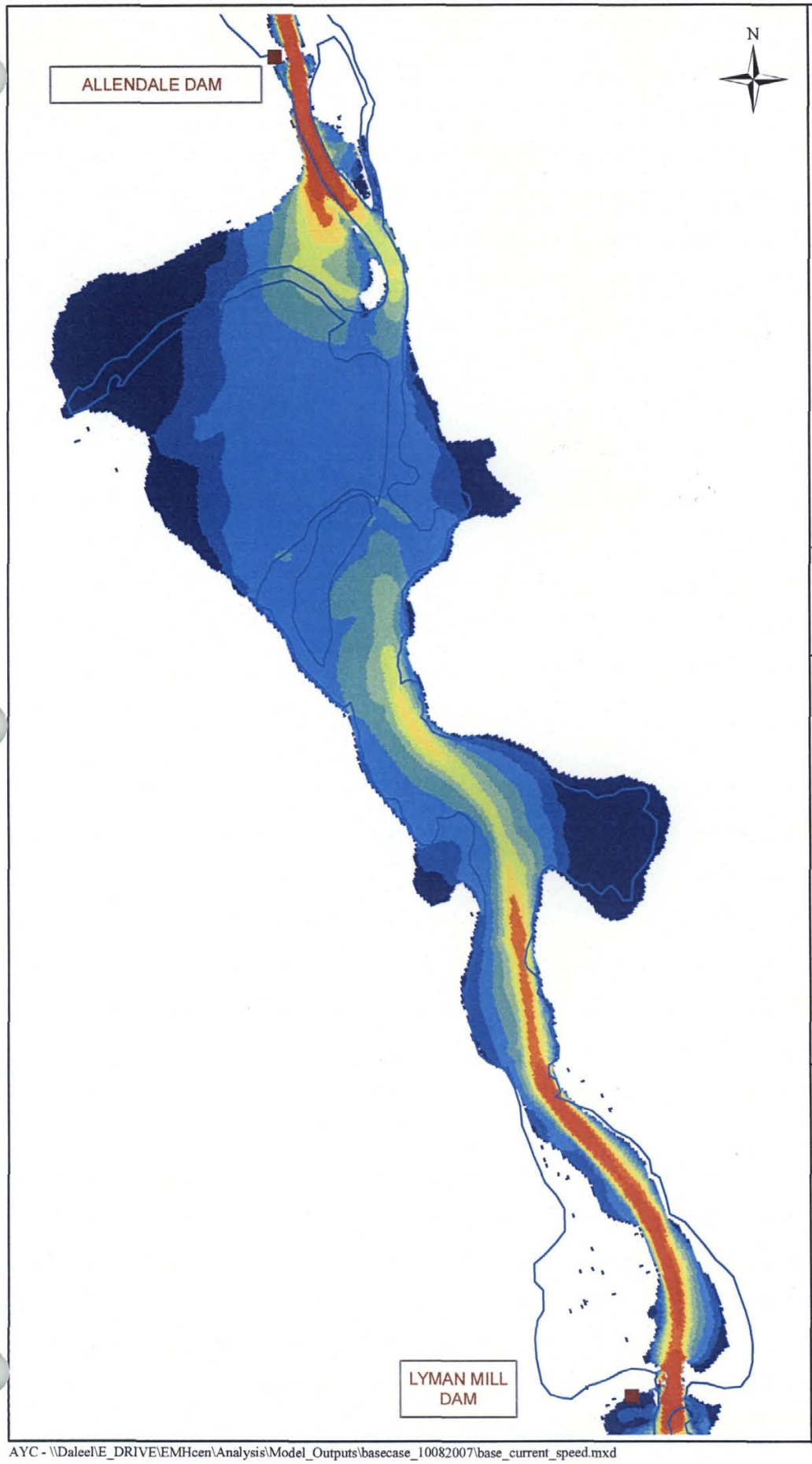
Figure 4-22.
Predicted water depth during 100-yr flood event.

Alternative 1: Partial Excavation - Channel.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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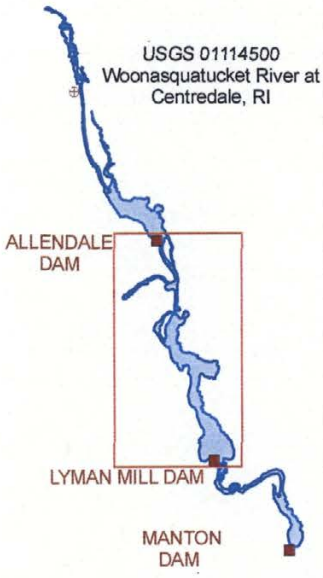


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

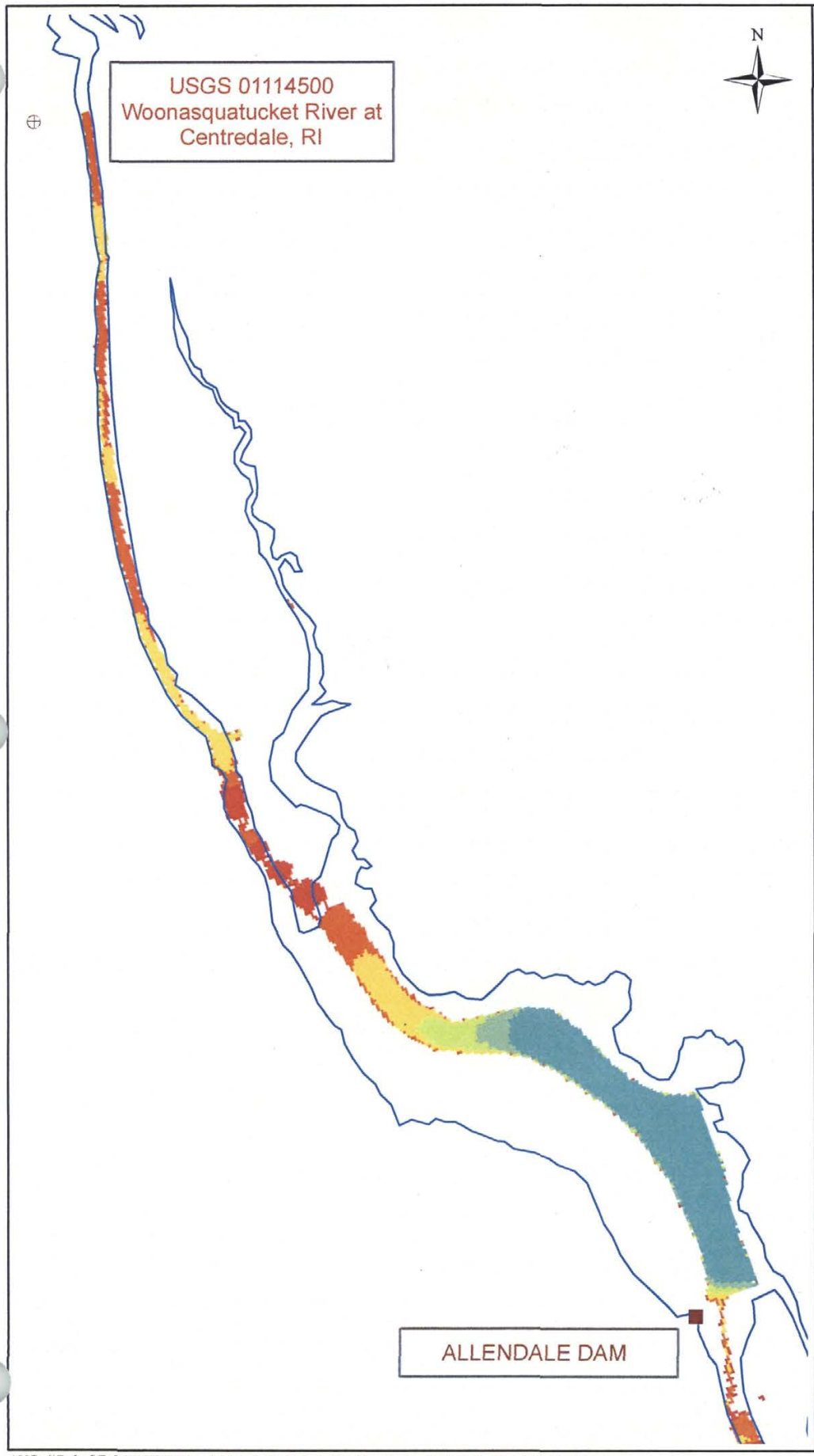
Figure 4-23.
Predicted current speed during 100-yr flood event.

Alternative 1: Partial Excavation - Channel.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



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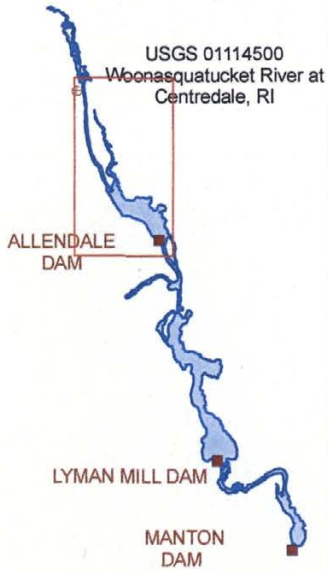


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

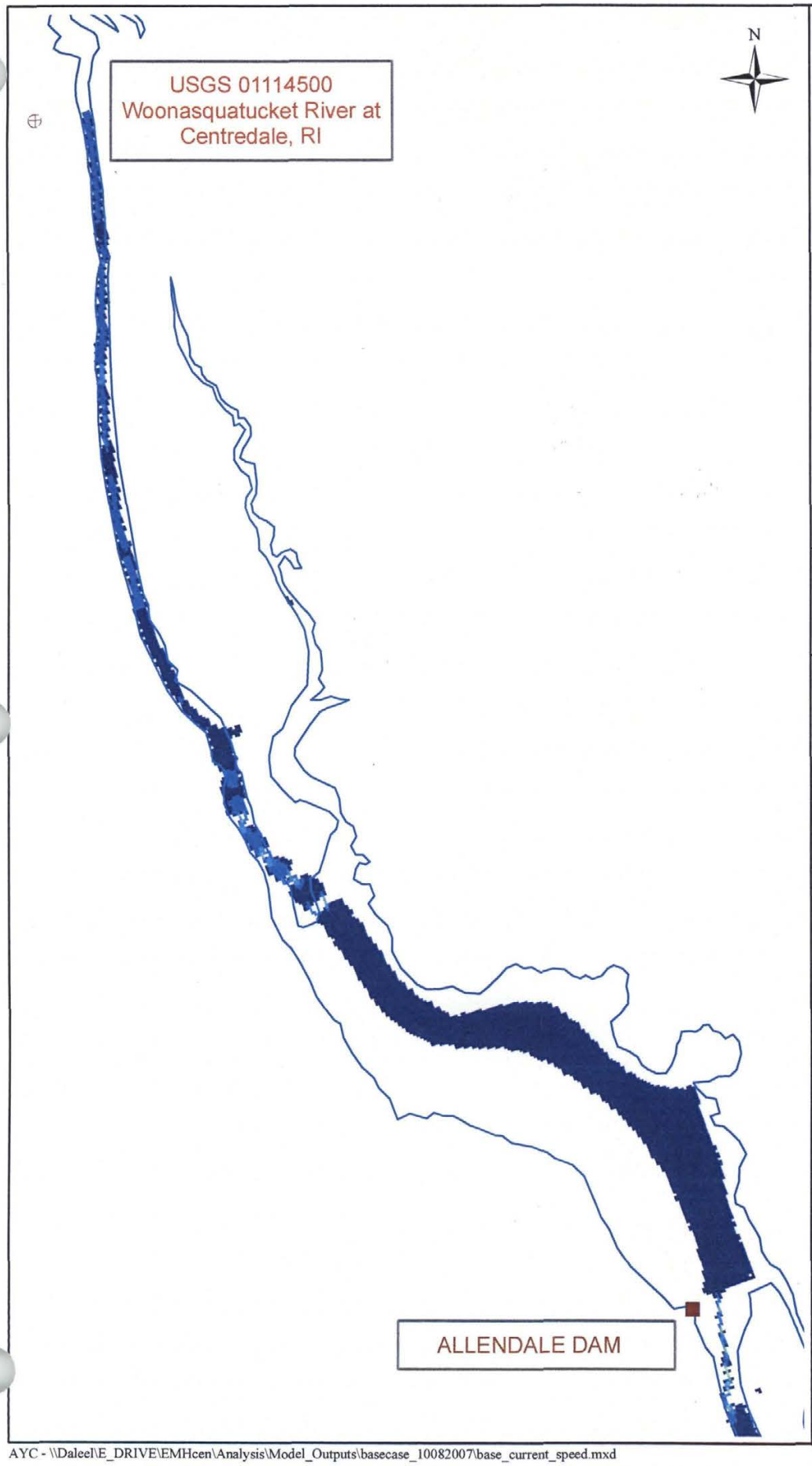
Figure 4-24.
Predicted water depth during 7Q10 discharge.

Alternative 2: Total Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

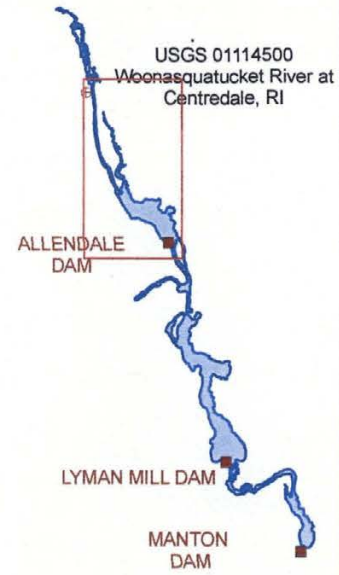
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

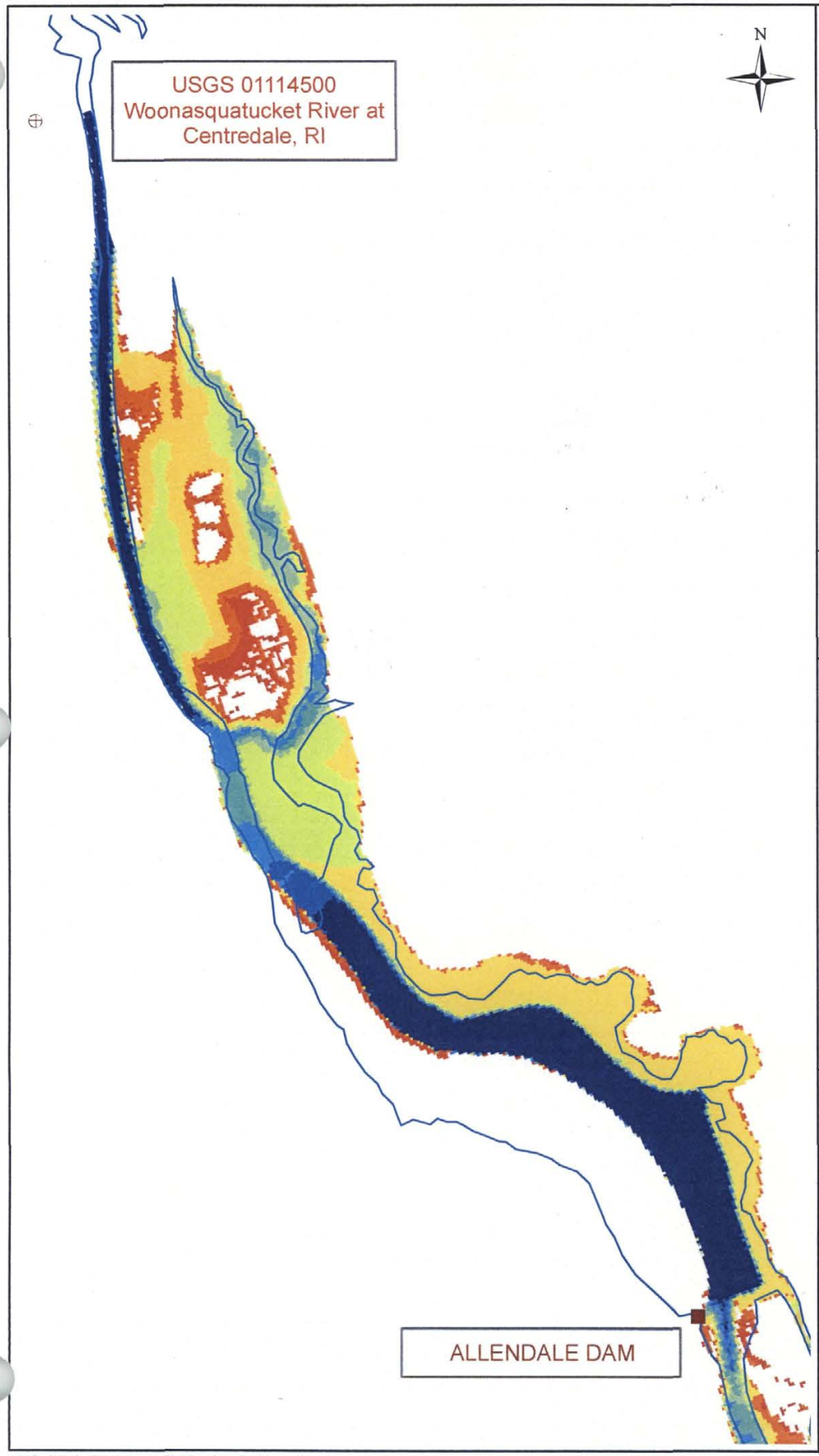
Figure 4-25.
Predicted current speed during 7Q10 discharge.

