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The river and the factory: Momentum and shifting dynamics between the Shenandoah River and Avtex Fibers, 1939-1989

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The River and the Factory: Momentum and Shifting Dynamics between the

Shenandoah River and Avtex Fibers, 1939-1989

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Dedication

To my nature-loving grandmother, Lois Howard Nicholls, who passed away during the final drafting of this project. All my love.

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Abstract

From 1940-1989, a huge rayon factory—at one time the largest in the world—operated on the banks of the South Fork of the Shenandoah River in the Town of Front Royal, Virginia. Three different companies owned the facility: American Viscose Corporation (AVC) built it in 1939 and ran it until 1963 when the Food Machinery Corporation (FMC Corp.) conglomerate purchased AVC. In 1976, an FMC executive bought the rayon plant in Front Royal in a leveraged buyout, renaming the facility Avtex Fibers, Inc.[1]

From early on, the plant had serious problems with waste materials—including many toxic substances—produced when manufacturing rayon. During nearly 50 years of operation, the plant's approach to toxic waste was to rely on insufficient and frequently outdated procedures and technologies, keeping a significant portion of the waste on-site. The South Fork of the Shenandoah, a crucial resource for the rayon plant and important ecological entity in its own right, suffered the consequences.

Although the plant's engineers were never able to protect the river, many outside people—from sport fishermen to state officials—attempted to do so. Over the plant's operating life, changes in environmental awareness led to changes in law that ultimately caught up with the plant. In 1989, after years of controversy, Avtex Fibers closed its doors. The operations might have ceased sooner were it not for close connections between the rayon plant and the

[1] For the past several decades, news reports and local parlance have referred to the facility as "the Avtex plant," a name now deeply associated with Superfund designation, cost litigation, and site remediation. This study looks beyond the Avtex years and thus utilizes more generic terms like "the rayon plant at Front Royal" unless specifically discussing the years when Avtex Fibers, Inc. owned the plant.

military, which granted it a strong degree of protection from environmental regulation for most of its operating life.

This paper examines the entwined histories of the Shenandoah River and the rayon factory at Front Royal, especially the origins of its problematic waste disposal practices, and focuses on the changing dynamics that ultimately gave the health of the river—treated for so many years as a raw material and waste receptacle—priority over the factory. This history provides a microcosm to examine human interaction with the encompassing natural world, highlighting the limits of human knowledge with regard to predicting environmental consequences, the agency of environmental systems, and the possibilities for checking the momentum of technological systems that harm the environment.

Figure 1. Map of the Shenandoah River Valley. The rayon plant at Front Royal was located in Warren County, at the confluence of the North and South Forks of the Shenandoah River. ***Source:*** **United States Geological Survey, "Shenandoah Valley Research Publications," http://va.water.usgs.gov/bib/bib/words_shen.html**

Introduction

The South Fork of the Shenandoah River crooks a meandering arm around 440 acres of floodplain in Front Royal, Virginia. For forty-nine years on that piece of ground, the river supported a major manufacturing facility making viscose rayon fiber for consumer and military use. The two entities—the river and the factory—formed a single complex, a hybrid of technological and environmental systems. The rayon produced at Front Royal profited the community and played important roles globally, but the prodigious waste products from rayon manufacturing polluted not only the river but also groundwater, soil, and air. Despite halting attempts at environmental reconciliation, the relationship between river and factory never obtained a healthy reciprocity. As a fundamental component of the rayon plant's operations and of many Shenandoah Valley communities, the South Fork's place within the river-plant complex shifted as societal attitudes toward the environment changed during the factory's operating life.

In the end, the hybrid relationship ended in a collision of circumstance and changing values that paints a picture of human society both hopeful and disturbing. Powerful environmental laws like the 1972 Clean Water Act and 1980 Superfund law made it increasingly expensive for the facility to pollute, and eventually accumulated pressure from state, federal, and citizen groups led to the plant's closure in 1989. As of 2010, remediation of the Avtex site under the Superfund law continues, with plans to make the land a riverside park and business zone.

Studying the history of rayon production at Front Royal provides both literal and metaphorical insights. The plant and its relationship to the South

Fork of the Shenandoah mirror a larger piece of the human experience, offering an industrial metaphor for the problematic relationship many human societies have with nature. The concept that people and nature are separate entities is merely a trick of perception; as historian William Cronon puts it, "all people…share with each other and with all living and unliving things a single earthly home which we identify as the abstraction called nature."[2] Yet conceptualizing the reality that humans *are* nature can be difficult. Being so wholly dependent on and enmeshed in a vast living system limits our ability to completely comprehend it. Sometimes the wider whole is best understood through microcosm.

The rayon facility gives us such a view, demonstrating a specific example of how human systems rely on broader ecological systems. The rayon factory was a large, complex, technological system, invented and organized by people. The South Fork of the Shenandoah River is one small part of the global ecosystem and one segment of the Shenandoah River watershed, which encompasses roughly 1.5 million acres.[3] The process of manufacturing rayon depended entirely on water supplied by the South Fork. If the river suddenly went dry, the factory would immediately cease to function.

Sadly, the rayon plant's relationship to the river mimicked the common response of many human societies to nature. While some individuals at the plant made real effort to protect the river from toxic discharges, the overall corporate attitude during the plant's operating life placed minimal importance

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[2] William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W.W. Norton & Co., 1991), 19.

[3] Potomac Watershed Partnership, "Shenandoah River," http://www.potomacwatershed.net/ijourney/shenando/shenando.html (accessed February 14, 2010).

on the health of aquatic life. The South Fork was a means to an end, an industrial extractive resource. The companies that operated the plant over its forty-nine year history followed components of federal and state environmental laws to a minimal degree, often paying off fines rather than repairing problems. Protection of the river ranked low on the operators' priority list, and military demand for some of the plant's products further complicated the relationship. In other words, the factory treated the river as we, societally, treat nature: a resource to be used, a vague concept in the back of our minds—far below profit, jobs, or family—that becomes a priority only when problems arise, such as contaminated drinking water, fish kills, or a river turned rank and milky white.

The interaction between society and nature is most visible and concrete in certain elements of the rayon plant's story, where the friction and disparity within the river-plant complex becomes most evident. Chapter one explores the histories possessed by each entity: the factory's genealogy of technology and concomitant waste on the one hand, and the river's geological epic and attendant human use on the other. Chapter two examines the important global role played by the river-plant complex during World War II and the steep price paid by the South Fork. During this era, the interests of the factory dominated; the river was largely treated as an extractive resource and a static waste receptacle.

The chapters three and four explain how rayon manufacturing creates toxic wastes and examine the rayon plant's early attempts to deal with that material. The fifth chapter considers the shift in dynamics between the river and the factory following World War II as concerns about the South Fork and the environment in general increased. For sport fishermen, the South Fork afforded a different kind of resource, one that required clean water and healthy aquatic life. After the war, fishermen began to advocate on the river's behalf, successfully lobbying for Virginia's first water quality law. The factory managers' attempts to adjust to new regulatory oversight continued for the remainder of the plant's operating life as the American response to environmental problems shifted, producing stricter pollution control legislation. The chapter also explores how regulation of toxics at the rayon plant displaced some of the waste to locations where it continued to cause harm.

Shifting dynamics between river and factory took place in predictable physical zones of interaction between plant and river, such as the wastewater treatment plant and the land surrounding the factory. But they occurred further afield as well—in courtrooms and negotiations with military officials, the Environmental Protection Agency (EPA), the Commonwealth of Virginia—interactions that redefined the concept of the river, of hazardous waste, and of harm. Chapter six discusses events in all of these arenas that finally halted the technological momentum of the rayon plant, leading to its closure in 1989.

Throughout the factory's forty-nine years of operation, the number of protections and advocates for the river increased, but its status as an independent ecological system remained on the periphery for the companies operating the plant, and even, it seems, for the regulatory bodies. Although regulatory permitting and monitoring provided tools for protection, the burden of proof remained on the river. Damage to it had to be quantifiable before action could be taken. Problems below a certain, somewhat arbitrary, threshold could be ignored. The power balance between technological and ecological systems in the river-plant complex remained lop-sided, a result perhaps of a technological momentum inscribed with the attitudes and design flaws that initiated the waste problems at the Front Royal plant. This study concludes with a discussion of how human actions can check technological momentum, and how precautionary measures can provide healthy inertia to the momentum of future technological systems.

The concept of technological momentum originates with historian Thomas Hughes; his writings on technology provide important architecture and vocabulary to this study. Hughes defines technological systems on a broad scale, using large and complex entities, such as the U.S. electric grid, as his examples. Nevertheless, his approach translates well for smaller units of technology, including the rayon plant in Front Royal. Despite its self-contained appearance, the technological system of this river-plant complex extended far beyond the facility itself. The system included predictable components, such as the physical infrastructure of the plant and the machines used to spin, wash, and stretch rayon fibers. Transportation infrastructure, especially the railroad, connected the factory to suppliers and purchasers.

But multiple additional entities were also part of the larger technological system, including all three companies that owned and operated the rayon facility, as well as banks that financed expansions, educational facilities that trained employees, unions that represented workers, and more. Going further afield, Hughes also suggests that technological systems include "legislative artifacts."[4] At the Front Royal plant, state and federal laws regarding a broad range of topics—from military procurement, labor issues, and taxes, to worker

[4] Thomas P. Hughes, "The Evolution of Large Technological Systems," in *The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, MA: The MIT Press, 1987), 51.

safety, environmental protection, and import-export restrictions—all shaped decision-making by managers and workers throughout its operating life.

Finally, Hughes argues that natural resources, when "they are socially constructed and adapted to function in systems,… also qualify as system artifacts."[5] Viscose rayon production combined a variety of natural resources, all of them transformed from their original state before arriving at the plant. Cellulose from tree fiber was a primary ingredient for viscose. Made from chipped and pulped softwood trees harvested in Alaska, Canada, and the Pacific Northwest, the cellulose arrived at the factory already pressed into thick white sheets resembling blotting paper.[6] The production process also involved multiple chemicals, synthesized off-site from various raw materials and delivered to Front Royal via gas lines and railroad tank cars. Mining techniques to dig the coal that powered on-site turbines intensified in environmental impact during the rayon plant's lifetime, from deep mines to strip mines. Limestone used in the wastewater treatment plant also had to be mined, cleaned, and transported.

Charting the flow of materials and resources into the rayon plant paints a miniature version of William Cronon's depiction of Chicago in *Nature's Metropolis*. The resources required to manufacture this one product shaped landscapes across the U.S., each linked to Front Royal and the rayon market by miles of railroad track. Like the meat packing plants in 19th century Chicago, behind the Front Royal factory and the skeins of rayon it produced "were the

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[5] Ibid.

[6] American Viscose Division/Fiber Operation, "Welcome to FMC-Front Royal," Pamphlet, Avtex Collection, Local #371T Amalgamated Clothing and Textile Workers Union Papers (Union Papers); Laura V. Hale Archives. Warren County Heritage Society. Front Royal, VA (WHS).

ghost landscapes that had given it birth."[7] Perhaps the most haunting landscape was that immediately surrounding the rayon facility. Like the Chicago factories, the rayon plant could not adequately process or safely dispose of its byproducts and waste. The nearby land and river bore the brunt of this excess.

Of all the natural resources that supplied the rayon plant, the water of the South Fork was the least processed and the least transformed.[8] The rayon plant required a river; it could not have functioned away from a consistent water source. Thus, river water did not require long-distance transport and needed only modest treatment for use in the plant and power house. It was a truly raw material, not requiring chemical synthesis, mining, logging, pulping, pressing, or shipment across the nation. Unique among the other natural resources used at the factory, the river's water also played a dual role as a resource for extraction and receptacle for waste. Thus, the river was not just a raw material, it was also a place—what historian Joel Tarr calls a "sink," where wastes can be "disposed of in the cheapest and most convenient way possible."[9] Transactions between the river-plant hybrid occurred within a physical zone of overlap, a space where the river was simultaneously adapted to the functions of the plant while still functioning as part of a larger ecosystem.

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[7] Cronon, 263.

[8] It appears Avtex filtered the river water and used rock salt as a water softener. See Susan Groves and Frank Settle, "The Avtex Saga: National Security versus Environmental Protection," *Journal of Chemical Education* 79, no. 6 (June 2002), 686; and Richard K. Daniels, "Avtex Fibers Rayon Plant," http://ourworld.compuserve.com/ homepages/rdaniels2/layout2.htm (accessed May 8, 2009). Note that this CompuServe server shut down on July 6, 2009.

[9] Joel A. Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, OH: University of Akron Press, 1996), 385.

Hughes identifies a powerful force that helps to clarify the reasons behind the factory's dominance of the river-plant complex for most of its operating life: the momentum of technological systems. Using the language of physics, he ascribes mass to the organizational elements of a technological system, direction to the goals of a system, and velocity to its growth rate. As a result, "mature systems have a quality that is analogous… to inertia of motion."[10] This helps to explain the factory's longevity in spite of the pollutants the plant discharged into the river even as social values shifted to emphasize the importance of environmental protection. The technological system that both incorporated and emanated from rayon production created multiple buffers, as the company provided jobs, tax revenue, political contributions, and so on. The most powerful buffer, however, came from military interests.

During its forty-nine year operating life, the Front Royal facility manufactured two militarily critical products: high tenacity rayon tire cord for World War II operations and carbonizable rayon for missiles and other aerospace purposes during the Cold War years. The momentum acquired from this component of rayon's technological system single-handedly kept the plant in operation in its final years. The socially constructed dichotomy between national security and environmental concern multiplied the difficulty of effectively regulating the plant's pollution. The military rayon products webbed the factory and the Front Royal community into the global technological system of weapons manufacturing, from tank tires during World War II to nuclear warheads carried on missiles built with Front Royal rayon. Environmental

[10] Huges, "The Evolution of Large Technological Systems," 77.

protection, therefore faced vastly amplified obstacles due to the "conservative momentum of the military-industrial-complex"[11] and its global implications.

Part of Hughes' explanation for this contributes another valuable concept to this study. The momentum of technological systems includes social influences from the times in which they originated; these values, attitudes, and intentions also have a different kind of "inertia, [that of] conservative momentum."[12] Likewise, the physical components of a system "project into the future the socially constructed characteristics acquired in the past when they were designed."[13] Hughes theorizes that characteristics adapted to the social values of a certain time period continue into the present due to technological momentum. By the late 1980s, the factory carried with it, in the decaying buildings and chemical waste disposal system, not just the basic manufacturing infrastructure of the 1930s (and before) but also the values and expectations of those times. More significantly, it carried internal bureaucratic expectations from its earliest years of operation—World War II and immediately after—when chemistry and industry had won the war and operated within an environment of patriotic enthusiasm and self-regulation. Cold War values emphasizing military preparedness and massive weapons systems reinforced these technological learned behaviors.

Hughes has suggested that only counter-momentum of equal force could change the imperative of such massive systems of values, goals, expectations,

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[11] Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970* (Chicago: University of Chicago Press, 2004), 460.

[12] Hughes, *American Genesis*, 459.

[13] Hughes, "The Evolution of Large Technological Systems," 77.

and military demand.[14] But the technological system of rayon production in Front Royal broke down not because of a unified counter-momentum, but due to a slipshod collection of cumulative but highly-contingent events. Within that process are the stories of multiple smaller counterforces, growing over the same decades, nudging at the plant's managers to address its pollution problems. Many entities within the rayon plant's technological system—particularly state regulatory agencies and politicians—initially helped to facilitate the plant's continued operations, but then, in the final days, shifted sides to respond to other forces, other socially constructed values of newer times.

In one sense, the multiple forces countering rayon production's momentum at Front Royal plant did have a degree of unity, in that they coalesced around the question of the river. The river was the bellwether and whistleblower; it clanged the alarm bell and provided the data to quantify the toxic discharges of the factory, its unhealthy human-built appendage. For the most part, the people who responded on the river's behalf did so seeking some kind of "extractive" or consumptive gain, based in personal desire, political expediency, economic interest, or some combination of these. For some, the situation at the rayon plant replicated a trend that grew out of the technological explosion following World War II. Historian Adam Rome explains that some Americans began to see "the new machinery of production as a threat to the new dream of consumption."[15] Along the Shenandoah, these new dreams

[14] For example, in *American Genesis,* Hughes theorizes that "in order to bring about a substantial change in the motion and direction of massive systems of production… a counterforce of comparable magnitude becomes imperative," 461-462.

[15]Adam Rome, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism* (Cambridge: Cambridge University Press, 2001), 5.

embraced such things as sport fishing and other recreational activities, and enjoyment of the river's aesthetic values as tourists or landowners. Such connections between human desires and a healthy natural world are crucial components for stirring environmental protection, but there remains another side of the river: a space where it escapes the embrace of human desire or social construction and exists unto itself, feeding a far broader range of life than just the human species.

Alongside the socially constructed idea of the river and its extractive uses, the biological reality of the river exists with its own complicated causes and effects, its own balance and dynamism. Many voices have spoken to this dualism. Richard White, for example, concluded from his study of the Columbia River that "no matter how much we have created many of its spaces and altered its behavior, [the river] is still tied to larger organic cycles beyond our control… the river has purposes of its own which do not readily yield to desires to maximize profit."[16] In her paradigm-shifting 1962 book, *Silent Spring,* Rachel Carson reflected upon this fluidity, writing "seldom if ever does Nature operate in closed and separate compartments, and she has not done so in distributing the earth's water supply."[17] The South Fork of the Shenandoah and its ecological system carry a physical momentum of their own, interwoven with the human-built world and also existing beyond it. The momentum of the river, like nature itself, is what humans too often fail to grasp, for it is diffuse,

[16] Richard White, *The Organic Machine: The Remaking of the Columbia River* (New York: Hill and Wang, 1995), 112.

[17] Rachel Carson, *Silent Spring* (Greenwich, CT: Fawcett Publications, Inc., 1962), 47.

connected in wider and more intricate ways than we are usually conditioned to detect.

The science of ecology provides terms that help convey something of this complexity and of the river's existence in a context that subsumes the human-built world. The term "ecology" is relatively new to our lexicon, coined in 1873 to describe the study of interactions between plants, animals, and their habitats.[18] An ecological system, or ecosystem, may refer to these organisms and interactions in a specific area, or something larger: the planetary ecosystem. Other terms express both the immensity and limits of natural systems. The definition of the "biosphere," another late 19the century term, is "the global sum of all ecosystems," and "the thin layer near earth's surface that contains all known life."[19] Our poet-scientists name these phenomena in language that speaks to our senses. Rachel Carson writes, "Water, soil, and the earth's green mantle of plants make up the world that supports the animal life of the earth,"[20] and the land, Aldo Leopold adds, "is a fountain of energy flowing through a circuit of soils, plants, and animals."[21]

Even in a relatively contained ecosystem like the Shenandoah River, the process of cataloging the organisms and interactions that drive this fountain of energy is an immense task. On the broad scale, the ecosystem embraces the river's watershed: all the river's surface and ground water tributaries, all the

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[18] "Ecology," *Etymology Dictionary Online*, http://www.etymonline.com/ (accessed February 21, 2010); and T.F. Hoad, "ecology," *The Concise Oxford Dictionary of English Etymology*, 1996, Encyclopedia.com (February 21, 2010).

[19] Gretchen C. Daily, ed. *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington, DC: Island Press, 1997), 2, 4.

[20] Carson, 64;

[21] Aldo Leopold, *A Sand County almanac: with essays on conservation from Round River* (New York: Ballantine Books, 1970), 253.

soil and plants that filter rainwater. Indeed, everything that exists within the watershed is part of the watershed, including roads and houses. On the opposite end of the scale are microscopic organisms—bacteria and molecules of oxygen and nitrogen, and the benthic macroinvertebrates—mayflies and mussels and many species in between—that live on the river bottom, feeding on fallen leaves and other organic matter.[22] Multiple species of fish feed on the macroinvertebrates and on each other. Then there are creatures, from birds to bears, who feed on the fish, as well as all manner of plant life that relies on the river. Humans are also in the mix, of course, many of us never considering that we live within a watershed and that our daily choices may directly impact the Shenandoah River ecosystem. The river simultaneously includes us and exists beyond us, with its own purposes. Understanding what happened at the rayon plant in Front Royal requires consideration of the history and momentum of both the river and the plant.

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[22] Environmental Protection Agency, "Benthic Macroinvertebrates in Our Waters," Biological Indicators of Watershed Health, http://www.epa.gov/bioiweb1/html/benthosclean.html (accessed February 21, 2010).

Chapter 1

Origins of the River and the Factory

The history of the Shenandoah River begins far beyond human constructs, deep in the bedrock of geologic time. The river is part of an ancient landscape of oceans, volcanoes, and vast tectonic shifts. The very oldest exposed rocks in the Blue Ridge Mountains formed roughly 1.2 billion years ago. A shallow ocean covered what is now the Shenandoah Valley and the eastern U.S. for roughly 400 million years, laying down sediment and sea shells that compacted into layers of shales and limestones. The sea began to recede about 350 million years ago, leaving swamps and meandering rivers in its wake. Another vast shift came 275 million years ago when the continents of Africa and North America collided, folding and breaking and shoving the flat sedimentary rocks, building the mountains that surround the Shenandoah Valley over the course of the next several million years.[23]

With the formation of the Appalachians, and for the recent 240 million years, erosion has shaped, formed, and reformed the limestone, sandstone, granite, and greenstone rocks into the mountains and valleys of today. The Shenandoah River does not have a birthdate because it is part of all the geological processes that shaped the landscape. Many of its tributaries flow underground, through fissures in limestone laid down during the era of the great shallow inland sea. The river's curves, depths, and shallows conform to rock types configured by mountain building, curling around ridges that resist

[23] W. Cullen Sherwood, "A Brief Geologic History of Rockingham County," Department of Geology and Environmental Studies, James Madison University, http://csmres.jmu.edu/geollab/vageol/ outreach/fieldtrips/ rockingham/whole.html (accessed February 21, 2010).

erosion and carving down through softer rocks.[24] The Shenandoah River and its tributaries shape every natural feature of the landscape. From ground level, the river's influence may be only marginally apparent, but viewed from above, ecological and landscape patterns become more evident, and "stream valleys are seen to dominate" the land.[25]

The river has a ecological history outside of human influence, based in geological change, weather events—including droughts and floods—as well as the interplay of organisms within the river and surrounding it. Yet human activities have played a drastic and dramatic role in the river's history. The earliest evidence of human interaction with the river dates back over 11,000 years when paleo-indians camped, hunted, and quarried stones for arrowheads along the South Fork. Archeological digs near Front Royal uncovered post holes from what may be the oldest structures in North America.[26] In 1699, John Lederer crossed the Blue Ridge at Manassas Gap near Front Royal, becoming the first documented European explorer to view the Shenandoah Valley. From then on, the river and its landscape gained names inscribed in written histories.

These now familiar names mark out the geography of the Shenandoah River system. Beginning in the upper reaches of Virginia's two great mountain ranges, the Blue Ridge and Allegheny, the river's watershed runs roughly 150 miles from south of Waynesboro to the confluence with the Potomac River at

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[24] Sherwood.

[25] W. Kenneth Hamblin, *Earth's Dynamic Systems, 6th edition* (New York: Macmillan Publishing Company, 1992), 234.

[26] Virginia Department of Historic Resources, "First People: The Early Indians of Virginia, Indians A.D. 1600-1800," State of Virginia, http://www.dhr.virginia.gov/arch_NET/timeline/contact_indian_4.htm (accessed November 15, 2009).

Harpers Ferry. The major tributaries are all directional in name. The South Fork has roots in both mountain ranges: Blue Ridge streams collect into the South River, and the North and Middle Rivers originate in the folded eastern front of the Allegheny Mountains. The three converge near Port Republic, becoming the South Fork of the Shenandoah. The river curves northward, continuously carving the Page Valley between the erosion-resistant granites in the Blue Ridge and sandstones in Massanutten mountain.[27] Meanwhile, the North Fork draws a fan of tributaries down from the Alleghenies and weaves them into deep ox bows that skirt the western side of Massanutten. The two undulating forks finally meet to form the main stem of the Shenandoah River a scant two miles downstream of the now-closed rayon plant site.

Figure 2. Flooding at the confluence of the North and South Rivers at Port Republic. Photo by the author.

[27] "The Potomac-Shenandoah System," *The Geology of Virginia: Rivers & Watersheds*, William and Mary Department of Geology. http://web.wm.edu/geology/virginia/rivers/potomac-shenandoah.html?svr=www (accessed May 4, 2009).

In 1937, American Viscose Corporation purchased 440 acres of land beside the South Fork of the Shenandoah in Front Royal, Virginia to build its largest rayon plant. At first thought, a hulking industrial plant on the banks of the Shenandoah may seem somehow incongruous. The Shenandoah River and the valley it carved are fabled places in America, the lyrical name woven into folk songs and images from a history that borders on legend: the Knights of the Golden Horseshoe expedition getting drunk on the river bank in 1716, a young George Washington hard at work surveying the valley, the famed breadbasket of the Confederacy in flames during the Civil War. The name Shenandoah also belongs to a nearby national park, evoking forests garlanded with autumn colors, a beautiful land. Upon seeing the Alleghenies on the far side of the valley for the first time, John Lederer wrote that he "could hardly discern whether they were mountains or clouds."[28] Perhaps they were both. There is truth in the romantic visions; the Valley, mountains, and river are the United States of America's original frontier, and they are lovely, inspiring the poetic imagination. But the Shenandoah River has been put to work by humans for centuries. It shares the encroachments and aquatic tragedies of any industrial river.

Humans have used the broad, flat Shenandoah Valley as a thoroughfare for millennia. Many major modern day roads follow long-distance Native American trails. One of these, now called the Valley Pike or Route 11, runs roughly north and south through the Valley. Multiple east-west trails are now also paved, passing through wind and water gaps in the mountains. Geography made the Front Royal area a crossroads for human travel early on. The

[28] "Knights of the Golden Horseshoe," Department of Historic Preservation, University of Mary Washington, http://umwhisp.net/germanna/node/6 (accessed February 22, 2010).

Manassas and Chester Gaps in the Blue Ridge allowed travelers to approach from the east. The Valley Pike and both forks of the Shenandoah River lay just to the west. This confluence of transport combined with a hydrological situation to make Front Royal an early center of trade. At a curve in the river near the present day Avtex site, the water slows down, depositing alluvial sediment, eroded off the mountains and valley.[29] The resulting shallows, called "The Flats," were an easy and convenient spot to pull canoes, and later barges, ashore. Native Americans built a fish weir near the site and gathered there to fish, process fish, and trade. Cleanup efforts at the Avtex site in the 1990s and 2000s uncovered numerous arrowheads and other Native American artifacts.

During colonial times, European settlers in the Shenandoah Valley produced crops and other resources for trade within the colonies and export to England, including timber, iron, hemp, grain, and flour. The river powered grain mills and iron furnaces and served as the main avenue for trade. Port Republic and Bridgewater (originally called Bridgeport) were loading points for transport of goods heading downstream on the South and North Forks of the Shenandoah. Settlers shipped their goods to market by gundalows, flat-bottomed barges that were poled downstream and then dismantled; the crew sold the wood then walked back home. The Flats again became a destination where gundalow drivers would empty their cargo into the carts of merchants who transported the goods through Manassas Gap to eastern markets at

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[29] U.S. Environmental Protection Agency, "Record of Decision, Decision Summary," [n.d., 1988?], Avtex Administrative Record, EPA. http://loggerhead.epa.gov/arweb/public/pdf/135790.pdf (accessed May 7, 2009): 1.

Alexandria and Dumphries. The Flats remained a transfer point when the railroad came to Front Royal in 1854.[30]

After the Revolutionary War, the Shenandoah River and its Valley continued as key resource caches for trade and consumption. For example, the Patowmack Company formed in 1785 with support from George Washington; in an effort to make the Shenandoah more navigable, the company dredged the river bottom and blasted rock to widen the river's channel. The company also built V-shaped dams in shallow parts of the river. An opening in the center of the dam increased flow, allowing easier passage for barges.[31] Human manipulation of the river for commercial purposes increased in intensity over time. The twentieth century brought heavier industry to the river and its tributaries. Beginning in 1922, Wampler Foods initiated industrial poultry production in Rockingham County. E. I. du Pont de Nemours and Company purchased land beside the South River in Waynesboro, relying on river water to manufacture acetate rayon beginning in 1929.[32] In addition, communities along the river used the South Fork and its tributaries for both drinking water and disposal of contaminants, such as sewage and industrial discharges.[33]

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[30] Personal conversations with Patrick Farris, director of the Warren County Heritage Society, and John Torrence, site manager with Environmental Resources Management (ERM), the company contracted by the former-owner, FMC Corporation, to carry out remediation efforts at the Superfund site; also Dan McDermott, "Daughter of the Stars: The rich history of the Shenandoah River," *Warren County Report* (October 15, 2008), http://wcrnews.wordpress.com/category/paleo-indians/ (accessed May 7, 2009).

[31] McDermott.

[32] "DuPont Heritage: Waynesboro, Virginia," E. I. du Pont de Nemours and Company, http://www2.dupont.com/Heritage/en_US/related_topics/waynesboro_va.html (accessed June 1, 2010).

[33] "Tommy" K.S. Bassford, *Evolution of Harrisonburg, 1780-1945* (Harrisonburg, VA, 1945), http://freepages.genealogy.rootsweb.ancestry.com/~bassfordbooks/Evolution%20of%20Harrisonburg.htm (accessed December 3, 2008).

When the American Viscose facility opened in 1940, people had used, polluted, and relied on the Shenandoah for centuries.

When American Viscose Corporation employees scouted the 440 acre site on the banks of the South Fork in 1937, they were operating in familiar territory. Twenty years earlier in Roanoke, Virginia, the company opened what was at that time the largest rayon plant in the world.[34] The rayon industry as a whole had a heavy presence in the state. By 1941, American Viscose plants in Roanoke and Front Royal and an Industrial Rayon Corporation factory in Covington manufactured viscose rayon; Celanese Corporation of America near Narrows produced an acetate rayon yarn; and E.I. du Pont de Nemours & Co., with plants in Waynesboro, Ampthill, and Martinsville, manufactured both acetate and viscose rayon fibers, as well as cellophane.[35] In the late 1940s through the mid-50s, "value added" for synthetic fibers production in Virginia was second only to tobacco.[36]

These industries connected into a larger technological system during the early twentieth century in which southern state governments offered economic incentives to support industrial expansion in their states. Virginia as a whole had quantities of "cheap and radical-free labor," as well as "lenient industrial

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[34] Victor S. Clark, *History of Manufactures in the United States, Volume III, 1893-1928*, 1929 edition, reprinted with permission of Carnegie Institution of Washington, (New York: Peter Smith, 1949), 347; and William Russell Edmunds, Jr., "Industrial Waste Disposal from the Rayon Industry to the Streams of Virginia," B.S. thesis, Virginia Polytechnic Institute, 1941, 4.

