TENNESSEE GAS PIPELINE COMPANY, L.L.C.

HYDROLOGIC & HYDRAULIC CALCULATIONS

FOR

WATERBODIES CROSSED BY

CONNECTICUT PIPELINE EXPANSION PROJECT

CONNECTICUT LOOP

Submitted by:

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INTRODUCTION

The attached hydrologic and hydraulic calculations were performed for all field surveyed waterbodies crossed by the Connecticut Pipeline Extension (Project) Hartford County Connecticut. The Project would consist of installing approximately 13.3 miles of pipeline looping: 1.4 Miles of 36-inch Pipeline Loop in Albany County, New York ("NY Loop") 3.8 Miles of 36-inch Pipeline Loop in Berkshire County, Massachusetts ("MA Loop"). 8.15 Miles of 24-inch Pipeline Loop in Hampden County, Massachusetts and Hartford County, Connecticut ("CT Loop)".

The primary objective of the attached calculations was to size temporary flume pipes at each waterbody crossing to convey, at a minimum, normal flow safely through the construction workspace. A typical waterbody crossing will consist of sand bag cofferdams placed at the upstream and downstream limits of the construction workspace, a smooth interior and exterior class I steel pipe (same as being used to construct the pipeline), and a temporary bridge equipment crossing. The equipment crossing type (i.e. bridge crossing or flume pipes backfilled with clean stone) will be based on a combination of the width of the waterbody and the flow present while constructing the crossing. Depending on the size of the waterbody, the majority of the waterbodies will be crossed within 24 – 48 hours.

DESIGN CRITERIA AND METHODOLOGY

The following design criteria and methodology was used to perform the calculations:

1. **Hydrologic Methodology**
   Hydrologic calculations were performed using a combination of the Rational Method, the NRCS (SCS) Peak Flow Method, USGS StreamStats, and USGS StreamStats with HydroCAD v.10.0. The specific method used to calculate the design flows for each waterbody varied based on parameters such as the watershed size, waterbody slope, basin elevation, and ground cover type (e.g. pasture, forest, urban).

   a. **Rational Method: Q=CIA**
   - Q = flow (cubic feet per second - cfs)
     C = runoff coefficient
     A = drainage area (acres – ac)
     I = rainfall intensity (inches per hour – in/hr)
   - This method was used for drainage areas up to 200 acres in size
   - NOAA Technical Memorandum NWS Hydro-35 was used to determine “I” in Connecticut County of Hartford.
   - The following Runoff Coefficients were used:

Cover Type	Slope Range (%)	Hydrologic Soil Group*	Runoff Coefficient
Pasture	0% - 6%	D	0.20
Forest	0% – 20 %	D	0.32
Forest	> 20 %	D	0.38

*Hydrologic Soil Group D was used for a conservative approach.

   - Time of Concentrations were calculated using the following:
     - **Sheet Flow:**
       Manning’s Kinematic Solution
       Maximum (max) sheet flow length of 150ft

- **Shallow Concentrated Flow**
  The travel time for shallow concentrated flow was calculated by dividing the travel path length by a calculated velocity. The velocity for specific cover types were calculated using Manning's equation.

- **Channel Flow**
  As upstream channel morphology is not constant, the travel time for Channel flow was calculated by assuming a channel velocity of 15.00 ft/s and applying it to the shallow concentrated flow formula.

b. NRCS (SCS) Peak Flow Method:

The computer program HydroCAD, Version 10.0, was used to determine the peak flow discharges for the watershed. HydroCAD is a program which employs TR-20 methodology which uses the unit-hydrograph runoff procedure. As with TR-20, the HydroCAD peak flow discharges are dependent upon parameters such as watershed size, the curve number for a given watershed, time of concentration, available flood storage, rainfall storm type, rainfall intensity and storm duration.

- The following curve numbers were used:

Cover Type	Hydrologic Soil Group*	Curve Number (CN)
Woods	D	83
Pasture	D	89
Urban	D	98

*Hydrologic Soil Group D was used for poor soil conditions, and a conservative approach.

- Depths were used in conjunction with a 24-hour storm duration.
- The Time of Concentration was calculated using the same methodology used for the Rational Method.

c. USGS StreamStats for Connecticut

StreamStats is a Web-based tool developed by the USGS and Environmental Systems Research Institute, Inc. (ESRI). This map-based Web application was designed to make it easy for users to obtain stream flow statistics, drainage-basin characteristics, and other information for userselected sites. StreamStats utilizes previously published information from gaging stations and previously gathered basin characteristics to develop stream flow statistics utilizing the appropriate regression equations to compute the stream flows. The StreamStats flows will only be utilized where the drainage area falls within the acceptable ranges for Mean/Base-Flow or for Peak Flow. Drainage areas outside the acceptable ranges generate flows that are based on extrapolations with unknown errors.

d. Design Frequency:

The design frequency utilized in the design varied based on the U.S. Weather Bureau Technical Paper 40. A 2-year design, a 5-year, and a 10-year maximum design storm were utilized for all watershed classifications. Average daily flow calculations were also performed for larger watersheds where the 2- and 5-year storms resulted in flows that cannot be completely passed within the designed pipes and it is unlikely that a 2-year or 5-year storm event will occur during the crossing.