Alternative 2: Total Excavation - Channel/Ponds
Upper-Bound Case
Allendale Pond

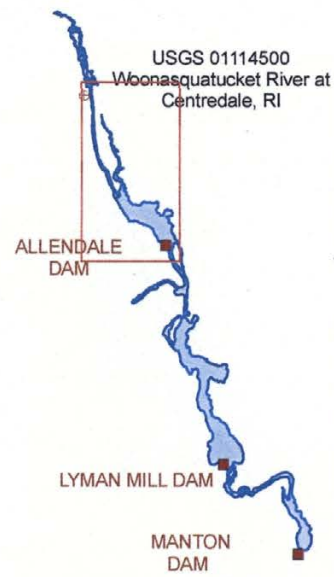
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

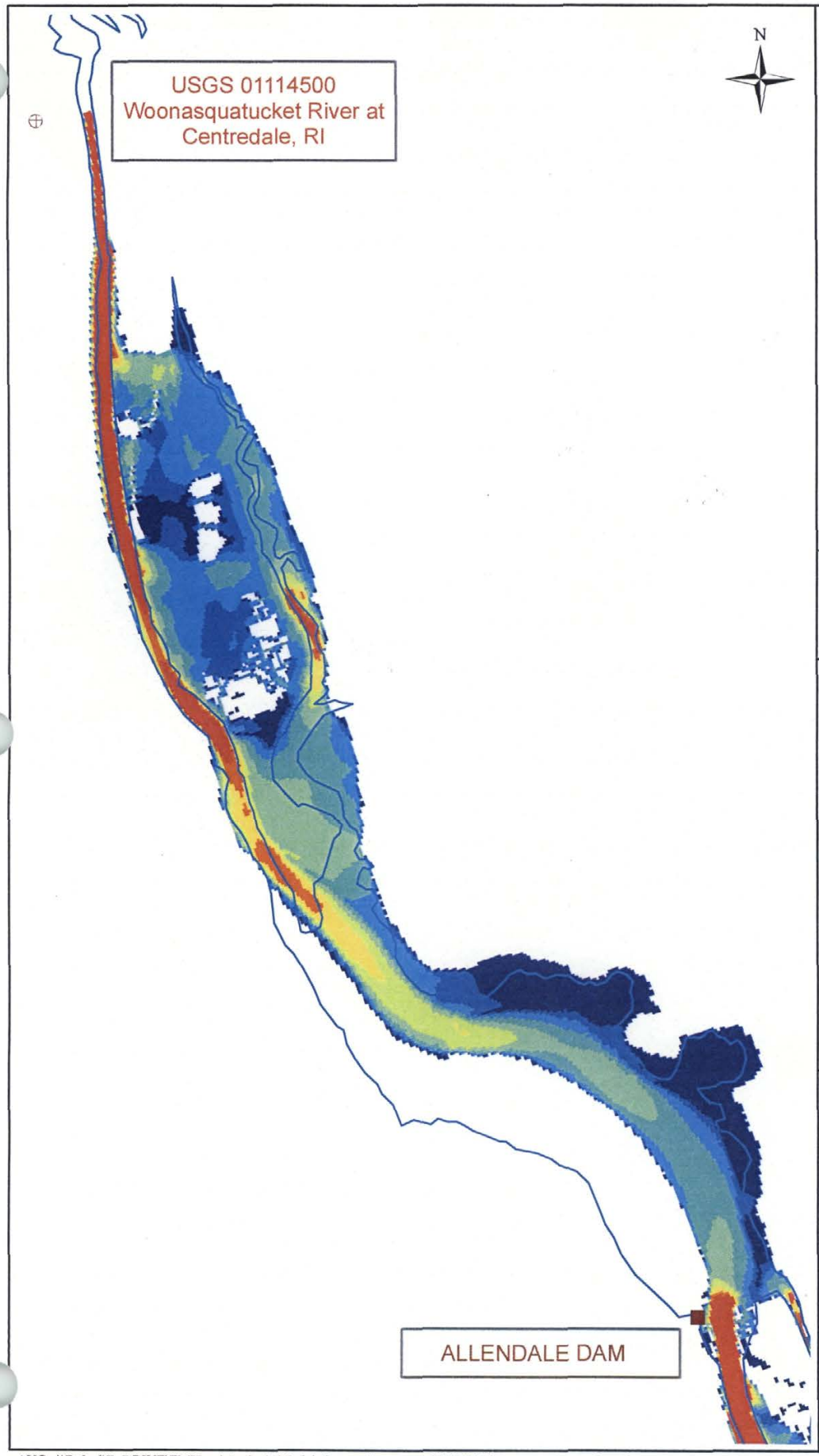
Figure 4-26.
Predicted water depth during 100-yr flood event.

Alternative 2: Total Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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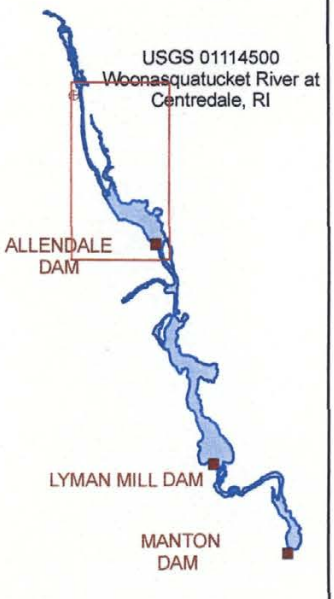


GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

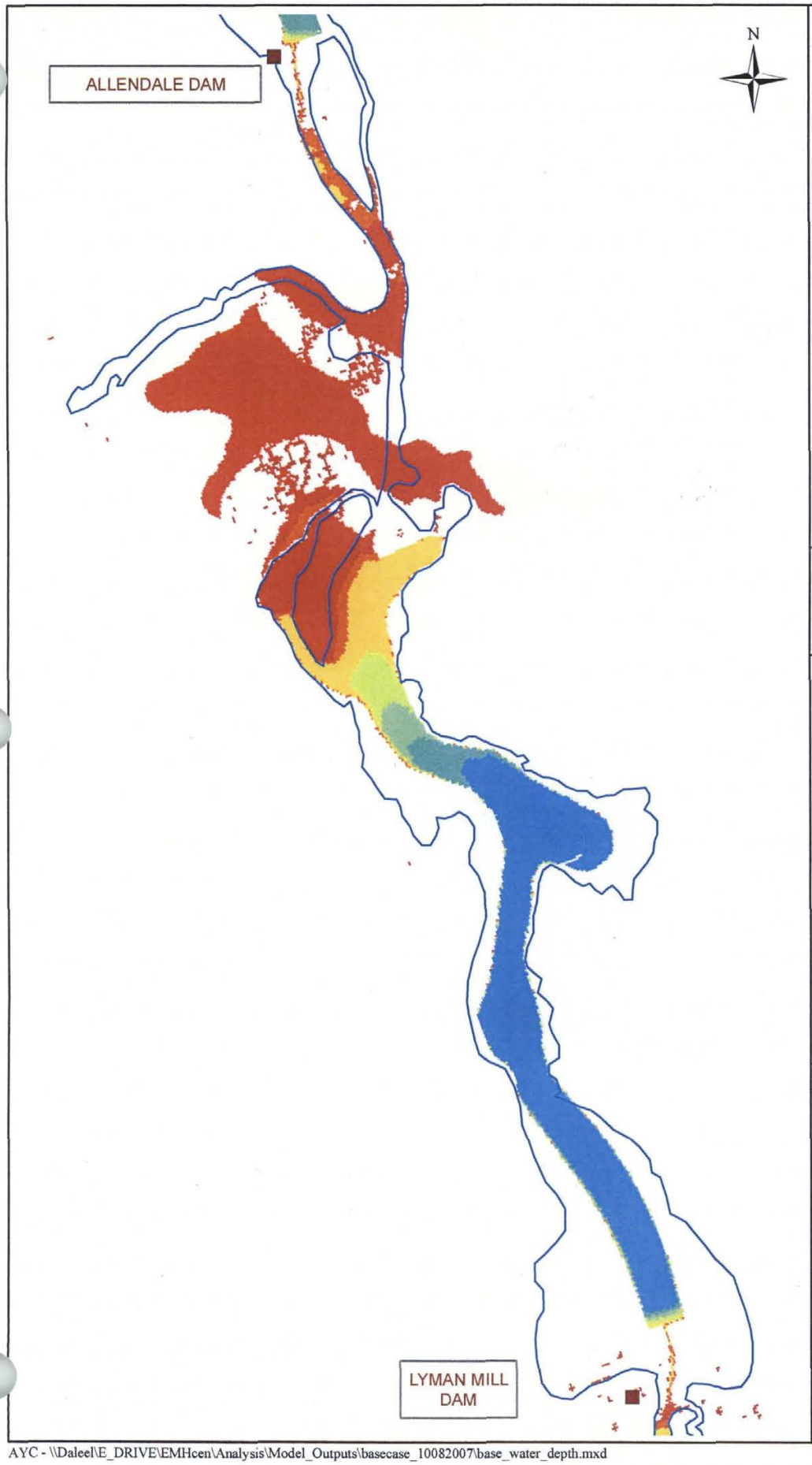
Figure 4-27.
Predicted current speed during 100-yr flood event.

Alternative 2: Total Excavation - Channel/Ponds
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



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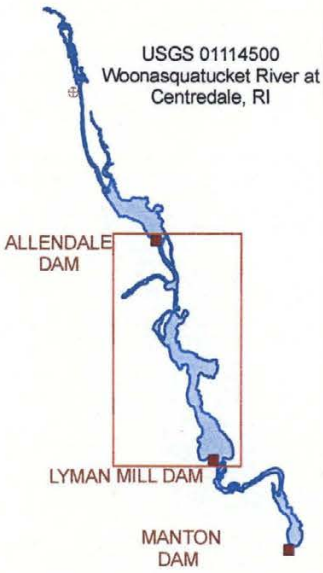


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-28.
Predicted water depth during 7Q10 discharge.

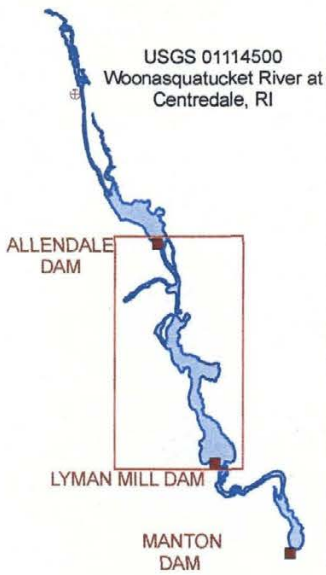
Alternative 2: Total Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd

LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

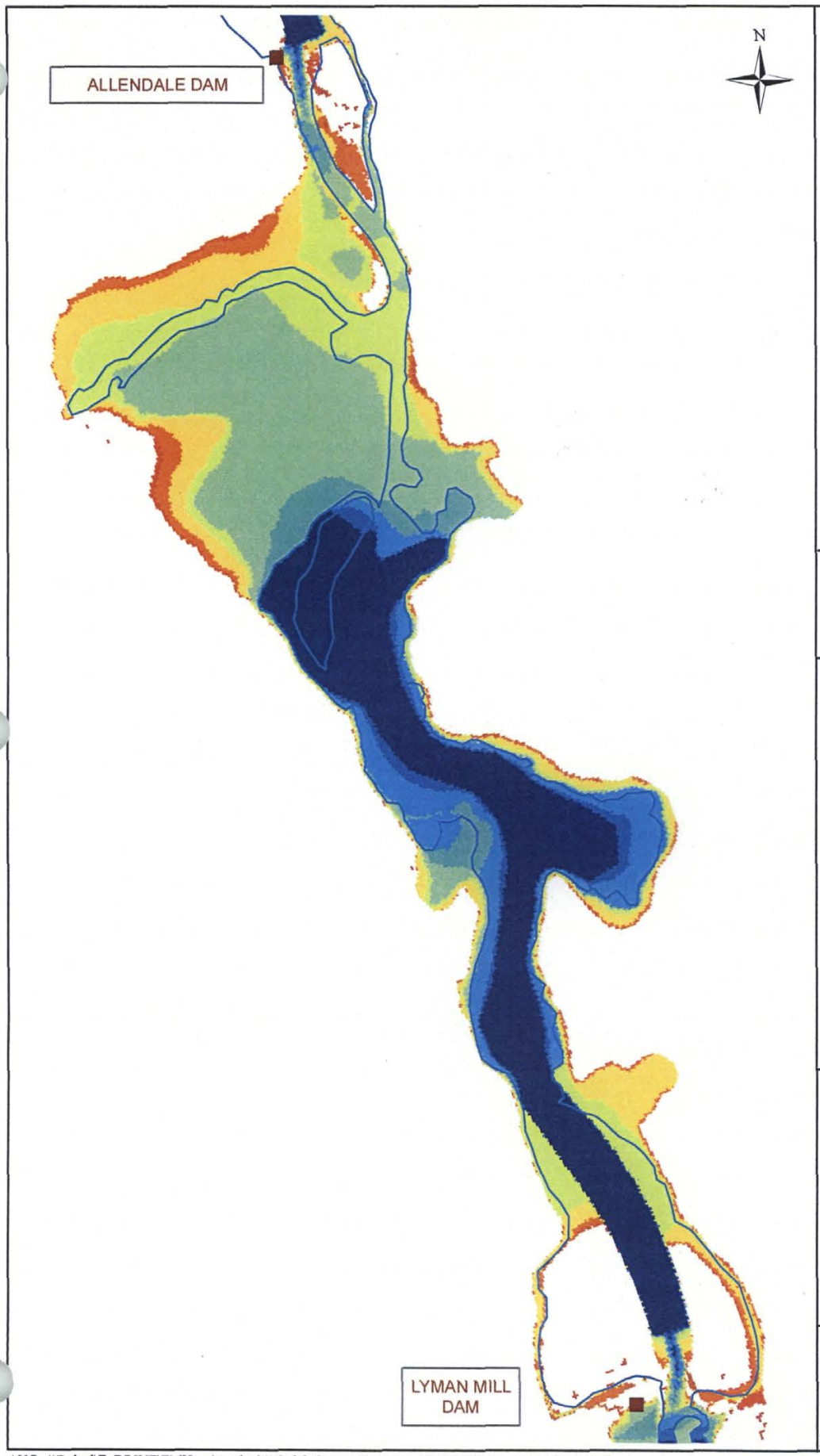
Figure 4-29.
Predicted current speed during 7Q10 discharge.

Alternative 2: Total Excavation - Channel/Ponds
Upper-Bound Case
Lyman Mill Pond

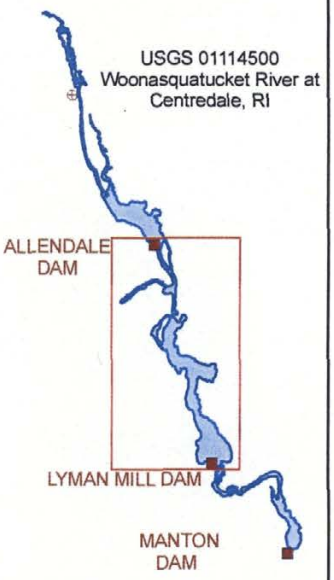
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

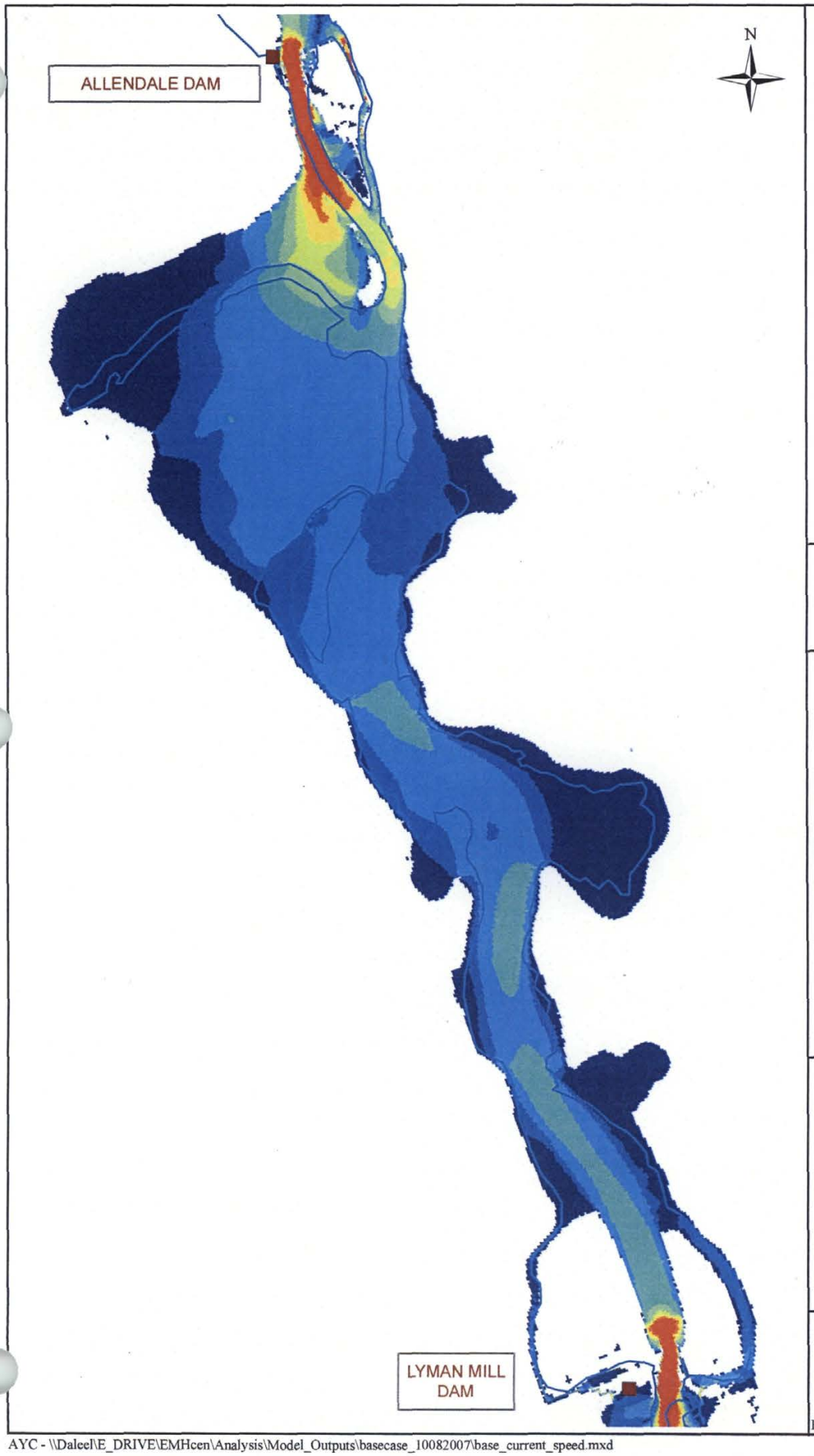
Figure 4-30.
Predicted water depth during 100-yr flood event.