[35] Edmunds, 4-6.

[36] U.S. Department of Commerce and Bureau of the Census, *United States Census of Manufactures 1954, Volume III Area Statistics,* prepared under the supervision of Maxwell R. Conklin (Washington, DC: United States Government Printing Office, 1954), 145-7 and 145-8.

relations policies."[37] Front Royal's Town Manager, L.B. Dutrow, told a reporter in 1938, "We were told that the representatives [of American Viscose] also had been looking over a site in North Carolina, but that they liked the Virginia tax laws better." He noted that they expressed particular interest in the location of the 440 acres: about three-quarters of a mile outside of town (at that time) and adjacent to both the railroad and the river.[38] Alongside direct financial supports for their industrial endeavors, many southern states offered companies virtually free reign with regard to natural resources.[39] Water was one of the key extractive resources that southern[40] states could offer. Oftentimes, industries selected rural sites where water and other raw materials were abundant and chemical discharges into air, land, and water would attract less notice. The Front Royal site, located in a rural region and in close proximity to the South Fork, offered American Viscose all these benefits, along

[37] Quotes from Edmunds, 1; see also Peter Carlson and Mary Ellen Mark, "Rayon Men," *The Washington Post Magazine* (Feb. 12, 1989), 22 for information on availability of labor when the plant opened in 1940. Regarding "radical-free labor," see D.C. Coleman, *Courtaulds: an Economic and Social History, Volume II, Rayon* (Oxford: Clarendon Press, 1969), 453-454. It is accurate to say that the union local at American Viscose's Front Royal plant was, on the whole, not radical, but the facility's labor situation was somewhat unique among southern industries. After almost twenty years of organizing and strikes, the Textile Workers Union of America gained formal recognition from AVC as sole bargaining agency beginning in 1937. Company documents show that the U.S. Supreme Court ruling that upheld the Wagner Act factored into AVC's decision to work with the union. The terms of the agreement applied to all AVC plants, including the new facility at Front Royal. TWUA's Local 371 (later the Amalgamated Clothing and Textile Workers Union of America, Local 371T) represented workers at the Front Royal plant and, in general, had a relationship with management that was cooperative and non-confrontational. Accounts vary as to whether TWUA ever went on strike at the Front Royal plant. Materials from the Avtex Collection of Local #371T of the ACTWUA at the Warren Heritage Society are inconclusive, although it is clear that the Local did send donations and other support to striking workers at other AVC factories.

[38] Christine Sadler, "Front Royal Prepares for $20,000 Rayon Plant, As Tourists, Scenery, Local Trades Keep Luray Busy," *The Washington Post* (Aug. 7, 1938), Union Papers; Laura V. Hale Archives; WHS.

[39] James C. Cobb, *Industrialization and Southern Society, 1877-1984* (Lexington, KY: University Press of Kentucky, 1984), 122.

[40] Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA* (Austin, TX: University of Texas Press, 1996), 47.

with a solid transportation infrastructure, tax incentives, cooperative labor, and a business-friendly political climate. More than anything else, however, American Viscose wanted the river.

Rayon manufacturing uses massive quantities of water. Current production methods require 175 gallons of treated water to produce one pound of rayon. Producing two million pounds of rayon annually required one million gallons of treated water per day.[41] The Front Royal plant opened in 1940 (see fig. 3) designed to produce 75 million pounds of rayon per year,[42] thus requiring—at full capacity—daily water input of somewhere in the ballpark of 37.5 million gallons. The manufacturing process required water to dissolve caustic soda to break down cellulose; water in large quantities washed rayon threads and diluted chemicals; it cleaned waste materials out of the plant and joined forces with coal to power the facility's steam turbines. Water treatment procedures, used at various times over the plant's operating life, also required additional amounts of water. Thus, in actuality, total water use in the early 1940s may have been quite a bit higher than 38 million gallons per day.

[41] Groves and Settle, 686.

[42] Edmunds, 6.

Figure 3. The Front Royal rayon plant in 1943, under the ownership of American Viscose Corporation. Courtesy of Warren Heritage Society.

Understanding the origins of the product manufactured at the rayon plant—viscose rayon—illuminates the depth of the facility's reliance on the river. The story began in the distant past at an unlikely crossroads: the intersection of human desire for status, comfort and luxury with the reproductive strategy of a species of grey moth, *Bombyx mori*, the silk worm. The moth's larvae ate white mulberry leaves and spun out a fine thread to weave cocoons. Silk making interrupted this process by boiling the cocoons and caterpillars, then unwinding the fine threads and twisting them into thicker strands for weaving. The ancient practice of silk production began in China thousands of years ago, and as a rare and exotic fabric, silk was favored among the wealthy across the Middle East and Europe. From early on, rulers sought to develop silk industries in their own countries or to control production abroad. Some scientists tried another avenue toward textile dominance: creating man-made, silk-like fibers. In the early 1800s, an epidemic disease fatal to silkworms decimated the European sericulture industry[43] and further stimulated interest in creating a synthetic substitute.

English scientist Dr. Robert Hooke first proposed the general method for manufacturing rayon. In a 1664 book titled *Micrographia*, he wrote:

> I have often thought that probably there might be a way found out, to make an artificial glutinous composition, much resembling, if not full as good, nay better, than that excrement, or whatever other substance it be out of which the silkworm wire-draws his clew. If such a composition were found, it were certainly an easy matter to find very quick ways of drawing it out into small wires for use. [44]

Decades later, in the 1740s, French scientist René de Réaumur, who might today be titled an entomologist, published *Mémoirs pour Servir à l'Historie des Insects* in which he considered the possibility of threads made of chemical varnish that would resemble silk in "brilliancy and strength."[45]

Scientists working in the 19th century sought to mimic the glutinous "excrement" of the silkworm by dissolving various types of fiber in various chemicals. The chemists who made the most progress were in search of light bulb filaments, not textiles. An English chemist named Sir Joseph Wilson Swan—most famous for his invention of the incandescent light bulb—dissolved nitrocellulose in acetic acid, then forced it though a small hole into a

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[43] Mahesh Nanavaty Rajat K. Datta, *Global Silk Industry: A Complete Source Book* (New Delhi : APH Publishing Corp., 2007), 20.

[44] Joseph Leeming, *Rayon: the First Man-Made Fiber* (Brooklyn, NY: Chemical Publishing, Co., 1950), 3.

[45] Leeming, 5.

coagulating bath of alcohol. The fibers produced were not only effective for filaments; they were also considered the first artificial silk. Using this procedure as a starting point, various chemists sought to perfect the process. Count Hilaire de Bernigaud de Chardonnet had the first commercial success in 1885, followed by a German company in 1899.[46]

The viscose method for producing rayon emerged in Britain in the late 1800s, eventually becoming the industry standard. Charles Cross, Edward Bevan, and Clayton Beadle devised and patented the first viscose in 1892. They treated cellulose from tree fiber with sodium hydroxide—a strongly alkaline substance commonly known as caustic soda or lye—in order to "swell the fiber" and create a thick solution. The resulting substance was dissolved with carbon disulfide, creating a "thick, straw-colored solution having the viscose consistency of honey or molasses."[47] The three men patented this viscose-production process, but it took two additional inventors to perfect a procedure for spinning viable viscose thread.

Englishman Charles Stearn headed the Zurich Incandescence Lamp Company in London, but Charles Topham, his assistant, was the real innovator. They experimented, unsuccessfully at first, by extruding the viscose substance through a spinneret and into an acid bath for hardening. Initially, the fibers were too weak to spin, but Topham discovered that aging the viscose before extruding and spinning created viable fibers.[48] Topham also invented a

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[46] "Company History: Courtaulds Plc.," Answers.com, http://www.answers.com/topic/courtaulds (accessed December 14, 2009).

[47] Leeming, 27.

[48] Leeming, 27 and 29.

pump to regulate the flow of viscose to the spinnerets, as well as a spinning box that caught the rayon filaments, wound them into yarn, and collected them into a "cake."[49] These same products and procedures became key to the technological system comprising the rayon industry. Machines based on Topham's model and reproduced on a mass scale were in use at the Front Royal plant when it closed in 1989.

Just as the invention of viscose rayon proceeded by trial and error, so too did the industry itself. The American Viscose Corporation (AVC), owner of the Front Royal plant from 1938-1963, originated as a subsidiary of the Courtaulds family's dynasty in the British textile business. Courtaulds held the first patent on the British process for making viscose rayon and for years dominated the market in viscose fabric both at home and in the U.S.[50] However, for several years after obtaining the patent, Courtaulds' ability to manufacture commercial-grade viscose rayon was by no means certain. Developing a large-scale commercially successful viscose rayon industry had a multidirectional character.[51] Like the process of invention and experimentation used by Topham, Stern, and others before them to develop viscose rayon, Courtaulds

[49] Virtual Plastics Museum, "Artificial Silk," http://www.plastiquarian.com/museum/viscose/viscose03.htm (accessed January 16, 2010).

[50] C.H. Ward-Jackson, *A History of Courtaulds: An Account of the Origin and Rise of the Industrial Enterprise of Courtaulds Limited and of its Associate the American Viscose Corporation* (London: Curwen Press, 1941), 90-95.

[51] The term "multidirectional" comes from Trevor J. Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," *The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, MA: The MIT Press, 1987), 40. The authors highlight the importance for historians of technology to demonstrate that the development of a technology is not linear or predetermined; rather, it proceeds through "alternation of variation and selection."

met failures and dead-ends that shaped decisions and technological developments.

In 1782, George Courtauld initiated the family's association with fabric production when he set up a business in London as a silk-throwster, twisting threads of raw silk to make them suitable for weaving. His son built a silk mill in 1816 that became extremely profitable manufacturing crêpe silk, a popular material for mourning clothes in the Victorian era. The Courtaulds' involvement with viscose rayon production commenced in 1904 when the company purchased British patent rights for the manufacture of textile yarn using Topham and Stern's viscose method.

Although the discovery of "artificial silk"[52] was several years old at that time, no company had successfully fabricated commercial quantities. Indeed, several had attempted to do so using the Topham and Stern method but found the process unreliable. Courtaulds, Ltd. too struggled with multiple problems. Production of useable quantities fluctuated wildly, and yarns tended to be flammable or explosive if not properly processed. Often threads were excessively hard and would neither cohere nor dye evenly. A Courtaulds manager complained of viscose rayon in 1906: "the material is no use for weaving." They could not produce top grade product, nor find a market for the material. Between 1905 and 1907, Courtaulds' first rayon plant, located in Coventry, England, turned no profit. The company's focus instead turned to

[52] Beginning in 1885, fabrics made from viscose textile yarn were dubbed "artificial silk." The National Retail Dry Goods Association in the U.S. officially adopted the term "rayon" in 1924. The name was mean to suggest "the bright sparkling rays of the sun, to describe the beautiful lustrous appearance of fabrics made of the yarn." From Leeming, 11, 84.

research, attempting to reinvent the Stearn and Topham method to allow for commercial production. [53]

Courtaulds' experimentation proved the need to refine and adjust almost every component of Stearn and Topham's viscose rayon process. Determining the proper composition of the chemical spinning bath proved to be the greatest challenge.[54] A patent dispute exacerbated the problem by hampering the company's ability to experiment with certain chemical combinations. However, in 1907, one of Courtaulds' in-house chemists discovered that adding glucose to a spinning bath of sulphuric acid created an attractive and flexible spun yarn. Problems with creating consistently high-quality material persisted until company chemists found that combining zinc sulphate with the acid bath led to more uniform production and made "a remarkable difference to the quantity, feel, and appearance of the viscose threads."[55]

During this time period, Courtaulds' scientists also struggled to find a dependable procedure to generate high quality viscose to the supply the plant. Minor discrepancies caused major problems: "variations in wood-pulp, variations in the conditions of steeping, variations in temperature, variations in ageing: all were capable of producing a viscose virtually incapable of being spun into yarn." A marked decline in top quality yarn in the spring of 1909 was traced to excavations for new construction at the Courtaulds' facility. These disturbances caused a slight drop in temperature in the factory cellars used for

[53] D.C. Coleman, *Courtaulds: An Economic and Social History, Vol. II, Rayon* (Oxford: Clarendon Press, 1969), 17, 44, 39.

[54] The chemical spinning bath was required to harden filaments of rayon formed when the viscose spinning solution was extruded through spinnerets. The process is described in detail later in this paper.

[55] Coleman, *Volume II, Rayon,* 46 and 50.

storing viscose. Though the viscose could be spun, the small temperature variance made the finished product low grade. Through such "zig-zag" patterns, Courtaulds' chemists pieced together a picture of the conditions required to produce top quality viscose for a high quality yarn. [56]

Between 1905 and 1913, the years of experimentation and consolidation, rayon became Courtaulds' core product, with profits outstripping those from silk and other fabrics. For the most part, the company now manufactured yarns for sale to textile companies rather than fabrics for consumers. Courtaulds' engineers, who designed looms and mills for weaving silk, continued to play an important role in the company, but rayon manufacturing placed company chemists in a central position. The Coventry plant had its own laboratory in which experimentation on spinning baths and viscose occurred. Consolidation of the viscose manufacturing process and its reliance on rigorous control of chemical processes resulted in expansion of the size and staff of Courtaulds' laboratories. Rayon and the technology required to produce it transformed Courtaulds from "a textile firm into a chemical firm with a textile branch."[57]

Courtaulds initially sold much of their rayon material for decorative braid, embroidery thread, ties, scarves, and pom-poms to decorate children's hats.[58] With growing market success in Britain, the company began to explore purchase of U.S. patent rights on viscose rayon production in 1907. Another

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[56] Coleman, *Volume II, Rayon,* 52.

[57] Coleman, *Volume II, Rayon,* 55, 37.

[58] C.H. Ward-Jackson, 9. Ward-Jackson noted that even once Courtaulds had the basic mechanism for commerical rayon production in hand, "all sorts of queer things happened to the yarn in those early days."

series of fits and starts occurred over the next three years as the company negotiated purchase of patent rights, located land and labor for a new factory, and assembled a management team in the U.S. The company's efforts gained urgency with word of a proposed new tariff act (passed in 1909) in the U.S. Congress that would raise duties on imported artificial silk by 30% or more. If Courtaulds could "get in behind the tariff wall," as sole owners of the U.S. patent, the company would have essentially no competition in the States until the last of their patent rights expired in 1921.[59] The company purchased land on the Delaware River in Marcus Hook, Pennsylvania and, in 1910, incorporated the American Viscose Company (also known as Avisco or AVC).[60]

By 1915, AVC was tremendously profitable, surpassing the rayon output of Courtaulds.[61] Initially, most of the product continued to be used for decorative fibers as well as knit goods, particularly men's socks. Rayon's mass popularity in the U.S., however, began with women's stockings. At the end of World War I when shorter, knee-length skirts became the fashion, sheer rayon stockings sold for about a dollar a pair—in contrast to five dollars a pair for silk—earning rayon the moniker "the middle-class woman's silk."[62] A historian of rayon quipped that "it was on the trim legs of the post-war flappers… that rayon first stepped out into big business."[63] With business booming, American Viscose continued to expand, building six additional factories, each located on a

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[59] Coleman, *Volume II, Rayon,* 105, 120.

[60] Ward-Jackson, 95 and 102.

[61] "Company History: Courtaulds, Plc."

[62] David A. Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: DuPont R&D, 1902-1980* (Cambridge: Cambridge University Press, 1988), 164.

[63] Leeming, 82.

major river: Roanoke, Virginia (1916) on the Roanoke River; Lewistown, Pennsylvania (1920) on the Juniata River; Parkersburg, West Virginia (1926) on the Little Kanawha River; Meadville, Pennsylvania (1928) on French Creek (a major tributary of the Allegheny River); Nitro, West Virginia (1936) on the Kanawha River; and Front Royal, Virginia (1937) on the South Fork of the Shenandoah (see fig. 3). By the time the American Viscose plant opened in Front Royal, Courtaulds and American Viscose had succeeded in building a new industry with powerful technological momentum. Although AVC lost its monopoly on the viscose rayon process in 1921 and had to compete with other manufacturers, the company remained the largest rayon producer in the U.S.

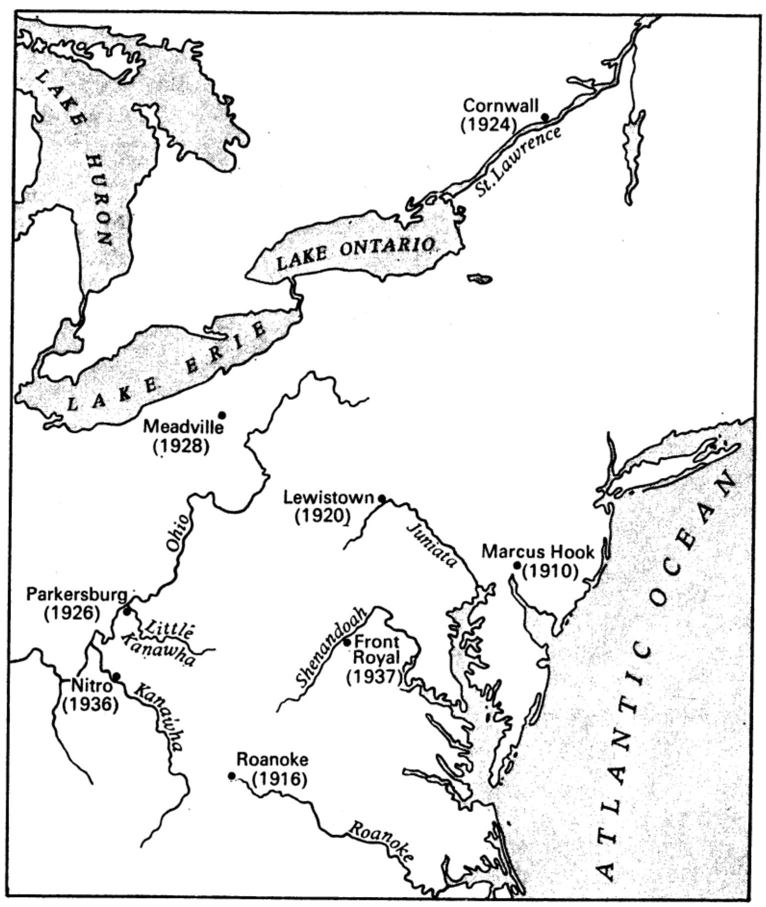

Figure 4. Locations of American Viscose plants along major river systems, circa 1937. *Source:* Coleman, *Volume II, Rayon,* 290.

Chapter 2

World War II Production and Momentum

By 1939, massive disruptions caused by war in Europe changed the field on which business and consumer transactions occurred. For Courtaulds, this led to an event that "marked the end of an era" in the history of the company.[64] Yet while Courtaulds' circumstances changed dramatically with the outbreak of World War II, the momentum of the rayon manufacturing technological system itself continued unscathed and, in fact, intensified.

In wartime, boundaries between industry, politics, and national interests become increasingly fluid. The mixture of Britain's dire need for military supplies, isolationist pressures in the United States, and American economic opportunism created a gap big enough for AVC to slip away from Courtaulds. The American Viscose Corporation's first major role on the global stage was not directly related to the products it manufactured, but to its status as a British-owned corporation. In March 1941, as Britain struggled with shortages of military supplies, the company stood suddenly center-stage in the political theater; with seven factories and eighteen thousand employees, American Viscose was Britain's most valuable industrial holding in the United States.[65]

President Franklin D. Roosevelt's administration walked a fine line in the months leading up to March of 1941. As other European nations fell rapidly

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[64] D.C. Coleman, *Courtaulds: An Economic and Social History, Volume I, The Nineteenth Century Silk and Crape* (Oxford: Clarendon Press, 1969), ix.

[65] "American Viscose is Sold by Britain to Bankers Here," *New York Times* (March 17, 1941): 1; Ron Chernow, *The House of Morgan: An American Banking Dynasty and the Rise of Modern Finance* (New York: Touchstone, 1991), 462.

under Nazi control, the United Kingdom fought for survival, financially strapped, and in dire need of supplies. Many factors tempered Roosevelt's ability to provide material support to Britain. The four Neutrality Acts, passed in the wake of World War I to keep the U.S. out of foreign conflicts, limited U.S. ability to declare war, make cash loans, or provide supplies to combatants on either side of a conflict. With strong isolationist and anti-British sentiment in Congress and the nation, and the presidential election looming in November of 1940, the Roosevelt administration used creative methods to aid the British.

For example, in 1940, Roosevelt declared large quantities of munitions "surplus" and shipped them off to England. However, to retain good public opinion, the administration believed that it was critical for the U.S. receive something in return for military supplies sent to the U.K. Britain purchased some materials under Roosevelt's "cash and carry" policy that allowed sale of military goods to combatants but required them to pay for and transport the goods immediately. In September of 1940, British Prime Minister Winston Churchill agreed to swap ninety-nine year leases on eight British colonial islands "for the establishment of naval and air bases" in exchange for fifty "surplus" U.S. Navy destroyers. Churchill's correspondence with Roosevelt, however, clearly demonstrates that the fifty destroyers were not nearly enough; the British need for military supplies remained dire.[66]

Following his re-election in November, President Roosevelt began to aggressively pursue means to aid the U.K. His friend and Treasury Secretary,

[66] Churchill to Roosevelt, London, August 27, 1940, in *Churchill & Roosevelt: The Complete Correspondence, Vol. I Alliance Emerging, October 1933-November 1942*, ed. with commentary by Warren F. Kimball (Princeton: Princeton University Press, 1984), 68.

Henry Morgenthau, Jr., recorded in his voluminous diaries Roosevelt's explanation of his proposal:

> It seems to me that the thing to do is to get away from the dollar sign… I don't want to put the thing in terms of dollars or loans, and I think the thing to do is to say that we will manufacture what we need, …increase our productivity, and then we will say to England, we will give you the guns and ships that you need, provided that when the war is over you will return to us in kind the guns and the ships that we have loaned to you… [67]

This approach would not require repeal of the Neutrality Acts, since this was not a cash loan or an outright gift to Britain. To the press, Roosevelt declared that Britain fighting Germany was analogous to a neighbor trying to put out a house fire. Rather than demand payment in the midst of the crisis, "certainly, he said, you would lend your garden hose to your neighbor and worry about repayment later."[68]

The President continued to press forth aggressively and eloquently in support of this plan, delivering his famous "arsenal of democracy" fireside chat on December 29, 1940. The blistering speech hammered home the vulnerability of the U.S. to hostile powers and the critical role played by Britain as the "spearhead of resistance to world conquest." Roosevelt also called on industrialists and labor to increase military production to defend the U.S. and support the Allies: "all our present efforts are not enough. We must have more ships, more guns, more planes—more of everything."[69]

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[67] John Morton Blum, *Years of Urgency 1938-1941*, vol. 2 of *From the Morgenthau Diaries* (Boston: Houghton Mifflin, 1965), 347.

[68] Warren F. Kimball in *Churchill & Roosevelt: The Complete Correspondence, Vol. I Alliance Emerging, October 1933-November 1942*, ed. with commentary by Warren F. Kimball (Princeton: Princeton University Press, 1984), 102.

[69] Franklin Delano Roosevelt, *Roosevelt's Foreign Policy 1933-1941: Franklin D. Roosevelt's Unedited Speeches and Messages*, compiled by Douglas Lurton (New York: W. Funk, Inc., 1942): 315, 316.

Behind the scenes, Treasury Secretary Henry Morgenthau, Jr. and his staff worked to put Roosevelt's ideas into legislative form, drafting the future Lend-Lease Act. The bill gave the President broad powers to apportion supplies and decide which countries could receive defense resources. It also left open the question of precisely how countries would repay the loans and leases at war's end.[70] Morgenthau was deeply involved, not only in crafting of the bill, but also in the political maneuverings to get it passed in Congress. As part of this effort, he pushed persistently for the British to demonstrate their commitment to reciprocity in lend-lease.

Many in Congress and the American public were skeptical that Britain could not afford to purchase U.S. military supplies outright. People theorized that England was secreting away billions in gold and other assets in their colonies around the world and trying to hoodwink the U.S. into "financing Britain's war."[71] Because of this concern, much of Morgenthau's Congressional testimony on the Lend-Lease Bill in January 1941 focused on demonstrating the financial need of the British Empire. His tables of expenditures and receipts showed that "British gold resources, holdings of American securities, and investments in the United States and elsewhere in the world, even if entirely liquidated, could not meet [Britain's] deficit."[72]

Despite these numbers, the Roosevelt administration remained of the opinion that Britain should reassure Congress and the American public of its

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[70] *Lend Lease Act of 1941*, Public Law 77-11, *U.S. Statutes at Large* 55 (1942): 32.

[71] D.C. Coleman, *Courtaulds: An Economic and Social History, Vol. II, Rayon* (Oxford: Clarendon Press, 1969), 461.

[72] John Morton Blum, *Roosevelt and Morgenthau: A Revision and Condensation of* From the Morgenthau Diaries (Boston: Houghton Mifflin, 1970), 353.

financial need and commitment by selling off some of its assets in the United States. Conversations between Secretary Morgenthau and his British counterpart on this subject had started as early as July of 1940. Pressure on the British increased in December with the announcement of Lend-Lease. As part of Morgenthau's Lend-Lease testimony in January 1941 before the House Foreign Affairs Committee, he conveyed the promise of a U.K. Treasury official that the British would sell some of their major assets in the United States "as rapidly as possible."[73]

Still the British stalled, scrambling to find other options rather than sell their American investments, which Churchill described as "of a special character… the result of decades of healthy competitive effort." As the U.S. Congressional debates on Lend-Lease continued into March of 1941, Morgenthau grew impatient with the British officials, stating that he had staked his reputation before Congress on what appeared to be a falsehood. On March 10th, the day before Roosevelt signed Lend-Lease into law, Morgenthau stopped by the home of Lord Halifax, the British ambassador to the U.S., to apply some personal pressure. Morgenthau explained that the President would be requesting an appropriation to fund Lend-Lease in a few days and needed to see movement on the U.K.'s promise in order to win Congressional support. His message got through: around midnight on the 10th, British treasury officials exchanged a message "to the effect that some very large company would have to be sold very quickly."[74]

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[73] Coleman, *Volume II, Rayon*, 464; Blum, *Years of Urgency*, 235.

[74] Blum, *Years of Urgency*, 235, 237; Coleman, *Volume II, Rayon*, 468.

President Roosevelt signed the Lend-Lease Act on Tuesday, March 11th, 1941 and immediately requested a 7 billion dollar appropriation from Congress to fund the program.[75] With Roosevelt's backing, Morgenthau set a deadline for the British to complete a sale: March 15th, the following Saturday. American Viscose, Britain's largest and most valuable industrial holding in the U.S., was selected.[76] Using wartime powers, the U.K. Treasury took over AVC's assets and approached potential outright buyers, including Du Pont, another major rayon manufacturer. Anti-trust laws prevented them from acquiring American Viscose, and no other single buyer emerged. The British officials then went to Morgan Stanley & Co. and Dillon, Read & Co., banking firms with whom the British had an existing relationship, to arrange a sale to a syndicate of American bankers.[77] British officials signed the sale agreement on Sunday, March 16th; the Senate approved the Lend-Lease appropriation on March 24th.

As it turned out, American Viscose was the only major British asset sold to U.S. interests; in future transactions, Britain was able to obtain loans using their American holdings as collateral. Unfortunately, due to the unusual circumstances of the sale, Britain received far less for American Viscose than the estimated value of the company. Although valued at over $100 million, the bankers paid less than $63 million and took such a hefty percentage for commissions and expenses that the British Treasury received less than $55

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[75] "President Signs, Starts War Aid; To Ask $7,000,000,000 Fund Today," *New York Times* (March 12, 1941): 1.

[76] Chernow, 462.

[77] Coleman, *Volume II, Rayon,* 461, 483.

million.[78] This remained a sore point with Courtaulds, as well as Churchill, who thought the U.K. had been "fleeced by the bankers."[79] It is interesting to consider that many of the military supplies reaching the U.K. through Lend-Lease in years to come would contain rayon materials from AVC factories. Courtaulds was able to continue rayon production in the U.K. for most of the war years but may not have been able to meet the massive increase in demand for certain rayon products. Perhaps it was fortunate that American Viscose, whose product would become so critical to the Allied powers, was the one major British asset sold to the U.S. Through the War Production Board (WPB) and other government agencies, the government could direct production priorities and raw materials to manufacture an adequate supply.

Events in the Pacific quickly made clear the importance of American Viscose's chemical yarns. Only five pages into his *Arsenal of Democracy: The Story of the War Production Board,* Donald M. Nelson, the first chairman of the WPB, began to write about rubber. It was January 1942; the United States was newly at war with Japan, Italy, and Germany. Nelson wrote that the Japanese "were cutting through the jungles down the Malay Peninsula, engulfing the plantations where the bulk of the world's raw rubber was produced… Soon no more cargoes of irreplaceable raw materials would be leaving those islands for North America. We were really in trouble."[80] Despite the recent expansions in U.S. production of military equipment for national defense and supplying Allied

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[78] Coleman, *Volume II, Rayon,* 461.

[79] Chernow, 463. According to D.C. Coleman on page 3 of *Courtaulds: An Economic and Social History, Volume III: Crisis and Change* (Oxford: Clarendon Press, 1980), the British government awarded Courtaulds £27 million in compensation in July of 1942.

[80] Donald M. Nelson, *Arsenal of Democracy: the Story of American War Production* (New York: Harcourt, Brace and Company, 1946), 7.

countries, America in 1942 faced significant deficiencies in military and material strength. President Roosevelt's administration and military officials knew they would be required to fight a "total war" against the Axis nations, one in which mobility—in trucks, tanks, planes, etc.—was critical.[81]

In Front Royal, Virginia, the new American Viscose Corporation facility had been in operation for one year. In short order, it would become the largest U.S. producer of war-critical high tenacity rayon cord for use in tires, helping stave off a rubber-shortage crisis, and ensure Allied military agility. The uses of rayon and the field of rayon producers diversified by the start of World War II; the major U.S. manufacturers were American Viscose, DuPont, Industrial Rayon, American Enka, and North American Rayon.[82] All of them employed scientists to research new rayon product possibilities. One of their goals was to produce rayon with a higher tensile strength, meaning it could bear greater longitudinal stress than normal rayon before tearing. Such a discovery could open a broad range of industrial uses for rayon.

