2.0 GULLY BACKGROUND

A gully is a landform created by running water, eroding sharply into soil, typically located on a hillside. Gullies can resemble large ditches or even small valleys, but with a much smaller drainage area. As water collects in surface depressions and begins to flow fast enough to detach and carry away soil particles, the power to erode increases, and a gully can grow in size (US Department of Agriculture, Natural Resources Conservation Service 2010). Without intervention, gullies will actively erode upstream until they are stabilized by natural conditions, such as bedrock outcrops, or intentional restoration projects (**Figure 1**).

Gullies develop all over the world, most commonly when land-use practices or surface hydrology change, but they may also be part of a natural landscape where steep slopes and susceptible soils are present. The following highlights how these four primary factors affect gully development:

1. **Land cover and use:** Changes in land cover and usage can alter surface stormwater runoff patterns, creating concentrated flows where none existed before. The quantity of stormwater runoff increases when land use is converted from rural landscapes to urban because the hardened urban landscape reduces the ability of water to infiltrate into the soil. Livestock grazing can also damage the protective vegetative cover, which can destabilize the underlying soils and allow gullies to form (Geyik 1986).
2. **Surface hydrology:** Changes in the surface hydrology often correlate with changes in land use. As impervious area is added to a watershed, the amount of stormwater runoff is also increased. Installation of underground drain tile in agriculture and stormwater conveyance systems in urban areas also affect the surface hydrology by preventing water from infiltrating back into the soil and underlying aquifers. Changes in rainfall patterns and climate change can also affect the development of gullies through frequent and intense rainfall events, which can saturate susceptible soils and make the landscape ripe for accelerated gully development (Geyik 1986). As noted in the LMRWD's 2020 *Fens Sustainability Gaps Analysis for Carver, Dakota, and Scott Counties*, intense and heavy precipitation events that cause localized flooding, streambank erosion, and increased sediment loading downstream are occurring more frequently in the District and are expected to increase in the future based on climate projections.
3. **Steep slopes:** Areas with steep and vertical slopes are more prone to gully development than flat or shallow-sloped watersheds. Increase in slope angle in turn increases the gravitational force acting on a soil mass, a driving force in slope movement processes. The angle of repose for different sediment types defines the maximum angle a hill slope can achieve without hillside failure. Slopes above the angle of repose are prone to slope movement and erosion, promoting

gully formation. In addition, steep slopes allow surface water to concentrate into channels and flow downhill with more rapid velocities, increasing the erosive power and potentially destabilizing the hillside (Jennings 2016). As shown in the District's Steep Slopes Overlay District, this area contains very steep, highly erosive areas.

4. **Susceptible soils:** Certain soil types, such as fine-grained cohesive sediments (e.g., silts) or coarse-grained non-cohesive sediments (e.g., sands), are more prone to hill-slope failure. Noncohesive soils that are not bound together by finer-grained materials are easily eroded by forces such as gravity and surface water flow, and have lower angles of repose. Fine-grained cohesive sediments are prone to swelling when saturated. This swelling can cause rotation failure in the sediment mass, resulting in downslope movement of the sediment (Jennings 2016).

2.2 Gully Development Causes

While the above represents the primary causes in the formation of gullies, many other factors can contribute to the development of new or exacerbation of existing gullies. The following are indicators of potential causes of gully development:

- **Channel obstruction:** Channel obstructions can deflect flow and cause turbulent water to carve and erode at the channel, eventually creating a scour.
- **Unstable drainage feature:** Existing outfall pipes discharging onto the land surface can down-cut and incise a downstream channel, forming a head cut and eventually a defined gully channel. Hanging pipes that lack an apron to dissipate energy from the water are especially problematic in worsening erosion.
- **Channel incision:** Water flow, whether from spring discharge or stormwater, can down-cut along a flow path or pre-established channel. Incised flow paths, if left unchecked, can erode away at the land surface and contribute to gully formation and increased instability within a channel.
- **Groundwater springs or seeps:** The intersection of the water table with the land surface in a gully channel can create a steady source of baseflow which is a consistent erosive force. Additionally, groundwater upwelling in the surrounding area of a gully signals saturated soil conditions. Pore-water within the soil media decreases the resisting forces of a hillslope, contributing to mass wasting and gully formation (Jennings 2016).
- **Trails:** Trails, including walking, biking, and game trails, along the head cut and banks of a channel can lead to erosion and bank failure due to the compaction of soil and the potential destruction to vegetation from use of the trail. This can reduce the amount of vegetation stabilizing an area and provide an opportunity for water to destabilize bare soil.

- **Dense canopy:** By limiting sunlight exposure reaching the ground, a dense canopy often prevents understory plants from establishing on the banks or within the channel of a gully. Given that this type of dense, low-lying vegetation can stabilize the soil, a dense canopy may contribute to the likelihood of exposed soil and mass wasting.

2.3 Unstable Drainage Features

Gully formation is largely driven by the presence of water and changes to the natural hydrology; it is important to identify locations where groundwater or surface water are entering susceptible areas. The condition of these locations can inform how the system responds to the addition of water and could be indicative of future gully development. Typical characteristics of an unstable drainage feature or pipe outfall include:

- **Hanging pipes:** If the slope or embankment has eroded away from the pipe, leaving the pipe hanging from the bank, this is a clear sign of an unstable pipe outfall and potential gully.
- **Erosion:** If there are signs of bank or channel erosion at the pipe outfall, this is a clear sign of an unstable outfall that may progress into the development of a gully.
- **Scour:** If there is the presence of scour downstream of a pipe outfall, this is a clear sign of an unstable pipe outfall which is eroding away at the land surface and may develop into a distinct gully channel.
- **Riprap:** Riprap or other energy-dissipating features at an outfall indicate high erosive power is present; depending on the condition of these features, the outfall itself may be unstable.

Figure 1. Example of gully erosion progression between 1992 (top photo) and 2006 (bottom photo) (San Francisco Estuary Institute 2006).