Addendum 4: Borehole Drilling and Construction Overview

Potential Casing and Cementing Requirements for Closed Loop Geothermal Boreholes

The New York State Department of Environmental Conservation (DEC) anticipates implementing specific borehole drilling and construction requirements for closed loop geothermal boreholes greater than 500 feet in depth. The potential requirements outlined below are intended to provide a general overview. Actual borehole construction requirements will be determined on a site- or project-specific basis.

1) Casing and Cementing - Specifications and Procedures

   a) Casing Requirements

      i) The installation of surface casing may be required to ensure groundwater protection and safeguard public health, safety, and the environment. The purpose of surface casing is to prevent fluid and gas migration in the subsurface and help ensure borehole integrity (see Figure 1). Surface casing will be required if there is an expectation or potential that hydrocarbons (e.g., natural gas, oil), brine, or other hazards will be encountered in the subsurface.

      ii) Casing specifications must conform to American Petroleum Institute (API) "5 CT Specification for Casing and Tubing" or ASTM international (ASTM) in "A500/A500M" standards, unless otherwise approved by DEC.

      iii) Hydrocarbons, brine, and other polluting fluids and gases encountered during drilling operations must be controlled, handled, and disposed of in a manner that will ensure public safety and prevent the pollution of land, air, groundwater, and surface waters. If there is an expectation or potential that hydrocarbons will be encountered, the qualified contractor must utilize equipment necessary to ensure proper borehole control and the use of a blowout preventor (BOP) or a DEC-approved flow diversion equipment may be required.

   b) Cementing Specifications and Procedures

      i) Surface casing must be cemented in place, unless otherwise approved by DEC (see Figure 1). Cement is the primary means by which the outer casing annulus is isolated or sealed to prevent the migration of fluids and gas in the subsurface.

      ii) Cement baskets or other approved devices must be installed above any voids or lost circulation zones.

      iii) Prior to conducting cementing operations, the borehole must be conditioned to stop the flow of any gas and fluid and the qualified contractor must make an attempt to establish circulation to promote adequate cement displacement and ensure a high-quality bond between cement and the borehole.

      iv) The pump and plug method must be used to cement casing unless an alternative method is approved by DEC. The amount of cement will be determined on a borehole-

specific basis and a minimum of 25% excess cement must be used, with appropriate lost circulation materials, unless additional excesses are specified by DEC.

v) The cement must achieve a minimum compressive strength of 500 psi prior to recommencing drilling operations. If cement returns are not observed at the surface, the qualified contractor may be required to run a log to determine the top of the cement.

2) Tubing and Grout - Specifications and Procedures

a) Tubing or Loop Specifications

i) Tubing and associated components must be approved by DEC.

(1) Acceptable tubing and components shall be high-density polyethylene (HDPE) and cross-linked polyethylene (PEX) pipe and tubing.

(2) Any proposed alternatives to HDPE or PEX tubing and components must be reviewed and approved by DEC prior to use.

(3) Alternative materials must:

(a) be corrosion, chemical, temperature, and impact resistant;
(b) be flexible;
(c) meet hydrostatic pressure necessary for the geothermal system; and
(d) meet or exceed any other system requirements.

b) Grout Specifications

i) Closed loop boreholes must be grouted to prevent migration of surface water and potential surface contaminants downhole into aquifers intersected by the borehole and prevent cross contamination between one aquifer and another.

ii) Grouting material must be bentonite- or cement-based unless an alternative is approved by DEC. Grouting material must have a composition suitable for the anticipated downhole conditions, have a known heat transfer capacity, seal the borehole in a manner that protects groundwater aquifers and prevents the migration of fluids and gases between subsurface formations, and remain flexible throughout the life of the borehole.

iii) The maximum allowable hydraulic conductivity or permeability must conform to the threshold established in ANSI/CSA/IGSHPA C448.3-16.

iv) Grouting material must be able to keep its thermal, hydrological, and mechanical properties over the lifetime of the borehole with less than 10% degradation of such properties over a 100-year period.

c) Grouting Procedures

i) Prior to conducting grouting operations, the borehole must be conditioned to stop the flow of any gas and fluid and the qualified contractor must circulate water or drilling fluids in the annular space to clear any potential obstructions.

ii) The amount of grout will be determined on a borehole-specific basis based on the depth and diameter of the borehole, but in all instances must fill the borehole from total

depth to surface and a minimum of 25% excess grout must be available for use on site to account for the loss of grout to subsurface formations or voids (see Figure 1).

iii) Grout must be placed in the borehole by pressure pumping through a tremie pipe unless an alternative method is approved by DEC.

iv) During grouting operations, the qualified contractor must verify the grout mixture properties, including density and water content, to ensure the grout is mixed in accordance with manufacturer specifications.

v) Tremie grouting of the entire borehole must be completed to the maximum extent possible in a single continuous operation upward from the bottom of the borehole. The closed loop borehole must be completely grouted from total depth to the surface to prevent fluid and gas migration and ensure groundwater protection (see Figure 1).

vi) Grout levels must be monitored for a minimum of 48-hours after initial placement. If settling occurs, the borehole must be topped with grout from the top of grout to surface.