By the early 1930s, Du Pont was producing a stronger yarn, spurring Courtaulds scientists to develop a better method. By 1935, Courtaulds patented a process for even higher tenacity cord. The key components were a different mix of salts in the acid spinning bath and a mechanism that simultaneously stretched the yarn while applying heat.[83] The added pressure "arranges the long-chain molecules into parallel lines." Since the groups of molecules are in parallel position and thus must be "broken as bundles," high

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[81] Michael Edelstein, "The Size of the U.S. Armed Forces During World War II: Feasibility and War Planning," *Research in Economic History* 20 (2001): 51.

[82] Leeming, 84, 100.

[83] Coleman, *Volume II, Rayon*, 188, 351, 189.

tenacity rayon can withstand much greater force without breaking.[84] Courtaulds started making this rayon for use in tire cord in 1939 at their Coventry plant in England. The American Viscose plant in Front Royal, still under Courtaulds ownership when it opened in 1940, manufactured rayon tire cord from the beginning.[85]

Tire cord plays an extremely important role in determine performance of pneumatic tires. Cords "give the tire its shape, size stability, load-carrying capacity, fatigue, and bruise resistance."[86] Prior to the creation of high tenacity rayon, tire manufacturers used cotton tire cord for this purpose. When World War II broke out, there was little data regarding the relative merits of rayon tire cord over cotton, although preliminary tests suggested that rayon was stronger and ran cooler than cotton.[87] After Japanese movements in the Pacific cut off natural rubber supplies, however, scientists engaged in developing synthetic rubber found that tires made from that substance worked best in combination with rayon tire cord. Thus, global circumstances suddenly made high tenacity rayon tire cord one of the war's most important resources. Although its American Viscose holdings were soon to disappear from their portfolio, "Courtaulds had made a breakthrough [with their 1935 patent] just in time."[88]

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[84] Leeming, 92-93.

[85] Coleman, *Volume II, Rayon,* 351.

[86] Roger A. Fleming and Daniel Isadore Livingston, *Tire Reinforcement and Tire Performance: a Symposium,* Volume 694 of Special technical Publication. American Society for Testing and Materials (Baltimore, MD: ASTM, 1979), 123.

[87] Leeming, 94.

[88] Coleman, *Volume II, Rayon,* 351.

With the marriage of rayon tire cord to synthetic rubber during World War II, the technological momentum of viscose rayon, its manufacturing process, and the corporate producers increased exponentially. At Front Royal, the direct connections between the AVC plant and Allied military efforts had specific long-term impacts. The military need, combined with the social values, aspirations, and fears of the war years, locked in a pattern of production and a relationship with the South Fork of the Shenandoah that changed very little over the remainder of the plant's operating life.[89]

During World War II, the organizational might of the War Production Board became a driving component of rayon's technological system, particularly at American Viscose's Front Royal plant. In January 1942, just over a month after the Japanese attack at Pearl Harbor, President Franklin Delano Roosevelt summoned Donald Nelson to a meeting. Nelson listened in awe as the President "named the coefficients of the unheard-of volume of production which would be necessary to supply the European and the Asiatic theaters of war" and the problems to date with organizing war production. Roosevelt selected Nelson to head up a new entity—the War Production Board—to coordinate a massive expansion of manufacturing. The WPB as presented to Nelson had a remarkable scope of responsibilities and powers:

> to co-ordinate the whole production program; organize, for production, American industry of all sizes and shapes; referee the claims of the Army, the Navy, and the Maritime Commission and get them sources of supply; apportion materials and the use of facilities among claimants—and yet keep our Armed Forces backed up by a stable civilian economy.[90]

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[89] Pinch and Bijker in "The Social Construction of Facts and Artifacts," 39 & 44, describe "stabilization" or "closure" in the form of a technology, in which methods and structures become standard, and the larger social group no longer perceives problems in the technological system.

[90] Nelson, 17, 18.

Within the WPB framework, different offices, divisions, and directors focused on production and conservation of multiple types of resources, including rubber, textiles, chemicals, and rayon. For example, there was an Office of Rubber, a Tire Cord Branch, a Textile, Clothing and Leather Bureau that included a Synthetic Textiles Division, and so on.[91] It was an enormously intricate government apparatus, charged with a mammoth task. Observing just a minute corner of this—the production of rayon for military use—reveals complexities, frustrations, and sobering realities that such a dramatic shift in industrial production required.

America's reliance on imported rubber emerged as one of the great material challenges of the war. By 1940, the U.S. transportation system was largely motorized and thus reliant on rubber for tires. By the time of Pearl Harbor, the nation had built a rubber reserve approximately equal to one year's *peacetime* usage.[92] The WPB's Donald Nelson wrote of the failure to stockpile more rubber during 1940 with frustration: "We had the money and we knew where to get the stuff. Why we didn't exchange the money, of which we had plenty, for war goods or raw materials, I don't know exactly."[93]

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[91] United States Civilian Production Administration, *Industrial Mobilization for War: History of the War Production Board and Predecessor Agencies 1940-1945, Vol. 1, Program and Administration* (Washington, D.C.: United States Government Printing Office, 1947), viii; See all the National Archives collection: Rayon Cord, High Tenacity, Program 1944-1945; War Production Board: Rayon (WPB: Rayon); Records of the War Production Board, 1918 – 1947 (Records of the WPB), Record Group 179 (RG 179); National Archives at College Park, College Park, MD (NACP).

[92] Paul A.C. Koistinen, *Arsenal of World War II: The Political Economy of American Warfare, 1940-1945* (Lawrence, KS: University Press of Kansas, 2004), 148.

[93] Nelson, 153.

First with Lend-Lease and then as the U.S. entered the war, the urgent need for rubber for tire production became increasingly clear. Historian Michael Edelstein wrote that this necessity for rubber and other resources grew from the U.S. decision to fight a "capital intensive war," relying heavily on equipment like tanks and planes. This was in part an effort to avoid the heinous trench warfare of World War I, but the U.S. also faced a German army that had successfully used tank and air offenses against Poland, France, and Russia.[94] Meeting this fast-moving enemy compelled the U.S. to rapidly create mobile, military machinery in quantity, and that required rubber tires for trucks, tanks, planes and numerous others military resources.

The nascent production of synthetic rubber as of 1941 was nowhere near adequate to meet wartime demand. Soon after Pearl Harbor, Nelson reported to Roosevelt and Churchill that the U.S. had inadequate supplies of natural rubber and no synthetic rubber facilities, only "a rather promising technique for the manufacture of synthetic rubber…" He wrote, "I think we are going to be in terrible straits… The United States travels on rubber, and our army is helpless without it. We even use tremendous quantities in building warships and airplanes."[95] In order to buy time to develop synthetic rubber manufacturing, the War Production Board placed limits on civilian use of rubber, rationing tires, tubes, and gasoline, lowering the speed limit, and prioritizing allocations.[96]

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[94] Edelstein, 51.

[95] Nelson, 188.

[96] Koistenin, 149.

As efforts to put synthetic rubber into production intensified, high tenacity rayon cord became increasingly important. Military and civilian tests undertaken in the early years of the war indicated that cotton cord was “probably unsatisfactory” for use with synthetic rubber. The Army and Navy Munitions Board requested a priority designation for rayon tire cord in the spring of 1942. A May 3rd confidential report named high-tenacity viscose rayon as the military’s preferred choice for tire cord due to its strength, resistance to high temperature, greater mileage, and use of “less strategic raw materials than the other types.” While stating that, “no substitutes are available for rayon,” the report also identified the major drawback of high tenacity rayon: like natural rubber and synthetic rubber, it too was in short supply. “Motor transport alone could consume about three times the entire proposed production of 1943.”[97] In September 1942, the War Production Board signaled its concurrence and gave rayon tire cord an Urgency rating.[98]

The designation granted the WPB power to require rayon manufacturers to produce high tenacity cord and to dictate quantities. The WPB worked with companies to supply machinery and raw materials, locate adequate labor, and expand facilities. The five rayon-manufacturing companies in the U.S.—American Viscose, DuPont, Industrial Rayon, American Enka, and North American Rayon—expressed willingness to participate and submitted plans to shift production from rayon for consumer use to high tenacity rayon. Only

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[97] “May 3, 1942 Confidential Report, Commodity Status Report from the Commodities Division of the Army and Navy Munitions Board: For use of the Army, Navy, and Maritime Commission only.” Rayon Reports and Histories CONFIDENTIAL (Declassified); WPB: Rayon; Records of the WPB, RG 179; NACP.

[98] “Memorandum from Saul Nelson to Mr. Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945,” Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP; 3-4.

American Viscose tried to stipulate conditions for increasing their supply of high tenacity rayon, requesting that the government "assure a market for the yarn 'for a long enough time to justify conversion and the investment involved'… and 'grant a price increase sufficient to reimburse the corporation for its loses resulting from conversion.'"[99]

Quantities of synthetic rubber manufactured in the U.S. jumped over the course of the war, from 28 million tons in 1942 to nearly 922 million tons in 1945.[100] Rayon producers and the War Production Board had to scramble to keep up. Internal WPB documents demonstrate the challenges inherent in this process. For the first two years, rayon production always lagged behind projected military needs, as expansion at the factories took longer than expected. In March of 1943, new tire tests found that rayon cord was absolutely essential for larger sizes of synthetic rubber tires. Other tire cord materials, such as cotton, could not adequately support the weight of large tanks and trucks. Projected requirements for high tenacity rayon cord for the remainder of 1943 and 1944 grew dramatically. Requirements for 1944 more than doubled.[101]

Demand increased further as military supply units adjusted their requests for tire cord to fit emerging needs. In early 1944, Donald Nelson at the WPB broke the news that a new manufacturer of synthetic rubber would

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[99] "Memorandum from Saul Nelson to Mr. Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945," 5. It is interesting to note that throughout the WPB rayon files, American Viscose often crops up as one of the more troublesome producers in the rayon industry.

[100] Koistenin, 149.

[101] "Memorandum: Saul Nelson to Mr. Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945," 5-6.

increase production considerably, so that supplies of synthetic rubber threatened to "exceed the corresponding supply of tire cord." Rayon mills were already strained, needing to produce enough material for both military use and "essential civilian requirements."[102] The military demand strained supplies for "vital and indispensible civilian activities as transportation and farming."[103] To meet these demands, the WPB had no option but to shift materials and labor to support rayon cord manufacturing.

Certain requirements for production of high tenacity rayon compounded the challenge of manufacturing adequate supplies. For one, processing the material required sufficient quantities of chemicals. By 1942, the War Production Board controlled all allocations of sulfuric acid, one of the main chemicals involved in rayon production.[104] The agency covered all costs for General Chemical Company to build and operate a new factory adjacent to American Viscose. An elevated pipeline crossed the fence between the properties and pumped sulfuric acid directly into the rayon plant.[105] Early in the war, the WPB also designated Stauffer Chemical Company to build a factory near Front Royal to produce 26.4 million pounds of carbon disulfide annually.

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[102] Ibid., 4.

[103] "Memorandum: Donald M. Nelson to Textile Division. Subject: Tire Cord, February 28, 1944," Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

[104] "Plaintiff's Pretrial Memorandum, Phase I – Liability (Amended as of 3/20/91)," 33-34; DOJ Documents, (Box 7 of 10) FMC v. Commerce, Court of Appeals, Appendix, Vol. 1, Dist. Ct. Docket; Avtex Fibers records, 1942-1997 (Avtex Fibers records), Call number 37962 (CN 37962); Library of Virginia State Records Center, Richmond, VA (LVASRC).

[105] Information gathered from two documents in the Avtex Fibers records at the Library of Virginia State Records Center (LVASRC): "Deposition of Richard R. Almy, Nov. 8, 1990," 74; DOJ Documents, FMC v. Commerce, Court of Appeals, Appendix, Vol. 3, Depositions; and "Testimony of Herman F. Stuhr, Plaintiff's Witness – Excerpt of Non-Jury Trial Before the Honorable Clarence Newcomer, US District Judge, March 25, 1991, Philadelphia, PA – Civil No. 90-1761," 93; DOJ Documents, (Box 7 of 10) FMC v. Commerce, Court of Appeals Appendix, Vol. 2, Trial Testimony; Avtex Fibers records, CN 37962; LVASRC.

The plant's "entire output was to be consumed by the [American Viscose] Facility."[106]

The WPB sought to keep their investments safe, highlighting again the critical value of high tenacity rayon to the military. As the war went on, security guards were organized and enrolled into a civilian auxiliary to the Army's Military Police. The Brigadier General in charge of the military police spoke to the Guard about preventing "espionage, sabotage and other threats."[107] Herman F. Stuhr, a manager at the rayon plant from 1940-1976, described his realization of the true military importance of high tenacity rayon when the guards at the plant began to wear guns.[108]

The military need was such that the WPB even converted some munitions factories over to manufacturing machinery for rayon production. The machines used to make rayon yarns for fabrics and other civilian goods could not produce high tenacity rayon tire cord. Facilities needed specialized equipment to stretch, spin, and twist rayon yarn into cord. This was one of the disadvantages of rayon over cotton: "the twisting and weaving of rayon cord require[d] considerably more facilities than for an equal poundage of cotton."[109]

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[106] "Plaintiff's Pretrial Memorandum," 35; DOJ Documents, (Box 7 of 10) FMC v. Commerce, Court of Appeals, Appendix, Vol. 1, Dist. Ct. Docket; Avtex Fibers records, CN 37962; LVASRC.

[107] "Stipulated Testimony of Ralph Minnick, FMC Corp. v. US Dept of Commerce et al., Civil Action No. 90-1761," 2; DOJ Documents, (Box 8 of 10) FMC v. Commerce, Federal District Court, District Court Pleadings; Avtex Fibers records, CN 37962; LVASRC. Minnick explained in his testimony that he began work at AVC as a security guard in 1940 and enrolled in the Army's civilian auxiliary to the Military Police in 1943.

[108] "Testimony of Herman F. Stuhr," 132.

[109] "Memorandum: T.R. Milne to George Lanier. Subject: Tire Cord Program—Twisting and Weaving Facilities, December 6, 1943." Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

Unfortunately, the existing facility at Front Royal did not have adequate space to accommodate the new spinning machines and other necessary equipment.

Despite the setbacks, the American Viscose plant at Front Royal grew to be the largest producer of high tenacity rayon in the U.S., increasing its capacity from 25 million pounds to 82 million pounds annually,[110] and manufacturing roughly a third of total U.S. output. Expansion of the plant to accommodate this production proceeded with a variety of twists and turns. A shortage of labor ranked among the most difficult challenge for the WPB. Stonewalling by both the War Manpower Commission and the Virginia Draft Board delayed WPB requests for draft deferments for textile workers. Bureaucratic wrangling also slowed the transfer of additional workers from other industries to the Front Royal facility by several months. J. Spencer Love, Director of the Textile, Clothing and Leather Bureau of the WPB, fumed that if the requested employees had been made available to all U.S. rayon producers, "hours of operation would have been brought to 144 per week with a resultant increase in production of 16,500,000 pounds of cord per half year."[111] Industry wide, the estimated shortage of manpower in early 1944 was 2,500 people or 6%. According to Love, this was "the main problem confronting the industry." New cord twisting machines arrived at the rayon plants with no one to run them.[112]

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[110] "Memorandum from Saul Nelson to Mr. Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945," Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP, 8.

[111] "Memorandum: J. Spender Love to James Jacobson, January 12, 1944." Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP, 2.

[112] "Memorandum: J. Spencer Love to L.R. Boulware. Subject: Monthly Report on Status of Tire Cord Program, Feb. 8, 1944." Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

These challenges manifested in a variety of ways at the American Viscose plant in Front Royal. At its peak, the plant employed a combined total of nearly 4,000 people either working inside the plant making rayon or doing construction to expand the facility. Labor shortages due to military enlistments and the draft required plant managers to scour the countryside in search of workers. In order to conserve tires and supply as much local labor as possible, the WPB sponsored buses to crisscross the Shenandoah Valley picking up workers for the various shifts at the plant. Workers transferred from out-of-town by the War Manpower Commission in Front Royal only to find a severe housing shortage in the community. The WPB faced additional bureaucratic struggles, this time with the National Housing Agency, to gain authorization to construct new housing, which in turn required additional labor to complete.

Difficulties at the top sifted down into dissatisfaction among workers. By coincidence, a special tire cord meeting, called by WPB chief Donald Nelson in March of 1944, occurred the same morning that employees of Rust Engineering at the plant in Front Royal went on strike. Most of the workers were imported construction labor working on the many expansions to the plant. Housing shortages led to the strike; the community needed about 400 trailers, as well as barracks and houses, to accommodate both the construction labor and the "in-migrants" supplying the mill with new operating personnel. The meeting minutes blame the War Manpower Commission for the delay and reflect the selection of a special representative to ensure delivery of the trailers. The meeting minutes also note with alarm that the strike could further destabilize efforts to meet rayon objectives for the year.[113]

In response to such events, Nelson's staff encouraged him to take steps to improve morale at facilities like Front Royal. They note questions among men in the mills about "whether the government was really serious in their desire for increased production." [114] Long hours and challenging working conditions increased the workers' frustrations with the company. The WPB attempted to pressure the U.S. rayon plants to run mills seven days a week. Some met the requirement; others could not convince "their labor to operate at all on Sunday."[115]

These challenges were never completely remedied, but the WPB and American Viscose made an effort to reward employees and emphasize the importance of their work for the national cause. Nelson visited factories and met in-person with producers. He specifically recommended that manufacturers show their workers a certain motion picture that demonstrated vividly "the urgency of the entire war program and the need for its full support."[116] Actress Greer Garson visited Front Royal and gave a talk at

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[113] "Minutes of the Tire Cord Meeting, March 10, 1944." Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP, 3. Also see "Deposition of Charles Leadman, Nov. 7, 1990," 75; DOJ Documents, FMC v. Commerce, Court of Appeals, Appendix, Vol. 3, Depositions; Avtex Fibers records, CN 37962; LVASRC. Charles Leadman served in various leadership positions in the Textile Workers Union of America's Local 371, which represented workers at the rayon plant, for nearly forty years. He made emphatically clear in his testimony that TWUA members did not join or endorse the construction workers' strike.

[114] "Minutes of the Tire Cord Meeting, March 10, 1944," 2; Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

[115] "Memorandum: J. Spencer Love to James Jacobson, January 12, 1944." Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

[116] "Minutes of the Tire Cord Meeting, March 10, 1944," 4-5; Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

American Viscose emphasizing the importance of increased production for the war effort.[117] Toward the end of the war, the WPB organized a rally at the Front Royal plant to award to the facility "the E for Excellence that the War Production Board awarded for excellence in War Production."[118] In addition, AVC organized "family nights" at the plant featuring shows, food, and games with prizes for children (see fig. 5). *Avisco News,* a company publication, included employee appreciations, as well as news and letters home from AVC workers in military service overseas.[119]

Figure 5. Family night at the AVC plant, 1943. Courtesy of Warren Heritage Society.

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[117] "Deposition of Richard R. Almy," 41. Almy trained as a mechanical engineer and served first as assistant chief plant engineer, later promoted to plant engineer, at AVC: 4, 12

[118] "Testimony of Herman F. Stuhr," 108.

[119] *Avisco News* collection and photographs from the Avtex Collection, Union Papers; Laura V. Hale Archives; WHS.

In addition to labor problems and friction from other government agencies, challenges to rayon production sometimes came from within the War Production Board. In October of 1944, the WPB Operations Office—without the knowledge of the WPB's Tire Cord Branch—removed high tenacity rayon yarn from the Production Urgency List. Inclusion on the list meant that plants received priority in the apportionment of labor and construction of facilities.[120] The director of the Textile, Clothing and Leather Bureau, J. Spencer Love, expressed grave concern to the Operations Vice Chair, and requested that "high tenacity rayon construction and production" be reinstated on the list. Love explained that the Rubber Bureau continued to increase its requirements for the rayon cord, while yarn production lagged behind forecasts. Most of the delay, Love wrote, stemmed from "labor shortages or work stoppages of one sort or another." The continued protection of the Urgency List was crucial, "particularly at Front Royal, VA" and two other facilities. Love closed his memo with a plea: after suffering from chronic labor shortages for a year and a half, reducing the urgency status of rayon tire cord would be demoralizing for the mill workers, "just at a time when they are beginning to climb the hill toward full utilization of their facilities."[121]

Throughout World War II, American Viscose at Front Royal faced constant challenges, proceeding by a multilinear path, rife with trail and error. In January of 1945, expansion at the facility still lagged months behind

[120] United States Civilian Production Administration, 840.

[121] "Memorandum: J. Spencer Love to Hiland G. Batcheller. Subject: Production Urgency List, October 21, 1944," 1; Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

schedule. A thirty-three page memo on the "Development of War Production Board Tire Cord Program" outlined reasons for the hold-up:

> While the principal difficulty in connection with this project appears to have been the shortage of labor as such, some contributing factors are suggested by the following statement contained in the May 15, 1944 Monthly Progress Report of the Tire Cord Branch: "The project at Front Royal has suffered from lack of coordination of the efforts of scores of individually competent people, representing the government and the company, to do something about labor, housing, community services, and a multitude of related matters."[122]

The WPB thus summarized the difficulties and failings during World War II at the American Viscose plant in Front Royal. One issue, however, that proved to have lasting and devastating repercussions, remained unmentioned in any existing War Production Board documents: the disposal of huge quantities of chemical byproducts from manufacturing high tenacity rayon.[123] The priorities and urgency of the war sidelined any concerns about waste disposal or protection for the Shenandoah River.

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[122] "Memorandum: Saul Nelson to Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945," 12; Rayon Cord, High Tenacity, Program 1944-1945; WPB: Rayon; Records of the WPB, RG 179; NACP.

[123] It is possible to make such a broad statement with a fair degree of confidence. Several federal agencies and the FMC Corporation filed lawsuits over liability for cleanup of these wastes in the 1990s. The extensive research undertaken by each side located no direct reference to chemical wastes in WPB documents. However, using eyewitness reports and secondary documentation, FMC successfully demonstrated that the WPB had knowledge of waste disposal practices and problems. The courts ruled that the Department of Commerce (which absorbed the WPB after the war) was liable for a percentage of cleanup costs due to the WPB's control of production of high tenacity rayon and heavy involvement with supplying machinery, chemicals, raw materials, and labor that contributed to increased waste.

Chapter 3

Manufacturing Rayon, Manufacturing Toxic Waste

World War II added a tremendous amount of technological momentum to the rayon plant at Front Royal. At the same time, however, the massive increase in production destabilized the plant's relationship to the South Fork of the Shenandoah. American Viscose's dependence on the river grew more than threefold since the start of the war. With an output, by 1945, of 82 million pounds of high tenacity rayon cord per year, the plant used at least 41 million gallons of water every day, and probably a good deal more.[124] The river helped to win World War II. Unfortunately, the massive increase in rayon production created a flood of chemical wastes needing treatment and disposal.

Technologies for treating chemical waste in the 1940s were inadequate to begin with. The wastewater treatment facility at American Viscose was engulfed and overwhelmed, an example of how the managers of rayon's technological system interacted with the river "without fully understanding what they [had] created" and what rayon waste could do.[125] By 1945, the river was a casualty of war. From the American Viscose outflow pipe to the confluence with the Potomac at Harper's Ferry, the Shenandoah was essentially dead. The chemical

[124] Descriptions of manufacturing procedures for high tenacity rayon suggest that the process required more water than regular rayon fiber production. In addition, since the facility continued to produce smaller quantities of rayon staple (a fiber that resembles and often is used as a substitute for wool) throughout the war, the daily water needs were probably even larger. See "Deposition of Charles Leadman, Nov. 7, 1990," 55; DOJ Documents, FMC v. Commerce, Court of Appeals, Appendix, Vol. 3, Depositions; Avtex Fibers records, CN 37962; LVASRC.

[125] White, 113.

wastes entering the river had "almost eliminated aquatic life in the Shenandoah River for a 50-mile stretch."[126]

The chemicals that devastated the river came from each stage of the viscose rayon manufacturing process. Each step in the transformation of wood cellulose into rayon yarn involved some sort of chemical; none of them were healthy for the South Fork. Viscose rayon begins with tree pulp. American Viscose sourced most of its pulp from softwood trees such as spruce and hemlock grown in Alaska, Canada, and the Pacific Northwest. Chipping, pulping and pressing the trees occurred off-site, so that the cellulose arrived by boxcar at the Front Royal site as white sheets, said to resemble blotting paper (see fig. 6).[127]

Sodium hydroxide, frequently referred to as caustic soda or lye, was the first chemical used on-site in the rayon process. The cellulose sheets soaked in large tanks full of caustic soda diluted with water; this expanded the fiber, leading to a thicker viscose solution.[128] The sheets were mechanically pressed to remove excess liquid, then crumbled and shredded into a material termed "white crumb" (see figs. 7-9). The crumbs had to age for two or three days in carefully controlled conditions in order to correctly oxidize the material. Carbon disulfide (CS_2) in gas form was the next chemical involved in the process. Churning the aged white crumb with carbon disulfide created a cellulose xanthate, yellowish in color, and thus referred to as "yellow crumb." This

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[126] Versar, Inc. "Avtex Fibers Responsible Party Search and Financial Assessment: Draft Final Report, Prepared for U.S. Environmental Protection Agency. January 29, 1985," Avtex Administrative Record, EPA, http://loggerhead.epa.gov/arweb/ public/ pdf/136013.pdf (accessed May 6, 2009), 3.

[127] American Viscose Division/Fiber Operation, "Welcome to FMC-Front Royal," Pamphlet, Union Papers; Laura V. Hale Archives; WHS. *Note:* Figures 6-15 can be found on pages 62-66.

[128] Leeming, 27.

material, when mixed again with dilute caustic soda, dissolved into a viscose: a thick, honey colored, cellulose xanthate suspension.

Viscose "ripened" for four or five days in climate-controlled viscose cellars. Part of the xanthation reaction (the chemical reaction of carbon disulfide with cellulose) reversed at this time, leaving a material that regenerated more easily to cellulose in the next phase of production. The reversible reaction also freed CS_2 gases from the viscose into the air. The viscose next underwent filtering and degassing; if it met specifications, the material was pumped to the Production Department.

The next phase of the process regenerated the cellulosic fibers in the viscose into continuous filaments. Pumps forced the viscose through platinum spinnerets, devices resembling very small shower heads, each punctured with hundreds of small holes. The resulting fibers immediately entered an acid spinning bath that solidified the cellulose into continuous rayon fibers. The spinning bath comprised a mix of chemicals; the composition varied for different types of rayon, but in general, the bath contained sulfuric acid, sodium sulfate, zinc sulfate, and glucose.[129] Again, amounts varied depending on the type of rayon, but in general, making one pound of rayon required approximately one pound of wood pulp, "1.8 pounds of sulfuric acid, 1.4 pounds of sodium hydroxide, 0.5 pounds of glucose, 0.4 pounds of carbon disulfide, 0.4 pounds of other chemicals," as well as caustic soda, and at least 175 gallons of water.[130]

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[129] Information on the production of viscose rayon from "Rayon Fiber (Viscose)," FiberSource, http://www.fibersource.com/f-tutor/rayon.htm (accessed April 22, 2009); and Daniels, "Avtex Fibers Rayon Plant."

[130] Groves and Settle, 686.

As they emerged from the acid baths, the rayon threads wound through several wheels and spun into a revolving box (see figs. 10-11). The process, called box spinning, stretched the threads, causing the cellulose chains to line up in approximately parallel lines and giving the rayon threads greater strength. Higher levels of tenacity required more extensive stretching later in the process and thus additional equipment (see figs. 12-13). When the box filled up, the spinning machine had to be shut down to remove the spun yarn, now referred to as a "cake." Special cabinets stored the cakes for a short time to allow further venting of carbon disulfide. Next the Cake Wash Department sent the material through a huge machine that washed, bleached, and dried the cakes of rayon yarn (see figs. 15-16).[131] Creation of the major chemical wastes essentially stopped at this point in the procedure; remaining steps involved twisting the yarn and preparing it for shipping. While the plant was in operation, this process from steeping cellulose to shipping finished rayon yarn was continuous. Thousands of gallons of viscose moved through the plant every hour.[132]

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[131] Daniels, "Avtex Fibers Rayon Plant."

[132] "Testimony of Herman F. Stuhr," 54.

Figures 6-19. Rayon production procedure at the American Viscose plant in Front Royal, early 1940s.

Figure 6. Cellulose sheets in storage, 1941. Courtesy of WHS.

Figure 7. Loading cellulose sheets for steeping in sodium hydroxide, 1941. Courtesy of WHS.

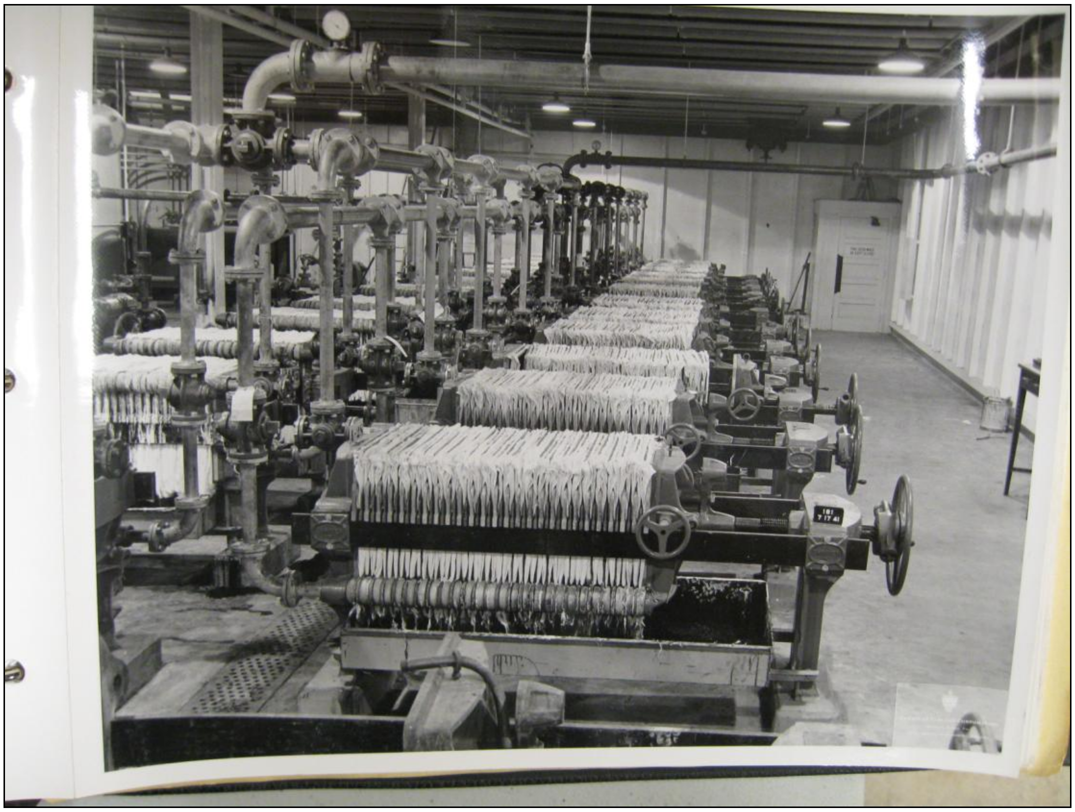

Figure 8. Pressing cellulose sheets after steeping in sodium hydroxide, 1941. Courtesy of WHS.

