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February 25, 2026

Submitted via email to lori.k.devereux@wv.gov

Lori Devereux
Environmental Resource Associate
Division of Water and Waste Management
West Virginia Department of Environmental Protection
601 57th Street SE
Charleston, WV 25304

Re: Appl. No. WV0023281, Empire Trimodal Terminal LLC Application for a West Virginia National Pollutant Discharge Elimination System Water Pollution Control Permit

To Ms. Devereux:

On January 23, 2026, West Virginia Department of Environmental Protection ("WVDEP") publicly noticed an application ("Application") submitted by Empire Trimodal Terminal, LLC ("Empire") for a National Pollutant Discharge Elimination System ("NPDES") Water Pollution Control Permit to discharge "untreated storm water and groundwater" into the Ohio River through an outfall ("Outfall 001") located near mile point 69.7 near Follansbee, West Virginia. West Virginia Citizen Action Group ("WV CAG") and West Virginia Rivers submit the following comments on behalf of themselves and their members, some of whom live, work, and recreate in the area impacted by the proposed discharges of pollutants.

Empire's application is rife with inconsistencies and fails to mention key activities and pollution sources at the site. WVDEP's antidegradation review fails to meet Clean Water Act requirements by refusing to account for Empire's ongoing and egregious violations of water quality standards. Lastly, the Draft Permit impermissibly includes relaxed effluent limitations, and eliminates one limitation altogether, in violation of the Clean Water Act's anti-backsliding provisions. Accordingly, WVDEP must deny Empire's Application and refrain from further review until Empire has submitted a complete application that fully addresses the activities and potential pollution sources on the site.

WV CAG also asks for a public meeting for community members, including WV CAG members, to share information pertaining to the site, express concerns, and ask questions regarding Empire's operations. There is substantial public interest in this permit application and the draft permit, necessitating a public hearing pursuant to West Virginia law.

I. Background

A. The Site

Details about Empire's operations at its site in Follansbee, West Virginia vary within the permit application and associated permitting materials. According to various permitting documents, the site occupies between 80 and 130 acres of brownfields along the Ohio River.[1] According to Empire's Groundwater Protection Plan, and those familiar with the site, Empire is located in Follansbee, Brooke County, West Virginia, bordered by the city of Follansbee to the east, the Ohio River to the west, the former Mountain State Carbon Coke Plant facility to the northeast, Empire Green Generation LLC to the northwest, and the Wheeling-Nippon Steel facility to the south and east.[2]

At the site, Empire, along with third parties hosted by Empire, conducts a litany of activities, including: iron-rich slag recycling; cargo and freight transloading of railcars, barges, and trucks; general port activities; iron-rich material screening; metallurgical coke storage; materials storage; slag excavating; diesel storage; hydrochloric acid transloading and blending; truck parking; warehousing and stockpiling of cargo.[3]

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[1] *See* State of West Virginia, Department of Environmental Protection Division of Water and Waste Management, Basis for Limitations, Empire Trimodal Terminal LLC WV0023281, November 2025 (stating the site consists of 130 acres in Moundsville, West Virginia), attached as Exhibit 1 [hereinafter "Basis for Limitations"]; Application 2025-WV0023281-renewal (08/22/2025), February 02, 2026 (stating the site consists of 80 acres of developing brownfields) [hereinafter "Reissue Application"]; Empire Trimodal Terminal The Port of West Virginia, Groundwater Protection Plan, September 2025 [hereinafter "2025 Groundwater Protection Plan"].

[2] 2025 Groundwater Protection Plan.

[3] *See* Basis for Limitations; Reissue Application; 2025 Groundwater Protection Plan.

In addition to these activities, an October 2025 WVDEP inspection found Empire to be hosting "an open dump of solid waste consisting of metal, wood, and soil onsite."[4] WVDEP also noted several issues relevant to stormwater permitting, including that material screening operations take place "in close proximity to" Outfall 001, that "stormwater is also gathered from surrounding facilities," and both "[t]his site and surrounding sites have known historic contamination."[5] Another WVDEP inspection in December 2025 found a pyrolysis reactor, various stockpiled waste plastics, and "an open dump of waste tires" on the site.[6] These inspections detailed general sloppy operations in addition to the open dumps, including gypsum sand "tracked out around a dump truck," minimal control structures, and an improperly sealed 500-gallon diesel tank with staining around it.[7]

B. Empire's History of Noncompliance

Empire's discharge monitoring reports ("DMRs") show the site regularly discharges PAH pollutants—including benzo(a) anthracene, benzo(a) pyrene, benzo(b) fluoranthene, benzo(k) fluoranthene, chrysene, dibenzo(a,h) anthracene, and indeno(1,2,3-cd) pyrene—at levels that are hundreds and thousands of times in excess of the state's water quality criteria.[8] These pollutants are known carcinogens, accumulate in the marine environment, and pose serious risks to both human health and aquatic life.[9]

WVDEP has issued Empire numerous notices of violations during its years of operation. Most recently, WVDEP issued Empire notices of violations in October 2025

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[4] West Virginia Department of Environmental Protection, Environmental Enforcement Industrial Facility Inspection Form, October 2, 2025, attached as Exhibit 2 [hereinafter "October 2025 Inspection Report"].

[5] October 2025 Inspection Report at 3.

[6] West Virginia Department of Environmental Protection, Complaint Investigation/Emergency Response, December 19, 2025, attached as Exhibit 3 [hereinafter "December 2025 Inspection Report"].

[7] October 2025 Inspection Report.

