United States
Environmental Protection
Agency

Henry's Knob Site Case Study

Revitalizing Mine Tailings in Clover, South Carolina

This case study highlights ecological revitalization outcomes at the Henry's Knob Superfund Alternative Approach[1] site in York County, South Carolina. Working with state and federal regulatory agencies, ABB Inc., (ABB), a proactive responsible party is using an adaptive management approach to address environmental impacts from decades of kyanite mining.

From 1947 to 1965, Commercialores, Inc. of New York (Commercialores) operated and mined the 185-acre Henry Knob area for kyanite. Open pit mining in a large pit quarry took place on top of the knob or mountain. Mined ore-grade rock was ground up followed by a floatation process to liberate the kyanite from the other minerals in the ore. Leftover ground-up waste rock and spoils, called tailings, were dewatered in ponds and piles, in accordance with acceptable practices, were left on site. In 1970, Combustion Engineering, Inc. (CE) merged with Commercialores, and in 1990, ABB acquired CE, and the environmental legacy associated with the mine property.

During site investigations, EPA and ABB identified an opportunity to mitigate on-going erosion of the mine tailings and minimize the potential for further impacts to groundwater and nearby streams from acid mine drainage. With approval from EPA and the South Carolina Department of Health and

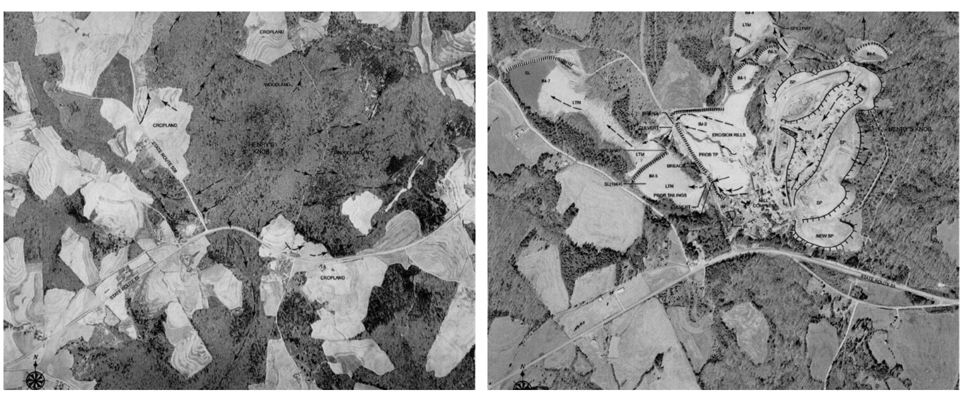


Figure 1. Henry's Knob in 1941 (left) prior to mining and Henry's Knob in 1981 after mining (right). (*Source*: ABB Inc.)

1.The Superfund Alternative Approach uses the same investigation and cleanup process and standards that are used for sites listed on the National Priorities List (NPL). https://www.epa.gov/enforcement/superfund-alternative-approach

This case study is part of a series focused on ecological revitalization as part of contaminated site remediation and reuse; these case studies are being compiled by the U.S. Environmental Protection Agency (EPA) Technology Innovation and Field Services Division (TIFSD). The purpose of these case studies is to provide site managers with ecological reuse information, including principles for implementation, recommendations based on personal experiences, a specific point of contact and a network of sites with an ecological reuse component.

Topics Highlighted in this Case Study:

- Ecological Revitalization
- Greener Cleanups
- Mine Tailing Revegetation
- Native Plants Plantings
- Wildlife and Pollinator Habitat

Ecological Revitalization

Ecological revitalization is the process of returning land from a contaminated state to one that supports functioning and sustainable habitat.

Environmental Control (SCDHEC), ABB took an adaptive management approach to addressing these issues. This approach consists of the implementation of media-specific remedies in steps and evaluated for effectiveness.[2] As the first step in the adaptive management remedy approach, ABB is in the process of revegetating former mine tailings areas. The vegetation reduces the erosion of the tailing and reduces infiltration of water through the tailings thus reducing the generation of acid mine drainage as a source of impact to groundwater and nearby streams. Ongoing monitoring will evaluate the effectiveness and other benefits associated with the revegetation. Based on this evaluation implementation of a groundwater remedy may or may not be necessary. The site's final cleanup plan, which may incorporate the revegetation work completed, is under development and will take at least two years to complete. Figure 1 shows Henry's Knob before and after mining activities occurred.

Figure 2. Aerial photo of Henry's Knob in 2012 prior to revegetation (*Source*: ABB Inc.)