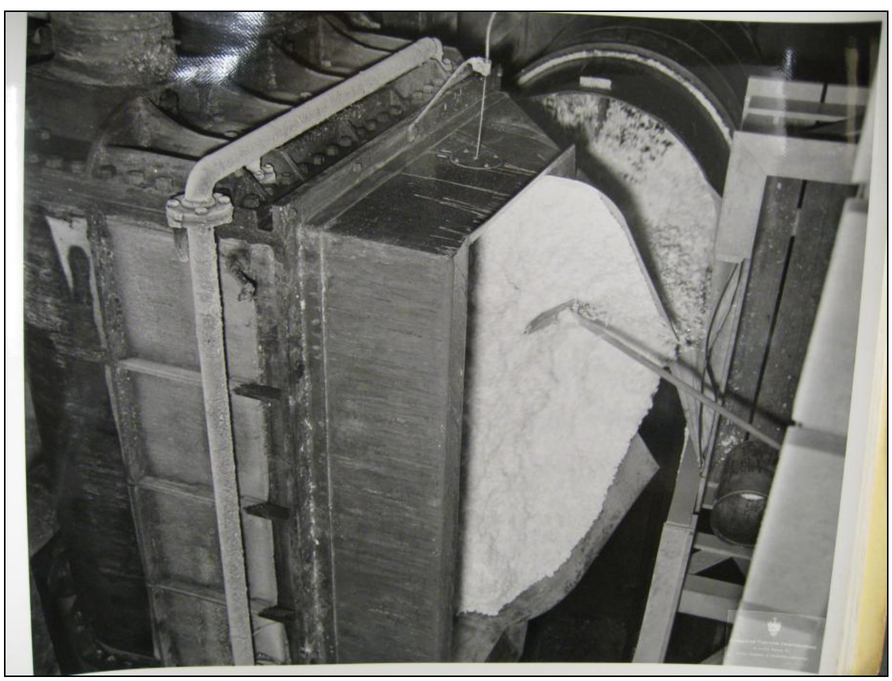

Figure 9. White Crumb, 1941. Courtesy of WHS.

Figure 10. Spinning machines. Courtesy of WHS. ***Note:*** **It is unclear whether this photo shows machines used to spin high tenacity rayon yarns for tire cord or a lower tenacity fiber.**

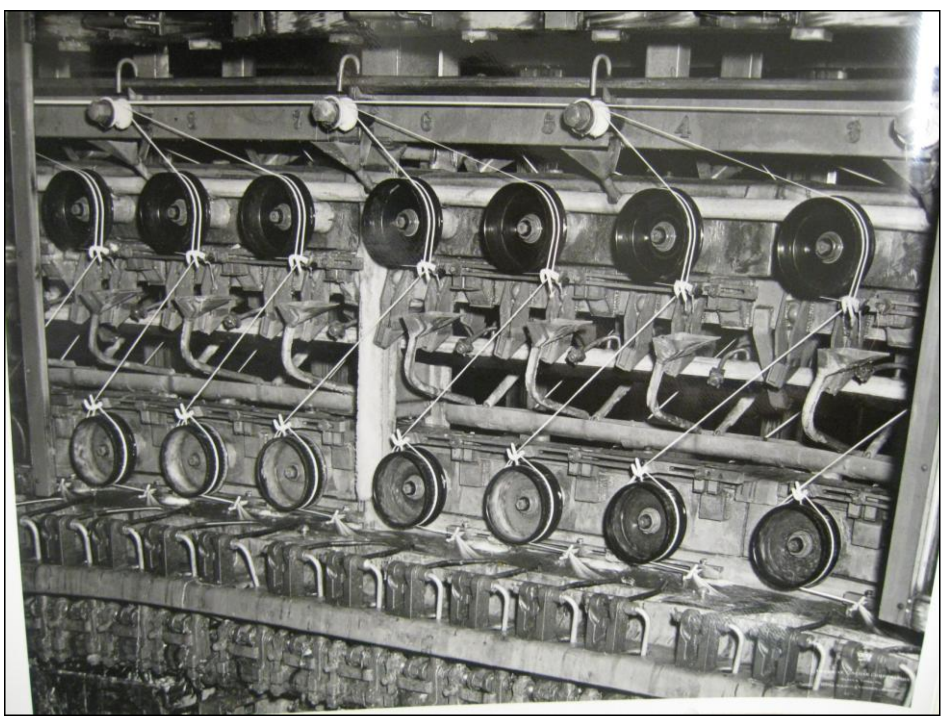

Figure 11. Detail of spinning machines. Courtesy of WHS.

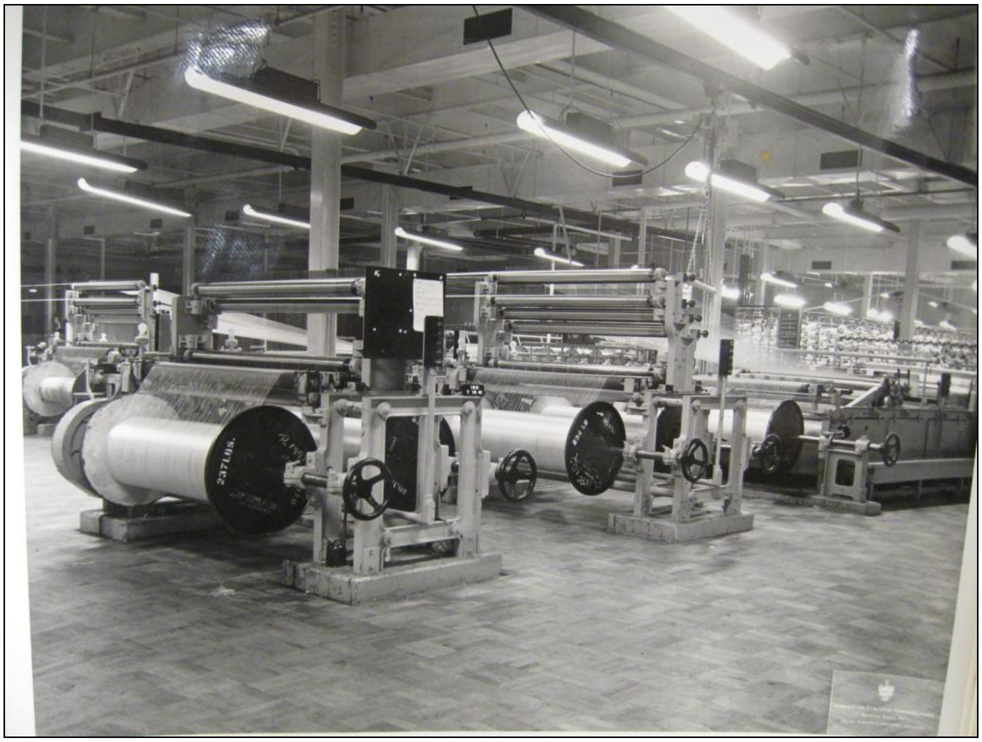

Figure 12. Stretching and winding rayon yarn to make high tenacity cord. Courtesy of WHS.

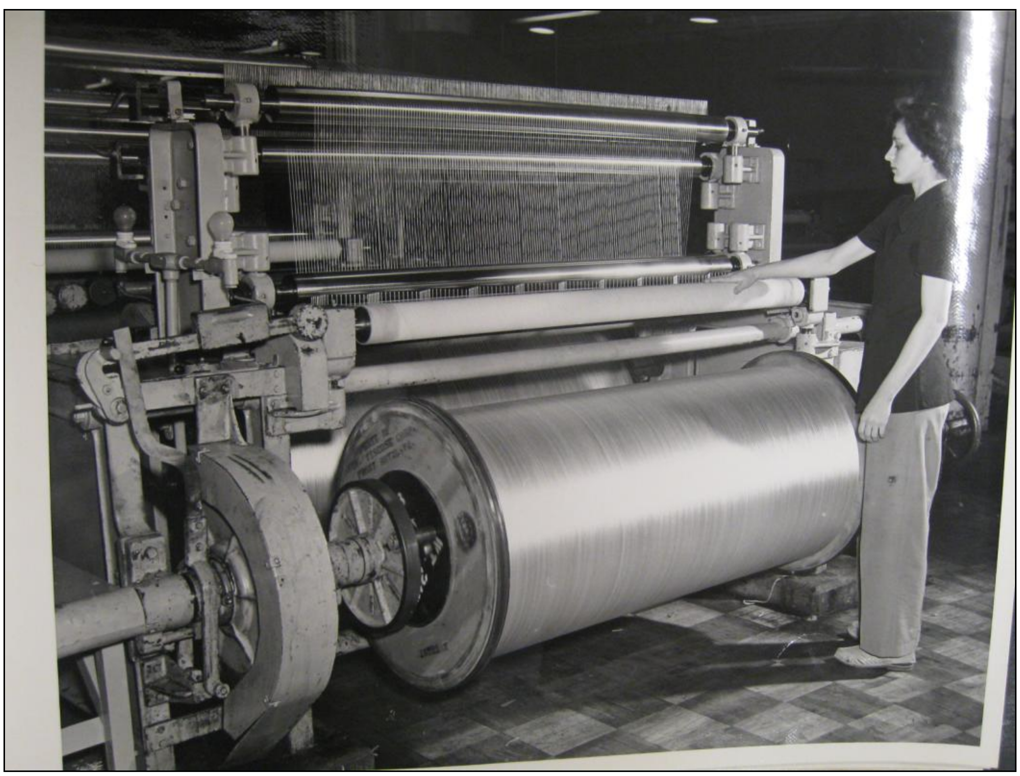

Figure 13. Close up of stretching machine and worker, 1943. Courtesy of WHS.

Figure 14. Loading cakes of rayon into cake wash machine, 1941. Courtesy of WHS.

Figure 15. Detail of cake wash machine, 1941. Courtesy of WHS.

The continuous rayon manufacturing process required a tremendous amount of electricity. While the plant was under construction in 1938, Front Royal's Town Manager noted, "they will use about 80 times as much electricity out there as we use in the whole town."[133] To meet this need, the facility built its own coal-burning power plant with six boilers on-site. Train cars delivered coal directly to the plant from the Norfolk and Western tracks that bisected the property. In the 1980s, estimates showed that the plant used roughly 1,000 tons of coal a day; it would likely have used much larger amounts in previous decades when production levels were higher. Many other materials for the facility also arrived by rail: tank cars with chemicals and fuel oil, box cars of pulp sheets, lumber, machinery, and rock salt for softening water.[134]

The technological system of the rayon plant required inputs of these multiple materials and produced a range of toxic outputs, all of which had an eventual harmful impact on the health of the South Fork of the Shenandoah River. All told, the rayon facility produced three main hazardous waste streams: fly ash from burning coal in the power plant; alkaline wastes, especially off-specification sodium cellulose xanthate-based viscose, commonly referred to as "waste viscose;" and liquid acid wastes with zinc-hydroxide and other salts from the acid bath process.[135] The Avtex facility made several types of viscose rayon yarn over the course of its operating life, each requiring

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[133] Sadler, "Front Royal Prepares for $20,000 Rayon Plant."

[134] Daniels, "Avtex Fibers Rayon Plant."

[135] B.N. Scheuer, *Waste Treatment at the Front Royal Plant of the American Viscose Corporation*, Report, (September 12, 1947), 1; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC; see also Exponent Engineering and Scientific Consulting, "Feasibility Study Work Plan: Avtex Fibers Superfund Site, Operable Unit 7. Report prepared for FMC Corporation, August 2000," Avtex Administrative Record, EPA, http://loggerhead.epa.gov/arweb/public/pdf/ 464550.pdf (accessed May 3, 2009), 6.

variation on this basic manufacturing procedure. However, the processes were similar enough that the waste streams and avenues by which the chemicals migrated into the environment were essentially the same.

Carbon disulfide entered the environment as a liquid, gas, or component of waste viscose. Since the reaction of CS_2 with the cellulose in "white crumb" was reversible, the chemical constantly released from the resulting viscose substance into the surrounding environment. Thus, during every stage of the process after xanthation occurs—the ripening, spinning, venting, and washing processes—carbon disulfide returned to its original chemical composition and "escaped" into the air, the acid spinning bath, or the cake wash water. The factory vented airborne CS_2 through its smokestack. At present, viscose rayon factories remain the primary source of carbon disulfide in the atmosphere and the environment in general. In modern day rayon plants, ventilation into the atmosphere can total anywhere between 15 and 40 tons per day.[136] For years, residents of the Front Royal community ruefully joked that the rotten-egg stench of carbon disulfide "smelled like money."[137]

The financial benefit of the rayon plant came with a high cost, both to human health and to riverine life in the South Fork. Excessive exposure to carbon disulfide has dramatic health effects in humans and other mammals, including nerve, vascular, and ophthalmologic damage, as well as psychological

[136] World Health Organization, "Chapter 5.4 Carbon disulfide," *Air Quality Guidelines for Europe*, Second Edition, WHO Regional Publications, European Series, No. 91, Copenhagen 2000, http://www.euro.who.int/ document/aiq/5_4carbodisulfide.pdf (accessed May 8, 2009), 1.

[137] B. Drummond Ayres, Jr., "Jobs Are Lost in Plant Shutdown, but So Is Foul-Smelling Air," *The New York Times* (Tuesday, November 21, 1989), http://www.nytimes.com/1989/11/21/us/jobs-are-lost-in-plant-shutdown-but-so-is-foul-smelling-air.html?pagewanted=all (accessed November 22, 2009), A16.

disturbances.[138] Safety reports compiled by the union at American Viscose in 1946, before protective eyewear became mandatory, described employees suffering from an undisclosed set of symptoms termed "fume eyes."[139] Aquatic species in the South Fork of the Shenandoah River also demonstrated adverse reactions. The most impacted were at the bottom of the food chain: aquatic invertebrates experienced reduced hatching and development defects; frogs and small fish showed deformities, and growth of algae was inhibited.[140] Carbon disulfide could also contaminate the environment when waste viscose was disposed of improperly. As the viscose continued to age, carbon disulfide continued to release into whatever medium was available. If left exposed, rainwater could percolate through the waste viscose, capture CS_2 and carry it into groundwater, streams, or into the river.

Alkaline wastes from American Viscose also contaminated the South Fork. The equipment at the factory reclaimed much of the caustic soda used in the steeping presses; however, some cellulosic material remained mixed in the caustic soda after the pressing process. The reclaim system separated the two, leaving a material called "heavy cellulose." Standard operating procedures in the early 1940s called for the substance to be discarded into a chemical sewer; it is unclear whether this sewer drained directly to the river in the early '40s. Heavy cellulose in an aquatic environment could be dangerous. The material

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[138] World Health Organization, 1 and 4.

[139] Textile Workers Union of America Local 371, Safety Report from 1946; Safety – Am. Vis. Co. 1946; Avtex Collection; WHS.

[140] These impacts vary by species. From R. Newhook, M.E. Meek, and D. Caldbick, "Concise International Chemical Assessment Document 46: Carbon Disulfide," (Geneva: World Health Organization, 2002) http://www.who.int/ipcs/publications/cicad/ cicad46_rev_1.pdf (accessed February 27, 2010), 21.

had a high biochemical oxygen demand (BOD). Herman Stuhr, a chemical engineer and manager at the plant from 1940-1976, explained that BOD "is a very common problem with almost anything that gets in a river. It tends to reduce the available oxygen for fish or anything else that lives in the river." In addition, despite the reclaim system, some caustic soda still left the plant either with the heavy cellulose, in the cake wash water, or in the form of waste viscose. If improperly aged, the alkaline "white crumb" material could become unusable and join the waste stream.[141] At certain concentrations, caustic soda—aka sodium hydroxide—is extremely corrosive, dangerous to human and environmental health. It can raise the pH of aquatic environments and is extremely toxic for fish and aquatic plants.[142]

Acid and zinc wastes from the spinning baths comprised the third major waste stream from the rayon plant at Front Royal. Although a reclaim system allowed reuse of much of the acid bath, a significant quantity still left the plant. In fact, wastewater treatment efforts in the early 1940s targeted sulfuric acid. The water used to wash rayon yarn was the main carrier, although accidents and overflow from other parts of the process caused occasional blasts of acid into the treatment system. Sulfuric acid is also a highly corrosive substance, but unlike caustic soda, it drops the pH level in aquatic ecosystems. Sulfuric

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[141] "Testimony of Herman M. Stuhr," 47, 51.

[142] "Case: Kinder Morgan Sodium Hydroxide Spill, N.J.," Damage Assessment, Remediation, & Restoration Program, Northeast Region, National Oceanic and Atmospheric Administration, http://www.darrp.noaa.gov/northeast/kinder/index.html (accessed February 28, 2010).

acid in high enough concentrations can wipe out a wide range of aquatic life, from macroinvertebrates, to shellfish, fish, and aquatic plants.[143]

Courtaulds' chemists discovered that zinc sulphate was an important addition to the sulfuric acid bath used to solidify rayon fibers. As Herman Stuhr noted, "anything that had the slightest trace of spin bath in it had zinc in it." Zinc, then, left the plant via the same paths as sulfuric acid, the cake wash water and any accidental acid overflows. Manufacturing high tenacity rayon required a higher concentration of zinc in the acid bath—5% for high tenacity versus 1% for textile yarns. High tenacity rayon also required more washing, resulting in increased waste water.[144] Zinc compounds joined the list of wastes from the rayon plant that, at sufficient concentration, are "extremely toxic to aquatic life." Zinc wastes posed an additional challenge since conventional wastewater treatment facilities cannot adequately treat the material; it must be precipitated out of the waste stream. Properly done, zinc can be reclaimed and reused. However, only in the 1970s did the plant's waste treatment system include that procedure.

Even under peace time operating conditions, manufacturing rayon was a messy and inefficient process. All of the possible ways to create waste became more likely and frequent during the World War II years, due to the huge increase in production, the requirements of high tenacity rayon, and the shortage of well-qualified labor. The urgent need for tire cord pushed the limits of the rayon technological system. In the rush for production, the plant's

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[143] Lowell L. Trent, Rue S. Hestand III, and Chris C. Carter, "Toxicity of Sulfuric Acid to Aquatic Plants and Organisms," *Journal of Aquatic Plant Management* 16 (1978), http://www.apms.org/japm/vol16/v16p40.pdf (accessed February 28, 2010), 41.

[144] "Testimony of Herman M. Stuhr," 94.

emergency release value was to purge masses of polluting material. The river became the overflow receptacle for all the weaknesses in the system; any production problems flowed downstream into the South Fork.

As a rule, manufacturing high tenacity rayon created more polluting waste than regular textile rayon yarns. The spinning process required greater quantities and concentrations of sulfuric acid and zinc, and the sharp increase in production during the war necessitated greater quantities of all chemicals. In addition, every element of high tenacity rayon had to meet stricter, more stringent, specifications. Stuhr explained that the disparity in quality control occurred because tire cord had to stand up to much more rigorous conditions than, for example, a shirt made of rayon fabric. Thus every element of the process must be precisely controlled: “when you make high tenacity rayon, you’re pretty close to the ragged edge of making it all the time simply because you’re asking the yarn to assume properties that it can only assume if everything is perfect… Any little catastrophe… can interfere with this operation.” To obtain such high standards, any materials that did not meet specifications had to be discarded. In particular, off-spec or scrap viscose could not make “first class tire yarn;” the material could not be reclaimed and was unusable for any other purpose.[145]

Unfortunately, many aspects of the manufacturing process for high tenacity rayon exacerbated the inefficiencies within the regular rayon system. A staff engineer at the facility noted that, throughout its operating life, any time

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[145] “Testimony of Herman F. Stuhr,” 69-70, 54.

the plant was in operation, viscose waste was constantly created.[146] Under normal circumstances, any of a number of events could make viscose unusable. CS_2 is highly explosive, and churns occasionally blew up, scorching the viscose. Workers might mix an incorrect ratio of "white crumb" to carbon disulfide. Most frequently, viscose had to be thrown out because it had aged too long. Since CS_2 begins to escape from viscose as soon as it is mixed, the aging process must be carefully timed. Stuhr explains that "aging doesn't stop no matter where the viscose is, whether it's in the pipes or whether it's out in the truck somewhere."[147] Once ripened viscose reaches the proper composition, it must be spun within a precise timeframe. For high tenacity rayon, the margin of error was extremely slim.

The mechanical procedures used within rayon's technological system required a certain amount of waste. Even in an ideal manufacturing scenario in which every element of the facility's technology functioned continuously, waste was inevitable. The balance of chemicals, timing, and mechanical design was simply too fragile. Some batches of viscose would always go bad from being aged improperly or acquiring impurities. Viscose filters would inevitably clog, backing up aging viscose in the lines. The spinning machines caused another kink in the system. Anytime the machines turned off, viscose aged in the pump lines and had to be flushed out to join the facility's waste stream. Even without motor failure or other mechanical problems, shut down had to occur a few times per shift in order to remove finished cakes of yarn.

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[146] "Deposition of John H. Mallinson, Nov. 8, 1990," 28; DOJ Documents, (Box 7 of 10) FMC v. Commerce, Court of Appeals, Appendix, Vol. 3, Depositions; Avtex Fibers records, CN 37962; LVASRC.

[147] "Testimony of Herman F. Stuhr," 52 and 59.

In general, problems with machinery occurred more frequently with high tenacity rayon. As a thicker thread, high tenacity rayon cakes filled the spinning boxes more quickly and had to be removed five to ten times more often. The frequent shut downs led to frequent motor burn out, further heightening waste production. In addition, high tenacity rayon required a higher viscosity thicker viscose mix, clogging filters more quickly. To produce high tenacity rayon, all spinning machines were upgraded at the outset of the war. Shutting down each machine for several days to make the upgrades greatly increased the quantity of off-spec material.[148] Richard Almy, the plant engineer at AVC, noted that two major power outages occurred during the course of the war—one caused by a flood, another by a fire. Both times, all the viscose in the plant had to be scrapped.[149]

Deployment of hundreds of American Viscose employees overseas further multiplied the waste problem at the factory. Although the War Production Board did procure draft deferments for some workers, labor shortages were a constant problem at the Front Royal facility. Employees were needed not just to replace those serving in the military but also to staff the new machines for increased production. In the face of greatly increased production requirements, management sought employees all across the region, running buses in shifts to pick up workers. In the words of a union official at Local 371, they would hire "anyone who was warm."[150]

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[148] "Testimony of Herman F. Stuhr," 67, 66, 50, and 65.

[149] "Testimony of Richard R. Almy," 123.

[150] "Deposition of Charles Leadman ," 32.

Higher numbers of workers under any conditions meant an increased opportunity for human error, but drastic recruitment measures at American Viscose resulted in an under-trained and sometimes unreliable workforce. With almost the entire plant's production shifted suddenly and rapidly to high tenacity rayon, not only the new employees but also the managers had to adapt to a new set of procedures. The high specifications for high tenacity rayon, coupled with these labor problems, led to a vast increase in waste, particularly waste viscose.[151]

The company struggled with the problem of absenteeism throughout the war years. The spinning room had a particularly high rate, probably in part because of unpleasant work conditions: hot, with constant acid fumes. In the words of Charles Leadman, a union official, it was "not a glorious place to work."[152] Herman Stuhr provided a manager's perspective on the new employees and the absenteeism problem:

> the ones we were able to dredge up out of the back country during the war… in all probability had never seen an industrial plant of any kind let alone a rayon plant. They weren't accustomed to working in that kind of environment and they weren't accustomed to making as much money as… [an] industrial job paid him and the result was that between the two influences, they would tend to work as many days in the week as they felt supplied them with as much money as they could live on that week, then they just wouldn't come to work the rest of the week.

On weekends, sometimes as many as 10 to 20 percent of employees would not show up. This happened with a fair degree of frequency. Without enough men and women to run all the spinning machines, the viscose produced for that purpose had to be disposed of. The company installed an emergency pump to

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[151] "Testimony of Richard R. Almy," 67.

[152] "Testimony of Herman F. Stuhr," 57; and "Testimony of Charles Leadman," 32.

allow all the waste viscose to simply be pumped directly from the viscose cellar to the trucks that would take it to the dumping pits. If twenty percent of the work force did not come to work, the company had to scrap roughly 14,000 gallons of viscose, enough to make 10,000 pounds of rayon tire cord, enough for 1,000 truck tires. Stuhr estimated that 14,000 gallons of viscose would fill "a tank ten feet in diameter and 24 feet high."[153]

The problem ended, Mr. Stuhr notes, at the end of the war when soldiers returned home to their jobs, and "the hillbillies went back to the mountains."[154] Part of his perspective seems born out by numbers reflecting waste viscose outputs. After the war, production at the Front Royal plant of rayon for tire cord and other purposes continued to grow, though at a slower rate, for several years.[155] However, the amount of waste viscose decreased from a high point of 21,000 cubic yards per year in 1945 to roughly 10,000 cubic yards per year. Stuhr attributes that to a return to "normal operation. The fellows that had been in the Army came back and the crisis of incompetent help and that sort of thing got straightened out and everything went back to normal."[156]

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[153] "Testimony of Herman F. Stuhr," 57, 58-60. It is unclear from his testimony whether Mr. Stuhr means that this amount of waste was created when the workers did not show for one day or an entire weekend.

[154] "Testimony of Herman F. Stuhr," 61.

[155] "Testimony of John H. Mallinson," 36; "Testimony of Charles Leadman," 74; "Testimony of Herman F. Stuhr," 86. John H. Mallinson was a staff engineer at AVC from June 1941 until Oct 1979; he was away in the navy from September 1943-October 1945.

[156] "Testimony of Herman F. Stuhr," 86. These quantities represent a very broad estimate based on approximations by EPA contractors of the volume of waste viscose in the viscose basins on-site. Estimates made in the 1980s may be limited in accuracy, but the rough ratio between 1945 and years following provides a useful comparison. The contractors' study is included in the court documents: Exhibit 103: G&M Consulting Engineers report; DOJ Documents, (Box 8 of 10) FMC v. Commerce, Dist. Court Exh. (Plaintiff's); Avtex Fibers records, CN 37962; LVASRC.

Chapter 4

Treating Toxic Waste

"Normal" conditions at the American Viscose plant in 1945 did not equate to normalcy for the South Fork of the Shenandoah. Downstream of American Viscose's sewer and effluent lines, the riverine half of the river-plant complex was in tatters. Considering the content and quantity of the plant's waste streams during World War II, it is not surprising that the river's aquatic life was nearly eliminated. Unaffected by devastated downstream water quality, American Viscose rode the post-war boom, increasing water withdrawals from the river without consequence. Yet the river was never entirely without advocates. Before and during the war, some individuals within the larger technological system made efforts to keep toxics out of rivers and streams, through capture, recycling, or safe disposal of wastes from rayon manufacturing.

For decades before American Viscose came to the Valley, there were always those who responded to the fouling of the Shenandoah with the goal of protecting the river, and who defined the river differently, not simply as a resource and a dump, but as a recreational, aesthetic, or biologically valuable location. They responded to pollution using what tools they had—whether they were sportsmen lobbying the General Assembly for water pollution controls, or state scientists using fines and permits to enforce pollution controls, or engineers at the rayon plant in search of effective methods to limit pollution. Heroes and villains change places over course of the half-decade that the plant operated, until it becomes evident that most of the time there were neither heroes nor villains, just people reacting to challenges with limited tools and foreknowledge.

The trajectories by which human beings come to understand and adapt to their natural environment are always multilinear, involving experimentation to find what works. Modern technological systems, however, shift, and sometimes limit, multilinear exploration by providing buffers from environmental harms. People who can afford to use these systems, or buy their outputs, frequently include those in decision-making positions. Technological buffers distance them from human-caused burdens on the natural environment and erase the direct cause and effect between people's actions and environmental harm. In addition, Western spiritual and scientific thought has long fostered the idea that humans are separate from the natural world in some way, obscuring our reliance on nature, breeding "disregard to nature's inherent value and fragility."[157]

With buffers both physical and psychological, no longer does the cause of an environmental hazard necessarily have to be halted. A vast range of other options are available. Some water-born pollutants can be filtered, diluted, or rendered harmless by the addition of other chemicals. Government agencies can permit a measurable amount of environmental harm to occur so long as it stays below certain thresholds. If these options do not work, polluters often use money and influence to reset agency thresholds, rewrite permits, change laws, or simply pay off fines rather than clean up harms. Complicating this picture for American Viscose and many other polluters in the 1940s was the incomplete

[157] Paul Charles Milazzo, *Unlikely Environmentalists: Congress and Clean Water, 1945-1972* (Lawrence, KS: University Press of Kansas, 2006), 90.

knowledge available at that time about exact correlations between types of chemical waste and environmental degradation. This knowledge is by no means complete now, nor will it ever be, as consequences in the natural world can never be predicted with absolute accuracy.

Part of the problem in the 1940s was that disposing of large quantities of chemical waste remained relatively unexplored. As Craig Colten and Peter Skinner explain in their history of industrial waste:

> except for plating, smelting, and certain refinery wastes… most persistent and toxic industrial wastes were manageable, at least until the 1930s—largely because the volumes produced were relatively small. During the 1930s and 1940s, the organic chemicals industry flourished and created a new spectrum of wastes whose quantities, toxicity, and persistence took quantum leaps.[158]

Nevertheless, awareness among industry and the public about hazardous waste in the early twentieth century is well documented.[159] As early as 1917, a leading sanitary engineer argued that "the impression that the [industrial] wastes cannot be successfully treated is in many cases not true."[160] Scientists understood the potential hazards of certain waste disposal practices. A 1931 chemical engineering textbook made clear that disposing of "liquid wastes to the ground surface could lead to contamination of groundwater supplies down

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[158] Craig E. Colton and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before the EPA* (Austin: University of Texas Press, 1996), 5.