[8] Meghan Betcher & Kasey Osborne, *Review of water quality data at Outfall 001 at the Empire Trimodal Terminal LLC facility in Follansbee West Virginia*, Downstream Strategies, at 2, (Feb. 20, 2026), attached as Exhibit 4 [hereinafter "Downstream Strategies Report"].

[9] *Id.*

and December 2025 after Empire submitted the pending permit request.[10] In October 2025, WVDEP identified 93 occasions when Empire violated effluent limitations in its stormwater permit between September 2023 and August 2025, including 92 times for exceedances of limitations for Polycyclic aromatic hydrocarbons ("PAHs") and one exceedance of its mercury limitation.[11] In December 2025, WVDEP issued Empire a notice of violation for operating an open dump of tires on the property.[12] These incidents are not standouts, but rather the most recent in a long history of violations, including failures to timely submit discharge monitoring reports and failures to employ legally required testing protocols.[13]

C. The Community & West Virginia Citizen Action

Empire's location places it near community members who live, work, and recreate in Follansbee, on the Ohio River, and in nearby areas on the Ohio side of the river. Empire's activities at the site have resulted in numerous community members complaining of noxious smells and smoke emanating from the site. The city of Follansbee relies on three groundwater wells for its municipal water supply.[14] Follansbee's city water already has elevated levels of numerous pollutants associated with increased cancer risk, including "forever chemicals" (also known as PFAS).[15]

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[10] Documents suggest WVDEP conducted no inspections of the site between 2019 and the October 2025 inspection. *See* Basis of Limitations (describing the last site inspection as occurring in 2019).

[11] WVDEP, Notice of Violation, NOV#: W25-05-052-KJE, October 31, 2025 [hereinafter "October 2025 NOVs"], attached as Exhibit 5.

[12] WVDEP, Notice of Violation, NOV#: W25-05-063-KJE, December 19, 2025 [hereinafter "December 2025 NOV"], attached as Exhibit 6.

[13] *See* Appalachian Mountain Advocates, 60-Day Notice of Intent to File Citizen Suit under the Clean Water Act for Violations of WV/NPDES Permit No. WV0023281 by Empire Trimodal Terminal, LLC (dba The Port of West Virginia), attached as Exhibit 7 [hereinafter AppalMad NOI"].

[14] Follansbee Municipal WV 3300506 Consumer Confidence Report 2025, https://thecityoffollansbee.com/wp-content/uploads/2025/06/2025-CCR_FOLLANSBEE-MUNICIPAL-WV3300506.pdf.

[15] Environmental Working Group, Follansbee Municipal, https://www.ewg.org/tapwater/system.php?pws=WV3300506 (finding levels of the following pollutants at levels above health-based guidelines: Bromodichloromethane, Chloroform, Dibromoacetic acid, Haloacetic acids, Dichloroacetic acid, Dibromochloromethane, Nitrate, Nitrite, Radium 226 and 228, Trichloroacetic acid, and Total trihalomethanes); WVDEP, *WVDEP seeks input on PFAS Action Plans in Northern Panhandle*, EIN Presswire,

Community members, including WV CAG members, currently enjoy the area of the Ohio River where Empire discharges from Outfall 001 for recreational purposes, including fishing, kayaking, boating, and wildlife viewing.

Since 1974, West Virginia Citizen Action Group has advocated for better public policy, rights of individuals, a clean environment, and a stronger democratic process. The philosophy of WV CAG is that full-time citizen participation in the decision-making processes of our state is absolutely essential. WV CAG staff and members work to increase the voice of the average citizen in public affairs through research, education, lobbying, organizing and coalition building—speaking out on behalf of the consumer, speaking out in defense of a cleaner environment, and speaking out in favor of a government that is honest, open, and accountable to the needs of all its citizens. WV CAG works to empower individuals by providing them with resources to be effective advocates on issues that affect their lives, such as a healthy environment and government accountability and transparency. WV CAG submits these comments based on these principles and on behalf of its members.

Since 1990, West Virginia Rivers Coalition has advocated for reducing pollution into our rivers and streams. West Virginia Rivers Coalition was founded by recreational paddlers who witnessed degradation of the quality of water in which they recreated. WV Rivers has since become the leading voice in the state for the improvement of water quality. WV Rivers believes water is a human right and works to enforce the Clean Water Act so that all West Virginians have access to fishable, swimmable and drinkable rivers and streams. WV Rivers has signed on to these comments on behalf of their members because their members use and enjoyment of the Ohio River is impacted by Empire Trimodal.

II. Legal Framework

The goal of the Clean Water Act ("CWA") is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters by reducing, and eventually eliminating, the discharge of pollutants into these waters."[16] To carry out this objective, the Act prohibits the discharge of any pollutant except in compliance with a National Pollutant Discharge Elimination System ("NPDES") permit.[17] Stormwater

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https://www.einpresswire.com/article/863022606/wvdep-seeks-input-on-pfas-action-plans-in-northern-panhandle.

[16] *Nat. Res. Def. Council, Inc. v. U.S. E.P.A.*, 16 F.3d 1395, 1399 (4th Cir. 1993) (citing 33 U.S.C. § 1251(a) (internal quotes omitted).

