Summary of Findings and Recommendations
High Knob Brook Culverts – Starksboro, Vermont

Prepared by Milone & MacBroom, Inc.
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A culvert that matches the size and shape of the stream it carries that has ample space for water, sediment, debris, and ice to pass naturally (i.e., a geomorphically compatible structure) lasts longer than a culvert that is not appropriately matched to the channel. Geomorphically compatible culverts allow stable instream habitat to be maintained, and more readily pass both fish and wildlife.

Geomorphic assessment of High Knob Brook sponsored by Lewis Creek Association and performed by Milone & MacBroom in summer 2008 suggests that several culverts may have reduced geomorphic compatibility and are likely limiting movement of fish and wildlife (Figure 1). On-going watershed management planning performed by South Mountain Research & Consulting indicates that improvements at the four Town-owned culverts are a high priority for replacement in the future.

A field trip was conducted on High Knob Brook on October 13, 2009 with Starksboro Road Foreman Tom Estey, Starksboro Selectboard member Peter Marsh, Starksboro Planning Commission Chair Dennis Casey, Starksboro Conservation Commission member and LCA board member Louis duPont, and Milone & MacBroom Water Resource Engineer Roy Schiff. Town-owned structures on Brown Hill Road (1), Stokes Hill Road (1), and Big Hollow Road (2) were visited to discuss assessment findings and view the current condition of the structures. Normal flow conditions were present during the field trip. The four Town-owned culverts appeared to be structurally sound and effectively conveying flow.