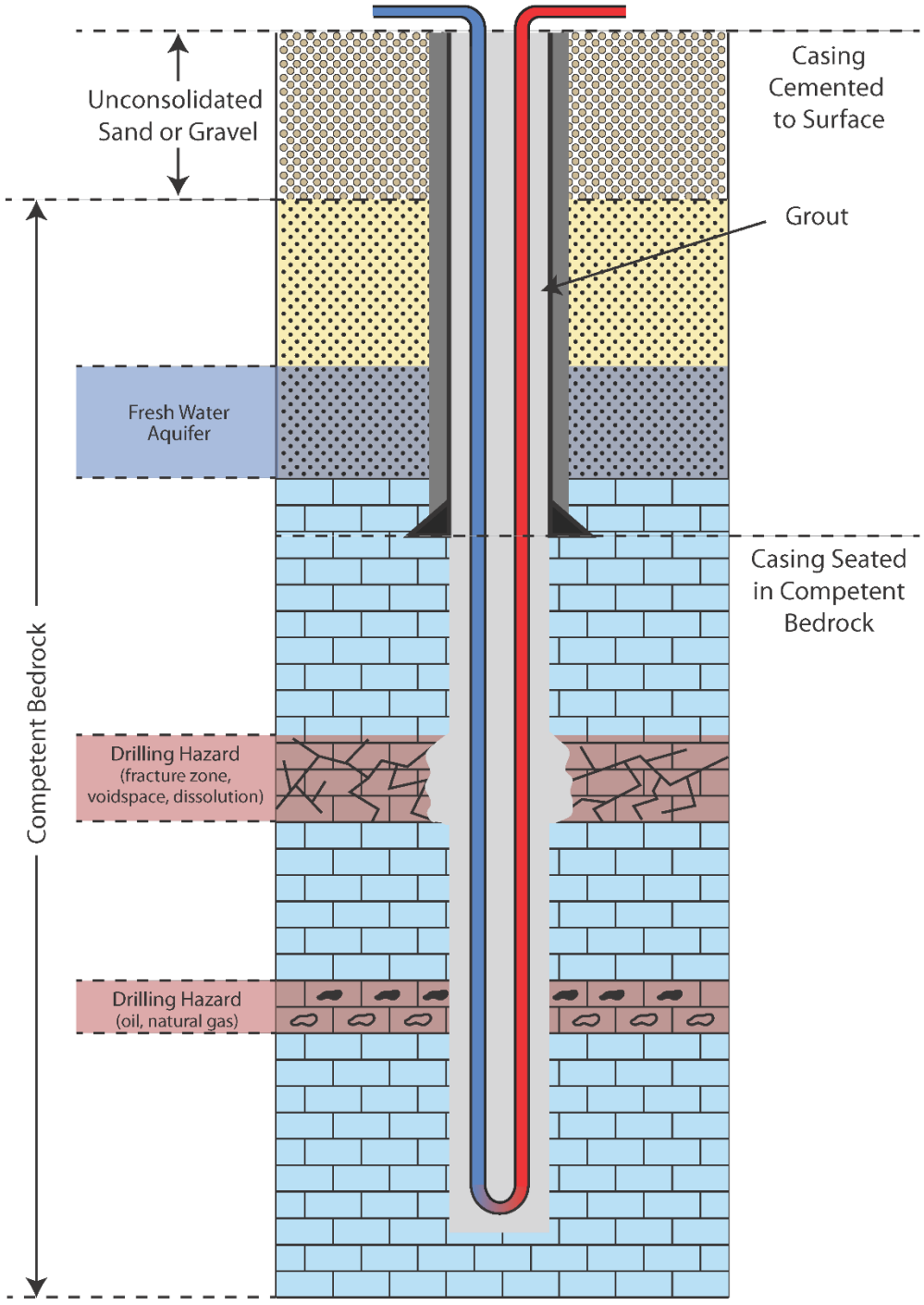

Figure 1 – Cross-section of a closed Loop geothermal borehole