[17] 33 U.S.C. § 1311(a); *see also* W. Va. Code R. § 47-10-3.

collected and channeled to outfalls that discharge to water is a point source discharge under the Clean Water Act.[18]

Water quality standards are an integral part of the CWA's regulatory scheme.[19] Water quality standards consist of: "(1) one or more designated uses of the state waters involved; (2) certain water quality criteria, expressed as numeric pollutant concentration levels … representing a quality of water that supports a particular designated use; and (3) an antidegradation policy to protect existing uses and high quality waters."[20]

Under the NPDES permit program, EPA or states that have been granted NPDES permitting authority issue permits to discharge pollutants under certain amounts and conditions.[21] All NPDES permits must set limitations representing the level of control necessary to ensure that the receiving waters attain and maintain state water quality standards.[22] EPA's and WVDEP's NPDES regulations further specify that no permit may be issued when the conditions of the permit do not provide for compliance with the applicable requirements of CWA and state regulations.[23] Once the agency issues a NPDES permit, the CWA contains an "anti-backsliding" provision that prohibits, with limited exceptions, any subsequent or modified permit from containing "effluent limitations which are less stringent than the comparable effluent limitations in the previous permit."[24] West Virginia's regulations make clear that the CWA's anti-backsliding provision applies to reissued permits.[25]

West Virginia passed its Groundwater Protection Act in 1994, recognizing that over half of the state's population relied on groundwater for drinking water, that the rural lifestyle of West Virginia is highly valuable, and that maintaining that lifestyle

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[18] 33 U.S.C. §§ 1362(14) and 1342(p).

[19] *See Natural Res. Defense Council*, 16 F.3d at 1399 ("Water quality standards are a critical component of the CWA regulatory scheme because such standards serve as a guideline for setting applicable limitations in individual discharge permits.").

[20] *Natural Res. Defense Council*, 16 F.3d at 1400 (citing 33 U.S.C. § 1313(c)(2)(A) and 40 C.F.R. § 131).

[21] 33 U.S.C. § 1342.

[22] *Nat. Res. Def. Council, Inc.*, 16 F.3d 1395, 1400.

[23] 40 C.F.R. § 122.4; W. Va. Code R. § 47-10-3.6.a.

[24] 33 U.S.C. § 1342(o).

[25] *See* W. Va. Code R. § 47-10-6.3.j.

required protecting groundwater.[26] The West Virginia Department of Environmental Protection is the lead agency for groundwater and promulgates the rules and regulations governing groundwater use.[27] Part of these regulations require that where a substantial potential for outdoor, uncontained storage or disposal of raw materials have a substantial potential to contaminate groundwater, the areas shall have runoff and/or infiltration control systems in place.[28] Further, any new areas used for storage or disposal of raw materials, products, or waste are required to be designed, constructed, and operated to prevent release of contaminants to the groundwater.[29] Existing and new impoundments are regulated in the same manner.[30] Together, these regulations provide the requirements that must be followed in the applicant's Groundwater Protection Plan.

III. WVDEP Should Deny the Permit Because the Application Is Incomplete, Rife with Inconsistencies, and Fails to Address All Activities on the Site that Will Contribute to Discharges of Pollutants

WVDEP should not issue the final permit because the application is incomplete and there are material factual inconsistencies between the permit application materials, the Basis for Limitations, WVDEP inspection reports, and the pending Draft Permit—including the omission of a myriad of activities at the site that will contribute to discharges of pollutants. As a result of these inconsistencies and omissions, the Application and associated permitting materials, fail to accurately characterize the discharge and fail to provide a reasonable basis for effluent limitations. Further, these inconsistencies and omissions deprive WVDEP and the public of the ability to evaluate whether the draft permit is accurate, lawful, implementable, and enforceable.

At minimum, WVDEP should require corrected submissions, place them in the public record, and re-notice a corrected draft permit and fact sheet. WVDEP cannot lawfully reissue the permit based on the current inconsistencies and omissions in the permitting record.[31]

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[26] W. Va. Code R. § 22-12-2 et. seq.

[27] W. Va. Code R. § 22-12-6(a).

[28] W. Va. Code. R. § 47-58-4.3.a.

[29] W. Va. Code R. § 47-58-4.3.b. (the regulation also states that liner systems and groundwater monitoring stations may be necessary).

[30] W. Va. Code R. § 47-58-4.5.

[31] *See* W. Va. Code R. § 47-10-4. (requiring the submission of a complete application).

A. The site identity, narrative, and receiving stream are different across the permitting record and deprive the public of accurate information needed to assess the site.

The Application lists the site at 600 Veterans Drive, Follansbee, Brooke County, WV.[32] The Draft Permit similarly identifies the site as Follansbee, WV.[33] The Basis for Limitations describes an entirely different location, over an hour away, in Moundsville, West Virginia, that formerly operated as a sinter plant.[34] While the site described in the Application and Draft Permit previously operated, in part, as a coke and sinter plant—part of the reason the Follansbee site is a brownfield today—the Application certainly does not claim the facility is located in Moundsville, Marshall County, West Virginia.[35]

The facility location error occurs at the top of the Basis for Limitations, the document that WVDEP uses to help explain the permitting conditions and the site history and one of the few documents the public can access to assess the site. Because WVDEP determined this is not a 'major source,' no Fact Sheet exists, and the Basis for Limitations is all the public can access to understand how WVDEP made its decisions.[36] Without providing commenters the ability to even locate the proper operational activities at the correct location, the Basis for Limitations fails to do its job.

The Basis for Limitations also states both that the receiving stream is and is not the Ohio River, making it unclear whether and when WVDEP applied relevant

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[32] *See* Reissue Application.

[33] State of West Virginia, Department of Environmental Protection Division of Water and Waste Management, Draft Permit WV0023281 (01/23/2026) [hereinafter "Draft Permit"].