Background

The 185-acre site is located near the intersection of Highway 55 and Henry's Knob Road in Clover, York County, South Carolina. The site is located in a highly mineralized zone of the Piedmont Province. The Piedmont is characterized by rolling hills, complex geology and clay-like moderately fertile soils. The site includes a 7-acre former open pit mine, tailings pond, spoils piles and remnant mine operations. In the 1950s and 1960s, Commercialores mined the site for kyanite (see text box). During the mining process, waste rock and spoils were dewatered in ponds and piles.

Acid mine drainage and acid rock drainage impacted surface areas, surface water and groundwater. Acid mine drainage is a common environmental impact at former mining sites. It occurs where iron sulfide minerals (principally pyrite) are present and exposed to water and oxygen (e.g., the atmosphere). Weathering of iron sulfides results in acidic water (low pH) and high concentrations of dissolved iron and sulfate. Acidic waters promote the weathering of other rock forming minerals. Similar acid weathering conditions occur in the absence of mining operations from the oxidation of pyrite from in-place bedrock. This occurs most notably at and between the water table and land surface.

Mining Waste

During mining efforts, waste is generated in the form of overburden, waste rock, tailings, slags and chat. These materials are generally acidic and have high concentrations of metals. Their properties make them difficult to vegetate, allowing erosion from natural processes such as wind and surface water runoff (for example, rainfall).

Kyanite

A mineral used in producing refractory, ceramic and porcelain materials that withstands high temperatures.

2. The Berm/Dam Stability and Surface Water Controls Time Critical Removal Action Memo outlines the site management approach. This approach is also discussed in the Response to USEPA Comments on the Regional and Telescoped Groundwater Modeling Report.

Manganese and cobalt are the primary constituents that have been identified in groundwater.[3]

To facilitate the cleanup of the site, ABB recently purchased the site's main tailings areas from a private owner. Another property owner owns Henry's Knob, the top of the mountain.

Initial Response

The site is being cleaned up using the Superfund Alternative Approach (EPA ID: SCN000407376). This EPA approach uses the same investigation and cleanup process and standards used for sites on the Superfund program's National Priorities List (NPL). The approach is an alternative to listing a site on the NPL; it is not an alternative to Superfund or the Superfund process.

In 2004, EPA and ABB signed an Administrative Order on Consent for the site's remedial investigation and feasibility study (RI/FS). The RI/FS identifies the extent and location of contamination and cleanup options. EPA and SCDHEC provide oversight for ABB's activities. Figure 2 shows an aerial photo of the Site in 2012.

EPA identified 10 Areas of Concern (AOCs) at the site as well as several off-site residences where contamination (primarily manganese and/or cobalt) was found in wells. The 10 AOCs are shown in Figure 3 and listed below:

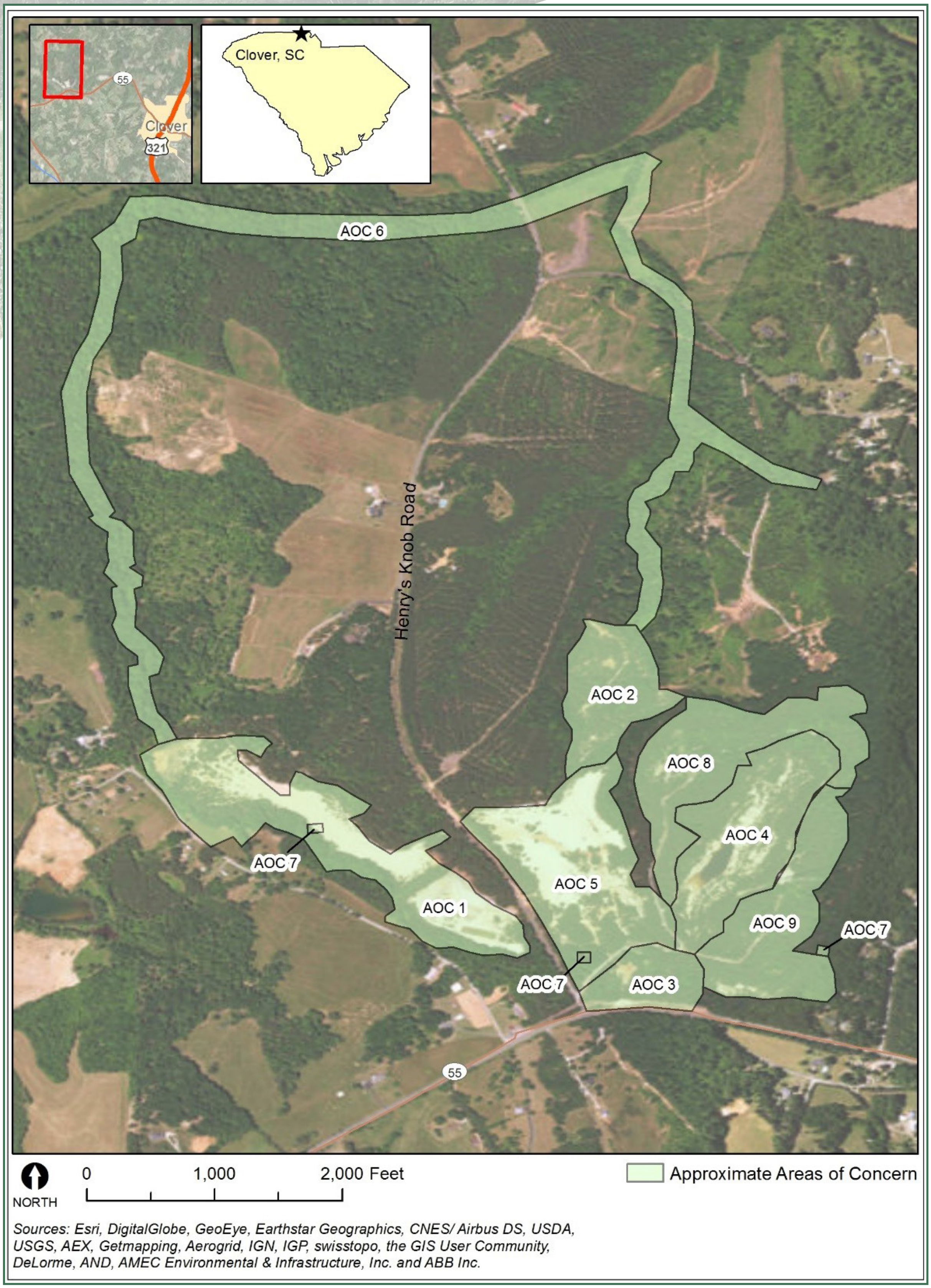
AOC 1 - West Tailing Pond (industrial waste lagoon on western side of Henry's Knob Road)
AOC 2 - North Tailings Pond (infiltration beds/settling ponds on eastern side of Henry's Knob Road)
AOC 3 - Former Mill Operation Buildings (eastern side of Henry's Knob Road)
AOC 4 - Mine Pit Pond
AOC 5 - East Tailings Pond (also known as Mine Tailings Area)
AOC 6 - South Fork of Crowder's Creek
AOC 7 - Dumping Area (eastern side of Henry's Knob Road)
AOC 8 - Northern Waste Rock Area
AOC 9 - Southern Waste Rock Area
AOC 10 - Site Groundwater

Timeline

- **<u>1950s and 1960s:</u> Mining operations active on site conducted by Commercialores.**
- **<u>1965:</u> Mining operations cease.**
- **<u>1970</u>: Combustion Engineering, Inc. (CE) merged with Commercialores.**
- **<u>1990:</u> ABB acquires CE**
- **<u>2004:</u> ABB signs agreement with EPA, agrees to investigate the site and identify cleanup options. RI/FS begins.**
- **<u>2013:</u> Pilot study takes place for revegetation of mine tailings.**
- **<u>2015:</u> Revegetation of Former Mill Operation Buildings AOC 3.**
- **<u>2016:</u> Revegetation of West Tailing Pond AOC 1.**
- **<u>2017:</u> Revegetation of North Tailings Pond AOC 2.**
- **<u>2017-2018:</u> Revegetation of East Tailings Pond AOC 5.**

3. Publicly available documents and data related to the site are located at: http://www.henrysknobenvironmentalforum.com/community

Figure 3: Henry's Knob Site Map



Initial Cleanup Efforts

Groundwater

Though the final groundwater remedy will be evaluated in a FS and documented in a Record of Decision, ABB and EPA began implementing a residential well treatment system in 2013 because some nearby residents were using groundwater. As of 2017, 15 residential well treatment systems are in place.

Adaptive Management Approach

An "adaptive management" approach is one wherein media-specific actions are implemented in steps within a structured plan and evaluated using performance metrics and success criteria. For the Henry Knob Site, remedial measures for stabilization of the impoundment dams, revegetation of the mine tailings, and control of stormwater water run on/off tailings (source control) are being implemented first and evaluated for improvements to downgradient surface and groundwater quality. Based on this evaluation implementation of a groundwater remedy may or may not be necessary. This step-wise, "adaptive management", approach is being used to design and implement technically appropriate, and cost-effective remedial actions.