Alternative 2: Total Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

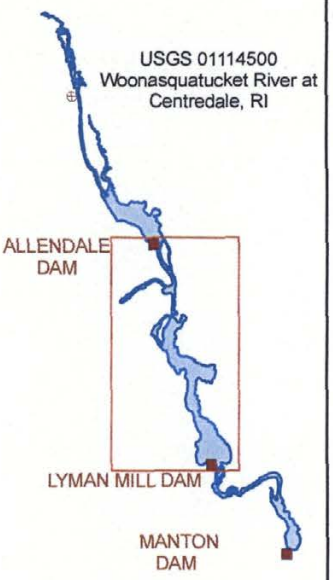
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

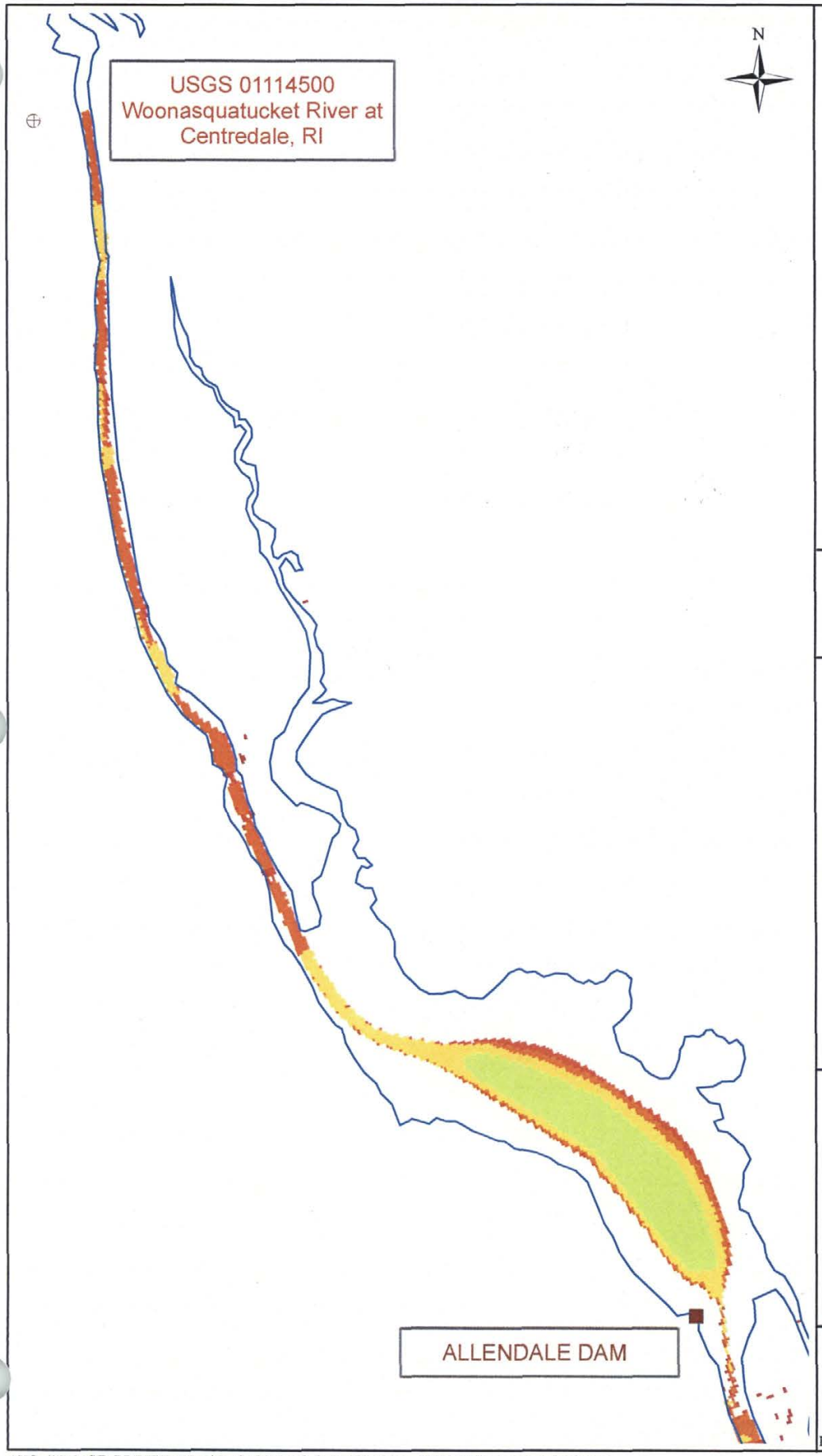
Figure 4-31.
Predicted current speed during 100-yr flood event.

Alternative 2: Total Excavation - Channel/Ponds
Upper-Bound Case
Lyman Mill Pond

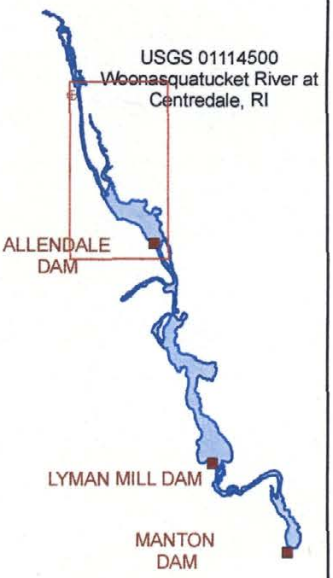
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

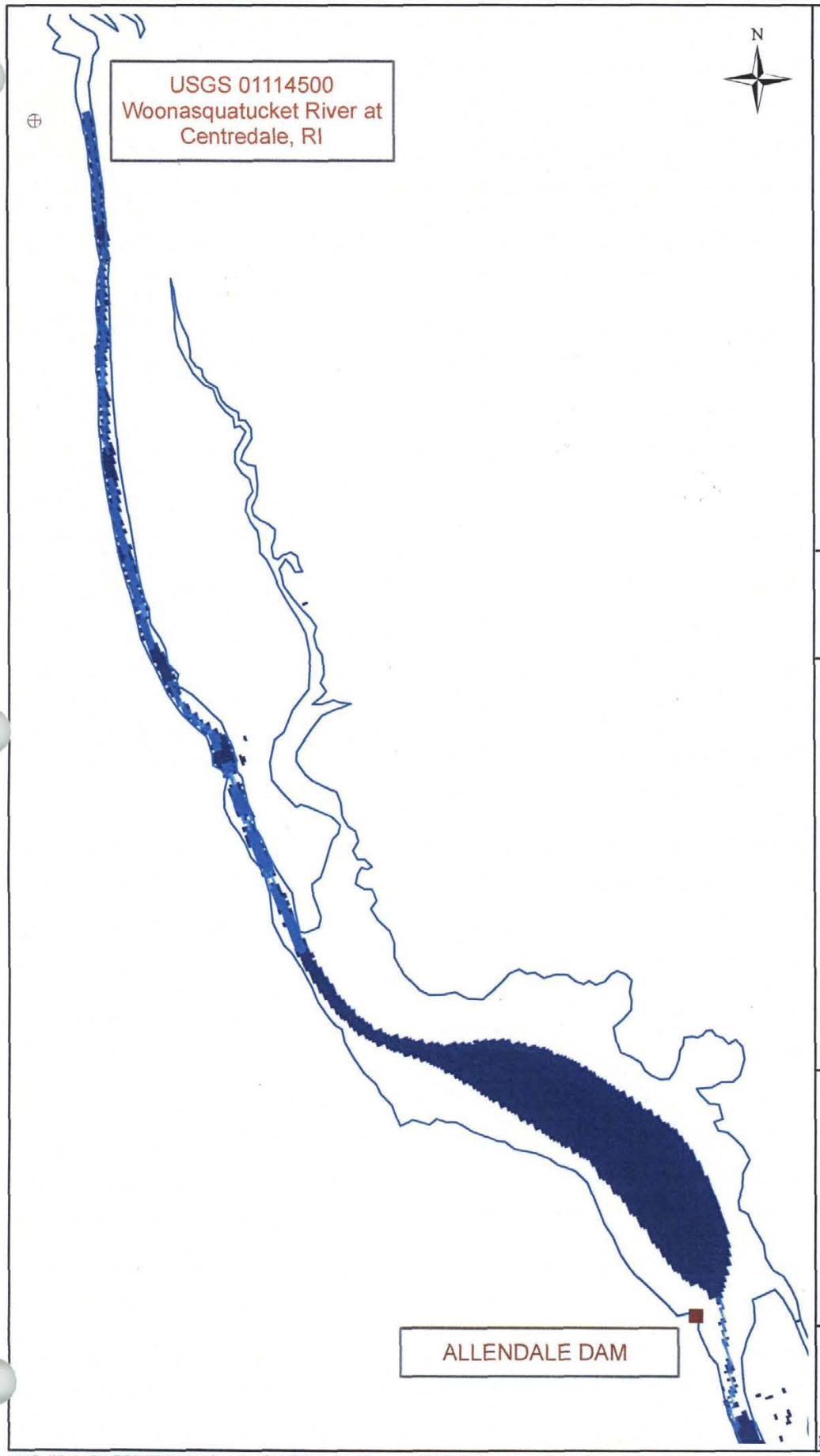
Figure 4-32.
Predicted water depth during 7Q10 discharge.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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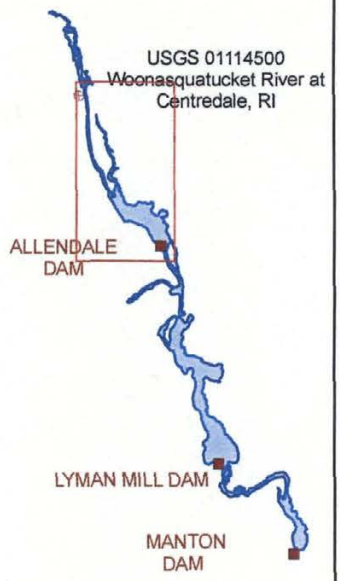


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

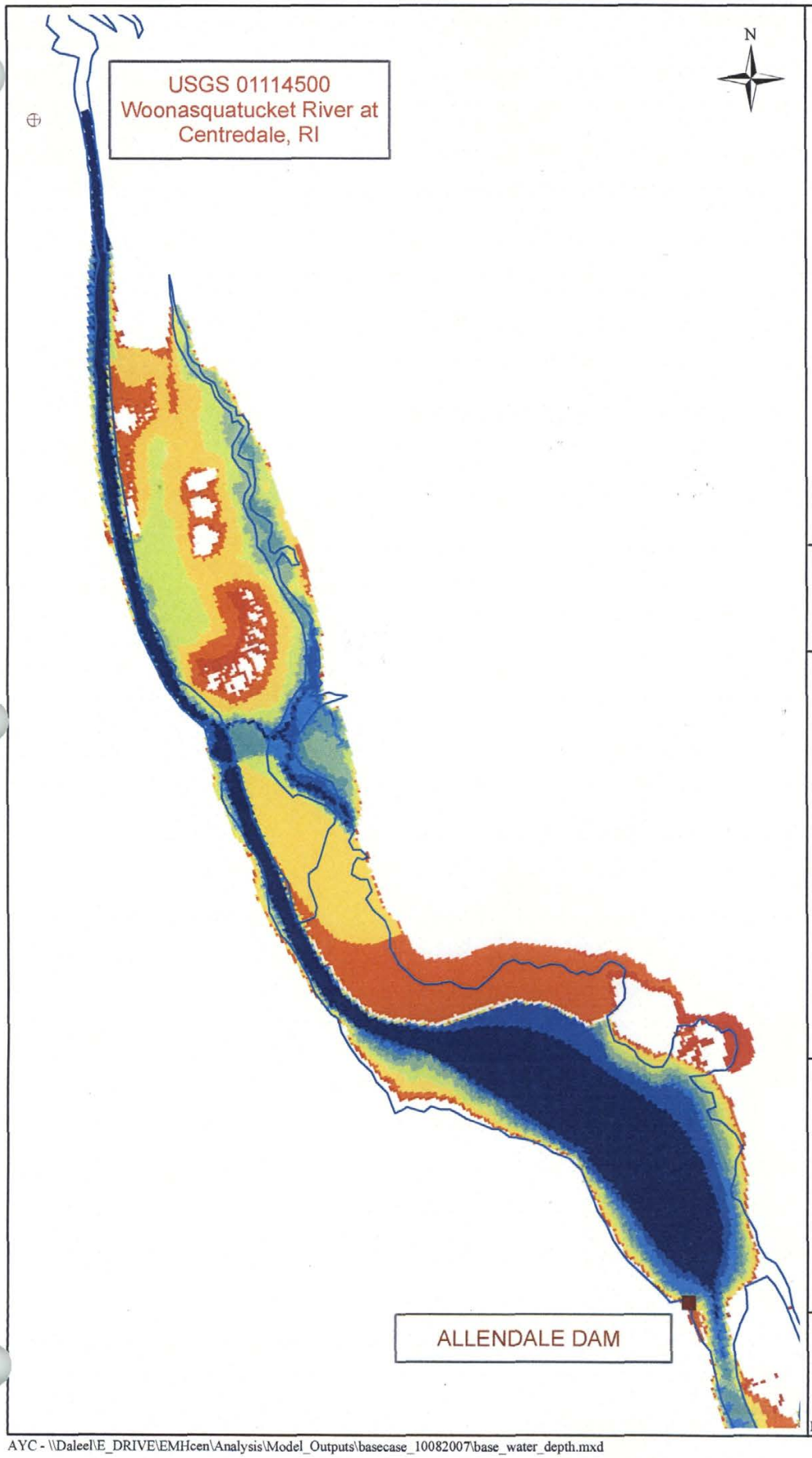
Figure 4-33.
Predicted current speed during 7Q10 discharge.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd



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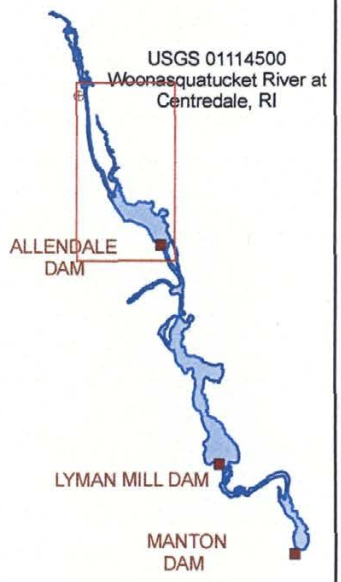