[159] In addition to Colton and Skinner's book, some of Craig E. Colton's many contributions to this subject include, "Creating a Toxic Landscape: Chemical Waste Disposal Policy and Practice, 1900-1960," *Environmental History Review* 18, no. 1 (Spring 1994): 85-116; and "Industrial Topography, Groundwater, and the Contours of Environmental Knowledge," *Geographical Review* 88, no. 2 (April 1998): 199-218. Other works include Martin V. Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: Johns Hopkins University Press, 2000), as well as Jean-Pierre Goubert, *The Conquest of Water: The Advent of Health in the Industrial Age*, trans. Andrew Wilson (Princeton: Princeton University Press, 1989), and Joel A. Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, OH: University of Akron Press, 1996).

[160] Quoted in Colten, "Creating a Toxic Landscape, 88.

gradient." Waste treatment practices during this time period tended to focus on removing a single "offending waste" from factory effluent. Although some treatment technologies did exist, more often than not companies chose to locate in isolated areas to protect them from complaints or relied on rivers to dilute their pollutants, based on "nineteenth-century concepts of natural purification."[161]

These theories viewed running water as uniformly healthy and capable of purifying any waste, while stagnant water harbored death and disease. An older theory, reaching back to Plato and Aristotle, speculated that "water was purified by the fire burning at the centre of the earth and protected from pollution by an impermeable layer… [therefore] water pollution was a phenomenon that could not exist."[162] Much common wisdom in the early twentieth century held to the belief that running water could purify itself of any substance through the "dilution of wastes and the movement of the water." Thus, in the 1920s, a tremendous amount of human and industrial wastes were discharged untreated in "oceans, large rivers, and lakes."[163] When the larger American Viscose Corporation (with its seven plants and eighteen thousand employees) was established in the U.S. in 1910, this form of disposal of industrial waste was common.

By the 1930s, however, enough shared knowledge was available that corporate malfeasance regarding industrial waste could be identified. A 1939 article in *Industrial and Engineering Chemistry* provides insight into the

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[161] Colten, "Creating a Toxic Landscape," 91, 94, 93.

[162] Goubert, 255 and 34.

[163] Melosi, 226.

behavior of some corporations with regard to pollution control. The author urged manufacturers to take certain steps to reduce their waste stream by working cooperatively with "trade organizations and pollution control agencies," rather than dodging responsibility by "attempting to avoid waste treatment, employing homemade makeshifts, or buying off lower riparian objectors."[164] An influential 1927 book on the rayon industry by engineer M.H. Avram reflected the problematic attitudes. He first explained that any water entering a rayon plant will become contaminated with caustic soda, sulfuric acid, and other chemicals; "If these waste waters can be dumped into a sewer or river without any neutralizing process it is an advantage. However, local restrictions may be so severe that excessive expense might ensue."[165] There are two insights here: first, that many communities were concerned about harmful chemicals entering the environment, and second, that many rayon companies were not.

Although the American Viscose plant was considered state of the art in 1940, its waste control system was never particularly good at protecting the river. Managers cobbled it together on the fly during World War II to deal with certain major problems while overlooking others. Throughout the rest of the plant's operating life, even with increasingly stringent pollution control laws, managers kept tweaking the system but never fixed it. The waste treatment and disposal practices remained essentially the same from the late 1940s until the plant closed in 1989 and were never capable of keeping pollution from reaching the Shenandoah.

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[164] C.R. Hoover, "Treatment of Liquid Wastes from the Textile Industry," *Industrial and Engineering Chemistry* (November 1939), 1358.

[165] Edmunds, 2, quoting from M.H. Avram, *The Rayon Industry* (New York: D. Van Nostrand Co., 1927).

American Viscose's original state-of-the-art design included a "complete recovery system"[166] to reclaim chemicals and control waste. This reflected 1930s trends in industry, perhaps pushed by Depression-era scarcity, to recover and reuse waste while conserving raw materials.[167] By 1940, such a system probably recovered some amount of both the alkaline and acid wastes from rayon manufacturing. New rayon plants in the late 1930s utilized what was known as the Cerini process to reclaim caustic solution via dialysis from the liquid used for steeping cellulose sheets. Recovering the solution was profitable for the company and also helped with the treatment of some waste, lowering its alkalinity and making further treatment and disposal less intensive.[168]

Courtaulds, the parent company of American Viscose, began to reclaim acid waste in 1915 at their Coventry plant due to shortages in chemical supplies.[169] It appears that some if not all of their AVC plants also included some kind of reclaim technology. At the Front Royal plant, Acid Reclaim constituted its own department, a section of the facility with "a maze of tanks, evaporators, coolers, and pipes." Mechanisms within the department pumped acid from the spinning baths and back, removing a by-product, anhydrous sodium sulfate, that was sold as an industrial product called Glauber's salt. The system contained millions of gallons of acid.[170]

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[166] Edmunds, 60.

[167] Colten, "Creating a Toxic Landscape," 93.

[168] Hoover, 1353; Edmunds, 14; "Testimony of Herman F. Stuhr," 47.

[169] Coleman, *Volume II, Rayon*, 141.

[170] This information comes from a description of the Acid Reclaim department from the 1980s. See Daniels, "Avtex Fibers Rayon Plant." Records from the Local 371 archive confirm the existence of an

Other than these reclaim systems, evidence of any additional methods in use when the plant opened to prevent chemical pollution at Front Royal is inconclusive. Documents suggest that the facility opened in 1940 either without a waste treatment system, or with one that only treated sanitary waste. According to a study carried out for the EPA in 1985, American Viscose had a basic but essentially ineffective waste-water treatment facility in place prior to 1946. Relying on limestone beds, the treatment was inadequate to neutralize acid waste or remove a host of other contaminants.[171] However, the study does not indicate whether the limestone beds were in use from the outset or installed later. A different study completed for the EPA in 2000 states that "waste streams produced during rayon manufacturing at the site were discharged directly to the Shenandoah River prior to 1948."[172] The statement is inaccurate on the surface—waste treatment and diversion are known to have occurred previously—though it does reflect the essential ineffectiveness of the early attempts at treatment.

The first clear statement in American Viscose documents regarding waste treatment systems at the Front Royal plant[173] appeared in February 1942 in a report written by Mr. E. Roetman. Roetman was a specialist overseeing waste treatment plants at all of AVC's factories and worked out of AVC's Engineering

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Acid Reclaim department in the 1940s. The note about Glauber's salt comes from Versar, Inc. "Avtex Fibers Responsible Party Search and Financial Assessment: Draft Final Report, Prepared for U.S. Environmental Protection Agency. January 29, 1985." Avtex Administrative Record. EPA. http://loggerhead.epa.gov/arweb/ public/ pdf/136013.pdf (accessed May 6, 2009), 3.

[171] Versar, Inc., 3.

[172] Exponent Engineering and Scientific Consulting, "Feasibility Study Work Plan," 7.

[173] The AVC reports and memorandum from the early 1940's are mysterious. While they clearly indicate problems, documentation of any follow-up steps is missing—they are either lost, destroyed, or perhaps never existed.

Department at central headquarters in Philadelphia, PA.[174] The report, titled "Progress Report on Trade Waste Treatment at Front Royal, 'Sulfide Waste,'" described a "leak of extremely strong acid" into the wastewater treatment plant. The acid destroyed the biological action of the plant's trickling filter, used to treat sulfide wastes.

Another early reference to the plant's waste treatment system came from John H. Mallinson, a staff engineer who worked for AVC from 1941 to 1979. He described the early treatment of acid waste. The facility installed a Dorr clarifier in 1946 that separated calcium sulfate and zinc hydroxide from the effluent. Prior to that, however, acid waste simply filtered through two chambers filled with calcium hydroxide. From there, it flowed straight into the river. The effluent was not adequately cleaned, according to Mallinson, because the calcium hydroxide was not changed frequently, thus the effluent would not be neutralized in the river for "five or six days." He took his concerns to the plant manager in 1943 and was told that "it was none of [his] business, to stay off."[175]

A December 1943 report, titled "Neutralization of Waste Acid" and addressed to seven AVC managers at company headquarters, corroborated the problems with the waste acid treatment system. The report emphasized with concern that acid waste from the Front Royal plant "will be greatly increased" by wartime expansion of the plant to produce high tenacity rayon. It notes the importance of neutralizing the wastes before they enter the Shenandoah "to render them as harmless as possible." However, previous attempts using the

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[174] "Deposition of John H. Mallinson," 53.

[175] "Deposition of John H. Mallinson," 52-54.

limestone rooms that Mallinson described had limited efficacy: the surface area of the limestone was too small and quickly became coated by viscose fibers mixed in the acid waste. In addition, "the volume and velocity" of waste entering the chamber overwhelmed the system's capacity. The report concluded: "Successful treatment has never been obtained."[176]

In addition to Roetman's 1942 report on AVC's acid waste, he wrote a second progress report on the same date discussing treatment of the alkaline waste produced at Front Royal. The engineers had examined sediments on the bottom of the South Fork, finding that "a large part of it" was "precipitated cellulose," likely exiting the plant from the viscose sewer. This heavy cellulose, with its high BOD load, originated with the Cerini process that separated cellulose from caustic soda. It is unclear whether, at the time of this report, all waste viscose passed through the viscose sewer into the river. Herman Stuhr made clear that the facility had no means of reclaiming waste viscose. Particularly during World War II, the volumes of waste viscose exiting the plant made it "completely impractical to even attempt this." Charles Leadman noted that the American Viscose plant in Nitro, WV did reclaim some waste viscose, but the Front Royal plant "never reclaimed any viscose at all. Never had the equipment to do it."[177]

As of 1943, AVC's primary mode of waste viscose disposal involved dumping the material into unlined pits on the far side of the railroad tracks. According to Richard Almy, a mechanical engineer at American Viscose, during

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[176] Sterner, R.R. "Neutralization of Waste Acid, December 9, 1943," 1-2; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

[177] "Testimony of Herman F. Stuhr," 53; "Testimony of Charles Leadman," 31.

the war "there was an almost continuous process of digging new basins. It became full quite rapidly, particularly in the instance of a power failure or major flood, which would generate tons and maybe hundreds of tons of waste" and fill up a basin.[178] Although no War Production Board documents make mention of chemical waste disposal, the agency assisted with dumping waste viscose, including purchasing buggies for transporting waste to the dumping pits. The convenience and speed of this disposal practice fit well with wartime need—it was a quick, easy way to get the materials out of sight and out of mind.

Two chemical engineers who worked on water treatment at AVC in the late 1940s noted the role of World War II in worsening pollution from the American Viscose facility. In an article in *VIW & SWA News,* a publication dealing with water and sewage issues in the northern Shenandoah Valley, B.N. Scheuer and C.W. Joseph explain several problems related to American Viscose water's treatment system. The war was a primary issue:

> If World War II had not occurred, this problem would have been solved much sooner than it was; not only were many of the technically trained employees called into the armed forces, but the company was ordered in favor of the war effort to expand its production facilities and manufacture new yarns by unfamiliar processes. The problems of this expansion demanded the full time service of the remaining technical manpower. These conditions coupled with a general shortage of men and materials precluded the development of a process and the installation of a plant for the treatment of the acidic waste.[179]

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[178] "Deposition of Richard R. Almy," 66. Almy made reference later in his deposition to a major flood of the South Fork in 1942 that caused a power outage, disrupting production at the facility. He also mentions a fire during the war years that led to another power outage (p. 113).

[179] B.N. Scheuer and C.W. Joseph, "Sewage and Industrial Waste Treatment at Avisco's Front Royal Plant," *VIW & SWA News* (March 1950), Article. Avtex Fibers, Inc. Newsclippings. SC # 4017. Special Collections. Carrier Library. James Madison University. Harrisonburg, VA, 6.

The article went on to acknowledge the facility's problem with waste and their difficulties discovering effective ways to deal with it. Their ultimate conclusion, however, was that the most effective tools for protecting the South Fork from pollution were dry dumps (i.e. the pits of waste viscose and other lagoons), fly ash lagoons, and the waste treatment plant. To the chemists of 1950, these constituted "a successful method for the treatment of 'all of the waste all of the time,'… facilities for safe-guarding the Shenandoah from pollution." Much of the theory behind American Viscose's early waste-disposal procedures had roots in old concepts. Pouring waste products into lagoons allowed dewatering "by percolation through the ground and evaporation." Remaining effluent discharged into the South Fork would be "easily assimilated by the river."[180]

The tone of Scheuer and Joseph's article is both celebratory and defensive, likely written in part in an attempt to improve public relations. They wrote the piece for a local audience roughly five years after the end of the war. The Shenandoah had been essentially dead—smelly, foamy, and milky white—causing frustration and complaint from neighbors, but the engineers noted that conditions were improving. The authors' praise of AVC's new wastewater treatment plant, however, obscured an important piece of history: the company had been ordered to build the treatment plant in 1948 by Virginia's newly-formed State Water Control Board (SWCB).[181]

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[180] Scheuer and Joseph, 6-7. Ironically, many of the same waste-disposal techniques that were celebrated in 1950 as steps in the right direction led to Avtex's classification as a Superfund site in 1989.

[181] Groves and Settle, 687.

Chapter 5

Shifting Dynamics and Polluted Consequences

Wastewater treatment at American Viscose did not significantly improve until after July 1, 1946, when Virginia Governor William Munford Tuck signed the State Water Control Law, one of the first comprehensive statewide efforts to control water pollution in the country. The law required the governor to develop a citizen board, with a mission to "protect existing water quality, to reduce and prevent water pollution, and to restore and maintain state waters to a quality that would protect human health and aquatic life." Unfortunately, it was a weak law with no enforcement mechanism, thus "manufacturers were under no legal obligation to make the [pollution] reductions."[182] Nevertheless, it marked the first steps toward official protection of the South Fork.

The law was one in a series of events marking a slow shift in dynamics between the river and the factory. These changes illustrate many themes of environmental history, including the role of sportsmen in preservation of natural systems, changing attitudes toward science and technology in the post-war years, and the steady unfolding of knowledge regarding the environmental and health impacts of certain chemicals. In Front Royal, requirements of the 1946 Water Control Law exposed some of the limits of this knowledge as engineers dealt with chemicals whose aquatic impacts were unknown. The law also marked the beginning of American Viscose's friction with regulatory agencies as the company focused on minimizing blame instead of harm.

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[182] Virginia Department of Environmental Quality, "An Environmental History," http://www.deq.state.va.us/history/1946.html (accessed December 13, 2009).

Throughout, consequences of the plant's continuing technological momentum to aquatic life in the South Fork continued to unfold, outpacing the ability and the determination of the company to prevent them.

In the years immediately following World War II, new and powerful allies came to the aid of the South Fork. As the intense focus on the war receded, the consequences of American Viscose's massive production operations on the river were evident, and there was room again in the political sphere for conversations about industrial harms. Beginning immediately after the war, changes in leisure time shifted some of the ways in which the river was used, bringing more people to it for recreational purposes. The tangible impacts of the chemical discharge from AVC's rayon plant caused grave concern among visitors to the Shenandoah and downstream residents. In 1947, despite the company's efforts to improve waste treatment, the milky appearance of the river—caused by viscose wastes and overflow from the plant's cooling tower—was still visible from the highway bridge en route to Winchester, some thirty-six miles by river from American Viscose,[183] and even further downstream. A company memo mentioned that a Winchester resident had complained multiple times to AVC headquarters in Philadelphia.[184] Another memo from the same time period stated that "the condition of the river below our plant has so

[183] Bruce Ingram, *The Shenandoah and Rappahannock Rivers Guide* (Corvallis, OR: Ecopress, 2003), n.p.

[184] "Memorandum: E.T. Roetman to Mr. R.M. Pfalzgraff: 10-69 Waste Treatment FR, November 3, 1947," 1; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

incensed the public that pressure is being placed on the State Water Control Board for action."[185]

Fortunately for the Shenandoah, some of those neighbors and visitors included sport fishermen with connections to the most politically powerful men in Virginia. Their efforts, organized under the auspices of the Izaak Walton League of America (IWLA), led to the passage of Virginia's 1946 State Water Control law.[186] The Virginia division of the Izaak Walton League boasted the nation's most famous fisherman of that era: President Herbert Hoover, an active member of the Orange County Chapter. The influential Virginia Senator A. Willis Robertson was also a League member, leading the effort to pass the Federal Aid and Wildlife Restoration Act of 1937 (better known as the Pittman-Robertson Act) that finances wildlife conservation, research, and acquisition of wildlife management areas into the present day.[187]

The IWLA was a major political force nationwide. Founded in 1922, it grew rapidly into America's largest conservation organization with 100,000 members by the late 1920s.[188] Politically, the Izaak Walton League pushed for protection of both wildlife and water quality. The organization had significant political success at the federal level in the 1930s, successfully lobbying for some

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[185] "Memorandum: E.T. Roetman to Mr. A.G. McVay: 10-69 – Addition to Waste Treatment Plant FR, October 8, 1947," 3; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

[186] Versar, 3.

[187] "Division History," Virginia Division of the Izaak Walton League of America, http://www.va-iwla.org/divhist.html (accessed February 22, 2010).

[188] Jouni Paavola, "The Izaak Walton League of America," in *Encyclopedia of World Environmental History, Vol. 2,* eds. Shepard Krech, John Robert McNeill, Carolyn Merchant (New York: Routledge, 2003), 718. In comparison, the Sierra Club and Audubon Society had less than 7,000 members each.

public works funds to be used for sewers and sewage treatment plants, as well as sealing old mines. The IWLA sponsored federal pollution control bills, one of which passed Congress in 1939 but was vetoed by President Roosevelt who argued that it was too expensive.[189]

Within five years of its founding, IWLA members were politically active and effective in Virginia. By 1928, the League was credited with making "insistent demands" for control of stream pollution and stirring up increased public interest in the issue. The IWLA had a seat on the cooperative committee formed to survey and study stream pollution along with representatives from industry, the health department, the game and inland fisheries commission and others.[190] In 1929, the group partnered with the Garden Clubs of Virginia and the Virginia Academy of Science to petition for establishment of what would become the Virginia State Park system. In 1940, the IWLA's Arlington-Fairfax Chapter won statewide adoption of a fish and wildlife law enforcement program.[191] By the end of World War II, the League was clearly a respected part of the political landscape in Virginia and an active advocate for conservation.

As a sportsmen's organization, the Izaak Walton League had a strong connection to the Shenandoah River. Prior to 1940, the river was "a Mecca for fishermen" and one of the best smallmouth bass fisheries in the east.[192] With

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[189] Paavola, 719.

[190] Wagner, A., "Stream Pollution Program in Virginia," *American Journal of Public Health and the Nation's Health* 20 (February 1930): 202.

[191] "Division History," Virginia Division of the Izaak Walton League of America, http://www.va-iwla.org/divhist.html (accessed February 22, 2010).

[192] Croswell Henderson, "The Shenandoah," *Virginia Wildlife* 11, no. 12 (December 1950), n.p.; and Virginia Department of Game and Inland Fisheries, "Shenandoah River – Main Stem – Fishing Opportunities," http://www.dgif.virginia.gov/fishing/waterbodies/ display.asp?id=171&section=fishing (accessed February 21, 2010).

less interference from pollution during those pre-war years, the Shenandoah River and its tributaries could provide varied habitats and food sources to support a multiplicity of aquatic life. The river's great sinuous meanders through the Valley contributed to structural variety within the river, creating a diversity of habitat niches. Deep pools of slow water were interspersed with multiple riffles—shallower areas of choppy or ruffled water where the smallmouth bass made their home. Meanders in the river molded the pattern of riffles and pools, with deeper water often located along the river's concave bank. The rocks underlying the river shaped its bends and contributed boulders, cobbles, sediment, and ledges to form the river bottom. The erosive interplay of "scour and deposition" between river current and surrounding rock, as well as periodic flood events, ensured that structural characteristics within the river remained dynamic. Riparian trees, growing along the river's banks, lent further heterogeneity to the river bed by contributing their trunks, limbs, and leaves.[193] Such features provided habitat to a wide range of fish and other aquatic organisms, each requiring niches within the river.

The relative purity of the pre-war Shenandoah River allowed riverine energy cycles to function and support this diversity of aquatic organisms. Energy entered the river system via aquatic plants—such as algae, mosses, and vascular plants[194]—as well as terrestrial sources, including the leaves and limbs

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[193] Henderson, n.p.; and Colbert E. Cushing and J. David Allan, *Streams: Their Ecology and Life* (San Diego, CA: Academic Press, 2001), 11, 26.

[194] Vascular plants have lignified vascular tissues, called xylem and phloem, used to conduct water and nutrients throughout the plant. The category includes a broad array of plants, from trees to tulips, and excludes only the bryophytes: mosses, liverworts, and hornworts. See M.J. Farabee, "Biological Diversity: Non-vascular plants and non-seed vascular plants," *Online Biology Book*, hosted by Estrella Mountain Community College, http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookdiversity_5.html (accessed July 5, 2010).

of riverside trees. Decomposition made plant matter available to other life forms, ranging from microscopic organisms to myriad benthic macroinvertebrates inhabiting the river bottom. Some river species digested these plant materials, others feasted on detritus, while the carnivory species ate one another. Higher up in the food webs, the Shenandoah River's diverse fish species ate smaller organisms and one another. In addition to the small- and largemouth bass favored by sport fishermen, darters, eels, sunfish, chub, trout, carp, catfish, darters, crappies, dace, and many more species inhabited multiple niches within the river's habitat structures and food webs.[195]

Such a brief sketch of the Shenandoah River's ecology falls far short of conveying the remarkable multiplicity of species and their intermingled food webs and habitat requirements. Demonstrating the layers of complexity in riverine ecology, two biologists noted that even a seemingly simple organism like biofilm, "the slippery film on the surface of [river] rocks, [is] "an entire ecosystem within itself." Beyond the obvious question of food availability, innumerable other factors affected riverine life and health. For example, water turbidity, temperature and pH, as well as concentrations of various nutrients and availability of dissolved oxygen could all determine whether particular species thrived, survived, or disappeared. The river's non-human history, its change over time, emerged out of interactions and relationships between all parts of the Shenandoah River ecosystem—from the smallest bacteria to the watershed's broad landscape. The very intimacy of these interconnections was

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[195] Tracey S. Sherman, "Fish of the Shenandoah River," Virginia Tech Department of Forestry, Feb. 25, 2003, http://www.cnr.vt.edu/PLT/potomacshenandoah/aquaticinsects/southfork.htm (accessed February 21, 2010).

where the river escaped human control and limited the extent of human understanding. In 2001, the two biologists noted that associations between some components of the river's ecology are still "poorly understood."[196]

As the country emerged from World War II, it became clear that the polluted effluent from American Viscose had severed these complex riverine relationships in the Shenandoah downstream of the plant. Surveys by the U.S. Fish and Wildlife Service found "practically no fish in the river and almost a complete destruction of bottom animals (fish food such as mayfly nymphs, caddis fly larvae, and hellgrammites)."[197] The Izaak Walton League's chapter in Berryville, Virginia—located just a few miles west of the Shenandoah River—took the lead in pressuring the Virginia General Assembly to clean up the river and curtail American Viscose's toxic effluent. A brief 1946 article in the IWLA newspaper, *Outdoor America,* credited the chapter's founder, H. Blackburn Moore, as being "largely responsible for drafting the legislation and steering it to successful passage… almost without opposition by the last Virginia legislature." The chapter sought to follow up this victory by securing IWLA representation on the State Water Control Board (SWCB) that the Governor of Virginia was in the process of appointing.[198] The Board's mission was to "protect existing water quality, to reduce and prevent water pollution, and to restore and maintain state waters to a quality that would protect human health and aquatic life."[199]

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[196] Cushing and Allen, 40, 35, 29, 42.

[197] Henderson, n.p.

[198] "Virginia Division," *Outdoor America: Official Publication of the Izaak Walton League of America* 11, no. 4 (May-June 1946): 15.

[199] Virginia Department of Environmental Quality, "An Environmental History."

Edgar Blackburn "Blackie" Moore—of unknown relation to H. Blackburn Moore—served as the Delegate representing Berryville in the Virginia General Assembly from 1933-1967, including a seventeen-year tenure as Speaker of the House. An extremely influential Democratic politician, Moore held a seat on the SWCB from its creation in 1946 until 1970, chairing the board for most of that time period.[200] It seems likely that Delegate Moore played an important role in passing the 1946 law. Although his relationship to the IWLA's H. Blackburn Moore is unclear, their similar names, Berryville addresses, and mutual interest in water quality suggest a close familial tie and likely political cooperation.

E. Blackburn Moore surfaces once, dramatically, in the American Viscose documents, hinting at the multilinear development of water quality law in Virginia and the potential for one person to significantly influence interpretations of law. In a memo dated October 10, 1947, AVC engineer T.F. Brastown described a visit to Richmond to meet with "Mr. Hedgepeth," an engineer employed as the Executive Secretary of the Virginia State Water Control Board. They arrived in Richmond to find Hedgepeth very upset. He had met "that same morning" with the Chairman of the SWCB, Mr. E. Blackburn Moore, who told him that he "could no longer discuss results or data, make any commitments, or venture any opinion as to what was adequate treatment or as to whether results were satisfactory. All cases would have to appear before the WCB, and they would be the judges of what constituted pollution." In addition, Moore interpreted the law to say that wastes from new

[200] "Historical Bio for E. Blackburn Moore," Virginia House of Delegates website, http://dela.state.va.us/dela/MemBios.nsf/7bf25d3bb19d05ab85256c23006d3f84/68d5ffec2d99b30685256d33004e31ba?OpenDocument (accessed May 22, 2010).

facilities or expanded production could not be grandfathered into existing waste streams but "must be completely treated so as to carry no pollution load."[201]

Moore's instructions did not sit well with Hedgepeth who told the AVC engineers that "this was not the type of job he had taken, and that if the policy continued the WCB did not need an engineer, but only lawyers." He continued, saying that "if the activities of the Board become influenced by politics, pollution control is dead."[202] The memo opens more questions than it answers about the contrast between Hedgepeth's philosophy and Moore's, but it offers a glimpse into the conflicts of interpretation and action surrounding early official attempts to regulate waste and protect water. The forces that shaped water pollution control were contingent and cultural human responses to the state of the river.

Within American culture, sportsmen—usually fishermen and hunters—in the Izaak Walton League and other sporting organizations came from a long tradition of conservation ethics and initiatives. Scholar John F. Reiger traces the origins of environmental conservation to "American sportsmen, those who hunted and fished for pleasure rather than for commerce or necessity." Although sporting clubs have a long history in the U.S., dating back to 1732, a sense of widespread group identity emerged later, in the years following the Civil War. National sporting newspapers—*American Sportsman, Forest and Stream,* and *Field and Stream*—helped created a sense of belonging to a group

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[201] "Memorandum: T.F. Brastow to Mr. A.G. McVay and Mr. E.T. Roetman: Visit to Mr. Hedgepeth – Virginia Water Control Board, October 10, 1947," 1; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

[202] "Memorandum: T.F. Brastow to Mr. A.G. McVay and Mr. E.T. Roetman," 2.

with a defined and shared code of ethics: "true sportsmen practice proper etiquette in the field, give game a sporting chance, and possess an aesthetic appreciation of the whole environmental context of sport that included a commitment to its perpetuation."[203]

The years following the Civil War also saw new public support for creation and enforcement of policies protecting fish and wildlife. Westward expansion, railroads, and industrialization were rapidly depleting wildlife, streams, and forests. The year 1873 found *Forest and Stream* editor Charles Hallock articulating a platform similar to that espoused by the Izaak Walton League decades later:

> protection of watersheds and scientific management of forests; establishment of uniform game laws dictated by geography, habitat, and migration patterns, rather than judicial accident; creation of a science and industry of fish culture that would develop new strains of game fish and restock depleted waters; abatement of water pollution…[204]

A "club movement" of anglers and hunters began in the 1870s to address these problems. They formed clubs and associations at local, state, and national levels focusing on issues like game-protection and fish culture laws. In 1874, William F. Parker, editor of *American Sportsman* celebrated "the sportsmen of America [who] are banding themselves together for the purpose of checking and controlling the wanton and wasteful destruction of nature's best gifts intended

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[203] John F. Reiger, *American Sportsmen and the Origins of Conservation,* 3rd ed. (Corvallis, OR: Oregon State University, 2001), 3.

[204] Reiger, 47-50; quote from Reiger, 50.

for the heritage of universal man, and not for the benefit of the reckless and greedy few." By 1878, Hallock counted hundreds of such clubs in the U.S.[205]

If sporting clubs helped generate a sense of identity and a venue for action, the private sphere, in which codes and traditions of ethical conduct were passed down between family members, remained important for shaping connections to the natural world. Many of the leading figures in conservation, from Thoreau to Pinchot, Leopold to Theodore Roosevelt, describe hunting and fishing both alone and with family and friends as key to their interest in the natural world. For many, "the pursuit of wildlife seems to have provided the crucial first contact with the natural world that spawned a commitment to its perpetuation."[206] Two of those early leaders, Teddy Roosevelt and George Bird Grinnell, founded the Boone and Crocket Club in 1887. Reiger credits this as the first private organization to deal with national conservation issues effectively, predating John Muir's Sierra Club.[207]

Reiger makes an important point that, even in the 1800s, interest in conservation measures originated in the upper classes. In general, these were people who did not need to hunt and fish to survive but could approach the activity as a leisure pastime. Publications frequently carried descriptions of conflicts between the angler wanting to protect his favorite fishing hole and the commercial fisherman, an early version of the "jobs versus the environment" debate. This trend is evident in Virginia in the 1930s and '40s with powerful political figures from the state's patrician class invested in protection of the

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[205] Reiger, 82, 58, 57; quote from Reiger, 60.

[206] Reiger, 65.

[207] The Sierra Club is often identified as the oldest environmental organization in the U.S.