[34] Basis for Limitations at 1.

[35] Reissue Application at 11 ("The site operations include port activities, iron-rich material screening, metallurgical coke storage, materials storage, and slag excavating."); State of West Virginia Department of Environmental Protection, Comprehensive Groundwater Protection Plan WV0023281 June 1995, at 2, attached as Exhibit 8 ("Past and current operations performed at the East Plant include the production of metallurgical-grade coke, coke gas byproducts (light oil, ammonium sulfate, fuel gas, coal tar, commercial-grade sulfuric acid) and sinter") [hereinafter "1995 Groundwater Protection Plan"].

[36] *See* W. Va. Code R. § 47-10-11.

standards in calculating effluent limitations.[37] The record needs to be corrected, and WVDEP should extend the comment period to allow the public and WVDEP time to review and form opinions on accurate materials.

B. The Draft Permit fails to account for all sources contributing to the discharge of pollutants through Outfall 001, and the Draft Permit cannot be approved unless and until that is resolved.

The permitting record also provides incomplete and contradictory information as to the activities and effluent sources that contribute to the pollutants Empire discharges through Outfall 001.[38] Specifically, the permitting record fails to account for the untreated groundwater exiting Outfall 001, and the myriad of activities on the site that likely contribute pollutants to Empire's effluent, either directly or through untreated groundwater discharge.

Several documents depict Outfall 001 as the endpoint of a capture/conveyance pathway—namely, a catch basin located near the base of the terrace where Follansbee municipal storm drains enter the property. A WVDEP inspection suggests Outfall 001 includes stormwater gathered from surrounding facilities.[39] The Application lists stormwater as the sole discharge, while other parts of the permitting record describe both untreated stormwater and untreated groundwater leaving the site through Outfall 001.[40] Lastly, Empire's groundwater protection plan makes clear that the stormwater leaving through Outfall 001 cannot represent "all site stormwater," but that Empire plans for most of its stormwater to seep into unpaved surfaces on the site and for untreated contaminated groundwater to then enter the Ohio River through Outfall

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[37] *See* Basis for Limitations at 4–5 (stating "no" in column labeled "Outfall discharges to Ohio River and is subject to ORSANCO Pollution Control Standards"); *see also* Spreadsheet provided by WV DEP where column indicating discharge to Ohio River is marked as "0" indicating no discharge to Ohio River.

[38] *See* Reissue Application, Figure 1; see also State of West Virginia, Department of Environmental Protection, Empire Trimodal Terminal Stormwater Prevention Plan NPDES Permit No. WV0023281 (September 2025), at 3 [Hereinafter "SWPPP"].

[39] October 2025 Inspection Report at 3.

[40] Reissue Application at 5; Basis for Limitations at 1.

001.[41] The permitting documents suggest WVDEP has not evaluated the pollutants anticipated to be in this groundwater effluent stream.

The SWPPP, topographic map, and flowline map demonstrate that a portion of stormwater is collected and conveyed to Outfall 001.[42] Further, the SWPPP makes clear that the site sits in a floodplain and asserts that the majority of precipitation infiltrates the soil on site.[43] The SWPPP additionally claims that only a small portion of the property contains impervious materials, and, where those materials exist, stormwater runoff is expected to flow towards adjacent unpaved areas and infiltrate the soil.[44] The only catch basin on the site is near the base of the terrace and collects stormwater runoff from the terrace where the City of Follansbee's storm drain enters the property.[45] That untreated stormwater is then conveyed via a fixed, underground pipe beneath the property and discharges through Outfall 001 to the Ohio River.[46] Thus, the permitting record makes clear that Outfall 001 will only capture stormwater from those sources, and not from the whole site. The permitting record reconciles this by claiming, in simultaneous contradiction, that "all precipitation infiltrates the ground," or just "the majority of precipitation infiltrates the soil on site."[47] As a result of that infiltration, the groundwater becomes saturated with untreated stormwater, and then the untreated, contaminated groundwater is discharged, in part, through Outfall 001.[48]

The unknown portion of the untreated, contaminated groundwater that does infiltrate the groundwater presents serious problems to local drinking water supplies and the Ohio River. The City of Follansbee relies, partially, on public water system #WV3300512 known as "Follansbee Hooverson Heights.[49]" The most recent Consumer Confidence Report for this system shows that the source water includes surface water

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[41] SWPPP at 3.

[42] *See* SWPPP at 3; *see also* SWPPP Figure 1 and Figure 3.

[43] SWPPP at 3.

[44] *Id.*

[45] *Id.*; *see also* SWPPP at Figure 2.

[46] *Id.*

[47] SWPPP at 3.

[48] SWPPP at 3.