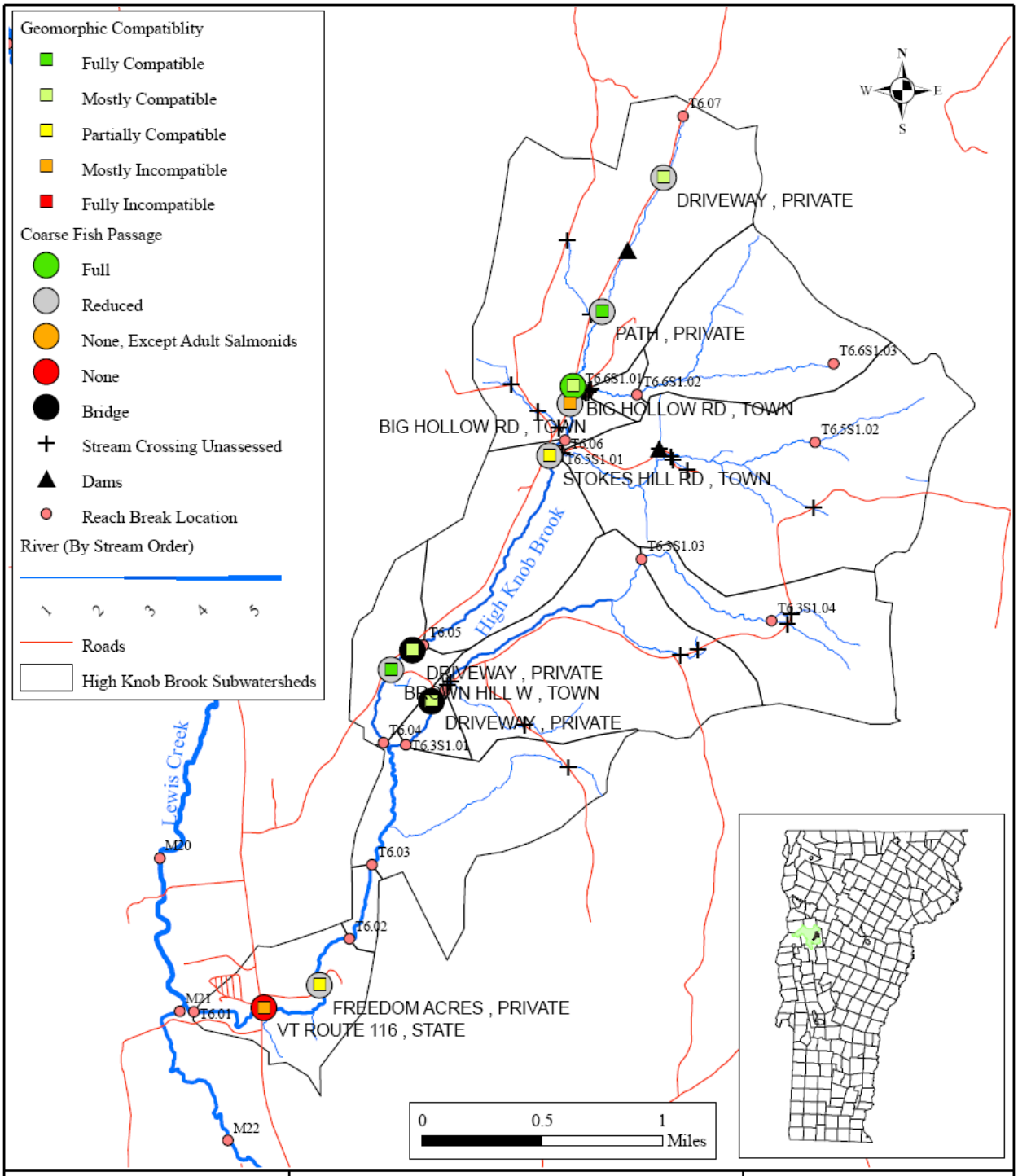
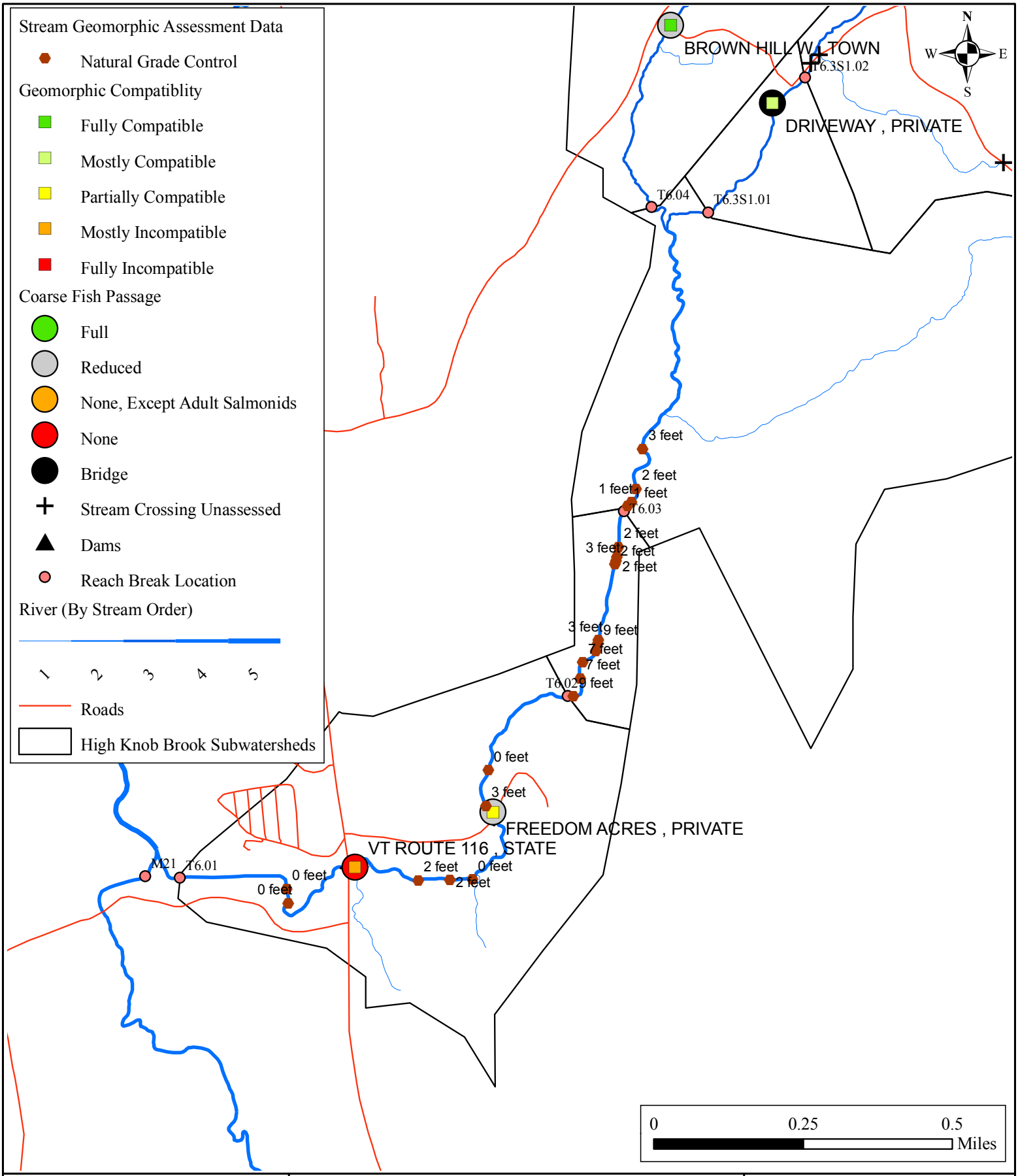