Shenandoah's water quality for fishing. Nevertheless, interest in the natural world grew among broader swaths of the American population in the 20th century. The 1928 stream survey, which the IWLA helped to initiate, cited increased public interest in stream quality as one justification for the study. They speculated that more people were getting out to the country due to an increase in road building, and more travelers came to rural Virginia because of advertising of the state's historical and recreational sites.[208]

Interest in wildlife also began to shift following World War II, especially as suburban sprawl despoiled the countryside. Public pressure from scientists and citizens led to changes at the federal Bureau of Sport Fisheries and Wildlife (SFW), which in 1974 became the Fish and Wildlife Service. Segments of the urban and suburban population sought opportunities to "watch wild animals in the wild," not to hunt them. Surveys recorded millions of Americans participating in bird watching, nature walks, and nature photography. Meanwhile, scientists pushed the SFW to extend preservation efforts beyond fish and game to endangered species.[209]

Despite these shifts, sports fishermen and hunters continued to play important roles in conservation in the postwar years. In some instances, members of the "hook and bullet" groups could make headway on pollution abatement where "bird and bunny boys" and concerned housewives were more easily marginalized.[210] Automotive giant Ford's River Rouge production complex

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[208] Wagner, 203.

[209] Rome, 211-212.

[210] Tom McCarthy, *Auto Mania: Cars, Consumers, and the Environment* (New Haven: Yale University Press, 2007), 113, 115.

caused tremendous air and water pollution of the community of Dearborn, Michigan and the Rouge River.[211] Remarkably (from today's perspective), complaints about the pollution came not just from Ford's neighbors but also from their employees. Despite massive air pollution problems, water pollution received the most attention due to the involvement of sportsmen. In Michigan, customers, employees, and plant managers alike tended to hunt and fish and thus shared a common interest and respect. Cooperative efforts resulted in modest strengthening of the state's water quality law in 1949 and slow improvements in pollution abatement by Ford.[212]

Sportsmen in various states played a key role in an important water quality dispute nearly a decade later in 1957. The 1956 amendments to the federal Water Pollution Control Act strengthened the federal government's ability to enforce water pollution regulations in instances of interstate pollution. At the request of a state pollution control agency, the federal government could pursue an abatement suit, and if public health was endangered, the government no longer had to receive the consent of all States involved.[213] The first use of this law came at the instigation of sport fishermen in Louisiana. In much of the U.S., a state public health department oversaw water quality issues. In Louisiana, however, that responsibility resided with the state fish and game agency. As a result, the health of aquatic life became an important indicator for pollution problems. In this case, sportsmen's activity in centered

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[211] Bill Wolf in *Sports Afield* described the river in 1948: "I have seen some foul rivers but will stake the River Rouge from the Ford plant down to where the Rouge enters and contaminates the Detroit [River] against any stream for absolute, concentrated filth." McCarthy, 110.

[212] McCarthy, 114, 112.

[213] U.S. Environmental Protection Agency, "Water," EPA History, http://www.epa.gov/history/topics/fwpca/05.htm (accessed June 1, 2010).

around "ad hoc advocacy groups" rather than national organizations like the IWLA, but, with authority based in long traditions of "common access to fish and game," they effectively exerted pressure at local, state, and national political levels.[214]

Sportsmen played a mediating role, not only between levels of government and various economic interests, but also between old and new conservation values. Sportsmen wanting to protect the Shenandoah and other rivers exerted a different kind of force, based on their uses of the river and their perspectives on its importance. Although fishermen engaged in a type of extraction, it was non-industrial, based on enjoyment and enmeshed in a system of values that emphasized protecting both the fish as a species and the river as their natural habitat. The momentum of conservation grew in volume and intensity in the postwar years, picking up other concerns that went beyond protection of wildlife habitat and water quality.

The efforts of sportsmen, regulators, and other early post-war conservationists, however, did not generally seek to undermine business interests, and those with concerns about industrial activity kept a low profile. Facing a national "consensus" following World War II that encouraged patriotic conformity, respect for authority, and "a commitment to a vague notion of an American way of life defined by prosperity, material comfort, and a secure home," dissenters faced the threat of being labeled disloyal, or worse, Communists.[215] Scientists' role in creating successful wartime technologies led

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[214] Colten, "Contesting Pollution in Dixie," 609-610.

[215] Mark H. Lytle, *Rachel Carson, Silent Spring, and the Rise of the Environmental Movement* (New York: Oxford University Press, 2007), 120.

to an unprecedented leap in funding for research and development from government and industry, reaching "levels unheard of for any profession in the history of the United States."[216] Overall, America emerged from World War II with an uncritical commitment to technology and innovation provided by benevolent corporations. DuPont's slogan "better things for better living... through chemistry" had a literal meaning.[217]

This friendliness toward business and industry was evident in the way that regulators approached water quality protection. Corporations took a "go-slow" approach, pacing out improvements to their waste disposal practices to limit impacts on their profits. Regulators and plant engineers had tacit agreements to work together behind the scenes, usually without legal pressure or public input, in order to protect the national reputation of the corporation.[218] The situation at American Viscose in Front Royal mimicked this scenario. Memos clearly demonstrate that AVC engineers, both at the Front Royal waste treatment plant and at the company headquarter in Philadelphia, worked closely with the Virginia State Water Control Board. In return, Mr. Hedgepeth, the SWCB's lead engineer, stated "that his office was assuming that industry is honest and competent and will accept reports" made by AVC at face value.[219]

Although the Clean Water Act of 1972 gives the Virginia Department of Environmental Quality (DEQ) and the Environmental Protection Agency (EPA)

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[216] Kelly Moore, *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945-1975* (Princeton, NJ: Princeton University Press, 2008), 22.

[217] Lytle, 141.

[218] McCarthy, 112.

[219] "Memorandum: R.W. Haywood, Jr. to A.G. McVay, 10-69 – Waste Treatment – B.O.D. Procedure and Analytical Program, August 4, 1947," 2; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

significantly more regulatory authority, the current system in place today reflects that friendliness to business and remains largely self-monitoring; companies design their own pollution control systems and collect their own samples. Ralph Bolgiano, the State Water Control Board regional biologist who monitored Avtex's permits during its final years, explained that the current approach "wasn't always the best thing for the environment, but legally, it was the way it was set up." He noted that the system could work effectively: "it has some advantages. Most people live up to your expectations of them… You give some people the autonomy to do things the way they want to do them, and if they care at all, they'll probably do a better job."[220]

A variety of events and cultural trends converged in the decades following World War II to undermine the pro-technology consensus in the U.S. and build a critical debate about industrial environmental harms. Whereas sportsmen had access to power and the type of social authority necessary to challenge pollution in the years immediately following the war, other voices slowly gained a place in the public sphere. Rachel Carson's transformative voice might have entered the debate sooner; her concern about man's impact to the natural world intensified following the atomic bombing of Hiroshima and Nagasaki in 1945. Her research into the impacts from chemical pesticides began in the 1950s, yet in part because of the national attitude toward science and technology, she waited to publish her findings until 1962. By then, various national and global health scares were undermining popular perceptions of

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[220] Ralph Bolgiano, interview by Christina Wulf, digital recording, 18 January 2010, Shenandoah Valley Oral History Project, James Madison University, Harrisonburg, Virginia, 4.

industrial benevolence: strontium-90 from above ground nuclear tests appeared in milk and caused cancer in children; the carcinogenic herbicide aminotriazole entered the food supply despite government regulation; and the flu medicine thalidomide led to tragic birth defects.[221] All of these raised questions about the unqualified dependability of scientific discoveries.

These events and Carson's book raised questions within certain scientific communities and challenged them to take a more public and active role. A 1962 Ecological Society of America report stated: "*Silent Spring* created a tide of opinion which will never again allow professional ecologists to remain comfortably aloof from public responsibility." The ecologists realized the necessity of providing an "authoritative voice" to citizens and policymakers. "Popular ecologists" like Rachel Carson, Aldo Leopold, and others used the vocabulary of ecology to critique modern science and technology and build "a moral case about the proper relationship between society and nature." Their language and ideas found resonance among a public watching increasingly serious environmental harms unfold. Meanwhile, professionals within the discipline of ecology retained a deep connection to modern science, the military-industrial complex, and a managerial perspective toward natural systems.[222] This approach proved useful in appealing to many Congressional leaders interested in pollution control and concerned about the public anger over environmental degradation.

The public fear and anger that drove the passage of new water quality protection and toxic waste remediation laws expanded as examples of

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[221] Lytle, 143-145.

[222] Milazzo, 94-95 and 90-91.

environmental harm became more visible and had a more personal impact. Previous conservation activists tended to be drawn from groups like the IWLA and National Wildlife Federation, the Garden Club of America, outdoor and wilderness enthusiasts with the Sierra Club and Wilderness Society, as well as a smattering of scientists.[223] Environmental conservation in the late 1960s and '70s, however, grew into a widespread public concern that resulted in much stronger laws protecting water quality.

The factors feeding into this increased environmental concern were numerous. Part of the cause, as articulated by historian Tom McCarthy, was simply that "when industrial pollution got bad it affected someone's pursuit of 'the good life' and people complained."[224] Sportsmen complained sooner because their "pursuit of the 'good life'" put them in direct contact with environmental degradation early on. More widespread outrage about industrial pollution occurred as it affected more of the population. The growing network of roads and more widespread availability of automobiles opened the countryside and wilderness to Americans. Interest in outdoor recreation increased dramatically after WWII with the availability of "cheap unrationed gasoline, higher living standards, and paid vacations."[225] A report to the Outdoor Recreation Resources Review Commission, however, found that "water pollution [was] diminishing the number of recreation waters" for swimming and

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[223] Mark Harvey, "Loving the Wild in Postwar America," in *American Wilderness: A New History*, ed. by Michael Lewis (Oxford: Oxford University Press, 2007), 198. In addition to advocating for national and state parks, the Garden Club of America also pursued educational programs about the danger of aerial pest control. See Edmund Russell, *War and Nature: Fighting Humans and Insects with Chemicals from World War I to* Silent Spring (Cambridge: Cambridge University Press, 2001), 214.

[224] McCarthy, 111.

[225] Harvey, 187-188.

boating as well as fishing and waterfowl hunting.[226] Thus, while outdoor excursions and experiences sparked a greater interest in nature, they also exposed more Americans to polluted landscapes.

Likewise, car culture facilitated the expansion of human dwellings into the countryside. Suburbanization was an important part of post-war culture, spurred on by a housing shortage and increased demand for housing. During the war, the U.S. government urged citizens to save money and invest in war bonds as a patriotic duty to support the war effort and prepare for a post-war economy. Even before the war ended, advertisers promoted a post-war consumer culture: according to a Royal typewriter ad, "what this war is all about [is the right to] once more walk into any store in the land and buy anything you want."[227] The suburban single-family home topped the list of desirable consumer items and was promoted by government and industry in hopes that it (and appliances to fill it) would be a "pump primer for the postwar economy," preventing a return of the pre-war economic depression.[228] The success of this vision could be seen in vast single-family suburbs such as Lakewood Park and Levittown.

In suburban landscapes, however, environmental degradation often became personal. In historian Adam Rome's words, "the bulldozer was never far from the living room," and in that intimate space, the destructive nature of

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[226] U.S. Geological Survey, *Water for Recreation – Values and Opportunities: Report to the Outdoor Recreation Resources Review Commission* [ORRRC Study Report 10], (Washington, DC: USGPO, 1962), 14-18, quoted in Adam Rome, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism* (Cambridge: Cambridge University Press, 2001), 141.

[227] Lizabeth Cohen, *A Consumer's Republic: The Politics of Mass Consumption in Postwar America* (New York: Vintage Books, 2003), 70-71.

[228] Cohen, 73; also Carroll Pursell, *Technology in Postwar America: A History* (New York: Columbia University Press, 2007), 98.

post-war industry intruded into the comfortable world of post-war prosperity. Life in the suburbs exposed Americans to a range of environmental ills, including the disappearance of wildlife and scenic countryside as land was cleared and leveled for development. In addition, building in environmentally sensitive areas meant homeowners had to deal with problems like erosion and flooding.[229]

As for water pollution, Rome observes that that more Americans may have become attuned to the need for water quality protection due to living with a septic system in the suburbs than from observing industrial pollution in rivers and streams. Rapid suburban construction far away from centralized sewer systems required the use of septic tanks. Unplanned growth and problems with siting and design led to frequent system failures and contamination of streams, groundwater, and eventually drinking water. Synthetic laundry detergents also escaped into the environment via septic systems, appearing not just as suds in wells and tap water but also in rivers and lakes, sometimes forming “floating mountains of foam.”[230]

By the early 1960s, personal fears of drinking water contamination and health impacts from chemicals made water pollution an issue for millions of Americans who might otherwise have paid little attention.[231] The public outcry spurred passage of increasingly strong water quality protection laws. Indeed, during the debate surrounding the 1972 Clean Water Act, a Republican official in Long Island contacted President Nixon’s staff to express strong support for

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[229] Rome, 6, 3.

[230] Rome, 89.

[231] Rome, 106-107.

the law; his locality's rapid population growth was seriously exacerbating pollution of groundwater by leaking septic systems.[232] Polluting industries and politicians were both discovering that "any industrial firm that crossed purposes with the American homeowner's conception of 'home, sweet home' risked messing with a force more powerful than itself."[233]

Growing media attention also contributed to support for stronger environmental protections. The environment became a significant topic for news coverage in the 1960s, with the annual number of stories on the subject reaching an initial peak around 1970.[234] During the postwar years, the number of households with a television skyrocketed. In 1950, 9% of U.S. households had a television. By 1955, the number jumped to 64.5%. Ten years later, 92.6% of households had television, and by 1972, the year the Clean Water Act became law, that number was 95.8%[235]

The visual power of television also brought news of environmental harms and disasters into American living rooms. The Santa Barbara oil spill in January of 1969, followed by the Cuyahoga River fire a few months later, were powerful visible symbols of "the ability of modern industry to turn the grace and beauty of nature into something grotesque."[236] Wider availability of newspapers and other print media likewise increased knowledge of environmental problems

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[232] Milazzo, 251.

[233] McCarthy, 115.

[234] Anders Hansen, "The media and the social construction of the environment," *Media, Culture and Society* 13 (1991), 444.

[235] Television Bureau of Advertising, Inc. "Media Trends Track," http://www.tvb.org/rcentral/mediatrendstrack/tvbasics/02_TVHouseholds.asp (accessed June 1, 2010).

[236] Rome, 5.

occurring in other parts of the country and the world. Mainstream media often picked up news stories first covered by the publications of sportsmen's and conservation organizations. A *New York Times* editorial opposing aerial pesticide spraying in 1958 helped to bring that issue to public attention. Even before *Silent Spring,* articles voicing concern about pesticide spraying appeared in widely-read publications like *Reader's Digest*, *Life*, and *Saturday Evening Post*. Even *Sports Illustrated* covered the topic, showing the clear interest among mainstream media in exploring these issues.[237]

Years later, beginning in 1978, TV broadcasts and print media showed dioxin and other toxic chemicals, with their attendant health impacts, leaching into the homes and schools of residents in an upstate New York suburban community built in the post-war years. The Love Canal tragedy spurred another national outcry, this time in support of federal legislation to clean up toxic waste.[238] In 1980, President Carter signed into law the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as the Superfund Act.

Congress and the post-war Presidents responded to public fear and anger over environmental pollution and its public health threats with varying degrees of commitment. President Eisenhower, for example, referred to polluted waters as "a uniquely local blight" that should be dealt with accordingly. Business owners, as well as local and state officials, welcomed this approach,

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[237] Russell, 216.

[238] It is worth noting that Hooker Electro-Chemical Corporation, the main polluter at the Love Canal site, manufactured nearly 50% of the total synthetic rubber produced in the U.S. during World War II. This was the substance that was paired with high tenacity rayon cord to make tires for military use. See Richard Newman, "From Love's Canal to Love Canal: Reckoning with the Environmental Legacy of an Industrial Dream," in *Beyond the Ruins: The Meanings of Deindustrialization,* ed. Jefferson Cowie and Joseph Heathcott (Ithaca: Cornell University Press, 2003), 124.

and it was enshrined in the 1948 Water Pollution Control Act.[239] This first federal water quality law and its 1956 amendments lacked any federal enforcement power and focused mostly on public health.[240]

The shift from this approach to the commitment of Senator Edmund Muskie and his staff to steadily strengthen federal oversight of water quality protection shows the political momentum building around protection of the environment. Most important was the unveiling of industrial hazards combined with increasing public awareness of environmental problems. In the background, however, groups with no particular "environmentalist" stripes—from politicians seeking votes to local officials seeking "pork" appropriations for water control and water treatment projects—helped move federal water quality laws forward. Likewise, the philosophy that shaped the 1972 Clean Water Act was not based strictly on the holistic concerns of "popular ecology" but incorporated much from post-war professional science and systems thinking.[241]

By 1980, the federal government enacted a host of laws with the goals of, among others, preventing water and air pollution, cleaning up toxic waste, and protecting workplace health and safety: laws that would have tremendous impact on the 440-acre site of the rayon plant in Front Royal. They would also have broader implications, often leading to better methods of buffering the public from environmental hazards rather than stopping them at the source.

Although the new environmental laws and regulations were overwhelmingly beneficial overall, the ironies and unintended consequences of

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[239] Milazzo, 3, 19.

[240] Colten, "Contesting Pollution in Dixie," 609.

[241] Milazzo, 251.

increased public concern for the natural environment were plentiful: people pressed for a cleaner environment in part because new environment-harming technologies like cars and roads allowed them to explore previously remote areas and experience them more personally; likewise, suburban development brought people into closer contact with nature while causing environmental destruction. In other words, the new degree of public concern did not necessarily recognize the depth of public complicity.

A somewhat similar set of ironies accompanied efforts to clean up pollution. Unless pollution was stopped at the source—in other words, no longer created—attempts to clean it almost always resulted in displacement of the pollutants. For instance, adding scrubbers to the steel mill smokestacks in Gary, Indiana to meet Clean Air Act guidelines significantly lowered airborne emissions. Once removed, however, the particulate matter became a form of toxic solid waste. No harmless form of hazardous pollution disposal exists—it always impacts someone or some natural system. In Gary, the steel mill management chose to dumped the ash near low-income communities, particularly communities of color.[242]

The same phenomenon occurred with wastes that had previously been disposed of in the water. Water pollution regulation resulted in a number of corporations turning to landfilling techniques.[243] Hooker Chemical's decision to bury its chemical wastes at Love Canal was a common choice. The difference between Hooker and American Viscose in this regard was that the former had to

[242] Andrew Hurley, *Environmental Inequalities: Class, Race, and Industrial Pollution in Gary, Indiana, 1945-1980* (Chapel Hill: University of North Carolina Press, 1995), 172.

[243] Tarr, xliii.

bury waste off-site while AVC had adequate space to landfill chemicals, like the hydroxide sludge, on their own property. Nevertheless, toxics have a way of escaping human control, and much of the hazardous material cleaned out of AVC's acid and alkaline waste streams ended up back in the river.

American Viscose's troubles began early, following passage of the 1946 Virginia Water Control Act. In order to meet the new requirements, AVC installed new technology to neutralize the acid discharges. The process first involved mixing the alkaline, acid, and sanitary wastes coming from the plant in a large storage pit. The alkaline chemicals immediately neutralized part of the sulfuric acid and were "completely neutralized" in return.[244] The remaining waste acid was mixed with lime slurry to complete the neutralization process. The reaction between sulfuric acid and lime created a mix of calcium sulfate and zinc hydroxide, a material that "is perpetually the consistency of toothpaste." A Dorr filter, installed in September 1946 in response to the new Virginia law, separated the calcium sulfate and zinc hydroxide from the effluent.[245] The sludge was pumped to waste lagoons along the river's edge for final storage.[246] By 1989, these sulfate/hydroxide basins covered roughly 85 acres and held an estimated 936,000 cubic yards of sludge.[247]

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[244] B.N. Scheuer, "Four Wastes, One Effluent," *Chemical Engineering* (February 1948), 138-140. The original draft of this paper is part of the AVC documents collection at the LVRCA. It is dated September 12, 1947, so Scheuer's description of the system as an effective treatment of rayon waste was likely made with full knowledge of the extensive weaknesses within the system. Regarding the retention basins, Scheuer explains that "since these basins were located a short distance from the river and below the flood level, they are simple earth excavations with no material of construction involved."

[245] "Deposition of John H. Mallinson," 21.

[246] Descriptions of the rayon plant use the terms "sulfate basins" and "hydroxide basins" interchangeably to identify these storage lagoons.

[247] Exponent Engineering and Scientific Consulting, "Feasibility Study Work Plan," 8.

Although Scheuer and Joseph celebrated this waste treatment system in their 1950 article, and Scheuer published a scholarly paper about it in February of 1948, AVC's waste treatment did not work particularly well in practice. In October of 1947, the inadequacy of the system was causing serious problems. The volume of waste, AVC engineer Roetman wrote, ""has overwhelmed the plant." The quantity of calcium sulfate sludge incessantly clogged the vacuum filter meant to help separate it out of suspension. The sludge piled up in the settling tank, and as a consequence, some calcium sulfate consistently washed into the river, creating a milky appearance. In addition, the equipment for introducing lime into the acid wastes had to constantly operate at its maximum level, leaving "no reserve capacity to take care of the slugs of acid that frequently appear."[248]

Scheuer's article in *Chemical Engineering* revealed a willingness at American Viscose to stretch or obscure the truth. The company considered a response to the calcium sulfate build-up that reflects this attitude. Calcium sulfate built up so quickly on every surface at the treatment plant that the facility had to shut down weekly for cleaning. "During the periodic shutdowns," Roetman wrote, "the waste enters the river untreated." He continued, demonstrating the corporation's attitude toward the Virginia law and suggesting their past approach to the problem: "As these occur at frequent intervals, they cannot be passed off to the State as unforeseen accidents." Roetman concluded

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[248] "Memorandum: E.T. Roetman to Mr. A.G. McVay: 10-69 – Addition to Waste Treatment Plant FR, October 8, 1947," 3.

that AVC must add more equipment and facilities to deal with the overloaded treatment plant.[249]

Interestingly, the State Water Control Board engineer, L.L. Hedgepeth, was also willing to cut corners. In November 1947, he offered AVC engineers several suggestions to improve the appearance of the Shenandoah and thus decrease complaints from the public. The suggestions dealt with cosmetic issues rather than a serious effort to decrease waste or treat it more effectively. He proposed changing the design of the outlet pipe to eliminate foaming when the effluent went into the river. Multiple outlets into the South Fork, Hedgepeth thought, might prevent so much concentration of waste on one side of the river while mixing and diluting the "off color" material more thoroughly in the river water. Four or five outlets attached to separate sewers, he guessed, should do the trick.[250]

Some of AVC's struggle with toxic waste disposal, however, seemed to have been legitimately caused by a lack of knowledge about certain chemicals and their impacts. In August of 1947, for example, five of AVC's engineers sat down with the SWCB's Hedgepeth to discuss the company's application for a state certificate allowing discharge of wastes into the Shenandoah River. Two items on the agenda dealt with questions that neither the state official nor the AVC engineers could immediately answer. Neither knew for certain the level of B.O.D. in the cellulose bearing waste found on the river bottom or the duration of its impact in the river. In addition, the group lacked knowledge regarding

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[249] Ibid.

[250] "Memorandum: E.T. Roetman to Mr. R.M. Pfalzgraff: 10-69 Waste Treatment FR, November 3, 1947," 1; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

xanthates: sulfur compounds produced by the reaction of CS_2 with white crumb that was known to be toxic to aquatic life. The engineers' review of scientific research did not locate a method for determining xanthate levels in their waste stream. Hedgepeth promised to have the state look into both questions.[251] An AVC document from October of the same year reported that the engineers had found a basic testing technique but could not guarantee its efficacy for locating all xanthates. They could, however, state "*with certainty* that sulphur compounds exist in our waste etc."[252]

A 1948 memo showed American Viscose continuing to struggle with scientific uncertainty. The company initiated independent testing through the Institute of Textile Technology laboratory in Charlottesville, VA to see if the plant's treatment process was adequate to prevent toxicity to aquatic life. Even the experts at this lab did not have all the answers; they could determine "the effects of various wastes on fish life but at present cannot study the effects on fish food."[253] Despite these gaps in knowledge, however, the company continued to produce both rayon and polluting waste at full capacity.

Richard Almy, who worked as plant engineer at American Viscose, described another scenario from the early 1940s in which lack of knowledge combined with war time urgency to create environmental havoc. Almy

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[251] "Memorandum: R.W. Haywood to A.G. McVay: 10-69 Waste Treatment FR – B.O.D. Procedure and Analytical Program, August 4, 1947," 1-2; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

[252] Coxe, J.W. Jr., *Waste Disposal Analysis of Waste Acid,* October 24, 1947; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC. Italics are in the original document.

[253] "Memorandum: E.T. Roetman to A.G. McVay, Re: Toxicity Study of Treated Waste, March 8, 1948," 1; DEQ Documents, SWCB/DEQ v. Avtex Fibers (Front Royal), American Viscose Documents – 1942-1949; Avtex Fibers records, CN 37962; LVASRC.

explained that no impervious clay liners were ever installed in the viscose pits, hydroxide sludge lagoons, or other holding basins to minimize migration of chemicals. Foremen received minimal instruction: "get a bulldozer, go down there and dig the soil up on the sides of the basin with laborers and a bulldozer, make a road to it." Almy acknowledged that the technology to make clay liners was available at the time but stated that "nobody, to my knowledge, ever thought of the need for that sort of thing… We just dug a big hole and put the waste products in it." Speaking in 1990, Almy emphasized the change over time in his understanding of waste disposal procedures: "Of course in retrospect that was a bad decision, but we were learning, like everybody else was, about things like that. Now, that is a very bad thing to do, to dig a basin and not line it."[254]

Despite increasing knowledge about chemical waste disposal in the years following World War II, the engineers and managers at the rayon plant did not take appreciable measures to correct problems. Indeed, a degree of stasis seemed to hold sway at the rayon plant's waste treatment facility under all three of its owners: American Viscose Corporation, FMC Corporation, and Avtex Fibers, Inc. Despite the evident concern and efforts of some waste treatment engineers, the procedures in use when Avtex purchased the plant in 1976 were very similar to the process described by B.N. Scheuer in 1947. Modest changes occurred along the way. In the early 1970s, the company built a carbon disulfide recovery plant, and in 1974, began to reclaim zinc from the effluent

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[254] "Deposition of Richard R. Almy," 115-116, 114.

stream.[255] In 1983, under the direction of the EPA, Avtex began to run its waste viscose through the wastewater treatment plant instead of landfilling it on site.[256] The company continued to use lagoons as part of their waste treatment process; by the time the company closed, the viscose pits and waste lagoons covered 220 acres, approximately half the site (see fig. 16).[257]

The largest basins were located along the banks of the South Fork with only a modest dike separating toxic from aquatic. According to Ralph Bolgiano, no waste materials ever really left the Avtex site: "Everything that Avtex ever removed from their waste stream, they just pumped it back into one of their lagoons."[258] Acid and alkaline wastes were mixed and neutralized in unlined basins; the resulting hydroxide sludge went into six vast storage lagoons; and fly ash from the power house piled up in five large landfills (see fig. 17). The company could pay off fines when they violated the terms of their discharge permit, but the Shenandoah suffered the consequences of the unlined lagoons and waste viscose pits built to contain toxic wastes.

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[255] "Deposition of John H. Mallinson," 65. Mallinson noted that the company's actions were economically motivated: "zinc at that time was selling for like 80 cents a pound and you could recover it for a total cost of like 18 cents a pound."

[256] G & M Consulting Engineers, 1-4.

[257] Environmental Background Information Center, *Avtex Fibers, Front Royal, VA: A Corporate, Demographic, and Environmental Analysis* (Draft – December 12, 2001), 14.

[258] Ralph Bolgiano, interview by Christina Wulf, digital recording, 18 January 2010, Shenandoah Valley Oral History Project, James Madison University, Harrisonburg, Virginia, 6.

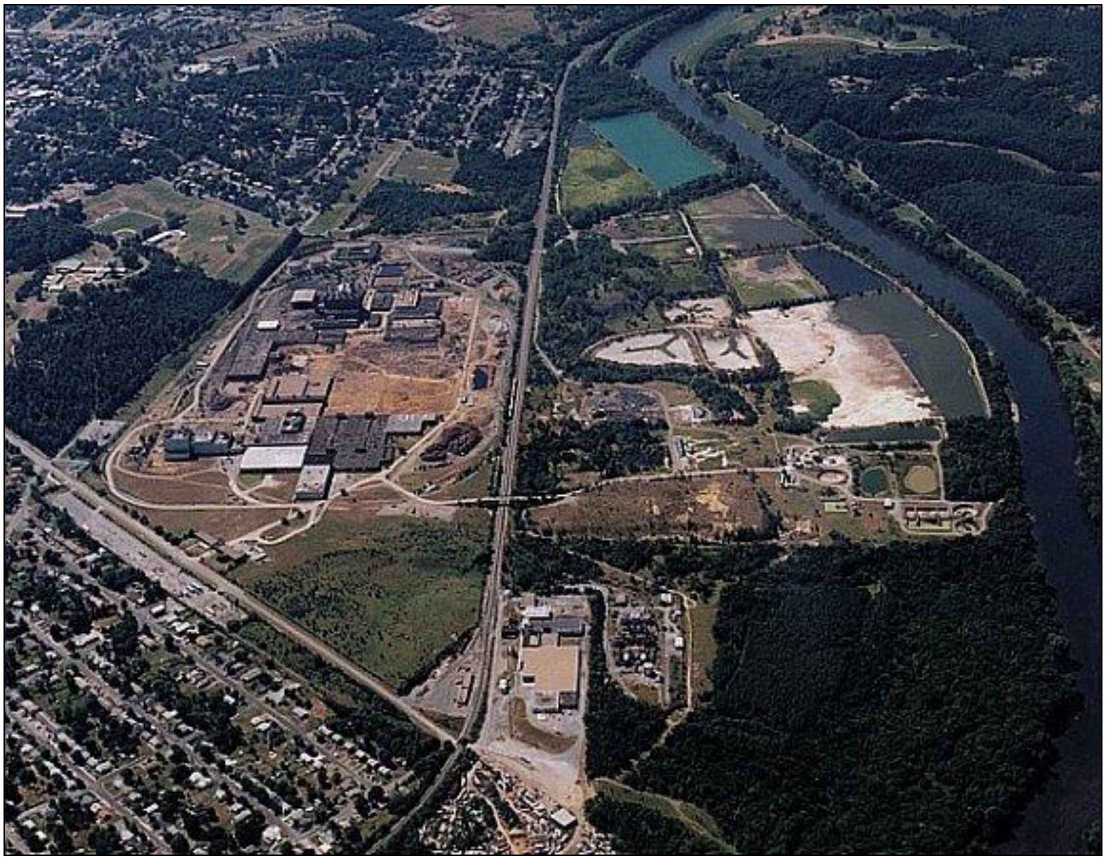

Figure 16. Aerial view of the Avtex site, 1998. Many of the factory buildings on the left-hand side of the picture have been demolished, but the unlined sulfate, fly ash, and waste viscose basins along the South Fork remain filled with waste almost a decade after rayon production ceased. *Source:* U.S. Army Corps of Engineers, "Front Royal Virginia: Avtex Superfund Site Aerial Views - 1998," http://www.nao.usace.army.mil/projects/Environmental%20Projects/Avtex/AvtexAerials.asp (accessed July 7, 2010).