[49] City of Follansbee, W. Va., 2025 Consumer Confidence Report: Follansbee Hooverson Heights (WV3300512) (Covering Calendar Year 2024), https://thecityoffollansbee.com/wp-content/uploads/2025/06/2025-CCR_FOLLANSBEE-HOOVERSON-HEIGHTS-WV3300512.pdf (last visited Feb. 25, 2026), attached as Exhibit 11.

from the Ohio River and three groundwater wells.[50] The Source Water Assessment Report for this system indicates that the groundwater wells are Ground Water Under the Direct Influence ("GWUDI") of surface water.[51] Figure 1 in the Source Water Assessment shows that the "source water protection area" for this municipal water supply includes portions of Empire's facility. Figure 1 also shows portions of the Ohio River are within the "source water protection area." The Groundwater Protection Plan ("GPP") acknowledges that the Empire site is within the alluvial aquifer and is hydrologically connected to the river.[52] A recent study by U.S. Geological Society ("USGS") further demonstrates groundwater-surface water connectivity along the Ohio River in alluvial aquifers.[53] Together, these scientific realities make clear that the untreated, contaminated groundwater is not only impacting the local well water, but it is also discharging directly into the Ohio River like the rest of the untreated water on this site.[54]

In this regard, the Groundwater Protection Plan does nothing to protect the groundwater. The Groundwater Protection Rule is clear that the GPP should do more: "each GPP must contain a discussion of all available information reasonably available to the facility regarding existing groundwater quality at, or which may be affected by the site."[55] The GPP wrestles with the fact that this is an alluvial aquifer, and the USGS study and the Source Water Assessment Report, both of which are reasonably available, discuss the issues of interconnectivity in this area. However, the GPP does nothing to discuss, let alone address, the issues that infiltration of Empire's untreated stormwater causes to the surrounding groundwater. This failure in the GPP must be corrected

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[50] *Id.*

[51] W. Va. Dept. of Health & Hum. Res., *Source Water Assessment Report Follansbee Hooverson Heights (PWSID WV3300512)* (Aug. 2012), https://www.wvdhhr.org/oehs/eed/swap/get.cfm?id=3300512, attached as Exhibit 12.

[52] GPP at 5 and Table 4.

[53] Mitchell A. McAdoo & Gregory T. Connock, *Water-Quality Indicators of Surface-Water-Influenced Groundwater Supplies in the Ohio River Alluvial Aquifer of West Virginia* (U.S. Geological Survey, Scientific Investigations Report 2023–5139, 2024), https://pubs.usgs.gov/sir/2023/5139/sir20235139.pdf, attached as Exhibit 13.

[54] Commenters are aware that this site is part of the Voluntary Remediation Program, and the EPA issued an Administrative Order of Consent in RCRA-03-2014-0048CA, and these activities could address some of these issues. However, those documents have not been made publicly available in time to file these comments. This, too, is reason to extend the comment period.

[55] W. Va. Code R. § 47-58-4.11(e).

before the NPDES permit can be lawfully issued, and the permit should be rejected until the GPP adequately describes the existing groundwater that might be affected by Empire's site in light of the GWUDI issues at play here.

As mentioned above, many activities occur at this site, despite the applicant's claims: cargo and freight transloading of railcars, barges, and trucks; general port activities; iron-rich material screening; metallurgical coke storage; materials storage; slag excavating; diesel storage; hydrochloric acid transloading and blending; truck parking; warehousing and stockpiling of cargo all occur here.[56] All of these activities fall under the Groundwater Protection Act and its implementing regulations, and the Groundwater Protection Plan is incorporated into the NPDES permit.[57] Currently, the Draft Permit, the Groundwater Protection Plan, and the Stormwater Pollution Prevention Plan fail to capture the possible pollution from these activities as required by Permit Condition C.

While some of the activities taking place on the site are conducted by tenants leasing the property, and those activities are covered by the tenant's own plans and practices, Empire Trimodal is still responsible for the contaminated groundwater discharge flowing through Outfall 001. For example, the activity of storing metallurgical coke on site is mentioned in the Basis for Limitations, but is not contemplated anywhere in the Draft Permit, Groundwater Protection Plan, or Stormwater Pollution Prevention Plan. At the very least, the permitting record needs to clarify how the metallurgical coke arrives onsite, and where it is stored. If it is stored outside, or is uncovered, it must be regulated under the Groundwater Protection Rule.[58] In other examples, the Application does not reckon with pollutants likely to emanate from materials stockpiled on the property and exposed to the elements, including discarded plastics and tires.

Additionally, the catch basin is an impoundment under the Groundwater Protection Rule, but the current, insufficient evaluation in the Groundwater Protection Plan does not evaluate the catch basin's potential to cause groundwater contamination.[59] If and when that evaluation shows that the catch basin does have a substantial potential

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[56] *See supra* n. 4.

[57] *See* Draft Permit, Section C – Other Requirements.

[58] W. Va. Code R. § 47-58-4.3.

[59] W. Va. Code R. § 47-58-4.5.

to cause groundwater contamination, the Groundwater Protection Rule requires that efforts be taken to eliminate that groundwater contamination.[60] These issues should be addressed through this permitting process, and the permitting process should be re-opened and extended for the full thirty days once appropriate evaluations and management practices are put into place to address the groundwater issues. Until then, WVDEP cannot lawfully grant Empire the requested NPDES permit.

IV. WVDEP Cannot Reissue the Permit When there Is Reasonable Potential Empire's Discharges Will Violate Water Quality Standards and Degrade Existing Uses

WVDEP's reissuance of the permit would run afoul of water quality standards and antidegradation regulations. State water quality standards must include an antidegradation policy, which is "a policy requiring that state standards be sufficient to maintain existing beneficial uses of navigable waters, preventing their further degradation."[61] The CWA further requires "[t]he antidegradation policy shall, at a minimum, be consistent" with certain federal standards specified in the regulation.[62]

Consistent with federal law, West Virginia bases its antidegradation standards on three tiers of protection: Tier 1 applies to all waters, and requires that existing water uses be protected; and Tier 2 and 3 protect high quality waters and outstanding national resources from any degradation.[63] In their Basis for Limitations, WVDEP identifies the Ohio River segment where the discharge occurs as a Tier 1 water. Accordingly, WVDEP looks to see if there is a "reasonable potential" for any anticipated stormwater pollutants to impact existing uses by potentially violating water quality criteria.[64]

WVDEP should deny the Application, or at the very least, add conditions to the permit that will ensure Empire meets effluent limitations, because numerous pollutants have a reasonable potential to violate water quality standards and impact the uses of the Ohio River. Further, Empire's egregious violation history, which shows discharges that greatly exceed water quality standards, and its analysis of its discharge, which it undertakes in a way that underreports pollutant levels, demonstrates that effluent limitations alone cannot ensure compliance with water quality standards. Additionally,

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[60] W. Va. Code R. § 47-58-4.5.