Mine Tailings

Prior to completion of the RI/FS, ABB expressed interest in investigating innovative remedies for the site, including revegetating tailings areas. The tailings areas had been barren for years. Tailings had historically eroded onto Highway 55 during major storms and generated clouds of dust during windy periods. Vegetating these areas would improve their appearance and reduced erosion from wind and water. An evaluation will be conducted to determine if the initial measures result in improvements to downgradient surface and groundwater quality.

The mine tailings consist of pulverized rock (mostly silica sand), with an organic carbon content of 0% and a pH of 2-2.5 standard units. The site's human health risk assessment (2011) and ecological risk assessment (2011) found no unacceptable risks associated with exposure to the mine tailings. The goals of the revegetation effort were to:

1. Increase pH and organic carbon content of the shallow tailings to support the growth of vegetation.
2. Reduce the amount of water that infiltrates and percolates through the tailings.
3. Mitigate erosion of the tailings.
4. Mitigate the tailings as an acid mine drainage source to groundwater and surface water.

Figure 4. Differences in vegetation growth across the Ridge and Furrow test plot (left), the Standard Farming test plot (middle) and the vendor test plot (right) in April 2015. (*Source*: ABB Inc.)

Following approval from EPA and SCDHEC, ABB consulted with local farmers as well as companies and experts that specialize in revegetation for guidance and recommendations. The responsible party also led several studies to create a soil profile with a sufficient organic content and pH that could support plant growth across the site's mine tailing areas. These studies included three test plots within AOC 1 – the Ridge and Furrow test plot, the Standard Farming test plot, and a test plot that tested some specific vendor provided amendments. The Standard Farming test plot was based on basic farming practices that incorporates organic materials and fertilizer into the upper portion of the mine tailings to create a soil material suitable for the establishment and sustainable growth of vegetation. Figure 4 shows differences in growth among the three tests plots. They demonstrate that the addition of organic material increases vegetation success.

During the two-year study (from 2013 until 2015), substantial growth was observed on the Standard Farming test plot. The community welcomed the study findings. Some community members stopped in the field office to compliment the appearance of the vegetated tailing.

The responsible party then took a series of steps to prepare the site wide mine tailings for vegetation, including AOC's 1, 2, 3 and 5.

1. Clearing, grubbing and regrading the proposed vegetative cover areas.
2. Performing initial disking and tilling of tailings.
3. Applying and incorporating locally sourced mulch hay.
4. Applying and incorporating locally sourced sustainably manufactured organic compost.
5. Applying and incorporating hydrated lime and agricultural limestone.
6. Applying and incorporating a water retention agent.
7. Applying fertilizer.
8. Applying seed, wheat straw and tackifier.
9. Restoring all other disturbed areas.

Use of Local Materials

ABB used locally available materials when possible, including hay mulch, organic food and plant based compost, native seeds and rip-rap for stabilization of drainage channels and dam faces.

Native Pollinators

Native pollinators provide a significant amount of America's food supply, contribute to the economy and perform key roles in ecosystems. By helping to keep plant communities healthy and able to reproduce naturally, native pollinators assist plants in providing food and cover for wildlife, preventing erosion and keeping waterways clean.

Source: http://www.plants.usda.gov/pollinators/Native_Pollinators.pdf

Ecological Revitalization

The local cooperative extension, EPA and SCDHEC also helped the responsible party add a pollinator seed mix to the original pilot study mix that would both establish native plants and support pollinators for all plantings. Native vegetation and pollinator habitat are now well established on the tailings areas of the site; all of the tailing areas will be vegetated by the mid-2018. Figure 5 shows before and after photos of revegetation on AOC 3.

Both vegetative cover and pollinator seed mixes are shown in Table 1 and Table 2 respectively.

Figure 5. AOC 3 Vegetative Cover before construction (top row, 2014) and after construction (bottom row, 2016). (*Source*: ABB Inc.)

Table 1: Vegetative Cover Seed Mix

Scientific Name	Common Name
Cynodon dactylon	Common Bermuda grass
Trifolium spp.	Clovers (Native Mix)
Setaria italica	Foxtail Millet
Schizachyrium scoparium (andropogon scoparius)	Little Bluestem
Bromus catharticus	Rescuegrass
Panicum virgatum L. (virgatum)	Switchgrass
Lolium arundinaceum	Tall Fescue (KY31)
Eragrostis curvula	Weeping Lovegrass
Notes:*Source: ABB Inc.*	