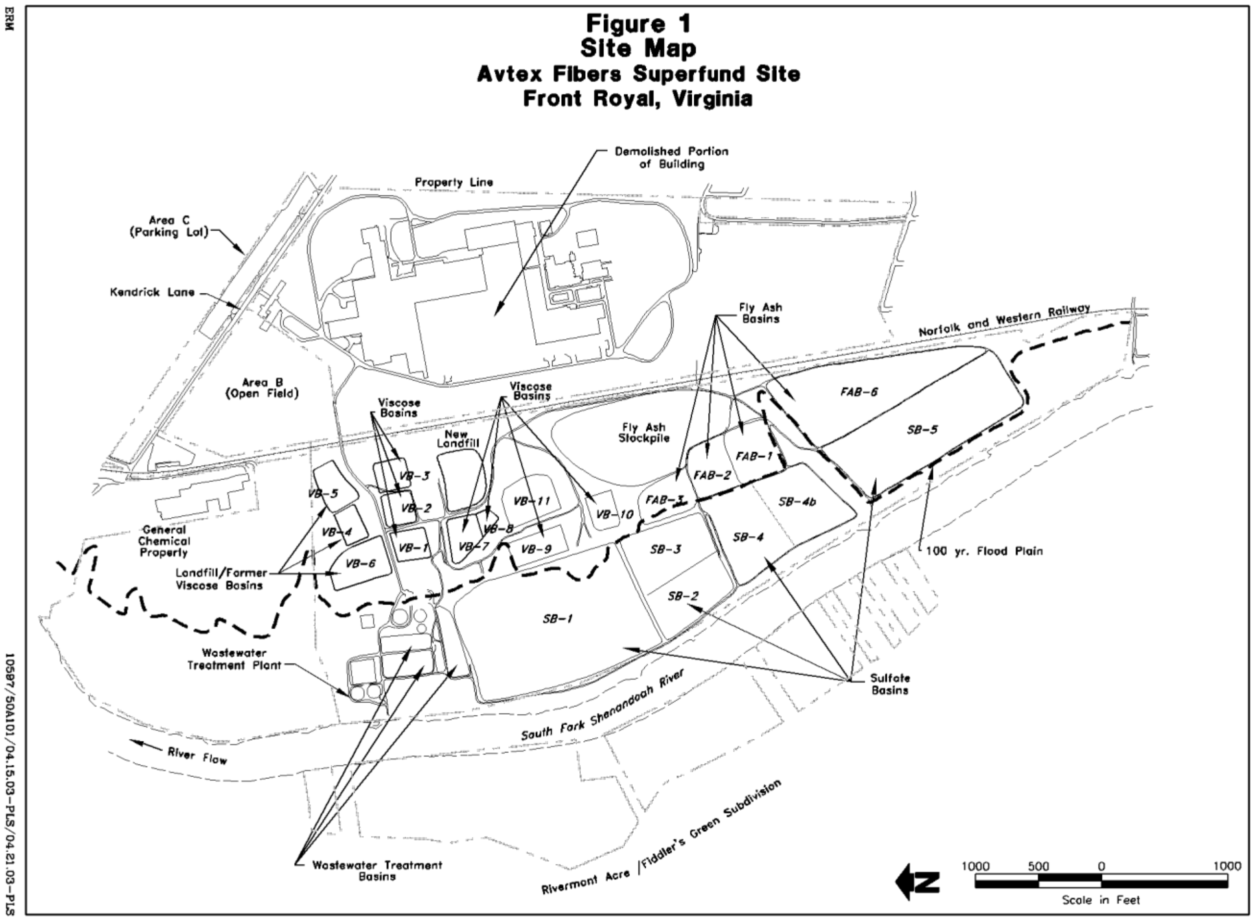

Figure 17. EPA map of the Avtex Fibers Superfund Site. ***Source:*** **EPA Mid-Atlantic Superfund, http://www.epa.gov/reg3hwmd/super/sites/VAD070358684/prap/ figure01.pdf (accessed April 27, 2009).**

The problem of unlined waste lagoons brings us back to the deeper history of the river, rooted in the geological formations beneath the Avtex site. The site is underlain with bedrock of the Ordovician-age Martinsburg Formation, a sedimentary rock type composed mostly of "alternating layers of shale and lithic sandstone, and minor limestone interbeds." These rocks can be found in various parts of the Valley, mostly associated with the Massanutten Synclinorium. A synclinorium is "different from mere synclines because they are more complicated: the overall synclinal shape is 'decorated' with numerous smaller anticlines and synclines."[259] The simplest explanation of anticlines and synclines is to say that they are rocks pushed together by opposing tectonic pressures into curved folds. A syncline, like the Massanutten formation, is a downward arc, like a bowl; the edges of the bowl are pushed upward while the competing pressures force the inner rocks downward. In the case of Massanutten, two long ridges of sandstone are the edges of the bowl with Fort Valley as the downward arc. Although millennia of erosion and weathering reshaped the rocks, traces of the Synclinorium and mountain building processes remain. Although Front Royal is separated from modern day Massanutten mountain, this major landscape feature still impacts surrounding areas as the lower level sedimentary rocks were uplifted as the Synclinorium formed.

Toxic materials from the unlined pits and lagoons on the Avtex site migrated through the "minor limestone interbeds" in the shale bedrock. Rock formations directed the leakage in different directions, but some ended up in

[259] Callan Bentley, "New Folds in the Massanutten Sandstone," Northern Virginia Community College NOVA GEOBLOG (February 11, 2009) http://www.nvcc.edu/home/cbentley/geoblog/2009/02/new-folds-in-massanutten-sandstone.html (April 26, 2009).

the South Fork. In the late 1980s, a neighbor of the plant and former Avtex employee, described "the place where…the river dies. 'You won't see a frog, a bug, a bird…' Gaseous bubbles come up from the bottom of the placid stream."[260] Bolgiano explained the source of the bubbles releasing from the sulfate lagoons into underground cracks in the rock:

> in the middle of the river, you could see places where everything would be nice and green, the water would look great, and then you'd see a little rock stick up there. It'd have a white hole in it, and the white was some bacteria or fungus that was capable of utilizing the sulphur… There'd be water coming out which, if you put your finger in the hole and jiggled it around, it'd be black because it would be sulfite down there before it hit the [river] water with oxygen in it… It'd be black, sticky, rotten-egg smell and so forth. You could find these on the river bottom, hundreds of yards – hundreds and hundreds of yards – from the lagoons.[261]

A significant portion of the underground pollutant stream did not, however, go directly into the South Fork. A smaller anticline (formed when competing tectonic pressures push rocks upward into an arched shape) in the bedrock beneath Avtex formed a kind of tube extending beneath the South Fork of the Shenandoah, providing "important structural control on the movement of the dense carbon disulfide plume."[262] This wave of pollution originated beneath the three newer waste viscose pits, filled between 1958-1983. The pits were

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[260] Dorothea Jackson, "Standing Our Ground," *APF Reporter* 15, no. 2 (n.d.). Published by the Alicia Patterson Foundation, http://www.aliciapatterson.org/APF1502/Jackson/Jackson.html (accessed January 12, 2010).

[261] Bolgiano, 19.

[262] Exponent Engineering and Scientific Consulting, "Feasibility Study Work Plan," 11 and 58. This interpretation of contaminant migration is corroborated by John Torrence, geologist and site manager for the current clean-up operations at the Avtex site.

probably excavated “close to, if not into, bedrock,” and contain a total of 9.8 million cubic feet of viscose sludge.[263]

The chemical reaction that allows cellulose to be regenerated into rayon also caused the carbon disulfide plume of contamination in the groundwater. Mixing “white crumb” with carbon disulfide to produce sodium cellulose xanthate (“yellow crumb”) is a reversible reaction. When left to age, waste viscose steadily releases carbon disulfide. In the waste basins, the CS_2 took an aqueous form as rainwater percolated through the viscose.[264] In addition, plant engineers used fly ash from the plant’s coal-fired boilers to build berms between some of the viscose pits. The berms, in turn, leached chemicals that interacted with the waste viscose to form arsenic.[265] All of the chemicals eventually entered and contaminated the groundwater.

The anticline prevented the contamination from spreading widely. Instead, it channeled the material under the river and directly into the wells of the neighborhood across the river from Avtex. In 1980, the regional engineer for the SWCB noticed that many residents of Rivermont Acres were purchasing water treatment systems for their wells.[266] State agencies investigated and found the groundwater polluted by an alphabet soup of chemicals: “arsenic, cadmium, carbon disulfide, chloride, iron, lead, manganese, phenols, sodium, sulfate, hydrogen sulfide, and zinc,” with highest quantities of carbon disulfide

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[263] Exponent Engineering and Scientific Consulting, “Feasibility Study Work Plan,” 7-8.

[264] Exponent Engineering and Scientific Consulting, “Feasibility Study Work Plan,” A-2. The same process allows waste viscose to slowly dewater and decompose, becoming significantly less toxic.

[265] G & M Consulting Engineers, 1-21.

[266] Groves and Settle, 687; Environmental Background Information Center, 7.

and phenols.[267] Although the chemical concentrations were not officially considered carcinogenic by governmental agencies, former residents of Rivermont Acres report a high incidence of cancers which developed at a young age.[268] Avtex did not deal with the source of the pollution problem. Instead, the company simply purchased the majority of the Rivermont Acres properties.[269]

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[267] G & M Consulting Engineers, 1-25.

[268] Carlson and Mark, 25.

[269] G & M Consulting Engineers, 1-13 and 1-14.

Chapter 6

Controlling Technological Momentum by Trial and Error: Efforts and Obstacles

From 1980 on, the cumulative problems associated with chemical waste at the Front Royal rayon plant took on a momentum of their own, albeit a disorganized momentum that moved in fits and starts. The final years of the rayon plant saw remarkable fluctuations in power dynamics between a broad cast of characters, including Avtex's Chairman John Gregg, the Commonwealth of Virginia, the EPA, branches of the U.S. national security apparatus, and the South Fork of the Shenandoah River. The numerous environmental laws passed between 1946 and 1980 gave the state and federal governments a variety of tools to try and knock the rayon plant out of its toxic slump. The 1946 State Water Control Law required American Viscose to curb its chemical discharges into the South Fork of the Shenandoah River. A 1959 addition to the law allowed the SWCB to levy a substantial fine against AVC after a major fish kill in the South Fork. The 1972 Clean Water Act gave the state and federal governments enforcement power to control discharge of pollutants into surface waters. The EPA set water quality standards, delegating to the states the responsibility of issuing and monitoring the National Pollutant Discharge Elimination System (NPDES) permits, which designated the specific amounts of polluting chemicals that any facility can discharge.[270]

The discovery in 1980 of well-water contamination in the Rivermont Acres community garnered Avtex increased attention from regulatory agencies.

[270] U.S. Environmental Protection Agency, "Summary of the Clean Water Act," EPA Laws & Regulations, http://www.epa.gov/lawsregs/laws/cwa.html (accessed June 20, 2010).

The EPA listed Avtex's 440 acres as a potential toxic site under the newly-enacted Superfund Act and began to study the facility in more depth. The Superfund law empowered the EPA to identify contaminated sites, determine liability, and enforce cleanup. In 1983, spurred on by evidence of carbon disulfide, arsenic, and phenol contamination in the aquifer beneath the Avtex site, the EPA added the company to its national priority list. As part of the required remediation, Avtex enacted certain reforms. The company purchased the homes in Rivermont Acres with contaminated wells. In addition, the plant's wastewater treatment plant began to process waste viscose rather than landfilling it and started pumping and treating groundwater in an attempt to contain chemical migration. The remediation efforts were insufficient to keep the plant from official designation; Avtex became Virginia's largest Superfund site in 1986.[271]

Violations of environmental laws were long a part of the company's operating culture. In testimony before Congress, an EPA official stated that Avtex violated the terms of its NPDES permit approximately 2,000 times between 1980 and 1989. In November 1988, after repeated warnings and citations, the Commonwealth of Virginia sued Avtex for $19.3 million for non-compliance with the NPDES permit.[272] It is interesting to note that although the state had a clear interest in pushing Avtex to clean up its act, it did not file suit until pushed to do so by a citizen lawsuit against Avtex. Under the Clean

[271] Environmental Background Information Center, 1; and Groves and Settle, 687.

[272] Statement of Edwin B. Erickson, Regional Administrator, Region III, U.S. Environmental Protection Agency, before the Senate Subcommittee on Toxic Substances, Environmental Oversight, Research and Development, *Environmental Issues and Avtex Fibers, Inc.*, 101st Cong., 2nd sess., June 20, 1990, 39.

Water Act, citizens can sue polluters directly, and in October 1988, the Natural Resources Defense Council (NRDC) filed a notice of intent to sue "because of the slow pace of state officials." The state responded with their own lawsuit against Avtex within a month, superseding the NRDC action.[273]

Upon hearing of the Commonwealth of Virginia's lawsuit, Avtex's Chairman, John Gregg shut down the plant in early November of 1988 and turned to the federal government for help. Gregg blamed "foreign competition" and the high price of raw materials for the plant's closure, but the increasing cleanup costs and fines must have also played a role.[274] Most importantly, however, closing the factory allowed Gregg to engage in brinkmanship with several federal defense agencies. At the height of the Cold War, the agencies needed to keep Avtex in business, if only for long enough to arrange a new supplier of a specialized product made only at Avtex in Front Royal: carbonized (or carbonizable) rayon, a critical component of certain military armaments and aerospace technologies.[275] Virginia Senator John Warner helped broker a federal bailout by securing $43 million in contracts from the Department of Defense and the National Aeronautic and Atmospheric Administration (NASA). Warner declared, "It is essential to our national security to keep this plant operating." Avtex had to hand over its patent rights to the carbonizable rayon manufacturing process to NASA, but the company survived, reopening the

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[273] "Suit Planned Against Va. Company," *The Washington Post* (October 16, 1988): B7.

[274] Some speculate that Avtex faced a further economic disadvantage because of large debts left over following Gregg's leveraged buy out of the facility in 1976. See Environmental Background Information Center, 5.

[275] Cindy M. Miller, "The Bruised Image: Public Relations and Avtex Fibers" (BS thesis, James Madison University, 1991), 17. (Please note that additional information on Avtex's military connections will be explored later in this paper.)

Front Royal plant on November 10, 1989.[276] Avtex settled the lawsuit with the Commonwealth of Virginia by agreeing to pay certain fines, fix safety violations, and clean up its mess. However, little changed in the coming months, and safety and environmental conditions continued to deteriorate.

Between November 1988 and November 1989, Avtex broke the terms of its lawsuit settlement, violated its NPDES permit on at least ninety-nine days, and received a cleanup order from the EPA that required Avtex and FMC Corporation—the facility's owner from 1963-1976—to decontaminate the site's groundwater at a cost of roughly $9.1-million.[277] The rayon plant was self-destructing due to decades of flawed waste disposal practices, but the final blow came from a chemical not directly involved in rayon manufacturing. In April of 1989, during routine monitoring studies, SWCB scientists found highly-toxic polychlorinated biphenyls (PCBs) in the tissue of fish in the Shenandoah River downstream of the Avtex site. Following Clean Water Act protocols, SWCB scientists routinely "monitor[ed] fish tissue and sediment" to detect aquatic contamination.[278] They painstakingly traced the PCBs back to Avtex. Further inquiry showed that the materials originated in a blown-out electrical transformer on the roof the plant. Records revealed that Avtex had knowingly discharged the pollutants into the South Fork for multiple years.

In August 1989, the Commonwealth of Virginia filed a second lawsuit against Avtex Fibers, focused this time on the PCB violations. The EPA's $9.1-

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[276] "Point Paper on Avtex Rayon Fiber Situation, prepared by Captain Shearer/SAF/AQQM/7-8123/15 Nov. 1988," DOJ Documents, (Box 6 of 10) FMC v. NASA, Federal District Court, Pleadings, Exhibits, Settlement Docs; Avtex Fibers records, CN 37962; LVASRC. Also, Groves and Settle, 688.

[277] Environmental Background Information Center, 9; Groves and Settle, 688.

[278] Virginia Department of Environmental Quality, "Fish Tissue and Sediment Monitoring Program," http://www.deq.virginia.gov/fishtissue/ (accessed February 21, 2009).

million groundwater cleanup order followed in early November. Then on November 9, 1989, the State Water Control Board took the unusual step of voting to revoke Avtex's NPDES permit. The situation demonstrated a profound reversal: during World War II, the river's aquatic species had few defenders; no limits existed on pollutants from the rayon plant; and environmental harms were not a priority for state or federal government. Now a major industrial facility and regional employer, with close ties to the national defense apparatus, faced steep fines and legal action by both the state and federal government for harming the Shenandoah River ecosystem.

The SWCB's permit revocation vote did not require the plant to shut down. In the NPDES system, revocation of a permit differed from permit termination, keeping open the possibility of future reissuance. In addition, Avtex had the right to appeal the Board's revocation order. Instead, John Gregg chose once again to close the factory. On November 10th, the day after the SWCB's vote, Gregg ordered the boiler room to shut down, cutting electricity for the entire facility. Employees were left standing next to their machines in the dark with no idea what had happened or where to go. John Torrence, FMC's manager of remediation for the Superfund site, said it took hours for the building to be evacuated.[279] The sudden closure violated labor contracts and left over 400 workers unemployed with no warning. For their part, Gregg and the other Avtex owners walked away largely unscathed; their company—Avtex Fibers-Front Royal, Inc.—declared bankruptcy three months later, leaving FMC and taxpayers to shoulder the cleanup costs.[280]

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[279] Torrence, personal conversation.

[280] Environmental Background Information Center, 10.

The actions of many managers of the rayon facility, particularly during its final years, reflect a degree of arrogance and carelessness with regard to the environment. The on-going relationship between the rayon plant and U.S. military interests is one possible reason behind this attitude. As the largest supplier of war-critical rayon tire cord during World War II, government requirements allowed American Viscose to ignore any environmental repercussions of their waste. The situation changed rapidly after the war with Virginia's 1946 Water Control law; however, a sense of stasis remained at the factory, limiting further improvements to the waste treatment system. By the 1970s, when stronger environmental laws came into force, the rayon plant, now operated by Avtex Fibers, was again manufacturing a militarily-critical material. This time, however, Avtex was not just a major producer but the sole supplier.

Connection to the powerful momentum of the Cold War military-industrial complex provided a degree of shielding against environmental regulation, particularly in the final years of the plant's operating life. During the 1960s, as part of the Cold War arms race and space race, scientists sought a material that could withstand high temperatures for use on rocket and missile nozzles. The most effective material developed was called carbonized rayon, created by converting rayon into graphite fibers. In the 1970s, Avtex purchased the patent to make the rayon yarn needed for carbonizable rayon. Although some of the rayon was used for tennis rackets and boat hulls, NASA and the Department of Defense were the main purchasers:

> Besides shuttle booster motors, the rayon material is critical to the MX and Trident 2 intercontinental ballistic missiles, the Delta, Atlas and Titan launch vehicles, reentry vehicles, and tactical missiles including AMRAAM, SRAM-2, Standard, Stinger and

> Tomahawk. Avtex is a fifth-level subcontractor to U. S. rocket motor manufacturers.[281]

Like American Viscose's importance during World War II as the largest manufacturer of high-tenacity rayon, Avtex held a crucial place during the Cold War as the sole producer of carbonized rayon. By relying on Avtex, however, NASA and the military put themselves in a precarious position. After Avtex closed the first time in 1988, defense industry contractors were told that if Avtex remained closed, the existing supply of carbonized rayon would last only until March 1989.[282] Avtex's managers used this unique position to leverage the NASA and military contracts that allowed the company to reopen after its first closure in 1988.

These federal contracts came with no requirement to clean up the environmental or safety hazards at Avtex. In essence, Avtex's supporters within the national security arena sanctioned the severe problems at the facility. It seems possible that Avtex's truculence was a result, or at least a side effect, of its deep engagement with military interests—not because these interests encouraged pollution per se, but because it was a second tier concern. During World War II and the Cold War, national security could, and often did, trump environmental regulations. As a result, federal facilities often have worse rates of compliance with federal water quality laws than privately-owned plants.[283]

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[281] "New Source Expected to Prevent Shortage Of Rayon for NASA, Defense Rockets," *Aviation Week and Space Technology* 131, no. 22 (November 27, 1989): 24.

[282] "Industry Briefing: Avtex Fibers Front Royal Inc. & Aerospace Rayon Fiber Position, November 1988, Salt Lake City," DOJ Documents, (Box 6 of 10) FMC v. NASA, Federal District Court, Pleadings, Exhibits, Settlement Docs; Avtex Fibers records, CN 37962; LVASRC.

[283] Steven R. Linke, *Managing Crisis in Defense Industry: the PEPCON and Avtex cases* (Washington, DC: Institute for National Strategic Studies, 1990), 49.

But times do change, and environmental damage can become so severe that attitudes change. The political climate shifted somewhat following the inauguration of George H.W. Bush. The EPA under Ronald Reagan was a weak agency, hesitant to use the full power of the Superfund Act against Avtex. In contrast, Bush's appointee for EPA Administrator was William K. Reilly, a former president of the World Wildlife Fund, who promised enforcement of hazardous waste cleanup laws during his confirmation hearings. Internationally, some Cold War tensions had eased with liberalization of Soviet regimes in the Eastern Bloc and the U.S.S.R.[284] Perhaps this helped Senator Warner to shift gears, stating in September 1989, after the PCB violations were confirmed, that the environment must take precedence over national security, and that Avtex should close if it was financially unable to stop polluting.[285] He took a tour of the facility just before the end of its operational life, saying, "As a lay person, I found it shocking… The management freely discussed that they could no longer operate this machinery because it was broken down, it was rusted, it leaked, and was presumably contaminated."[286]

Ralph Bolgiano, the former SWCB biologist, theorized that Avtex shut the doors on November 10, 1989 expecting to be bailed out a second time. He described a meeting that occurred immediately after the closure:

> I remember the [Avtex] plant manager saying, "we've got a real problem here." And the EPA said… "what's that? We want to know about that." And the plant manager said something like…

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[284] Indeed, Avtex's final closing practically coincided with East Germany's announcement on November 9, 1989 that its citizens could visit West Germany.

[285] Miller, 20.

[286] "Statement of Senator John Warner," Subcommittee on Toxic Substances, Environmental Oversight, Research and Development, 18.

> "we've got all the viscose in those lines, and if we don't do something quick, it's going to harden up." I remember the EPA guys saying, *"well, is that going to hurt the river?"* There's this big long pause. And the plant manager says, "well, no. But there's hundreds of millions of dollars worth of equipment that's going to be worthless." And the EPA guy said, "ok, next question." He really didn't care. It wasn't his job to care. Nobody had told him, "save the plant." And he didn't… That place hardened up, and it would have cost more to start it again than it was worth… That's the real reason they're gone. They thought they would be coaxed into firing up again, and nobody coaxed. Nobody blinked.[287]

This story illustrates the tremendous power shift between the river and the factory in the decades between 1940 and 1989. The Shenandoah had again attracted powerful allies willing—at least in this extreme instance—to privilege environmental protection over business interest.

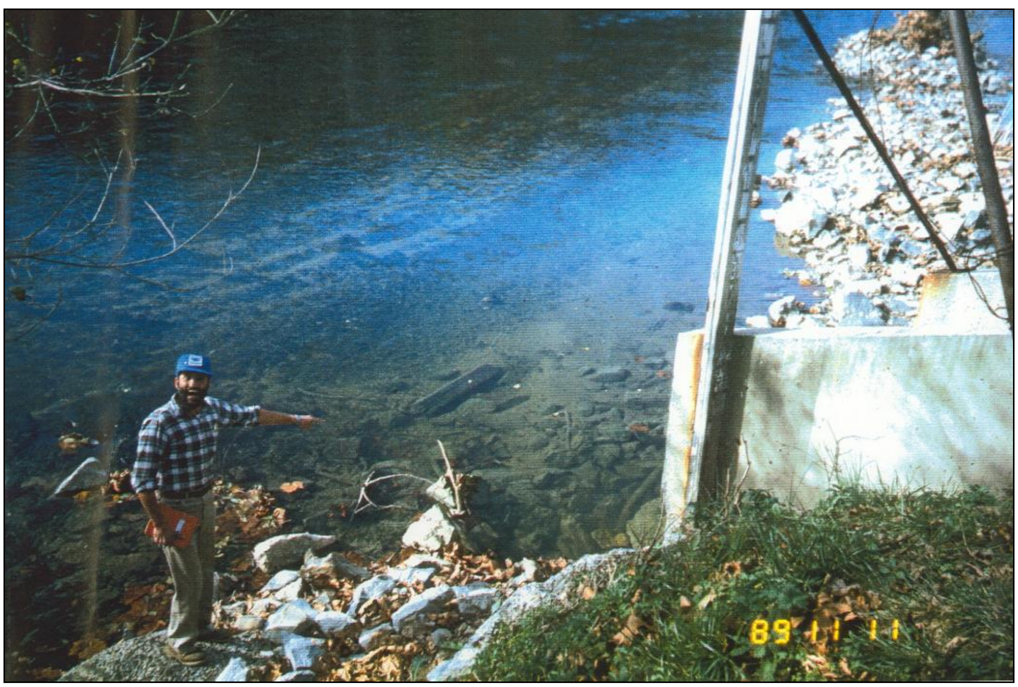

Figure 18. Ralph Bolgiano at the rayon plant's discharge pipe, no longer pumping out "hot, soapy, nasty water," on November 11, 1989, the day after the facility closed. *Source:* Virginia DEQ, "An Environmental History: The 1980s," http://www.deq.state.va.us/history/1980s.html

[287] Ralph Bolgiano, interview, 15.

Shutting down with no preparation did indeed leave chemical chaos behind, destroying costly machinery and creating hazardous conditions for others to clean up. Chemicals remained in pipelines, machines, and laboratories. Waste viscose hardened in the lines, rendering much of the equipment unsalvageable. As the EPA began the slow process of decontamination, they found dangerous conditions inside a devastated factory. Multiple potentially hazardous chemicals used to manufacture rayon were stored inside the plant, "such as carbon disulfide, sodium hydroxide, ethylene diamine, phenol, sulfuric acid, zinc salts, sodium sulfate, sodium hypochlorite, solvents, and fuels."[288] As the closed facility steadily degraded after 1989, containment and cleanup became more difficult and potentially dangerous.

Over time, off-gassing from clogged pipes and sewer systems created concentrations of carbon disulfide and hydrogen sulfide gases in the buildings that were both toxic and potentially explosive. In other locations, the acids used in the acid bath stage had eaten through pipes, sewers, manhole covers, even concrete. The PCB discharge into the South Fork had contaminated the storm sewer system for the entire facility. By all accounts, the place was a mess. A 1993 Halliburton report recommending remediation procedures describes some of the conditions:

> Solid and semisolid viscose and crumb remain in process vessels, and piping contains liquid process chemicals. Carbon disulfide in concentrations up to 20,000 ppm may be present in the viscose liquids and slurries. Dried viscose hangs from process equipment and crumb is strewn amid the equipment within the churn and

[288] Exponent Engineering and Scientific Consulting, "Feasibility Study Work Plan," 6.

> mix rooms. Laboratory chemicals are isolated within locked rooms.[289]

Descriptions of pictures taken in March 1987 by former employee Barry Mills show that similarly grim conditions existed several years before the plant closed: "dark rooms full of rusted machines, walkways covered with slime, open vats of acid, gaping holes where chemicals ate through concrete floors and, covering almost everything, the white residue of evaporating acids."[290]

The EPA took on the task of decontaminating the buildings to the extent that they could. The acid building was considered too structurally unstable due to corrosion and was simply demolished. In the end, the EPA ascertained that the buildings were so contaminated that the best option was to remove them all, opening the land for re-development. One of the final site remediation projects continuing as of 2010 is the removal of the plant's sewer system. The Army Corps of Engineers undertook the actual demolition of the Avtex buildings. It is a point of pride with John Torrence, also reflected on the Corps' website, that significant quantities of materials, including "structural steel, pipes, valves, ducts, metal siding, etc. [were] disposed of as recycled material for melting and reuse. Concrete and stone [were] crushed to pebble size for beneficial reuse on site."[291] Visitors to the site today can still see piles of crushed brick awaiting use to fill and stabilize the sulfate and viscose basins.

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[289] Halliburton NUS Corp. and Gannett Fleming, Inc. "Final Project Operations Plan: Vol. 5 Health and Safety Plan – Avtex Fibers Site, Warren County, Virginia, June 1993," Avtex Administrative Record. EPA. http://loggerhead.epa.gov/arweb/public/pdf/135758.pdf (accessed May 3, 2009), 3-2 and 3-3.

[290] Carlson and Mark, 26.

[291] U.S. Army Corps of Engineers, "Fact Sheet – Avtex Fibers, Front Royal, VA – August 2005," USACE Norfolk District, Avtex Fibers, Front Royal, VA. http://www.nao.usace.army.mil/Projects/ Environmental%20 Projects/ Avtex/USACE%20Avtex%20Fact%20Sheet.doc (accessed May 7, 2009).

Those viscose basins, the major source of groundwater contamination from the rayon plant, however, remain precarious over twenty years after rayon production ceased. The eight viscose basins filled prior to 1958 had substantially dried and decomposed; the EPA determined that these could be capped and left on-site as part of the remediation.[292] The three newer, leaking pits remain on-site and continue to leak. As Exponent Engineering notes, waste viscose is 85% water with a soft, rubbery consistency: "this type of material has never been remediated before, and its low load-bearing capacity precludes the use of heavy equipment that would normally be employed."[293] Without the ability to use bulldozers to excavate the material, the only option at present is to pump out leachate from the viscose basins to prevent further percolation into the groundwater and monitor the results.