[61] *PUD No. 1 of Jefferson Cnty v. Wash. Dep't of Ecology*, 511 U.S. 700, 704, (1994); *see also* 33 U.S.C. § 1313(d)(4)(B).

[62] 40 C.F.R. § 131.12.

[63] See W. Va. Code R. § 46-1-4.

[64] *See* Basis for Limitations; 40 CFR 122.44(d)(1)(i).

WVDEP improperly applied a mixing zone to certain pollutants, and these pollutants instead require effluent limitations and additional conditions.

A. WVDEP should deny the permit because, without additional conditions in the permit, it is unreasonable for WVDEP to assume that Empire will stop exceeding water quality criteria.

Empire has a known history of egregious violations of water quality standards for numerous pollutants, as well as permit violations for employing testing methods that fail to detect effluent limit violations. Despite these demonstrated water quality violations, WVDEP included no control measures in the Draft Permit to ensure Empire's discharges do not exceed water quality standards. WVDEP cannot rely on the arbitrary, unreasonable, and unsupported assumption that Empire will be able to meet the limits in the Draft Permit when the Draft Permit requires no conditions (such as treatment, or changes in site management practices) that would change the nature of Empire's pollutant discharges.[65] Accordingly, Empire's discharges have the reasonable potential to degrade existing uses by violating water quality criteria, and its Application must be rejected under the State's antidegradation policy.

WVDEP's regulations recognize that an applicant's "historic noncompliance with its permit" constitutes a "circumstance[ ] warrant[ing] ... review."[66] When confronted with a history of noncompliance, "it is arbitrary and capricious for an agency to predict future compliance without a rational explanation."[67] WVDEP has provided no rational explanation for why Empire will suddenly begin complying with water quality standards given its compliance history and without permit conditions mandating different actions.

Empire's own DMRs show that Empire regularly discharges polycyclic aromatic hydrocarbons ("PAHs") pollutants at levels that are hundreds and thousands of times more than the state's water quality criteria and the Draft Permit limits, creating acute and chronic dangers to the uses of the waterway.[68] These particular PAHs have been

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[65] Downstream Strategies Report at 3. ("Without implementation of controls, these contaminants will likely continue to be discharged to the Ohio River in concentrations exceeding limits imposed by the draft permit, thus decreasing water quality and posing harm to human health and aquatic species.").

[66] W. Va. Code R. § 60-5-5.6.a.2.

[67] *See Sierra Club v. W. Virginia Dep't of Env't Prot.*, 64 F.4th 487, 502 (4th Cir. 2023).

[68] Downstream Strategies Report at 2.

found to be highly carcinogenic and commonly found in stormwater runoff.[69] PAHs are known to accumulate in the marine environment and harm aquatic organisms.[70] Chronic exposure to PAHs can cause decreased immune function, cataracts, kidney and liver damage, and skin irritation.[71]

An inspection and review of Empire's DMRs by WVDEP in October of 2025 found over 90 violations of effluent limitations for PAHs in the roughly two-year period from September 2023 through August of 2025, including violations for benzo(a) anthracene, benzo(a) pyrene, and benzo(b) fluoranthene.[72] These violations were significant, far exceeding permit limits. For example, the DMRs show Empire discharged benzo(a) pyrene at a concentration more than 3,000 times its maximum daily water quality based effluent limitation and benzo(b) fluoranthene at a concentration 825 times greater than its maximum daily water quality based effluent limitation.[73] In the ten months between December 2024 and September 2025, seventy four percent of Empire's water quality based effluent limitation exceedances were more than ten times the water quality based effluent limit.[74]

In addition to violating water quality standards for PAHs, Empire has violated water quality based effluent limitations for mercury and cadmium.[75] Mercury accumulates in fish tissue and presents the greatest risk to human health through consumption of contaminated fish.[76] Cadmium can be acutely fatal to aquatic life in high concentrations, and chronic exposure can lead to adverse effects on growth, development, immune systems, and behavior in aquatic life.[77]

Notably, Empire's violations of water quality based effluent limitations include violations for some of the same pollutants WVDEP found to have a reasonable potential

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[69] EPA, Technical Factsheet on: POLYCYCLIC AROMATIC HYDROCARBONS (PAHs), attached as Exhibit 9; Downstream Strategies Report at 3.

[70] Brenda Tan Pei Jian et al., Study of the Water Quality Index and Polycyclic Aromatic Hydrocarbon for a River Receiving Treated Landfill Leachate, *Water* 2020, *12(10)*, 2877, https://doi.org/10.3390/w12102877; Downstream Strategies Report at 3.

[71] Downstream Strategies Report at 3.

[72] October 2025 Inspection Report at 3 & 6.

[73] Downstream Strategies Report at 2.

[74] *Id.*

[75] Downstream Strategies Report at 2; October 2025 Inspection Report at 3 & 5.