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

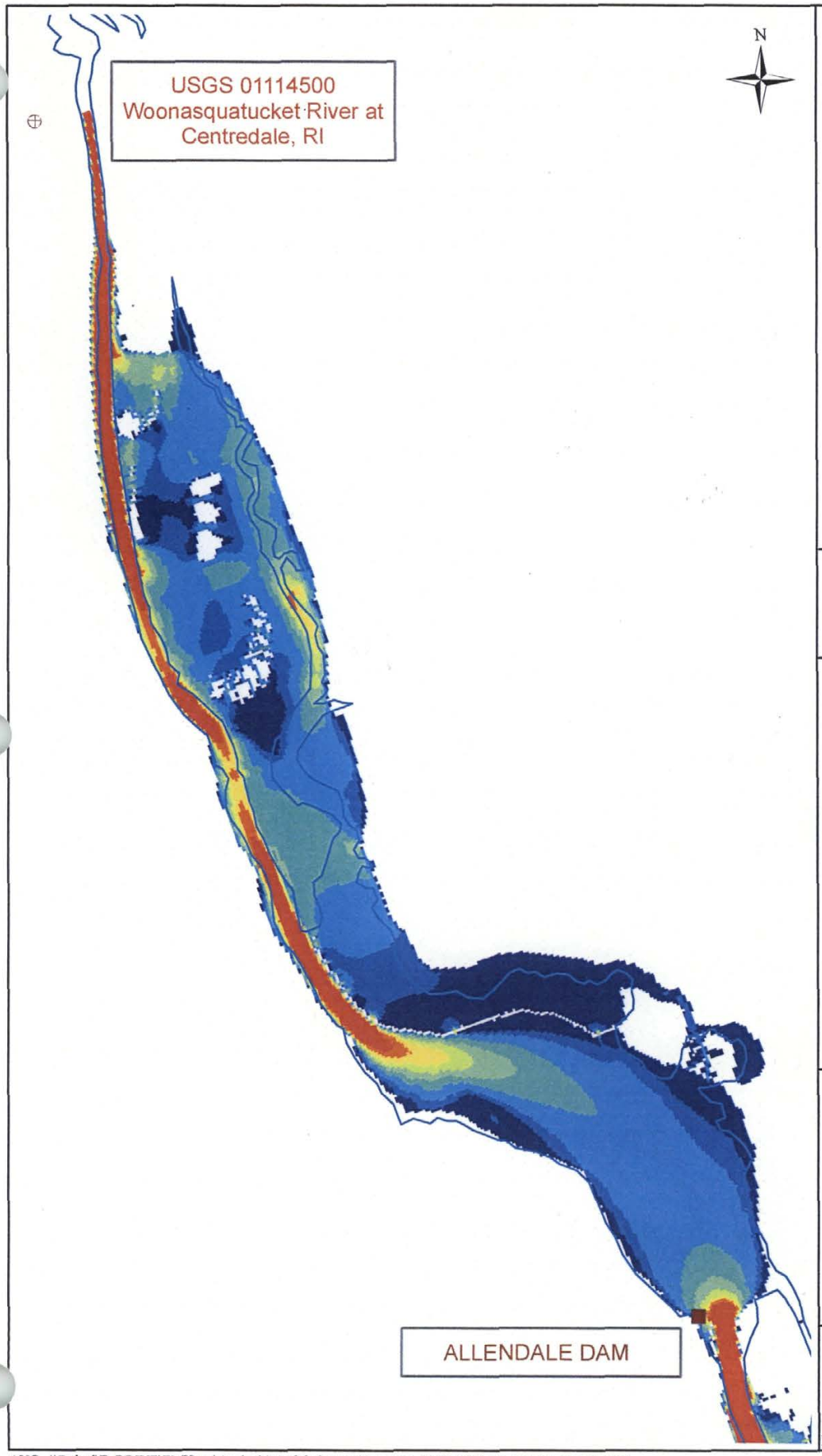
Figure 4-34.
Predicted water depth during 100-yr flood event.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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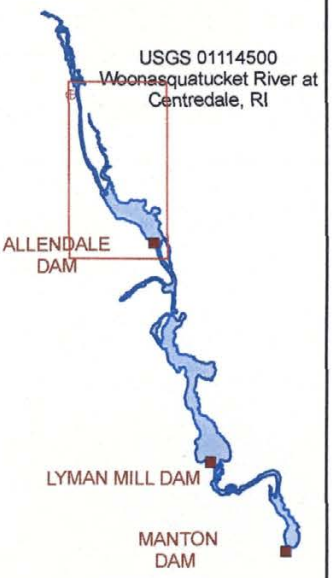

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

Figure 4-35.
Predicted current speed during 100-yr flood event.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Allendale Pond

QEA
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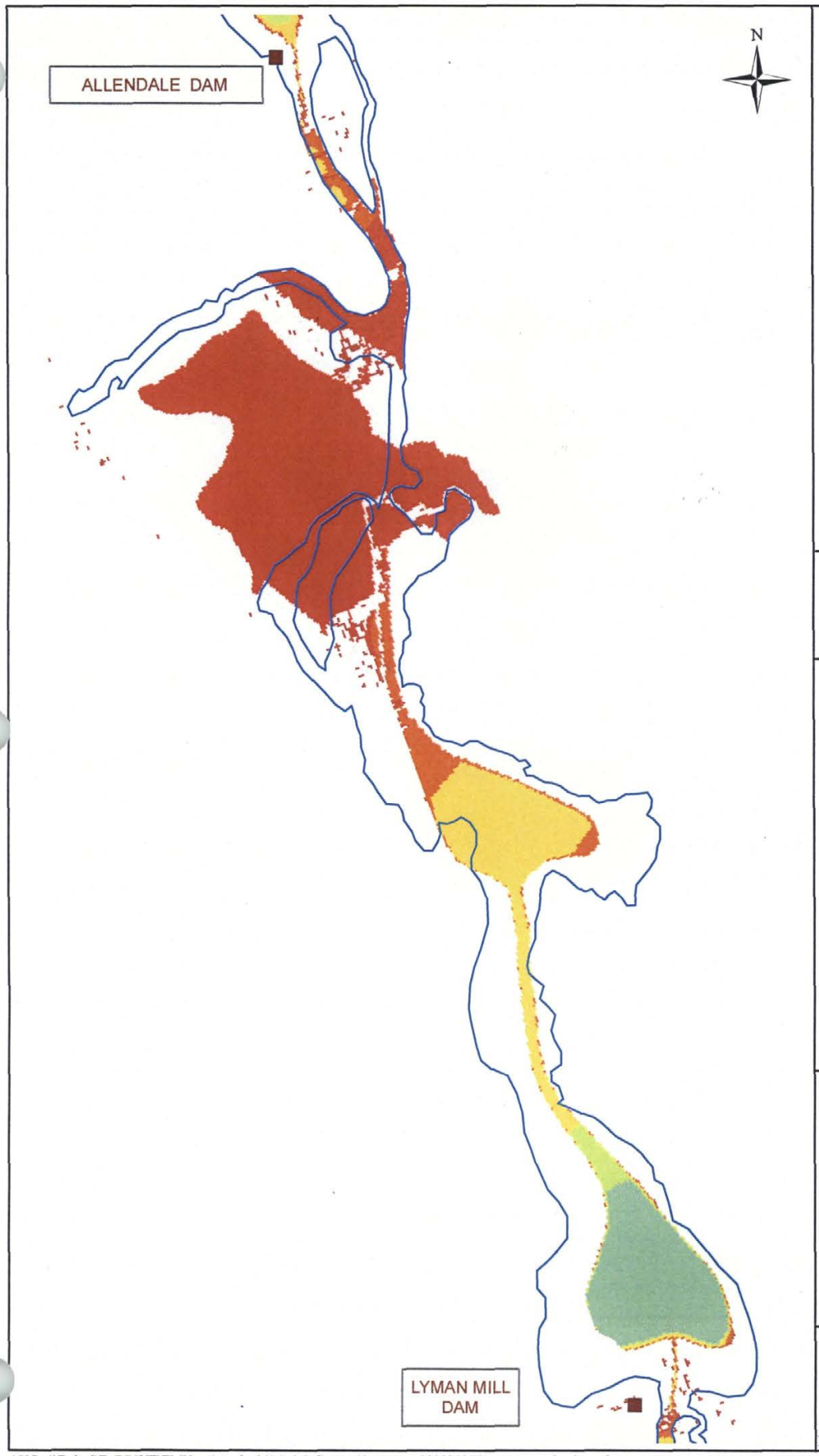
EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd



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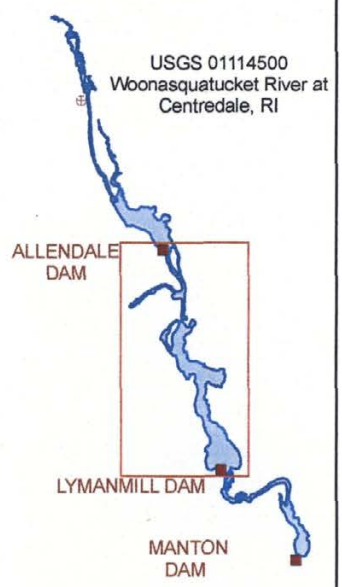


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-36.
Predicted water depth during 7q10 discharge.

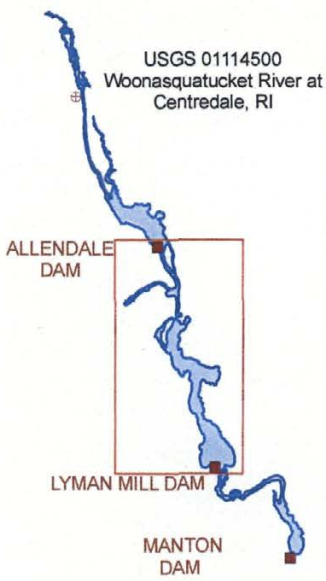
Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd

LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

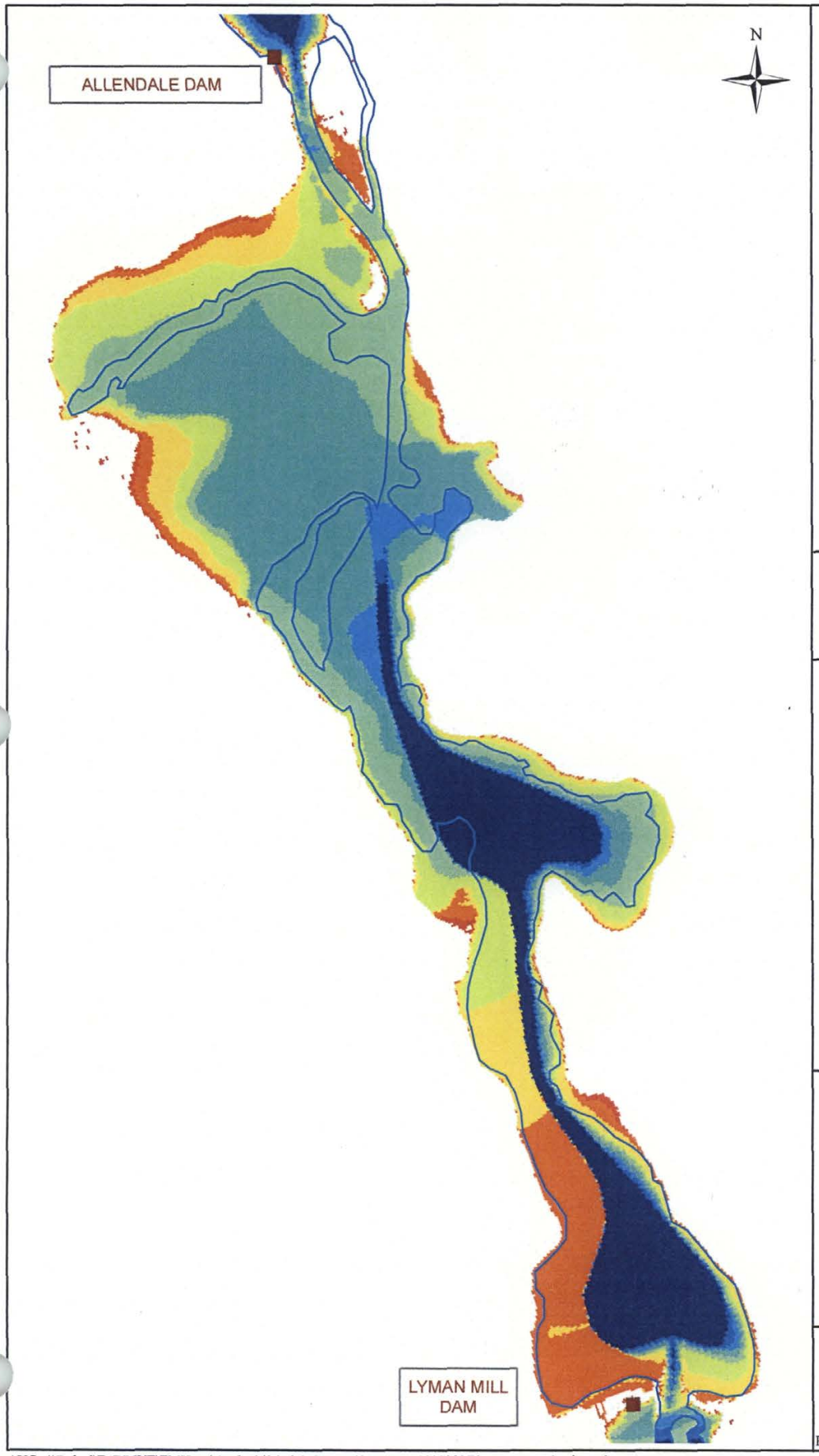
Figure 4-37.
Predicted current speed during 7Q10 discharge.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd



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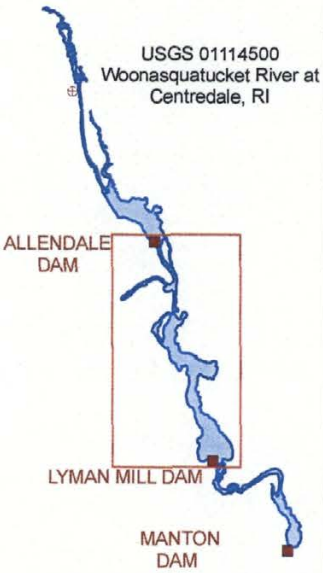


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

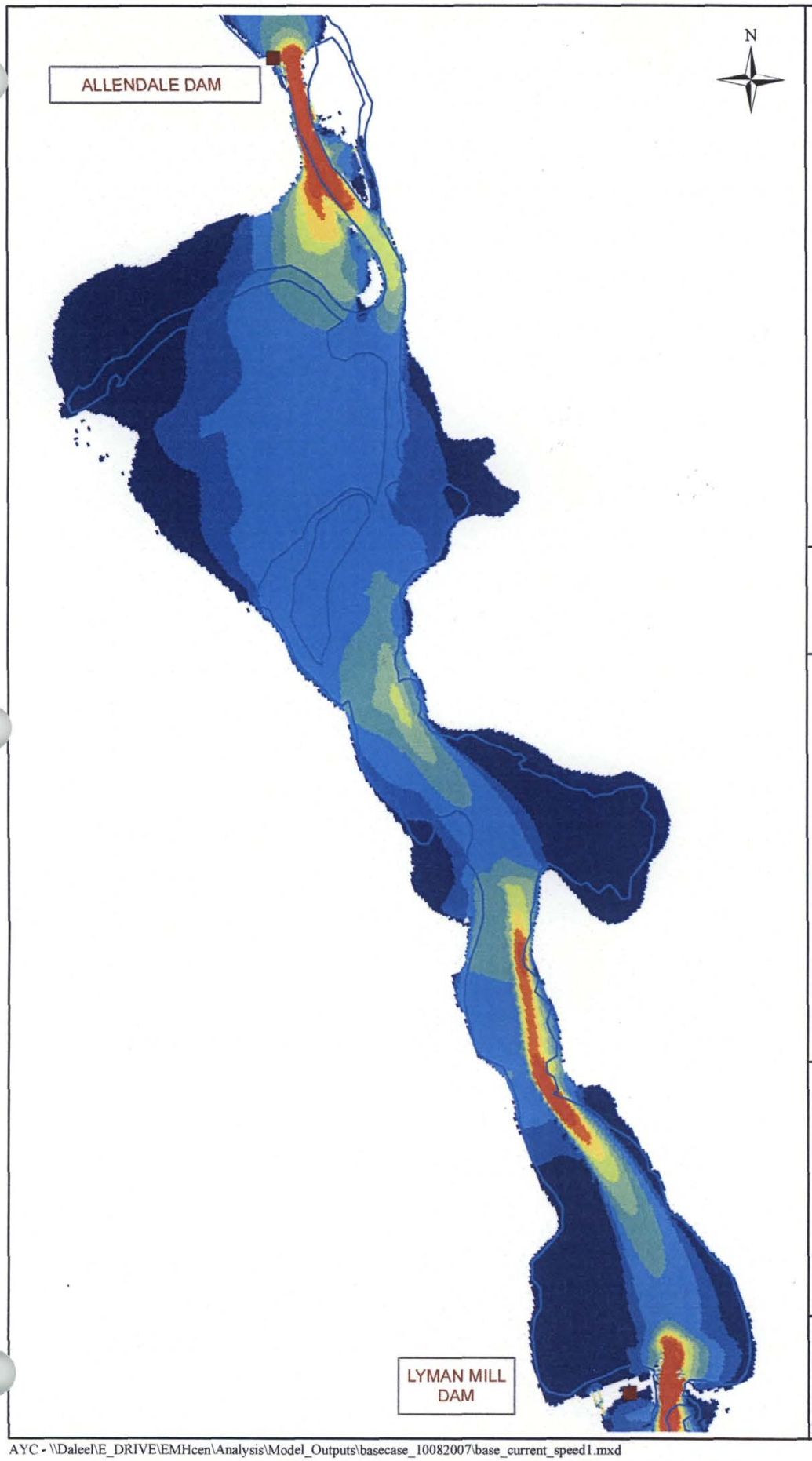
Figure 4-38.
Predicted water depth during 100-yr flood event.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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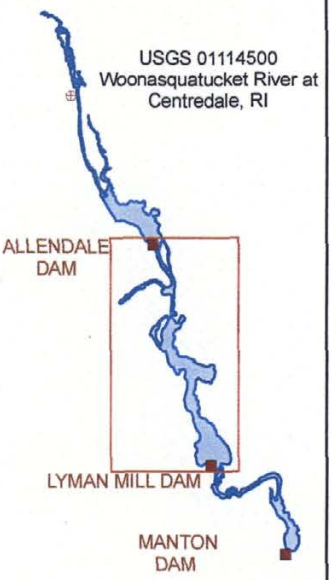