[292] G & M Consulting Engineers, 1-17.

[293] Exponent Engineering and Scientific Consulting, "Avtex Fibers Superfund Site, Front Royal, Virginia," Exoponent, Inc. http://www.exponent.com/Avtex-Fibers-Superfund-Site--Front-Royal-VA/ (accessed April 25, 2009).

Figure 19. Partial view of a full waste viscose basin, April 2009. The three newer basins, filled between 1958-1983, are responsible for contaminating groundwater beneath the site. Photo by the author.

As this problem highlights, remediation efforts on a Superfund site, like the waste treatment procedures at an operational rayon plant, are far from perfect. A tremendous amount of waste remains on the 440-acre site, either in landfills or in capped basins, requiring on-going monitoring to ensure that contaminants do not spread again in the future. By law, the EPA has to consider questions of cost, feasibility and effectiveness when deciding on a course of action, as well as the extent to which it will meet standards for protection of human and ecological health. In the case of the earlier viscose basins and various other contaminated landfill materials, capping the sites with soil, installing leachate drains, and long-term monitoring of the sites are considered the best cost-effective options. Maximizing safety and cleanup is not necessarily the goal; indeed, there is a philosophical dilemma of whether it is possible to maximize cleanup. Like the calcium sulfate and zinc hydroxide removed from the rayon plant's waste stream or the fly ash collected from the boiler plant, whatever toxics are removed from the 440 acres beside the South Fork must go somewhere. The materials not buried or reused on site now reside in various hazardous waste landfills in multiple locations including Ohio, Utah, and Canada.[294]

[294] Torrence, personal conversation.

Chapter 7

The Values of Precaution

The history of technology offers numerous examples of relationships like the river-plant complex formed by the rayon plant at Front Royal and the South Fork of the Shenandoah River. Courtaulds, Ltd. and its AVC subsidiaries, the original plant owners, innovated the viscose rayon-manufacturing technology and initiated the relationship with the South Fork, in search of economic gain. The plant opened in an era when water quality protection was a side issue, the domain of sport fishermen, public health officials, and sanitary engineers. Legal regulation of industrial pollution, in most instances, seemed to receive little consideration. Given its legacy of contamination, descriptions of the Front Royal rayon plant as "state of the art" in 1940, with a recovery system capable of reclaiming chemicals and keeping waste out of the river,[295] speak volumes to the assumptions and understandings of the time regarding chemical pollution.

Combining such limited foreknowledge with the agency of ecological systems—the South Fork's "life of its own beyond our control"[296]—creates a dangerous scenario, played out time and again as modern technological systems utilize more raw materials and produce more toxic wastes. For the rayon plant at Front Royal, World War II was the turning point, forcing expansion of the plant's technological system with astonishing rapidity, adding tremendous mass to the technology's momentum, and placing the river, and the environment in general, at the lowest level of consideration. Dismantling that

[295] Edmunds, 60.

[296] White, 109.

momentum took forty-nine years. Changes in societal concern for the environment led to a steady strengthening of environmental laws, culminating in almost a decade of trial and error efforts by the federal government, the Commonwealth of Virginia, sportsmen, homeowners, and many more to force the rayon plant into regulatory compliance. Even today, twenty-one years after Avtex closed, remnants of the rayon factory's technological momentum continue to interact with the river, as efforts to remediate contamination at the site continue.

Similarly, despite societal shifts toward environmental protection since World War II, social constructs from that era continue to haunt present-day efforts to prevent harm to ecological systems. Judgments regarding the primacy of military and economic needs over environmental protection went unquestioned in the years immediately following World War II. The "good" things provided by the rayon plant—materials to win a war and strengthen national security, products for consumers, paychecks and tax dollars for the community—had the highest value to the most people and were thus assumed to be most important. The benefits outweighed, and perhaps even justified, the "bad" pollution flowing into the Shenandoah River. These types of value judgments remain common in environmental disputes today.[297]

As the history of the river and factory demonstrates, however, human benefit and environmental harm exist in two physically interconnected but morally separate spheres. The moral necessity of defeating Nazi Germany on tires made with rayon cord had no impact on the ability of riverine life to

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[297] Comments based on the author's personal observations during a decade of full-time professional and/or volunteer service with several small, medium, and large-sized environmental advocacy organizations.

withstand the massive onslaught of chemical waste during the war. Indeed, none of the human enrichment derived from the rayon plant at Front Royal could ameliorate any of the physical harm done to the Shenandoah River. Likewise, neither the war nor the plant's employees caused the harm directly. Aquatic species died because concentrations of chemicals, nutrients, and particulate matter reached a level that aquatic insects, plants, fish, and other river life could not survive. The river has agency; it also has limits. The unpredictability of the Shenandoah River ecosystem escapes full human understanding, but when it comes to pollution—of any sort—the river cannot decide whether or not to die; it can only respond to changes in chemistry.

Current environmental laws do a reasonable job of taking this reality into account. An even more hopeful path would change the balance between rivers and factories in the future even further, placing the burden of proof on the factory to demonstrate its ability to prevent damage to the river in advance. Such a precautionary approach recognizes the agency of ecological systems and the limits inherent in human understanding of these systems. A formally-articulated concept of precaution exists already in scientific, advocacy, and global governmental circles. The values of this Precautionary Principle call for protection of health and environment in advance of moving forward with new technologies, even "in the absence of environmental certainty," as opposed to

> current policies such as risk assessment and cost-benefit analysis [that] give the benefit of the doubt to new products and technologies, which may later prove harmful. And when damage occurs, victims and their advocates have the difficult task of proving that a product or activity was responsible. The precautionary principle shifts the burden of proof, insisting that

> those responsible for an activity must vouch for its harmlessness and be held responsible if damage occurs.[298]

The precautionary principle works hand-in-hand with the "multilinear" nature of technological development and of human interactions with the natural world. The concept does not advocate a single designated outcome, rather it sets limits around multilinear developments, seeking to close off the most environmentally-harmful paths before they are taken.

Responding to calamitous pollution problems both in the Shenandoah River and around the world during the decades between 1940-1989, humans succeeded in shifting the power dynamics between the Shenandoah River and the rayon factory at Front Royal. This demonstrates the ability of human actions to counter the momentum of technological systems. Such momentum belongs to the human sphere; it is not an autonomous force outside of human control. As such, these technological systems, built by humans, can and should be judged by human values and self-interest. In contrast to ecological systems that have agency beyond human control, technological systems can incorporate and respond to changes in values. Thomas Hughes agrees that "contingencies and catastrophes" are not the only forces capable of breaking technological momentum; a change in values might do so as well.[299]

This is a difficult goal. As Hughes also intimates, the technological momentum surrounding many human-built systems includes a multiplicity of values—from greed to grace—gathered over the years of a technology's development and utilization. As the history of the rayon-plant complex at Front

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[298] Science and Environmental Health Network, "Precautionary Principle," http://www.sehn.org/wing.html (accessed July 6, 2010).

[299] Thomas H. Hughes, *American Genesis,* 466.

Royal demonstrates, merging or replacing those values with newer ones that place limits around human desire may take decades. Shifting societal values toward precaution will undoubtedly seem counterintuitive and uncomfortable to a great many people. The process of changing values may be messy and chaotic, rife with failures and unintended consequences, but it is, ultimately, possible.

Bibliography

Archival Materials

Avtex Collection, Local #371T Amalgamated Clothing and Textile Workers Union Papers. Laura V. Hale Archives. Warren County Heritage Society. Front Royal, Virginia.

In addition to the internal papers of the Local, the collection includes some American Viscose Corporation documents, newspaper articles, multiple volumes of AVC's employee magazine, *Avisco News*, and an extensive collection of photographs. The author inventoried and creating a finding aid for the Union papers collection during the summer of 2009.

Avtex Fibers, Inc. EPA ID# VAD070358684. Environmental Protection Agency Mid-Atlantic Superfund. On-line Archive. http://www.epa.gov/reg3hwmd/super/sites/VAD070358684/

The on-line archive includes the Administrative Record for the Avtex Fibers, Inc. Superfund site. The following reports from the Administrative Record are cited in this paper:

Exponent Engineering and Scientific Consulting. "Feasibility Study Work Plan: Avtex Fibers Superfund Site, Operable Unit 7. Report prepared for FMC Corporation, August 2000."

Environmental Protection Agency. "Record of Decision, Decision Summary," [n.d., 1988).

Halliburton NUS Corp. and Gannett Fleming, Inc. "Final Project Operations Plan: Vol. 5 Health and Safety Plan – Avtex Fibers Site, Warren County, Virginia, June 1993."

Versar, Inc. "Avtex Fibers Responsible Party Search and Financial Assessment: Draft Final Report, Prepared for U.S. Environmental Protection Agency. January 29, 1985."

Avtex Fibers records, 1942-1997. Call number 37962. Library of Virginia State Records Center, Richmond, Virginia.

The LVSRC's collection includes court documents from the numerous lawsuits filed over liability for the costs of remediating the Avtex site.

FMC Corporation v. United States Department of Commerce, 29 F.3d 833 (U.S. 3rd Cir. App. 1994). Folder: Department of Justice documents.

“Plaintiff’s Pretrial Memorandum, Phase I – Liability (Amended as of 3/20/91).”

“Deposition of Richard R. Almy, Nov. 8, 1990.”

“Testimony of Herman F. Stuhr, Plaintiff’s Witness – Excerpt of Non-Jury Trial Before the Honorable Clarence Newcomer, US District Judge, March 25, 1991, Philadelphia, PA – Civil No. 90-1761.”

“Stipulated Testimony of Ralph Minnick, FMC Corp. v. US Dept of Commerce et al., Civil Action No. 90-1761.”

“Deposition of Charles Leadman, Nov. 7, 1990.”

“Deposition of John H. Mallinson, Nov. 8, 1990.”

SWCB/DEQ v. Avtex Fibers (Front Royal) – [1989?] Folder: Virginia Department of Environmental Quality documents - American Viscose Documents, 1942-1949.

Coxe, J.W. Jr., *Waste Disposal Analysis of Waste Acid,* October 24, 1947.

“Memorandum: E.T. Roetman to A.G. McVay, Re: Toxicity Study of Treated Waste, March 8, 1948.”

“Memorandum: E.T. Roetman to Mr. A.G. McVay: 10-69 – Addition to Waste Treatment Plant FR, October 8, 1947.”

“Memorandum: E.T. Roetman to Mr. R.M. Pfalzgraff: 10-69 Waste Treatment FR, November 3, 1947.”

“Memorandum: R.W. Haywood, Jr. to A.G. McVay, 10-69 – Waste Treatment – B.O.D. Procedure and Analytical Program, August 4, 1947.”

“Memorandum: T.F. Brastow to Mr. A.G. McVay and Mr. E.T. Roetman: Visit to Mr. Hedgepeth – Virginia Water Control Board, October 10, 1947.”

Scheuer, *Waste Treatment at the Front Royal Plant of the American Viscose Corporation*, Report, (September 12, 1947.

Sterner, R.R. “Neutralization of Waste Acid, December 9, 1943.”

FMC Corporation v. NASA et al (Federal District Court), settled July 18, 1991. Folder: Department of Justice documents - Pleadings, Exhibits, Settlement Documents.

“Point Paper on Avtex Rayon Fiber Situation, prepared by Captain Shearer/SAF/AQQM/7-8123/15 Nov. 1988.”.

“Industry Briefing: Avtex Fibers Front Royal Inc. & Aerospace Rayon Fiber Position, November 1988, Salt Lake City.”

War Production Board: Rayon. Records of the War Production Board, 1918 – 1947, Record Group 179. National Archives at College Park, College Park, Maryland.

Folder: Rayon Cord, High Tenacity, Program 1944-1945:

“Memorandum: Donald M. Nelson to Textile Division. Subject: Tire Cord, February 28, 1944.”

“Memorandum: J. Spencer Love to Hiland G. Batcheller. Subject: Production Urgency List, October 21, 1944.”

“Memorandum: J. Spencer Love to James Jacobson, January 12, 1944.”

“Memorandum: J. Spencer Love to L.R. Boulware. Subject: Monthly Report on Status of Tire Cord Program, Feb. 8, 1944.”

“Memorandum: Saul Nelson to Mr. Hiland G. Batcheller. Subject: Development of War Production Board Tire Cord Program, January 10, 1945.”

“Memorandum: T.R. Milne to George Lanier. Subject: Tire Cord Program—Twisting and Weaving Facilities, December 6, 1943.”

“Minutes of the Tire Cord Meeting, March 10, 1944.”

Folder: Rayon Reports and Histories CONFIDENTIAL (Declassified);

May 3, 1942 Confidential Report, Commodity Status Report from the Commodities Division of the Army and Navy Munitions Board: For use of the Army, Navy, and Maritime Commission only.”

Avtex Fibers, Inc. Newsclippings. SC # 4017. Special Collections. Carrier Library. James Madison University. Harrisonburg, Virginia.

Additional Primary Sources

Blum, John Morton. *Roosevelt and Morgenthau: A Revision and Condensation of* From the Morgenthau Diaries. Boston: Houghton Mifflin, 1970.

_____. *Years of Urgency 1938-1941, vol. 2 of* From the Morgenthau Diaries. Boston: Houghton Mifflin, 1965.

Bolgiano, Ralph. Interview by Christina Wulf, 18 January 2010. Digital recording. Shenandoah Valley Oral History Project, James Madison University, Harrisonburg, Virginia.

Carson, Rachel. *Silent Spring*. Greenwich, CT: Fawcett Publications, Inc., 1962.

Churchill, Winston, and Franklin D. Roosevelt. *Churchill & Roosevelt: The Complete Correspondence, Vol. I Alliance Emerging, October 1933-November 1942.* Edited with commentary by Warren F. Kimball. Princeton: Princeton University Press, 1984.

Edmunds, William Russell. "Industrial Waste Disposal from the Rayon Industry to the Streams of Virginia." BS thesis, Virginia Polytechnic Institute, 1941.

Henderson, Croswell. "The Shenandoah." *Virginia Wildlife* 11, no. 12 (December 1950): n.p.

Hoover, C.R. "Treatment of Liquid Wastes from the Textile Industry," *Industrial and Engineering Chemistry* (November 1939): 1352-1358.

Lend Lease Act of 1941. Public Law 77-11. *U.S. Statutes at Large* 55 (1942): 32.

Nelson, Donald M. *Arsenal of Democracy: the Story of American War Production.* New York: Harcourt, Brace and Company, 1946.

Roosevelt, Franklin Delano. *Roosevelt's Foreign Policy 1933-1941: Franklin D. Roosevelt's Unedited Speeches and Messages*. Compiled by Douglas Lurton. New York: W. Funk, Inc., 1942.

Scheuer, B.N. and C.W. Joseph. "Sewage and Industrial Waste Treatment at Avisco's Front Royal Plant." *VIW & SWA News* (March 1950): 6-7.

Scheuer, B.N. "Four Wastes, One Effluent," *Chemical Engineering* (February 1948): 138-140.

United States Congress. Senate. Committee on Environment and Public Works. Subcommittee on Toxic Substances, Environmental Oversight, Research and Development. *Environmental Issues and Avtex Fibers, Inc.* 101st Cong., 2nd sess., June 20, 1990.

United States Geological Survey. *Water for Recreation – Values and Opportunities: Report to the Outdoor Recreation Resources Review Commission* [ORRRC Study Report 10]. Washington, DC: USGPO, 1962.

"Virginia Division," *Outdoor America: Official Publication of the Izaak Walton League of America* 11, no. 4 (May-June 1946): 15.

Wagner, A. "Stream Pollution Program in Virginia," *American Journal of Public Health and the Nation's Health* 20 (February 1930): 202-204.

Secondary Sources

Bassford, "Tommy" K.S. *Evolution of Harrisonburg, 1780-1945* (Harrisonburg, VA, 1945), http://freepages.genealogy.rootsweb.ancestry.com/~bassfordbooks/Evolution%20of%20Harrisonburg.htm (accessed December 3, 2008).

Bentley, Callan. "New Folds in the Massanutten Sandstone." Northern Virginia Community College NOVA GEOBLOG (February 11, 2009) http://www.nvcc.edu/home/cbentley/ geoblog/2009/02/new-folds-in-massanutten-sandstone.html (April 26, 2009).

Carlson, Peter and Mary Ellen Mark. "Rayon Men." *The Washington Post Magazine* (Feb. 12, 1989): 22-29.

"Case: Kinder Morgan Sodium Hydroxide Spill, N.J." Damage Assessment, Remediation, & Restoration Program, Northeast Region, National Oceanic and Atmospheric Administration. http://www.darrp.noaa.gov/northeast/kinder/index.html (accessed February 28, 2010).

Chernow, Ron. *The House of Morgan: An American Banking Dynasty and the Rise of Modern Finance.* New York: Touchstone, 1991.

Clark, Victor S. *History of Manufactures in the United States, Volume III, 1893-1928.* 1929 edition, reprinted with permission of Carnegie Institution of Washington. New York: Peter Smith, 1949.

Cobb, James C. *Industrialization and Southern Society, 1877-1984.* Lexington, KY: University Press of Kentucky, 1984.

Cohen, Lizabeth. *A Consumer's Republic: The Politics of Mass Consumption in Postwar America.* New York: Vintage Books, 2003.

Coleman, D.C. *Courtaulds: An Economic and Social History, Volume I, The Nineteenth Century Silk and Crape.* Oxford: Clarendon Press, 1969.

_____. *Courtaulds: an Economic and Social History, Volume II, Rayon.* Oxford: Clarendon Press, 1969.

_____. *Courtaulds: An Economic and Social History, Volume III, Crisis and Change*. Oxford: Clarendon Press, 1980.

Colten, Craig E. and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA.* Austin, TX: University of Texas Press, 1996.

Colten, Craig E. “Contesting Pollution in Dixie: The Case of Corney Creek.” *Journal of Southern History* 72, no. 3 (August 2006): 605-634.

_____. “Creating a Toxic Landscape: Chemical Waste Disposal Policy and Practice, 1900-1960.” *Environmental History Review* 18, no. 1 (Spring 1994): 85-116.

“Company History: Courtaulds Plc.” Answers.com. http://www.answers.com/topic/courtaulds (accessed December 14, 2009).

Cronon, William. *Metropolis Nature’s Metropolis: Chicago and the Great West.* New York: W.W. Norton & Co., 1991.

Cushing, Colbert E. and J. David Allan. *Streams: Their Ecology and Life*. San Diego, CA: Academic Press, 2001.

Daily, Gretchen C., ed. *Nature’s Services: Societal Dependence on Natural Ecosystems*. Washington, DC: Island Press, 1997.

Daniels, Richard K. “Avtex Fibers Rayon Plant,” http://ourworld.compuserve.com/homepages/rdaniels2/layout2.htm (accessed May 8, 2009).

Datta, Mahesh Nanavaty Rajat K. *Global Silk Industry: A Complete Source Book.* New Delhi: APH Publishing Corp., 2007.

Dillehay, Tom D. “Probing deeper into first American studies.” *PNAS: Proceedings of the National Academy of Science of the United States* 106, no. 4 (January 27, 2009). doi: 10.1073/ pnas.0808424106 (accessed November 16, 2009).

“Division History.” Virginia Division of the Izaak Walton League of America. http://www.va-iwla.org/divhist.html (accessed February 22, 2010).

“DuPont Heritage: Waynesboro, Virginia,” E. I. du Pont de Nemours and Company, http://www2.dupont.com/Heritage/en_US/related_topics/waynesboro_va.html (accessed June 1, 2010).

Edelstein, Michael. “The Size of the U.S. Armed Forces During World War II: Feasibility and War Planning.” *Research in Economic History* 20 (2001): 47-97.

Environmental Background Information Center. *Avtex Fibers, Front Royal, VA: A Corporate, Demographic, and Environmental Analysis.* Draft – December 12, 2001.

Exponent Engineering and Scientific Consulting. "Avtex Fibers Superfund Site, Front Royal, Virginia." Exoponent, Inc. http://www.exponent.com/Avtex-Fibers-Superfund-Site--Front-Royal-VA/ (accessed April 25, 2009).

Farabee, M.J. "Biological Diversity: Non-vascular plants and non-seed vascular plants." *Online Biology Book*, hosted by Estrella Mountain Community College. http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookdiversity_5.html (accessed July 5, 2010).

Fleming, Roger A. and Daniel Isadore Livingston. *Tire Reinforcement and Tire Performance: a Symposium*, Volume 694 of Special Technical Publication. American Society for Testing and Materials. Baltimore, MD: ASTM, 1979.

Goubert, Jean-Pierre. *The Conquest of Water: The Advent of Health in the Industrial Age.* Trans. by Andrew Wilson. Princeton: Princeton University Press, 1989.

Groves, Susan and Frank Settle. "The Avtex Saga: National Security versus Environmental Protection." *Journal of Chemical Education* 79, no. 6 (June 2002): 685-691.

Hamblin, W. Kenneth. *Earth's Dynamic Systems.* 6th ed. New York: Macmillan Publishing Company, 1992.

Hansen, Anders. "The media and the social construction of the environment." *Media, Culture and Society* 13 (1991): 443-458.

Harvey, Mark. "Loving the Wild in Postwar America." In *American Wilderness: A New History*. Edited by Michael Lewis. Oxford: Oxford University Press, 2007.

"Historical Bio for E. Blackburn Moore," Virginia House of Delegates website, http://dela.state.va.us/dela/MemBios.nsf/7bf25d3bb19d05ab85256c23006d3f84/68d5ffec2d99b30685256d33004e31ba?OpenDocument (accessed May 22, 2010).

Hounshell, David A. and John Kenly Smith, Jr. *Science and Corporate Strategy: DuPont R&D, 1902-1980*. Cambridge: Cambridge University Press, 1988.

Hughes, Thomas P. *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970*. Chicago: University of Chicago Press, 2004.

_____. "The Evolution of Large Technological Systems." In *The Social Constructions of Technological Systems: New Directions in the Sociology* *and History of Technology,* edited by Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch, 51-82. Cambridge, MA: The MIT Press, 1987.

Hurley, Andrew. *Environmental Inequalities: Class, Race, and Industrial Pollution in Gary, Indiana, 1945-1980.* Chapel Hill: University of North Carolina Press, 1995.

Ingram, Bruce. *The Shenandoah and Rappahannock Rivers Guide*. Corvallis, OR: Ecopress, 2003.

Jackson, Dorothea. "Standing Our Ground." *APF Reporter* 15, no. 2 (n.d.). Published by the Alicia Patterson Foundation. http://www.aliciapatterson.org/APF1502/Jackson/ Jackson.html (accessed January 12, 2010).

"Knights of the Golden Horseshoe." Department of Historic Preservation, University of Mary Washington. http://umwhisp.net/germanna/node/6 (accessed February 22, 2010).

Koistinen, Paul A.C. *Arsenal of World War II: The Political Economy of American Warfare, 1940-1945.* Lawrence, KS: University Press of Kansans, 2004.

Leeming, Joseph. *Rayon: the First Man-Made Fiber*. Brooklyn, NY: Chemical Publishing, Co., 1950.

Leopold, Aldo. *A Sand County Almanac: with essays on conservation from Round River.* New York: Ballantine Books, 1970.

Linke, Steven R. *Managing Crisis in Defense Industry: the PEPCON and Avtex Cases.* Washington, DC : Institute for National Strategic Studies, 1990.

Lowell L. Trent, Rue S. Hestand III, and Chris C. Carter, "Toxicity of Sulfuric Acid to Aquatic Plants and Organisms," *Journal of Aquatic Plant Management* 16 (1978): 40-43. http://www.apms.org/japm/vol16/ v16p40.pdf (accessed February 28, 2010).

Lytle, Mark H. *Rachel Carson, Silent Spring, and the Rise of the Environmental Movement*. New York: Oxford University Press, 2007.

McCarthy, Tom. *Auto Mania: Cars, Consumers, and the Environment*. New Haven: Yale University Press, 2007.

McDermott, Dan. "Daughter of the Stars: The Rich History of the Shenandoah River." *Warren County Report Newspaper* (Oct. 8, 2008). http://wcrnews.wordpress.com/category/ paleo-indians/ (accessed November 15, 2009).

Melosi, Martin V. *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present.* Baltimore: Johns Hopkins University Press, 2000.

Milazzo, Paul Charles. *Unlikely Environmentalists: Congress and Clean Water, 1945-1972*. Lawrence, KS: University Press of Kansas, 2006.

Miller, Cindy M. "The Bruised Image: Public Relations and Avtex Fibers." BS thesis, James Madison University, 1991.

Moore, Kelly. *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945-1975*. Princeton, NJ: Princeton University Press, 2008.

"New Source Expected to Prevent Shortage Of Rayon for NASA, Defense Rockets." *Aviation Week and Space Technology* 131, no. 22 (November 27, 1989): 24.

Newhook, R., M.E. Meek, and D. Caldbick. "Concise International Chemical Assessment Document 46: Carbon Disulfide." Geneva: World Health Organization, 2002. http://www.who.int/ipcs/publications/cicad/cicad46_rev_1.pdf (accessed February 27, 2010).

Newman, Richard. "From Love's Canal to Love Canal: Reckoning with the Environmental Legacy of an Industrial Dream." In *Beyond the Ruins: The Meanings of Deindustrialization,* edited by Jefferson Cowie and Joseph Heathcott, 112-135. Ithaca: Cornell University Press, 2003.

Paavola, Jouni. "The Izaak Walton League of America." In *Encyclopedia of World Environmental History, Vol. 2,* edited by Shepard Krech, John Robert McNeill, Carolyn Merchant, 718-719. New York: Routledge, 2003.

Pinch, Trevor J. and Wiebe E. Bijker. "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology*. Edited by Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch. Cambridge, MA: The MIT Press, 1987.

Potomac Watershed Partnership, "Shenandoah River," http://www.potomacwatershed.net/ijourney/shenando/shenando.html (accessed February 14, 2010).

Pursell, Carroll. *Technology in Postwar America: A History*. New York: Columbia University Press, 2007.

"Rayon Fiber (Viscose)." FiberSource. http://www.fibersource.com/f-tutor/rayon.htm (accessed April 22, 2009).

Reiger, John F. *American Sportsmen and the Origins of Conservation.* 3rd ed. Corvallis, OR: Oregon State University, 2001.

Rome, Adam. *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism.* Cambridge: Cambridge University Press, 2001.

Russell, Edmund. *War and Nature: Fighting Humans and Insects with Chemicals from World War I to* Silent Spring. Cambridge: Cambridge University Press, 2001.

Science and Environmental Health Network, "Precautionary Principle," http://www.sehn.org/wing.html (accessed July 6, 2010).

Sherman, Tracey S. "Fish of the Shenandoah River." Virginia Tech Department of Forestry, Feb. 25, 2003. http://www.cnr.vt.edu/PLT/ potomacshenandoah/aquaticinsects/southfork.htm (accessed February 21, 2010).

Sherwood, W. Cullen. "A Brief Geologic History of Rockingham County." Department of Geology and Environmental Studies, James Madison University. http://csmres.jmu.edu/ geollab/vageol/outreach/fieldtrips/ rockingham/whole.html (accessed February 21, 2010).

Tarr, Joel A. *In Search of the Ultimate Sink: Urban Pollution in Historical Perspective.* Akron, OH: University of Akron Press, 1996.

Television Bureau of Advertising, Inc. "Media Trends Track." http://www.tvb.org/rcentral/mediatrendstrack/tvbasics/ 02_TVHouseholds.asp (accessed June 1, 2010).

"The Potomac-Shenandoah System." *The Geology of Virginia: Rivers & Watersheds*. William and Mary Department of Geology. http://web.wm.edu/geology/virginia/rivers/potomac-shenandoah.html?svr=www (accessed May 4, 2009).

United States Army Corps of Engineers. "Fact Sheet – Avtex Fibers, Front Royal, VA – August 2005." USACE Norfolk District, Avtex Fibers, Front Royal, VA. http://www.nao.usace.army.mil/Projects/ Environmental%20 Projects/Avtex/ USACE%20Avtex%20Fact%20Sheet.doc (accessed May 7, 2009).

United States Civilian Production Administration. *Industrial Mobilization for War: History of the War Production Board and Predecessor Agencies 1940-1945, Vol. 1, Program and Administration*. Washington, D.C.: United States Government Printing Office, 1947.

United States Department of Commerce and Bureau of the Census. *United States Census of Manufactures 1954, Volume III Area Statistics*. Prepared under the supervision of Maxwell R. Conklin. Washington, DC: United States Government Printing Office, 1954.

United States Environmental Protection Agency. "Benthic Macroinvertebrates in Our Waters." Biological Indicators of Watershed Health. http://www.epa.gov/bioiweb1/html/ benthosclean.html (accessed February 21, 2010).

_____. "Summary of the Clean Water Act." EPA Laws & Regulations. http://www.epa.gov/ lawsregs/laws/cwa.html (accessed June 20, 2010).

_____. "Water." EPA History. http://www.epa.gov/history/topics/fwpca/05.htm (accessed June 1, 2010).

Virginia Department of Environmental Quality. "An Environmental History." http://www.deq.state.va.us/history/1946.html (accessed December 13, 2009).

_____. "Fish Tissue and Sediment Monitoring Program." http://www.deq.virginia.gov/fishtissue/ (accessed February 21, 2009).

Virginia Department of Game and Inland Fisheries. "Shenandoah River – Main Stem – Fishing Opportunities." http://www.dgif.virginia.gov/ fishing/waterbodies/display.asp?id =171&section=fishing (accessed February 21, 2010).

Virginia Department of Historic Resources. "First People: The Early Indians of Virginia, Indians A.D. 1600-1800." State of Virginia. http://www.dhr.virginia.gov/arch_NET/timeline/contact_indian_4.htm (accessed November 15, 2009).

Virtual Plastics Museum. "Artificial Silk." http://www.plastiquarian.com/ museum/viscose/viscose03.htm (accessed January 16, 2010).

Ward-Jackson, C.H. *A History of Courtaulds: An Account of the Origin and Rise of the Industrial Enterprise of Courtaulds Limited and of its Associate the American Viscose Corporation.* London: Curwen Press, 1941.

White, Richard. *The Organic Machine: The Remaking of the Columbia River.* New York: Hill and Wang, 1995.

World Health Organization. "Chapter 5.4 Carbon disulfide." *Air Quality Guidelines for Europe*, Second Edition, WHO Regional Publications, European Series, No. 91. Copenhagen 2000. http://www.euro.who.int/ document/aiq/5_4carbodisulfide.pdf (accessed May 8, 2009).