[76] EPA, Impaired Waters and Mercury, https://www.epa.gov/tmdl/impaired-waters-and-mercury.

[77] EPA, Aquatic Life Criteria - Cadmium, https://www.epa.gov/wqc/aquatic-life-criteria-cadmium.

to violate water quality criteria: mercury, benzo(a) anthracene, benzo(a) pyrene, and benzo(b) fluoranthene.[78] WVDEP found that "[t]he permittee had reasonable potential to exceed water quality criteria at the end of pipe and at the end of the default mixing zone for cadmium and mercury."[79] In addition, WVDEP found a reasonable potential to exceed water quality criteria at the end of pipe for benzo(a) anthracene, benzo(a) pyrene, benzo(b) fluoranthene, benzo(k) fluoranthene, chrysene, dibenzo(a,h) anthracene, and indeno(1,2,3-cd) pyrene.[80] All of these pollutants are harmful to human health and aquatic life.[81]

Moreover, Empire's violations are likely unreported. Empire has been violating its permit by using an analytic testing method that lacks the ability to detect "contaminants at concentrations small enough to determine if there were exceedances" of water quality based effluent limitations.[82] The permit requires the use of EPA Test Method Number 610 for all the PAH parameters.[83] But Empire has been using a different test method, EPA Method Number 625.1, to analyze its PAH limits. The problem with Method No. 625.1 is its detection limits are much higher than Method 610 and far above the PAH effluent limitations in the permit.[84] For example, for benzo(a)anthracene, EPA Test Method No. 610 has a method detection level of 0.01 µg/L (which converts to 10 NG/L), whereas EPA Test Method No. 625.1 has a method detection level of 0.075 µg/L (which converts to 75 NG/L) for that parameter.[85] Because benzo(a)anthracene has an average monthly permit limit of 3.8 NG/L and max daily limit of 6.95 NG/L, Empire has been able to violate its permit parameters by more than 18 times without its testing method detecting it. The same problems are true for the other PAH parameters, including benzo(k)fluoranthene (17 NGL compared to 88 NGL), benzo(a)pyrene (20 NGL compared to 53 NGL), dibenzo(a,h)anthracene (40 NGL compared to 72 NGL), and indeno(1,2,3-cd)pyrene (40 NGL compared to 85 NGL).

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[78] *See* October 2025 Inspection Report at 4–6. Basis for Limitations at 1–2.

[79] Basis for Limitations at 1.

[80] *Id*. at 2.

[81] Downstream Strategies Report at 3.

[82] *Id*.

[83] 2020 Permit at Condition C.13.

[84] *Compare* Report of Laboratory, Analytical Report at 10 (Jan. 2024) (attached hereto as Exhibit 10) *with* NPDES Permit at 4–5 (Monthly and Daily permit limits); *see also* Downstream Strategies Report at 2–3 (explaining that "[i]t is not possible to determine whether exceedances of permit limits occurred during many of the reporting periods … due to the detection levels of laboratory analyses" which "were not able to detect contaminants at concentrations small enough to determine if there were exceedances …"); *see also* AppalMad NOI at 4–5.

[85] *Compare* Report of Laboratory, Analytical Report at 10 (Jan. 2024) (attached hereto as Exhibit 10) *with* NPDES Permit at 4–5 (Monthly and Daily permit limits); *see also* AppalMad NOI at 4–5.

Between January 2024 and September 2024, eighty-four percent of analyses for PAHs were inadequate to determine if there were exceedances of water quality based effluent limitations due to improper testing methodology.[86]

Empire's failure to comply with the analytical method in its permit shows its refusal to comply with permit terms and suggests that Empire has likely violated its permit limits and impacted water quality standards of the Ohio River more consistently than it has reported.[87]

In addition to the conditions and effluent limitations all permits require, WVDEP's NPDES regulations require the agency to "establish conditions in permits as required on a case-by-case basis to provide for and assure compliance with all applicable requirements of the CWA and the State Act and regulations."[88] These conditions can include best management practices when "effluent limitations are infeasible" or the "practices are necessary to achieve effluent limitations and standards or to carry out the purpose of the CWA."[89]

Here, it is necessary for WVDEP to require additional conditions to achieve effluent limitations and protect the existing uses of the river. But instead of requiring actual control measures to ensure Empire's discharges do not cause exceedances of water quality criteria, WVDEP only modified effluent limitations for these pollutants in the Draft Permit—*raising* the limit for two pollutants, without justification, by more than four times in the case of benzo(k) fluoranthene and more than thirty times in the case of chrysene.

As demonstrated by Empire's operational history, DMRs, and past notices of violations, Empire's discharge requires more than just effluent limitations to ensure compliance with water quality criteria and prevent degradation of existing uses, and the management practices employed in the stormwater management plan have proven to be ineffective at limiting pollutant limits below effluent limitations.[90] Without treatment or some condition to limit the flow of pollutants, it is arbitrary and unreasonable for WVDEP to assume that Empire's future discharges will be different by simply installing permit limits. It is therefore arbitrary, capricious, and unlawful for WVDEP to approve

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[86] Downstream Strategies Report at 3.

[87] *Id*.

[88] W. Va. Code R. § 47-10-6.1.

[89] W. Va. Code R. § 47-10-6.3.i.

[90] *See* Downstream Strategies Report at 1 & 3.

the permit without additional conditions necessary to protect water quality standards and existing uses.