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

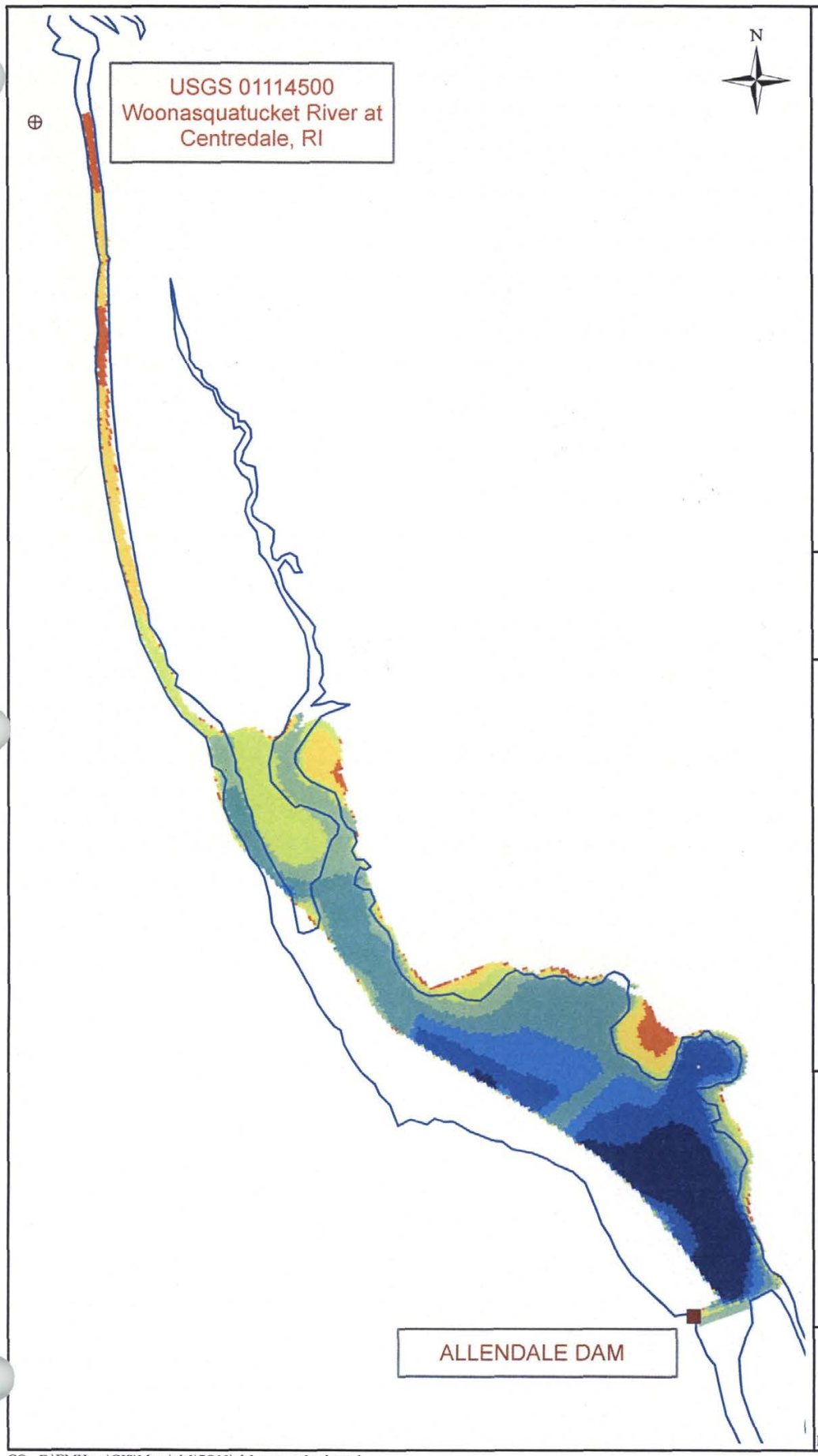
Figure 4-39.
Predicted current speed during 100-yr flood event.

Alternative 3: Partial Excavation - Channel/Ponds.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd



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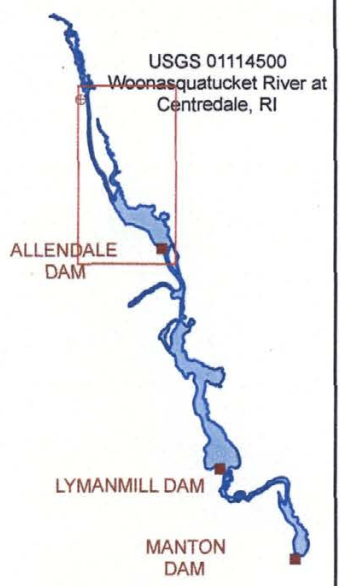

GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-40.
Predicted water depth during 7Q10 discharge.

Alternative 4: Nearshore CDF with Dams in Place Upper-Bound Case Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

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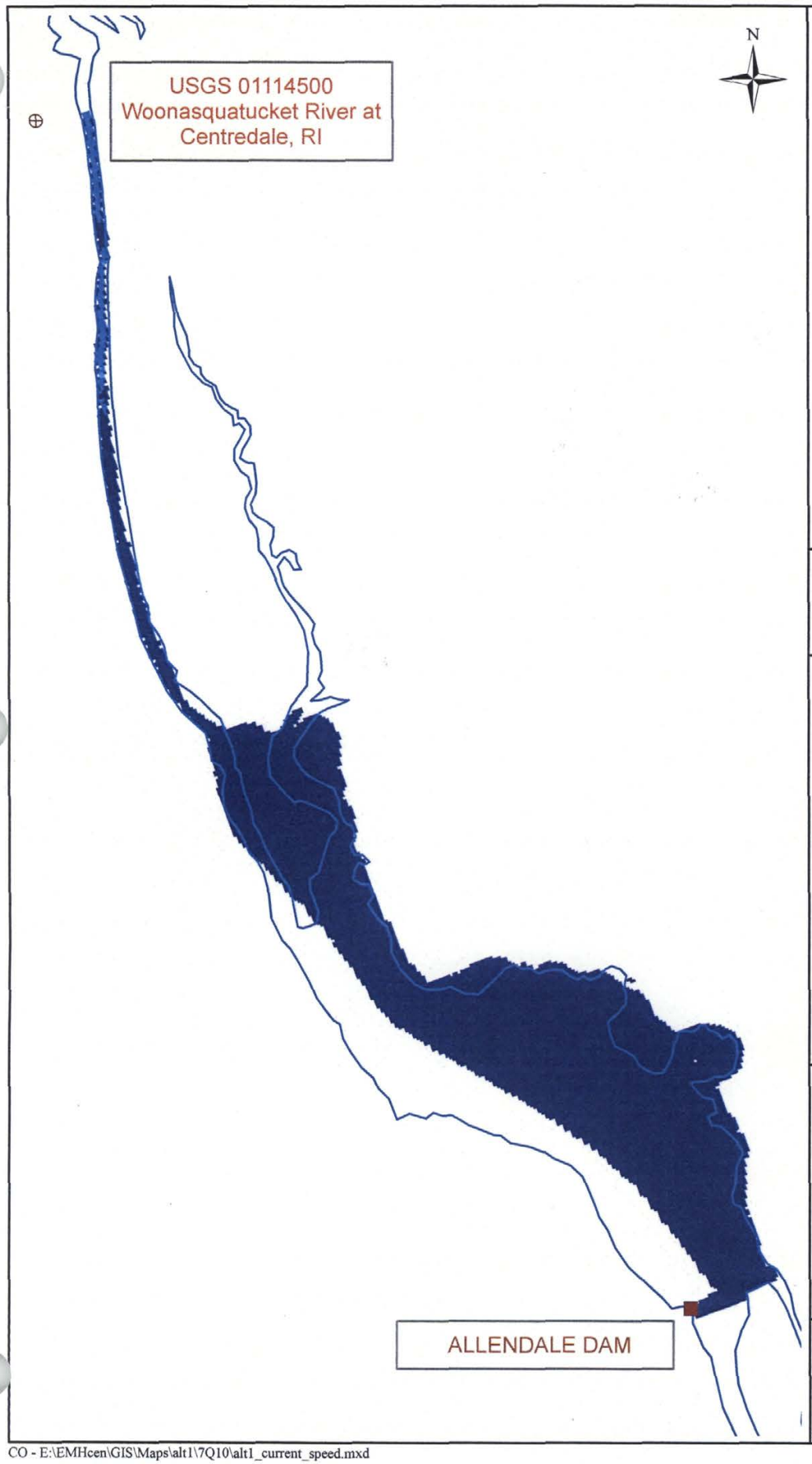

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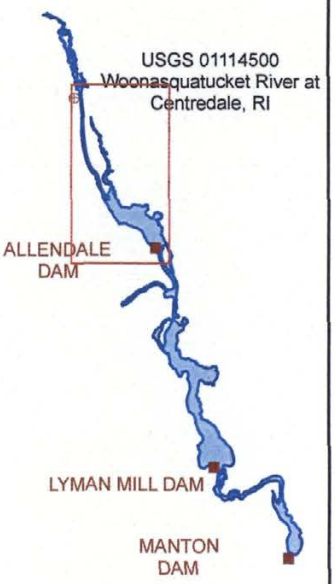

GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

Figure 4-41.
Predicted current speed during 7Q10 discharge.

Alternative 4: Nearshore CDF with Dams in Place Upper-Bound Case Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

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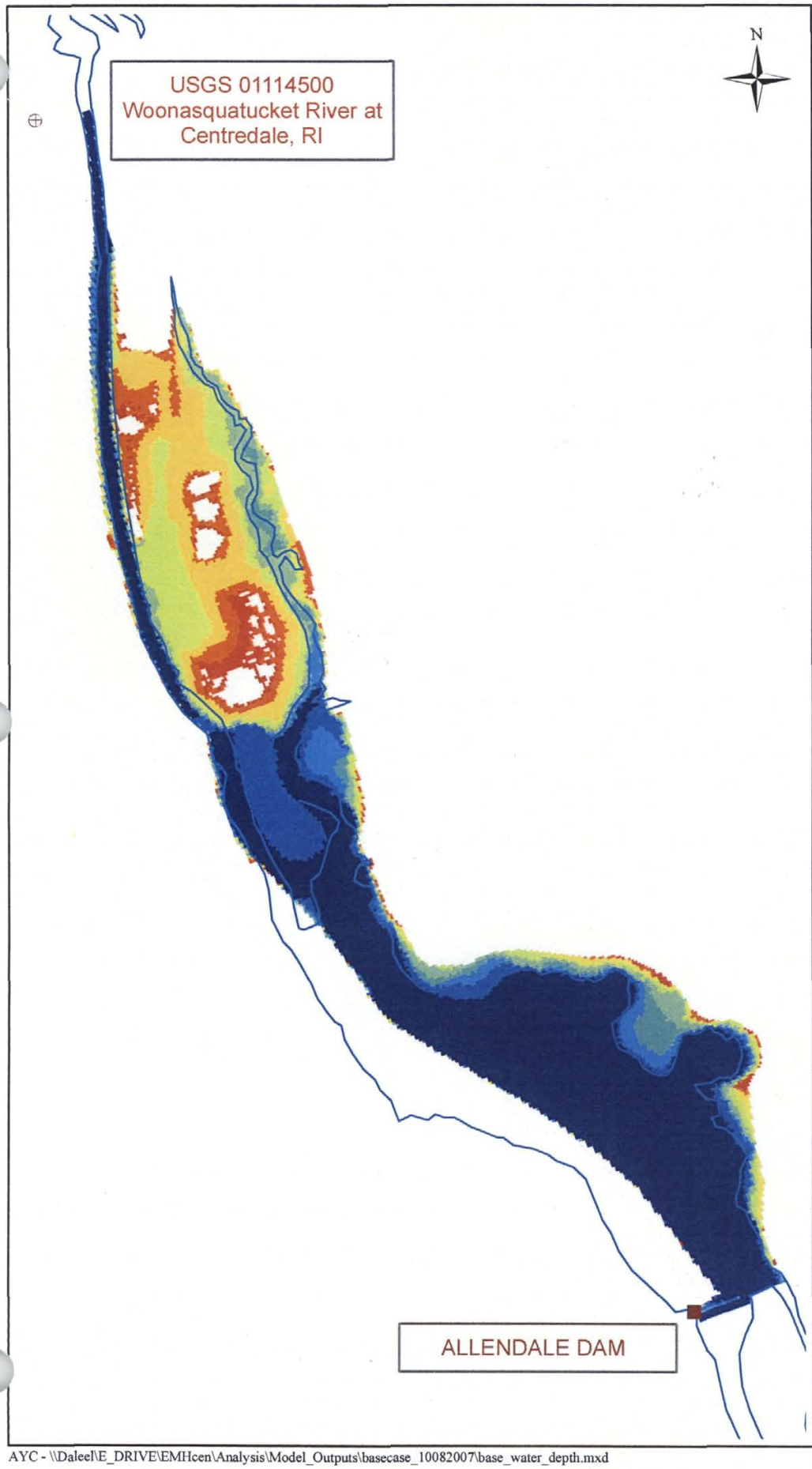

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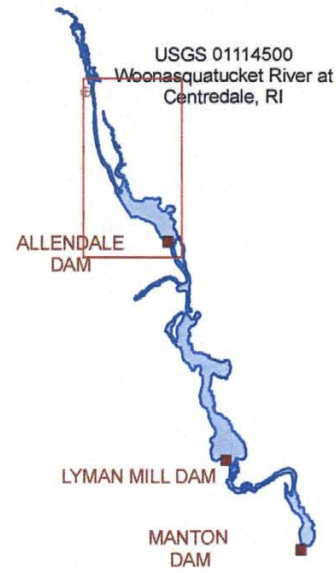


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

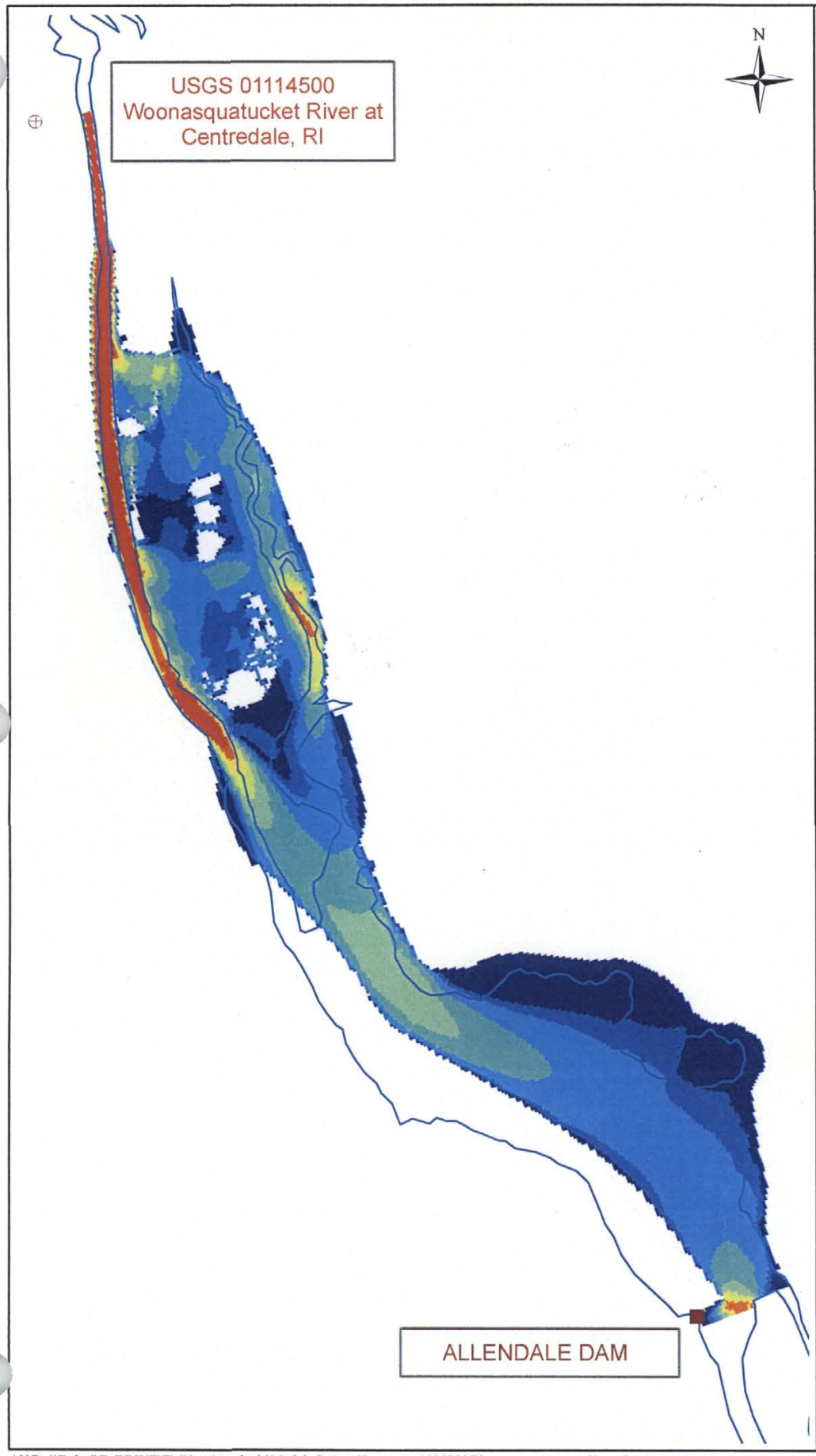
Figure 4-42.
Predicted water depth during 100-yr flood event.