FIGURE 1: HIGH KNOB BROOK BRIDGE AND CULVERT ASSESSMENT DATA



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Evaluation of High Knob Brook Culverts

LOCATION: Starksboro, Vermont

MMI#: 3452-08

MXD: HighKnobCulvertsGradeContols

SOURCE: www.vcgi.org / MMI

Crossing Structures and Natural Grade Controls

DATE: 04/12/2010

SCALE: see scale bar

SHEET: Figure 2

The most obvious problem with the structures was their undersized width relative to the bankfull channel (Table 1). The bankfull channel typically carries the 1- to 2-year flood. Each of the Town-owned culverts has a width that is approximately 50% of the bankfull channel width. Current state (e.g., Bates and Kirn, 2009) and federal (e.g., Baker and Votapka, 1990; FHWA, 2007) design guidelines recommend structure widths that are equal to (100%) or larger than (120%) the bankfull channel width.

TABLE 1: SUMMARY OF CULVERT ASSESSMENT DATA (TOWN STRUCTURES)

Road	Geomorphic Compatibility	Fish Passage	Primary Defficiencies	Future Corrective Actions
Brown Hill Road, off of Big Hollow Road	Fully compatible	Reduced	Structure width undersized (50% bankful width)	Enlarge structure to 100% bankful stream width
Stokes Hill Road, off of Big Hollow Rd	Partially compatible	Reduced	Structure width undersized (50% bankful width). Mild bend approaching structure. Failing upstream bank armor.	Enlarge structure to 100% bankful stream width, straighten approach, and stabilize upstream bank.
Big Hollow Road, just downstream of dugway road	Mostly incompatible	Reduced	Structure width undersized (50% bankful width). Sharp bend approaching structure. Failing upstream bank armor.	Enlarge structure to 100% bankful stream width, straighten approach, and stabilize upstream bank.
Big Hollow Road, corner of Dugway Lane and Big Hollow Road	Mostly compatible	Full	Structure width undersized (45% bankful width)	Enlarge structure to 100% bankful stream width

High Knob Brook bends approaching several of the Town-owned culverts. Bends slow the flow of water reducing conveyance and increasing the risk of blockage with sediment and woody debris. Bends can also create turbulent flood flows that lead to upstream bank erosion that can cause washouts. Design standards recommend straight approach and exits for culverts.

Future replacements of the four Town culverts on High Knob Brook should include increasing the structure width to a minimum of 100% of the bankfull channel width (11 to 17 feet) and establishing a straight alignment. These improvements will reduce the risks of washouts and increase the amount of time that fish and wildlife can pass through the structures. Future structures should be embedded in the stream channel a minimum of 6 inches in order to maintain a natural stream bottom and ample flow depth for fish passage. The additional height to embed the culvert should be factored into future designs and installations.

The VT 116 culvert owned by the state is the most problematic structure on High Knob Brook in terms of not matching the geomorphic stream type and limiting movement of fish and wildlife. This structure has a very high priority for replacement (Lewis Creek Watershed Management Plan) as it separates instream habitat on Lewis Creek and High Knob Brook during most flow conditions (Table 2). A replacement structure should be wider, have a straight alignment, eliminate the outlet drop, and be embedded to maintain sediment along the structure bottom. In addition, eroding banks should be stabilized. Discussions are under way with VTrans and State Representatives about the feasibility of improving this structure in the near term or future.