2. Hydraulic Calculations

The temporary flume pipes were sized using the Federal Highway Administration (FHWA) HY-8 computer program. HY-8 is a culvert analysis program that automates the design methods described in HDS No. 5, “Hydraulic Design of Highway Culverts”.

It should be noted that all flume pipes analyzed with HY-8 called for the pipe crossing materials to be High Density Polyethylene (HDPE) pipes. This is only for the modeling of the pipe crossings due to material limitations within the program. As previously noted, all flume pipes that are to cross the waterbodies for the construction of the pipeline will be temporary and consist of Class I smooth interior and exterior steel pipe, a material selection that is not available in HY8, therefore HDPE was selected in the model because its Manning’s roughness coefficient is the same as the steel pipe.

For the larger storm events, those with stream flows generated by Streamstats, the contractor will be responsible for determining the appropriate stream crossing method due to the flow conditions at the time of construction at the location specified. The contractor will provide crossing details as part of the construction submittal process. These methodologies may include, but are not limited to, temporary diversion channels, temporary bridges, temporary fords, and temporary pipe crossings. All temporary crossings will conform to all local, state and federal regulations.

3. Summary and Recommendations

For the waterbody crossings including for Stony Brook and Muddy Brook along the proposed pipeline, the Streamstats generated flows for even the 2 year storm event are significant and will require the Contractor to design water conveyance and handling facilities based upon his specific means, methods and equipment for each crossing and coordinate the construction activities with periods of lower or average daily flows to facilitate safe passage and conveyance of flows during installation of the proposed pipeline crossing under the waterbody. See Hydraulic Calculations above for further information and Table 1.0 on the following pages for summary of flows at each crossing.

Table 1.0
Waterbodies Associated with the Connecticut Expansion Project – Connecticut Loop

Waterbody ID	Waterbody Name (where applicable)[a]	Approximate Milepost[b]	Latitude	Longitude	Town / County	Quadrangle	Water Crossing Length[d] (feet)	Crossing Method[hi]	Pipe Size (inches)	Pipe Length (feet)	Number of Pipes	Design Flow 2 Year Storm (CFS)	Pipe Inv. In	Pipe In. Out	Top of Coffer Dam Elevation	Comment
Waterbodies Associated with Pipeline Facilities																
SCT-19	Muddy Brook	2.98	41.9956	-72.65913	Suffield / Hartford	Windsor Locks	55	II		Streamstats		417				Site Specific Design required. Contractor to provide engineer with means and methods for approval
SCT-37	Stony Brook	5.56	41.9638	-72.68815	Suffield / Hartford	Windsor Locks	29	II		Streamstats		419				Site Specific Design required. Contractor to provide engineer with means and methods for approval
SCT-55	Degrayes Brook	8.07	41.9353	-72.94044	East Granby / Hartford	Windsor Locks	23	N/A								Stream is located near Airport Park Road and will be bored in conjunction with the road crossing. No impact to stream.
Waterbodies Associated With Access Roads																
	N/A															

N/A = Not Applicable

a: Unnamed tributary: waterbody is not mapped as a tributary on available GIS datalayers; tributary name was identified based on review of USGS topographical mapping.

b: MP = milepost; MP provided for access roads indicate the point at which the access road meets the proposed pipeline.

c: P = perennial; I = intermittent

d: 0 = waterbody is not crossed but is in workspace. For minor waterbodies less than 3 feet in width delineated in the survey area and shown as a single line feature on the Project alignment sheets, an assumed 3 foot width has been used for this analysis.

e: MI = Minor (<10 feet); I = Intermediate (10 - 100 feet); MA = Major (>100 feet).

f: State Water Quality Designation:

A Known or presumed to meet water quality criteria that support potential drinking water supply, fish and wildlife habitat, recreational use, agricultural and industrial supply, and other legitimate uses, including navigation. Surface waters which are not specifically classified shall be considered Class A or Class AA (CTDEEP 2013). None of the waterbodies crossed by the Project are listed in DEEP fisheries management activities.

Water quality classifications were identified by AECOM through a desktop review of available GIS datalayers. Waterbodies that were not assigned a water quality classification on the GIS datalayer were given the same classification of the waterbody it drains into.

g: Construction Windows for fisheries are based on CTDEEP state fishery classification restrictions. Potential timing restrictions reflect dates during which construction activities may occur and are subject to CTDEEP review. Tennessee will adhere to the CTDEEP fishery timing restriction during construction; state fishery timing restrictions are designed by the state to protect the resources during the time period that the state has determined is critical.

h: I = Conventional, Wet Crossing Method; II = Dry Crossing Method including Flume and Dam and Pump. Intermittent streams containing discernable flow at the time of construction will be crossed using a dry crossing method.

i: Tennessee will implement a dry-crossing construction technique on all waterbody crossings with discernable flow at the time of construction unless an alternative crossing method is approved by CTDEEP and the USACE.