Table 2: Pollinator Seed Mix

Scientific Name	Common Name
Bidens aristosa	Bidens
Chamaecrista fasciculata	Partridge Pea
Coreopsis lanceolata	Lance Leaf Tickseed
Gaillardia pulchella	Indian Blanket
Achillea millefolium	Common Yarrow
Rudbeckia hirta	Blackeyed Susan
Echinacea purpurea	Coneflower
Senna hebecarpa	Wild Senna
Helianthus angustifolius	Swamp Sunflower
Helianthus maximilianii	Maximilian's Sunflower
Verbena hastata	Blue Vervain
Asclepias tuberosa	Butterfly Weed
Monarda punctata	Spotted Beebalm
Symphyotrichum pilosum	Heather Aster
Notes:*Source: ABB Inc.*	

The native vegetation on site attracts a variety of pollinator species, including bees, wasps, butterflies and birds. Blue Vervain, for example, attracts a variety of bees and birds, including Cardinals, Swamp Sparrows, Field Sparrows, Eucerine Miner Bees, Halictid Bees and the Verbena Bee.[4]

By the spring of 2017, vegetative cover had been planted on three AOCs – the West Tailing Pond (AOC 1), North Tailings Pond (AOC 2), and the Former Mill Operation Buildings (AOC 3). Grasses in some places reached over five feet high, with a 1-foot-deep root ball. Red-tailed hawks, deer, turkey, frogs, birds and turkey vultures are regular visitors to the site. Figure 6 shows photos of wildlife on site. Currently, the vegetation will be maintained for aesthetic beauty and wildlife habitat. In the future, the vegetated areas could be a wildlife conservation area or community park. In all cases, the vegetation on the tailings areas will remain, helping to protect public health and the environment.

4.USDA plant fact sheet on Blue Vervain: https://plants.usda.gov/factsheet/pdf/fs_veha2.pdf.

Lessons Learned

1. **Consider revitalization options early in the cleanup process.**
   At the Henry's Knob site, these discussions enabled an adaptive management approach and allowed the revegetation effort to be conducted as part of a pilot under the RI/FS process. Revegetation of the mining tailings piles has mitigated the erosion of tailings and the infiltration of precipitation while also providing a more visually appealing landscape for the community and ecosystem services.

2. **Use local knowledge and materials when possible.**
   Discussions with local farmers identified sustainable farming methods and locally sourced materials that could be useful in revegetating the tailings. The test plot utilized locally sourced organic materials incorporated into the existing tailings and was the most successful at growing vegetation. This knowledge was invaluable in making the vegetation process successful.

3. **Consider new cleanup ideas as well as traditional options.**
   Most mine tailings are remediated by capping them in place, restricting access or consolidating them in a repository. At the Henry's Knob site, the responsible party identified a viable alternative – revegetation – and was willing to conduct pilot studies to determine its feasibility.

4. **Purchase available materials locally.**
   The responsible parties worked to find local materials to support the revegetation efforts. Sourcing materials locally resulted in money being spent locally on products produced in the nearby community and reduced costs and emissions associated with long-distance transportation. Working with local resources also helped identify and incorporate the native seed species into the vegetation efforts.

Additional Resources and References

EPA Site Profile Page:
www.epa.gov/superfund/henrys-knob

EPA Site Cleanup Summary:
https://cumulis.epa.gov/supercpad/siteProfiles/index.cfm?fuseaction=second.CleanupActs&id=0407376

Henry's Knob Environmental Investigation Resource:
http://www.henrysknobenvironmentalforum.com

Berm/Dam Stability and Surface Water Controls Time Critical Removal Action. Henry's Knob Former Mine Site. AMEC Foster Wheeler Environmental & Infrastructure, Inc. November 19, 2014.

Construction Completion Report. AOC 1 Vegetative Cover Study Test Plot. Henry's Knob Former Mine site. AMEC Environmental & Infrastructure, Inc. on behalf of ABB Inc. December 13, 2013.

Final Baseline Ecological Risk Assessment. Henry's Knob Former Mine site. York County, South Carolina. Prepared for ABB Inc. by MACTEC Engineering and Consulting, Inc. June 21, 2011.

Final Field Study Work Plan. Henry's Knob Former Mine site. AMEC Environmental & Infrastructure, Inc. on behalf of ABB Inc. May 24, 2013.

Final Human Health Risk Assessment. Henry's Knob Former Mine site. York County, South Carolina. Prepared for ABB Inc. by MACTEC Engineering and Consulting, Inc. June 21, 2011.

Response to USEPA Comments on the Regional and Telescoped Groundwater Modeling Report. Henry's Knob Former Mine Site.

Revised Vegetative Cover Pilot Study Work Plan. Henry's Knob Former Mine site. AMEC Environmental & Infrastructure, Inc. on behalf of ABB Inc. August 29, 2013.

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