TABLE 2: SUMMARY OF CULVERT ASSESSMENT DATA (STATE STRUCTURE)

Road	Geomorphic Compatibility	Fish Passage	Primary Defficiencies	Future Corrective Actions
VT 116	Mostly incompatible	None	Structure width undersized (24% bankful width). Sharp bend approaching structure. Upstream bank erosion. Free fall at culvert outlet	Enlarge structure to 100% bankful stream width, straighten approach, stabilize upstream bank, embed outlet.

Most of the private structures crossing High Knob Brook are undersized and limit movement of fish and wildlife (Table 3). Although not the responsibility of the Town to maintain or replace, similar design recommendations as above (i.e., 100% bankfull channel width, straight, and embedded) are recommended to promote structures that last a long time, improve public safety at crossings, and create more natural stable channels. Geomorphic compatibility and fish and wildlife passage are most effective if implemented at the watershed scale, and thus we encourage the Town to adopt a long-term strategy to improve structures as they wash out or deteriorate over time.

TABLE 3: SUMMARY OF CULVERT ASSESSMENT DATA (PRIVATE STRUCTURES)

Road	Geomorphic Compatibility	Fish Passage	Primary Deficiencies	Future Corrective Actions
Freedom Acres	Partially compatible	Reduced	Structure width undersized (44% bankfull width). Slope too low and leading to excessive upstream sediment deposition. Located at break in slope. Some bank erosion.	Enlarge structure to 100% bankfull stream width, match structure and channel slope. Relocate as possible to move away from break in valley sope.
1127 Big Hollow Road driveway bridge	Mostly compatible	N/A	Structure width undersized (63% bankfull width).	Enlarge structure to 100% bankfull stream width.
Path behind home and barn off of Big Hollow Road	Fully compatible	Reduced	Structure width undersized (39% bankfull width).	Enlarge structure to 100% bankfull stream width.
Driveway 3382 Big Hollow Road	Mostly compatible	Reduced	Structure width undersized (16% bankfull width).	Upstream of driveway dam. Structure forming upstream of wetland. Enlarge structure to 100% bankfull stream width.
Private Drive Bridge off of Brown Hill Road	Mostly compatible	N/A	None	None

Many culverts, especially the smaller ones in headwater locations, are not assessed. More structures tend to be on small streams (order < 3) than on larger streams (order > 3) (Table 4, Figure 1). These small structures that often are most numerous in a watershed warrant assessment to understand both how upstream geomorphic processes and headwater habitat are being impacted. Upstream locations are critical for channel formation, sediment and woody debris supply, water quality establishment, and fish spawning. Failures of small headwater culverts can lead to downstream flood and erosion damages as pulses of water, sediment, and debris are sent downstream during floods. Again, the more the structures match the geomorphic stream type the longer they will last and the better instream habitat will be. It is recommended that an assessment of headwater culverts be performed to target problem structures for replacement.

TABLE 4: SUMMARY OF CULVERTS BY STREAM ORDER

Stream Order	Number of Structures
4	2
3	10
2	12
1	16
TOTAL	**40**

Stream order (Strahler, 1952) is one indicator of the size of a stream. Headwater streams are 1st order, when two 1st order streams meet they form a 2nd order stream, when two 2nd order streams meet they form a 3rd order stream, and so on. If two streams of different orders join, they retain the higher order downstream of the confluence.

With the high cost of culvert replacement it is often not practical to replace a structure unless it fails or is nearing the end of its engineering life span. Retrofit measures may be possible to improve fish passage at an existing structure. Retrofit measures include raising the downstream water surface elevation during fish passage flows, installing baffles in the structure, and roughening the structure and stream channel (Bates and Kirn, 2009). State and federal grants are available to fund feasibility studies, design, materials, and construction for culvert retrofit and replacement.

REFERENCES

Baker, C. and F. Votapka, 1990. Fish Passage through Culverts. FHWA-FL-90-006. Prepared by the USDA Forest Service for the USDOT Federal Highway Administration, Washington, DC.

Bates, K. and R. Kirn, 2009. Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont. Prepared by Kozmo, Inc. with Vermont Department of Fish and Wildlife, Agency of Natural Resources, Waterbury, VT.

FHWA, 2007. Draft Design of Fish Passage at Bridges and Culverts (HEC-26). Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Strahler, A. N., 1952. Hypsometric (Area-Altitude) Analysis of Erosional Topography. Bulletin of the Geological Society of America 63:1117-1142.