Alternative 4: Nearshore CDF with Dams in Place.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



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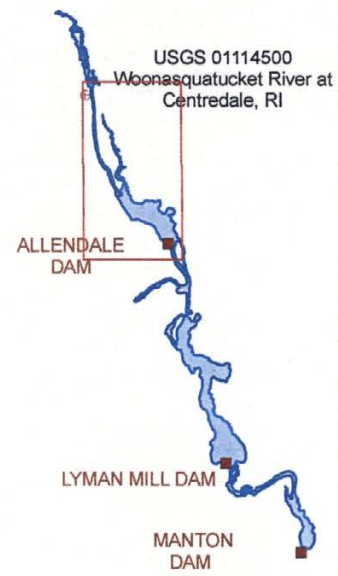


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

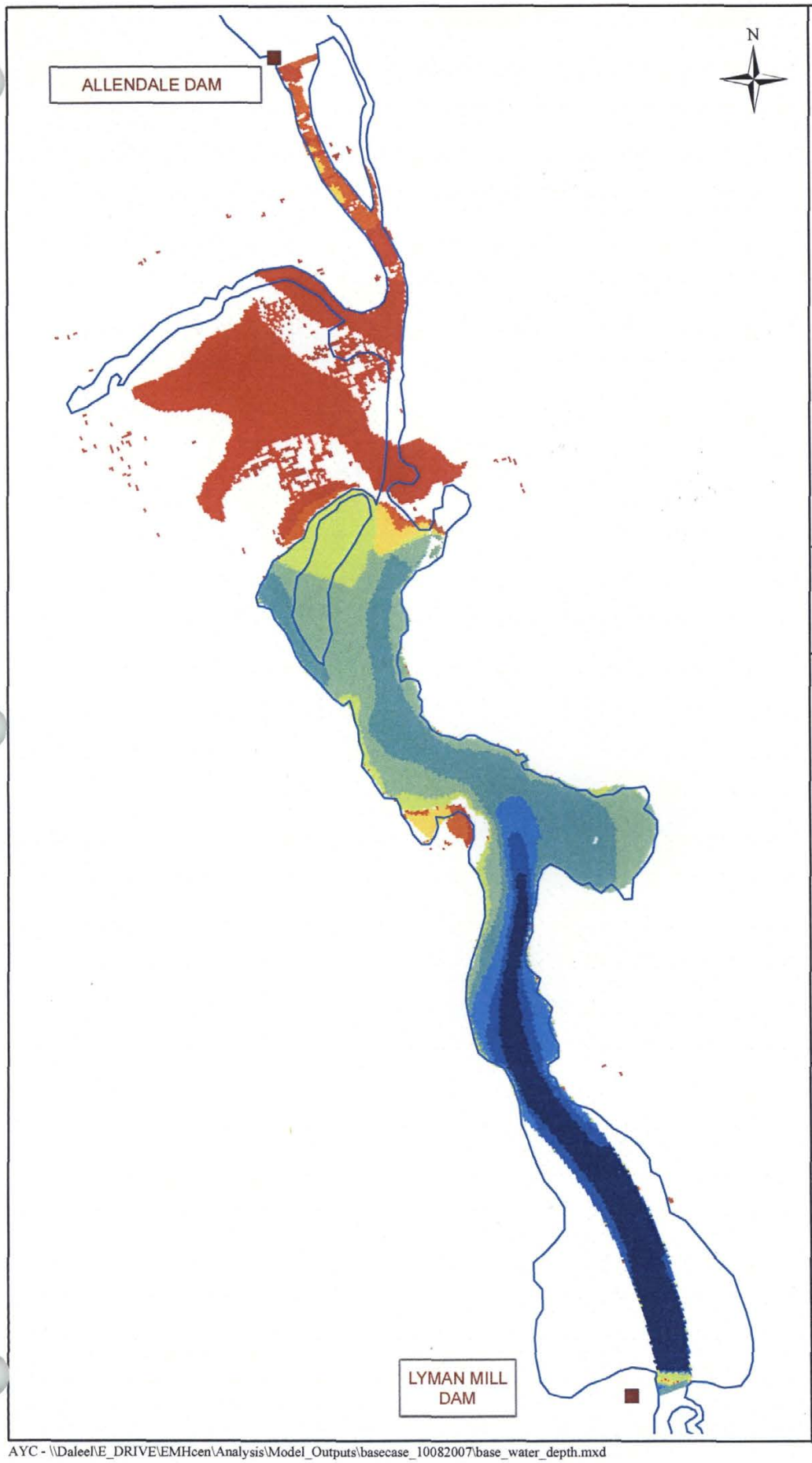
Figure 4-43.
Predicted current speed during 100-yr flood event.

Alternative 4: Nearshore CDF with Dams in Place.
Upper-Bound Case
Allendale Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd



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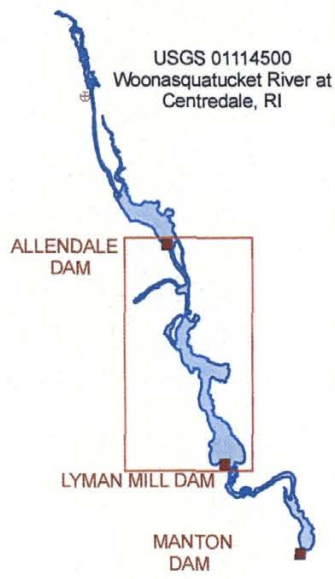


GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

Figure 4-44.
Predicted water depth during 7Q10 discharge.

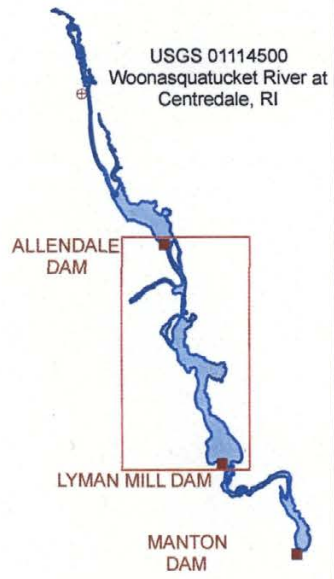
Alternative 4: Nearshore CDF with Dams in Place.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd

LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

Figure 4-45.
Predicted current speed during 7Q10 discharge.

Alternative 4: Nearshore CDF with Dams in Place Upper-Bound Case Lyman Mill Pond

QEA
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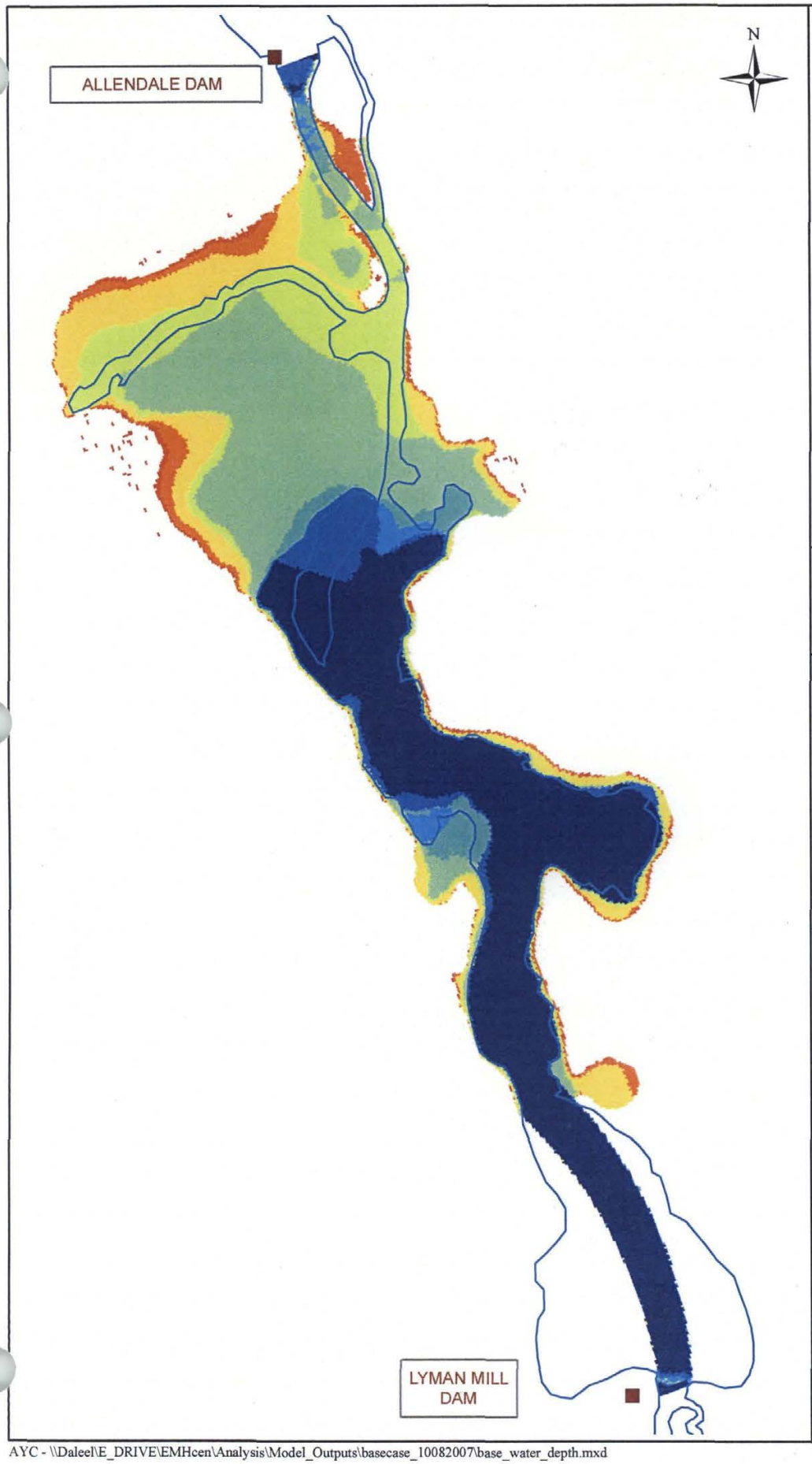
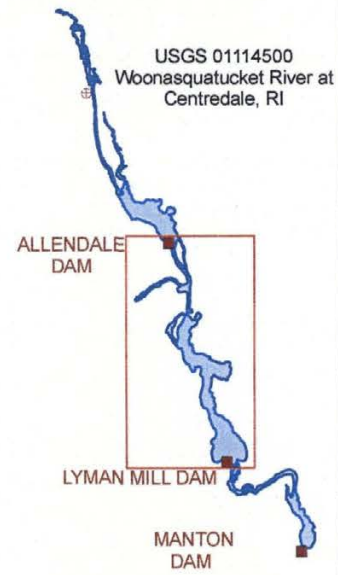
EMHcen:120 **October 2007**

CO - E:\EMHcen\GIS\Maps\alt1\7Q10\alt1_current_speed.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Water Depth (ft)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- > 7.0

CENTREDALE MANOR STUDY AREA

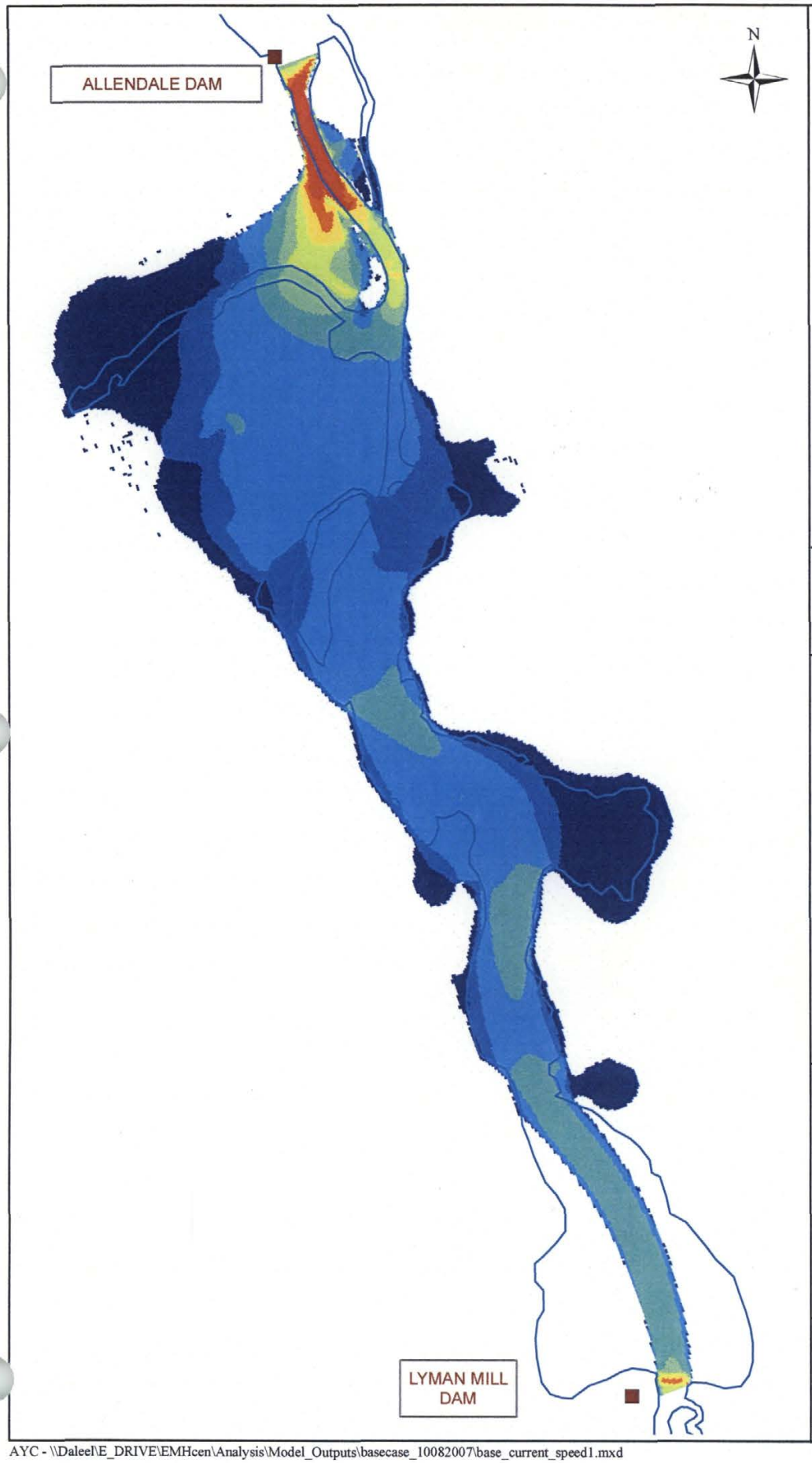
Figure 4-46.
Predicted water depth during 100-yr flood event.

Alternative 4: Nearshore CDF with Dams in Place.
Upper-Bound Case
Lyman Mill Pond

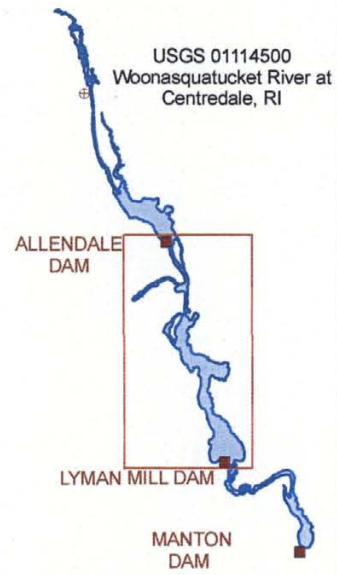
QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_water_depth.mxd



LOCATOR MAP



GRAPHIC SCALE

Feet

0 250 500

LEGEND

- Dam Location
- USGS Gage Station
- Shoreline

Current Speed (m/s)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- > 1.4

CENTREDALE MANOR STUDY AREA

Figure 4-47.
Predicted current speed during 100-yr flood event.

Alternative 4: Nearshore CDF with Dams in Place.
Upper-Bound Case
Lyman Mill Pond

QEA
Quantitative Environmental Analysis, LLC

EMHcen:120 **October 2007**

AYC - \\Daleel\E_DRIVE\EMHcen\Analysis\Model_Outputs\basecase_10082007\base_current_speed1.mxd

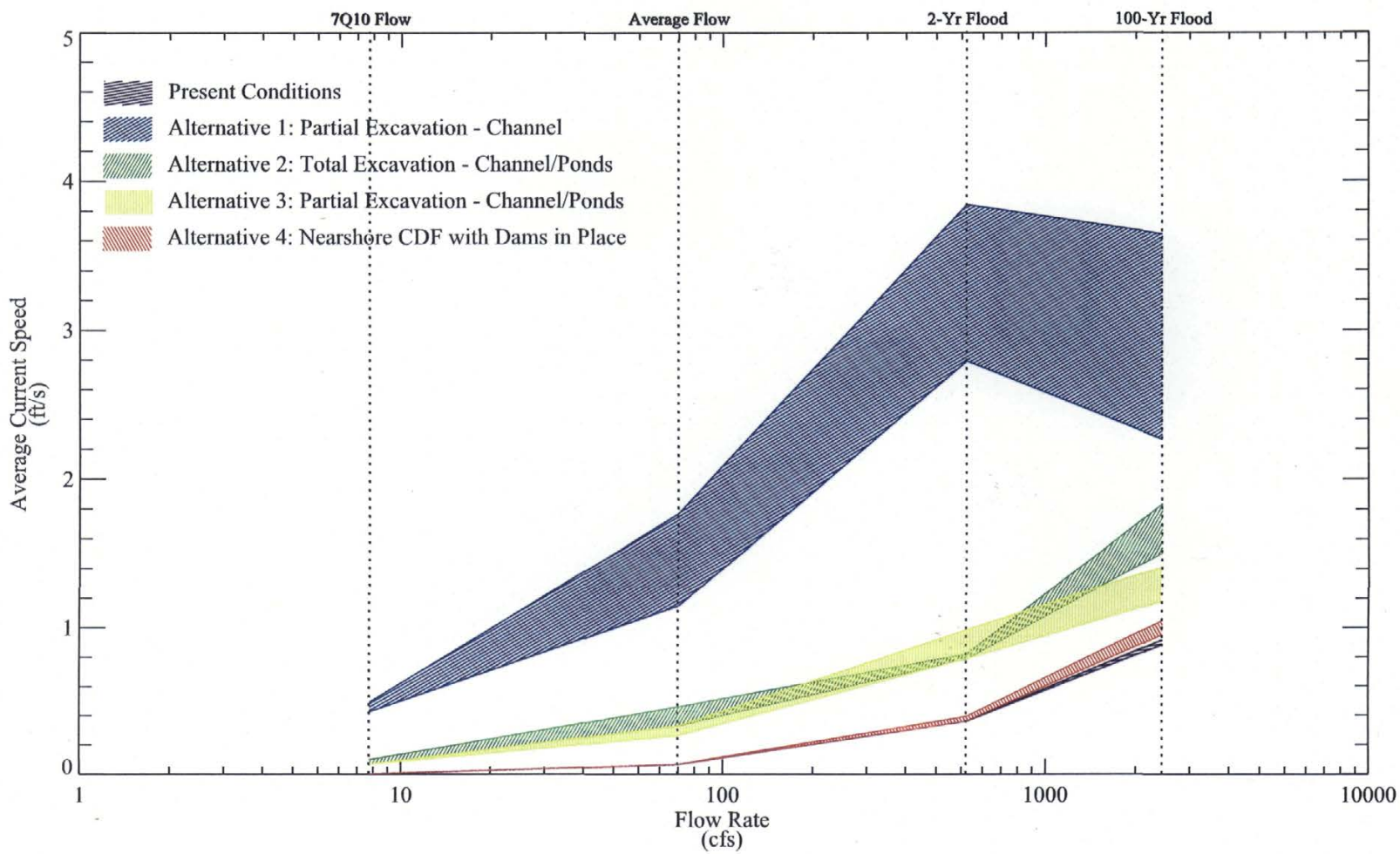


Figure 4-48. Average current speed in Allendale Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
Mon Nov 05 08:48:00 2007

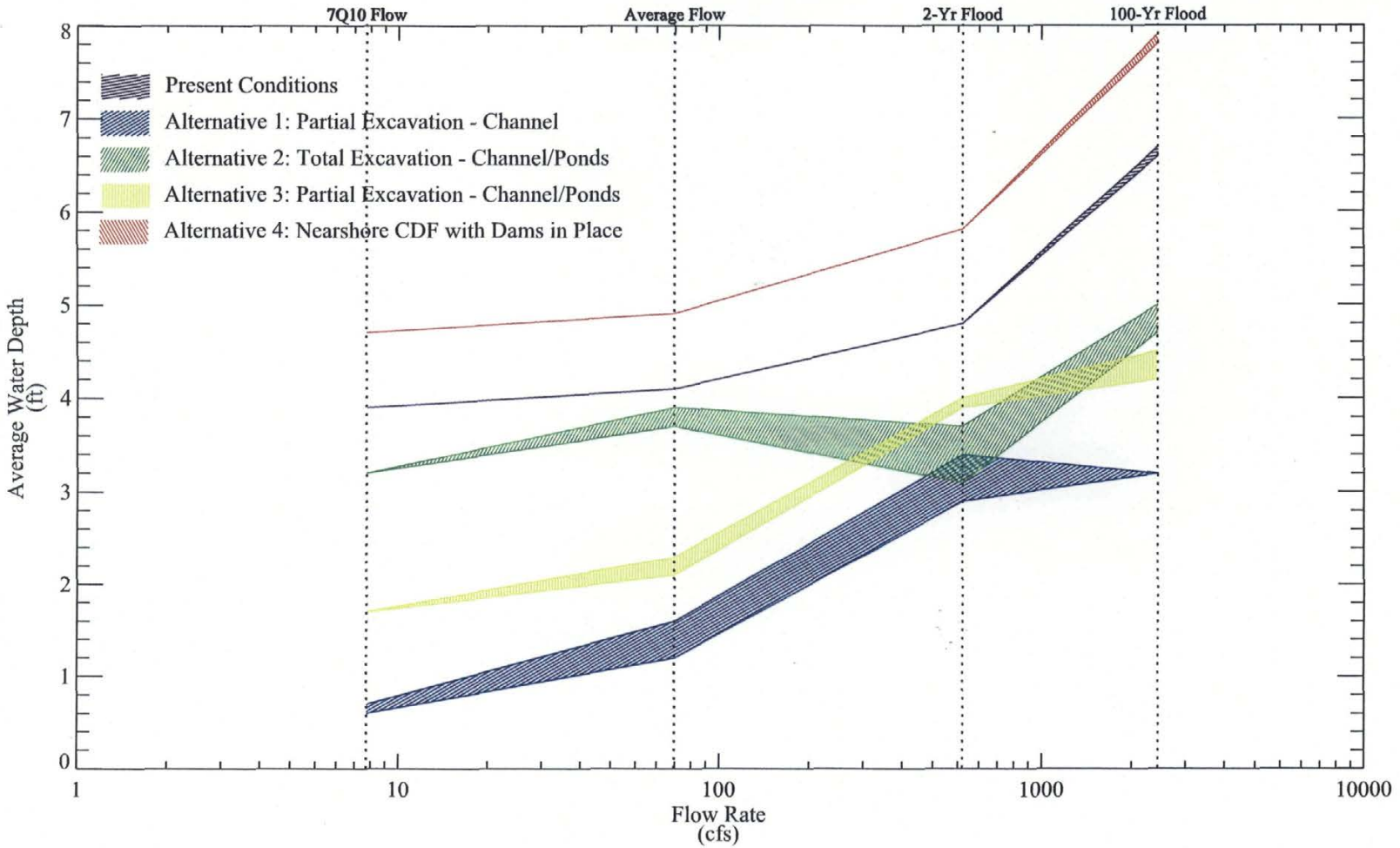


Figure 4-49. Average water depth in Allendale Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
Mon Nov 05 08:48:38 2007

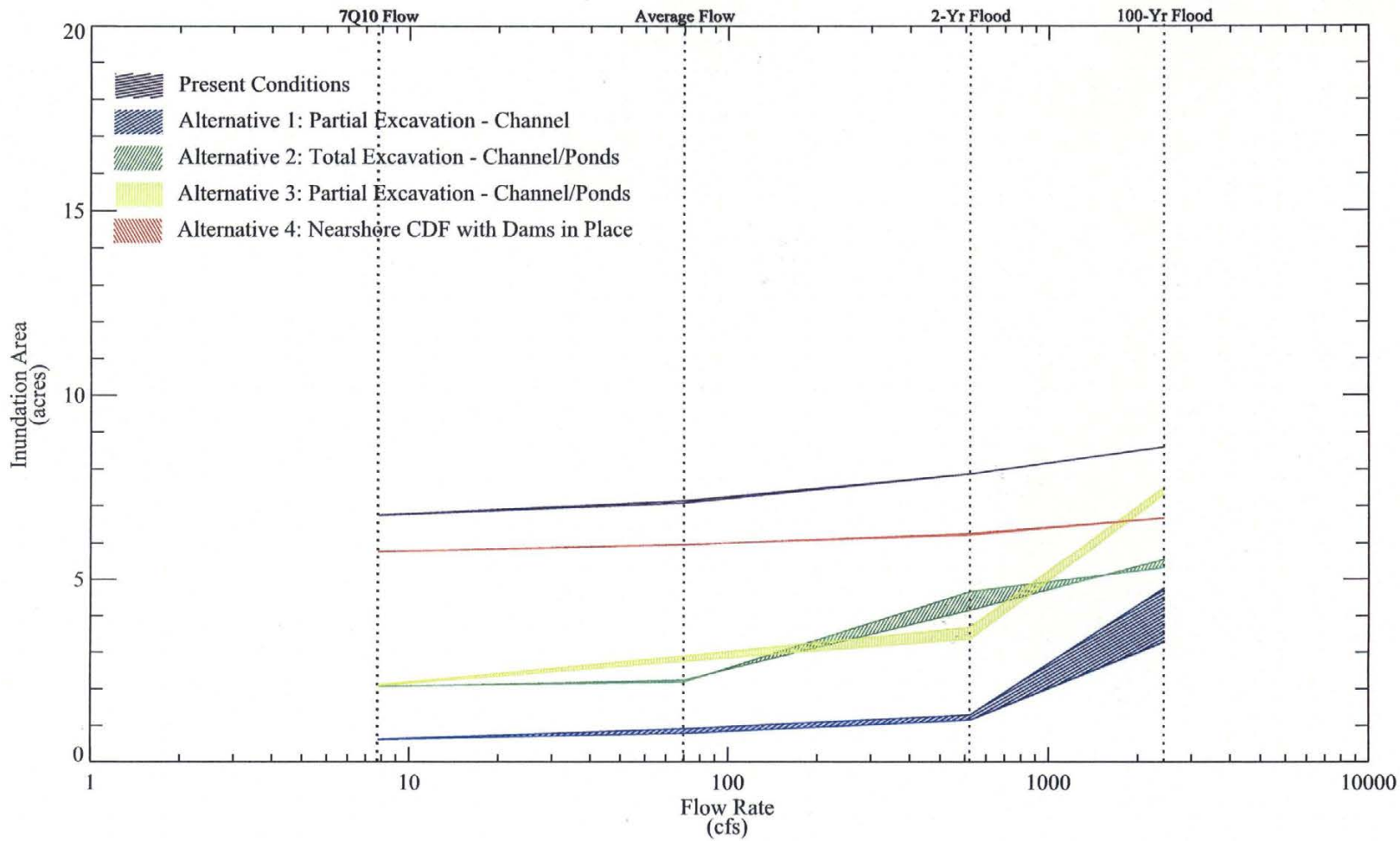


Figure 4-50. Total inundation area in Allendale Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\amy\D_DRIVE\EMHccn\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
Mon Nov 05 08:44:25 2007

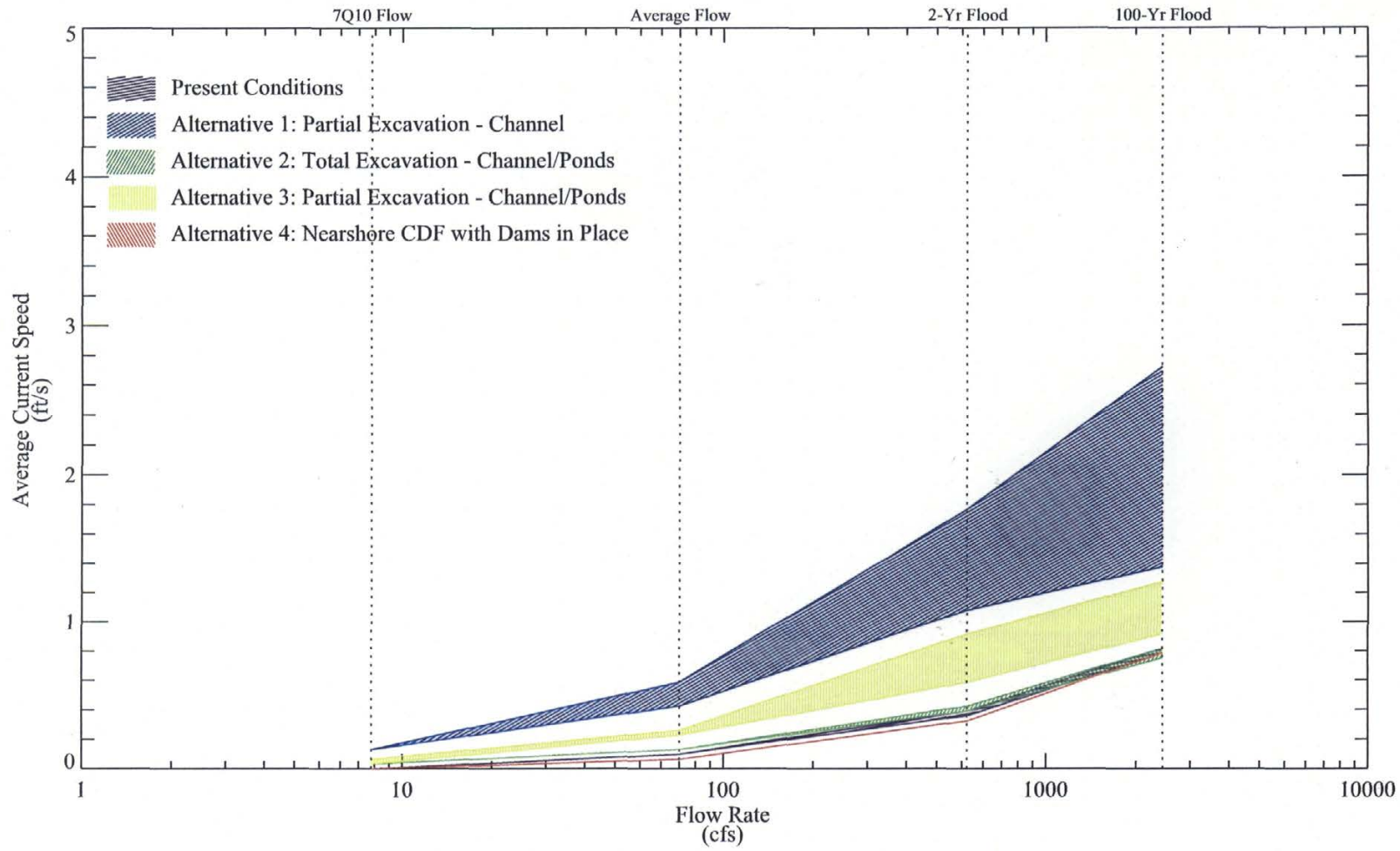


Figure 4-51. Average current speed in Lyman Mill Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
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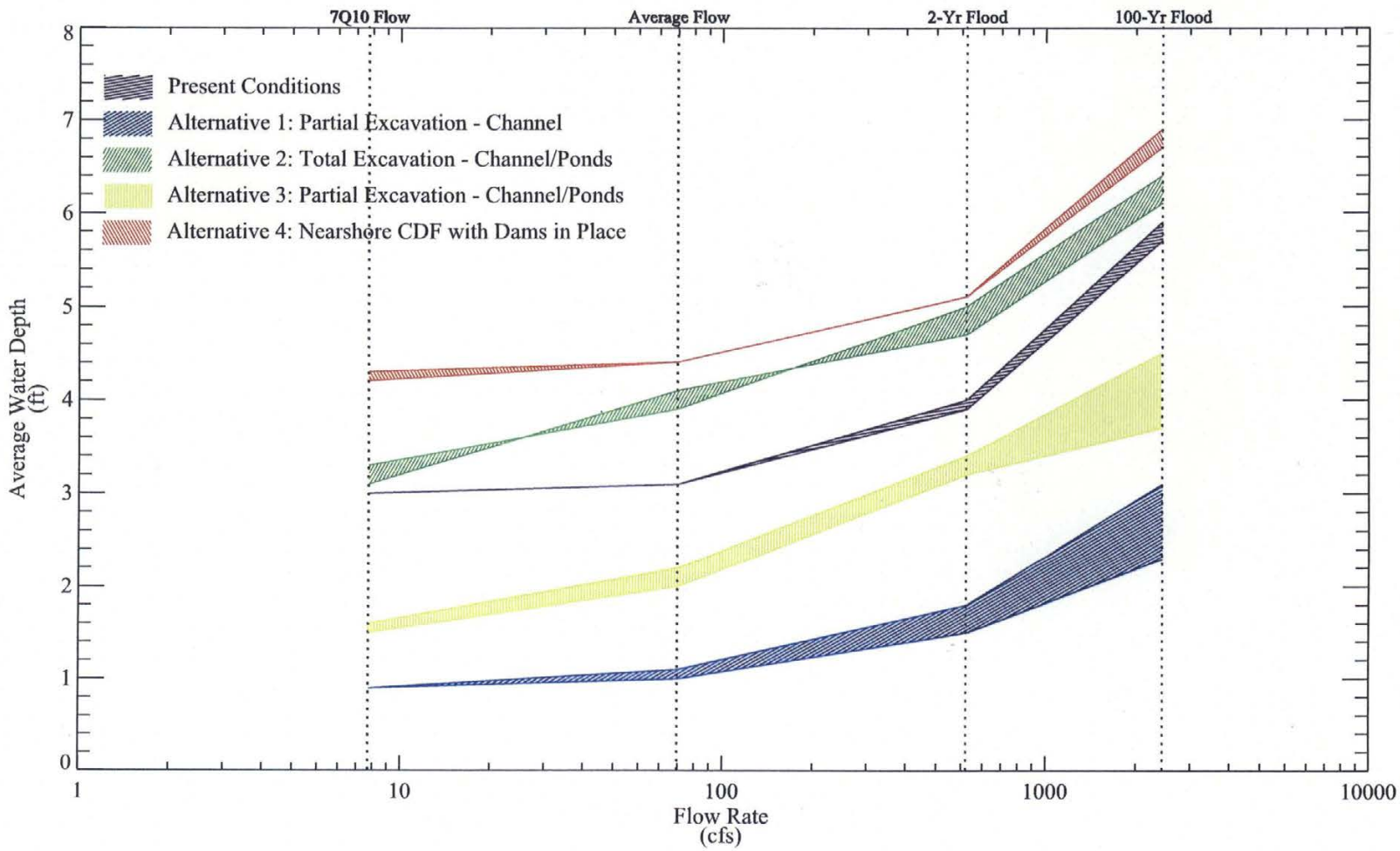

Figure 4-52. Average water depth in Lyman Mill Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
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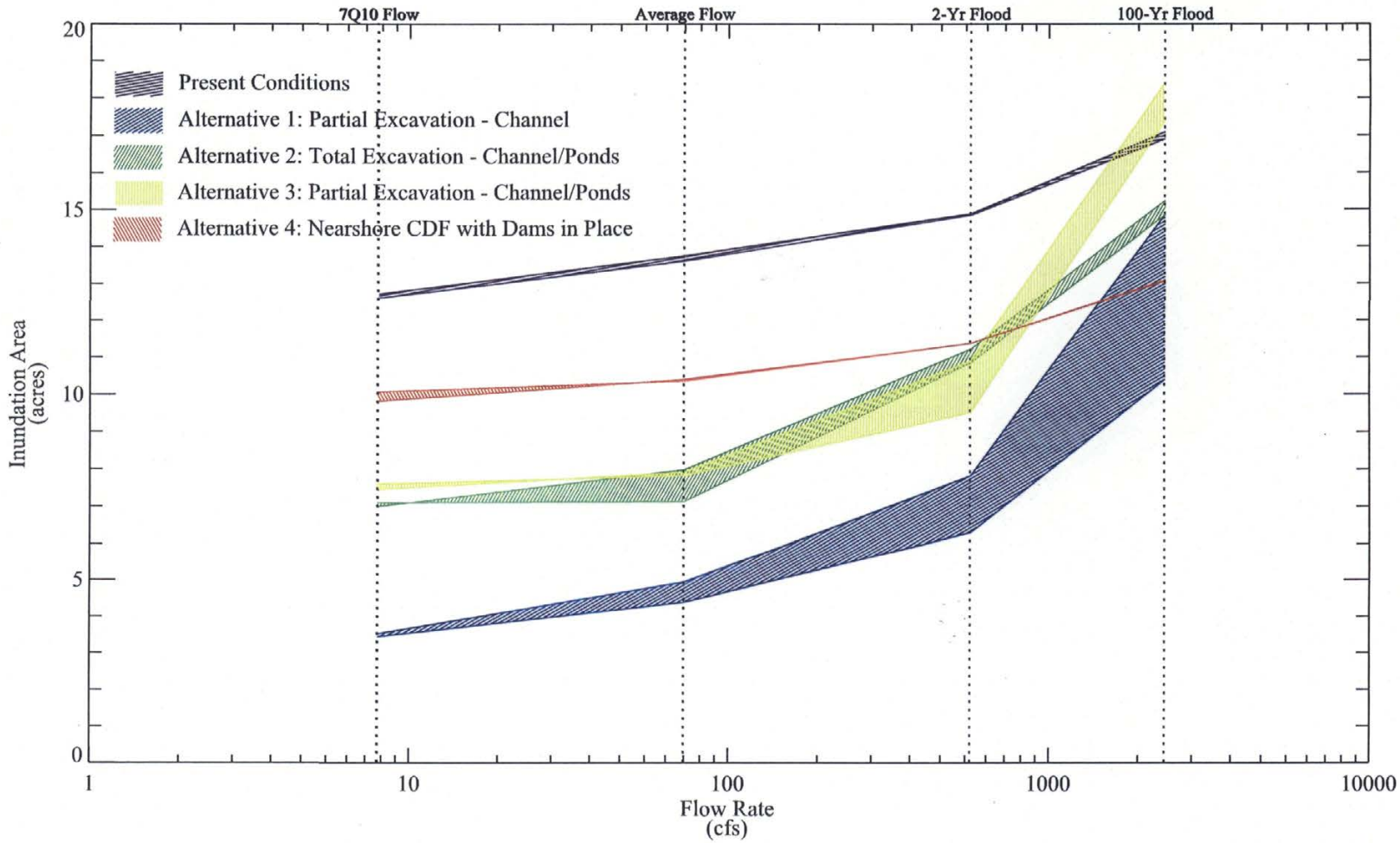

Figure 4-53. Total inundation area in Lyman Mill Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
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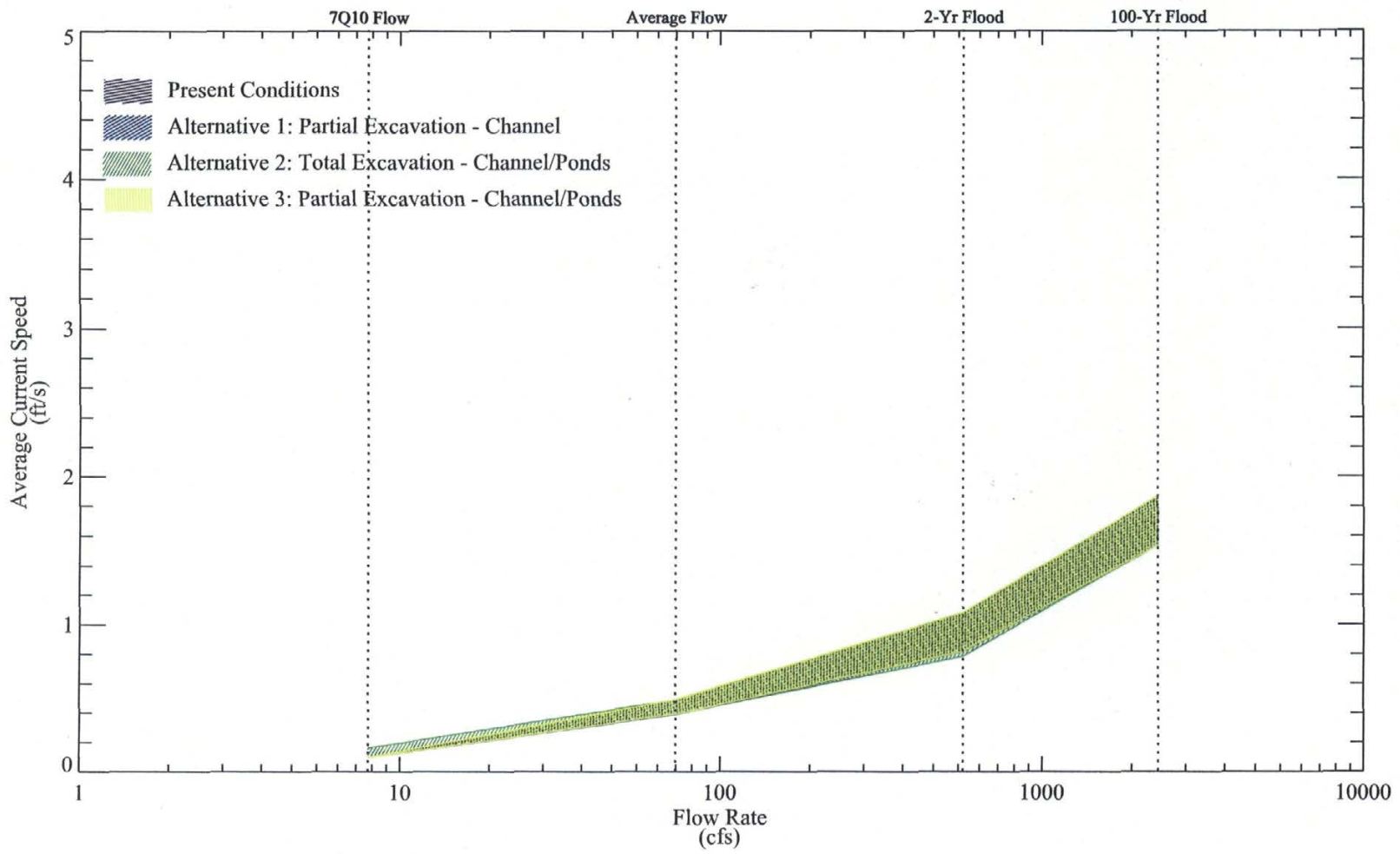

Figure 4-54. Average current speed in Manton Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
Mon Nov 05 08:48:00 2007

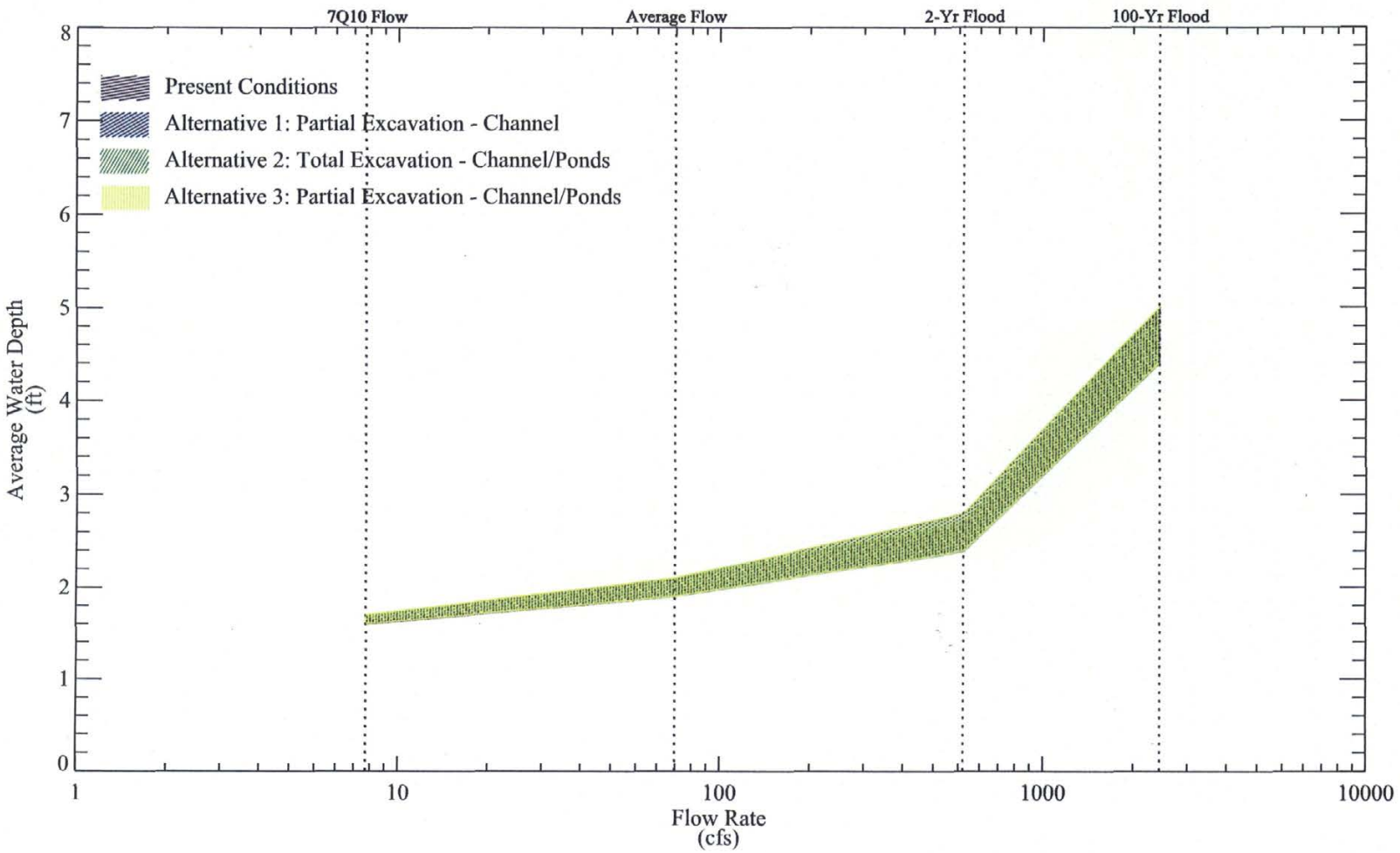

Figure 4-55. Average water depth in Manton Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\Amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
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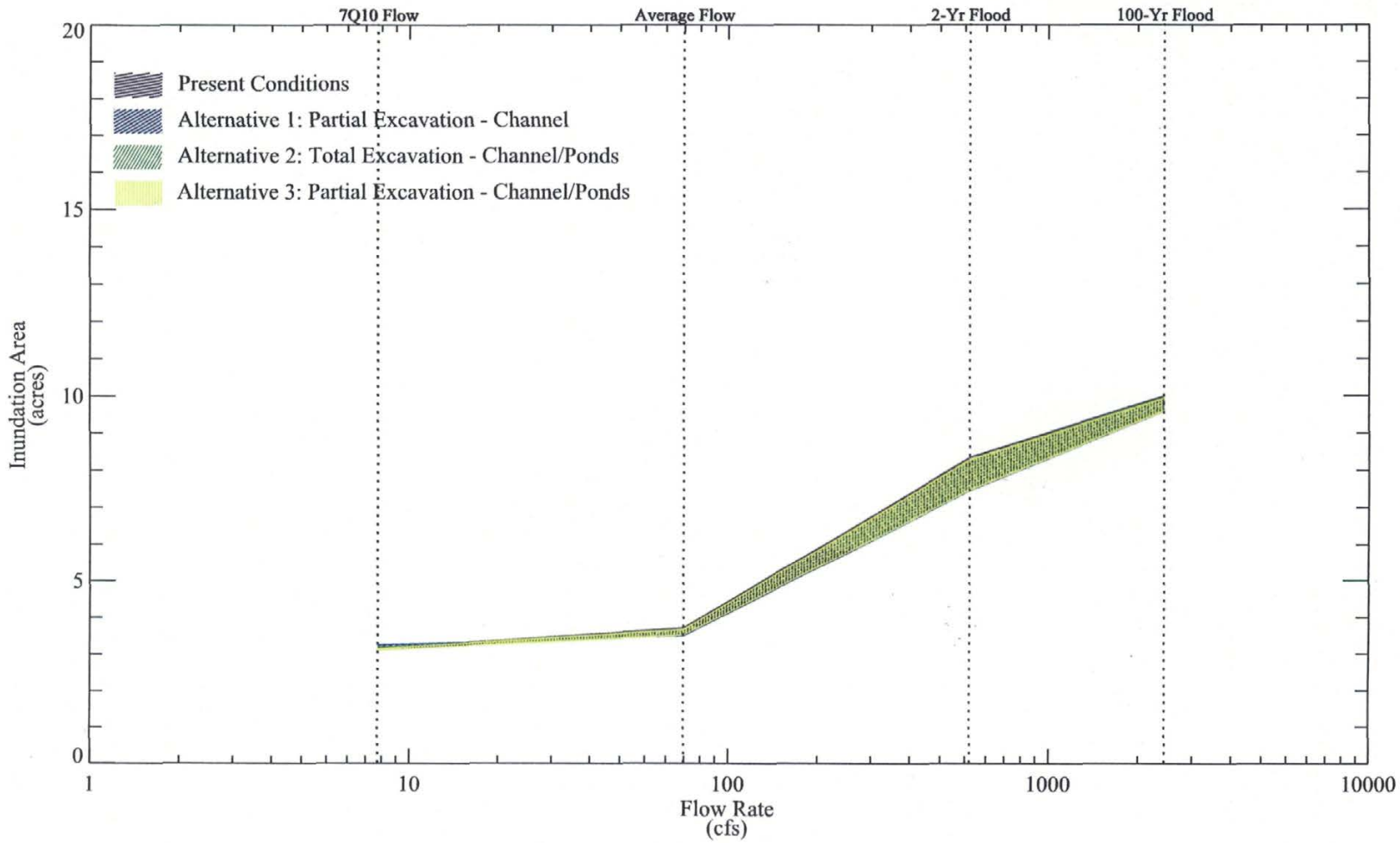

Figure 4-56. Total inundation area in Manton Pond as a function of flow rate.
Range of values represent results from upper- and lower-bound effective bed roughness simulations.

AYC - \\amy\D_DRIVE\EMHcen\Analysis\Model_outputs\flow_vs_para_analysis\plot_flow_vs_para_compare_11052007.pro
Mon Nov 05 08:44:25 2007