B. WVDEP cannot apply a mixing zone until it is justified in accordance with the regulations.

WVDEP found that Empire had a reasonable potential to exceed water quality criteria for aluminum, chloride, copper, hexavalent chromium, iron, and lead at the end of pipe, but did not apply permit limits or measures to control these pollutants. Instead, WVDEP used a mixing zone and only required monitoring and reporting on these pollutants. However, the permit record does not contain the required justification for applying a mixing zone.

A mixing zone is "a place where wastes and water mix." [91] It is "a limited volume of water serving as a zone of initial dilution in the immediate vicinity of a discharge point" where the receiving stream may not meet water quality standards or other requirements.[92] When WVDEP applies a mixing zone for a given pollutant, the polluter can discharge that pollutant at levels that may violate water quality standards within the limited geographic scope of the mixing zone, but must meet the water quality standard at the boundary of the mixing zone.[93] Mixing zones cannot be used to impair the designated use of a water body.[94]

Under West Virginia's regulations, mixing zones may only be granted where 1) specific geographic limits are assigned; 2) the concentrations of pollutants will not exceed acute criteria for the protection of aquatic life; 3) the concentration of pollutants will not exceed the criteria for the protection of human health, unless a mixing zone is assigned in consultation with the Commissioner of the West Virginia Department of Health; and 4) the mixing zone does not interfere with fish spawning, overlap with public water supply intakes or bathing areas, kill or preclude the passage of aquatic life, or harm or threaten any endangered species.[95] Moreover, where a mixing zone is implemented in a permit, the permittee is required to provide documentation that demonstrates the mixing zone is in compliance with the mixing zone regulations.[96]

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[91] 40 C.F.R. § 230.3(h).

[92] *Id.*

[93] Virtual WQS Academy, Permitting Tools with Roots in WQS, Mixing Zones and Permit Compliance Schedules, February 2026, https://www.epa.gov/system/files/documents/2026-02/17_healeyvlcan_permittoolswrootswqs-feb-2026_508c.pdf, at 4.

[94] *Id.* at 7; W. Va. Code R. § 47-2-5.2.

[95] W. Va. Code R. § 47-2-5.2.

[96] *Id*. at 47-2-5.11.

WVDEP did not evaluate any of the required demonstrations in the Basis for Limitations before applying a mixing zone for the six pollutants, and the Application published by WVDEP did not include a demonstration that the mixing zone for any of the six pollutants complies with the regulations. Without the required demonstrations, including that concentrations of these pollutants do not exceed any human health or acute aquatic life criterion, and that they wouldn't interfere with spawning or preclude the passage of fish and other aquatic life, WVDEP cannot apply a mixing zone to its reasonable potential analysis. As a result, WVDEP must deny the permit or at least include effluent limitations and conditions to ensure effluent limitations can be met.

There is good reason to assume the discharge will violate these mixing zone standards, particularly that they will exceed the water quality standards for the protection of human health and the acute standards for the protection of aquatic life, interfere with fish spawning, and preclude the passage of aquatic life.[97] Review of DMRs from the past two years shows that that Empire violated the water quality standards for lead and chloride, in one case violating the human health standard.[98] Lead is highly toxic to fish and other aquatic life species.[99] High amounts of chloride can negatively impact fish species and be fatally toxic to sensitive aquatic life.[100] Empire's discharge levels may therefore impact aquatic life in a way that precludes a mixing zone, such as potentially violating acute standards for aquatic life, precluding the passage of fish or other aquatic life, and impacting spawning areas.

For these reasons, WVDEP cannot rely on a mixing zone, and must therefore deny the permit or at least set effluent limitations for aluminum, chloride, copper, hexavalent chromium, iron, and lead in the permit, and require conditions or treatment to ensure these limitations can be met.

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[97] *See* W. Va. Code R. § 47-2-5.2.

[98] *See* Downstream Strategies Report at 2 (showing violations of human health and chronic aquatic life water quality standards).

[99] Ju-Wook Lee, et al., Toxic effects of lead exposure on bioaccumulation, oxidative stress, neurotoxicity, and immune responses in fish: A review, Environ Toxicol Pharmacol, (May 2019), available at: https://pubmed.ncbi.nlm.nih.gov/30884452/.

[100] EPA, Ambient Water Quality Criteria for Chloride (1988), available at: https://19january2021snapshot.epa.gov/wqc/aquatic-life-ambient-water-quality-criteria-chloride_.html.

V. The Draft Permit Violates Anti-Backsliding Provisions of the Clean Water Act

The Clean Water Act generally prohibits an existing permit from being renewed, reissued, or modified to contain effluent limitations that are less stringent than the original issuance of the permit.[101] The CWA does provide some exceptions to this general rule, such as when new information becomes available that was not available at the time of original issuance that justifies a lesser standard; however, a change in regulations does not constitute an exception to the anti-backsliding prohibition.[102]

The Draft Permit contains less stringent limitations for several pollutants, including: lead, mercury, chrysene, and benzo(k) fluoranthene. *See* Table 1 *infra*. Notably, for lead the permit limit is removed entirely. The permitting materials fail to provide any legal basis for weakening these limitations, and certainly none for removing limitations, which violate the Clean Water Act's anti-backsliding provisions.

Pollutant	**Units**	**2020 Permit Limit**	**Draft Permit Limit**	**Measurement Frequency 2020 Permit**	**Measurement Frequency Draft Permit**
Lead	Mg/l	0.02 avg. monthly/ 0.049 max. daily	None (report only)	1/month	1/quarter
Mercury	Ug/l	0.061 avg. monthly/ 0.18 max. daily	0.068 avg. monthly/ 0.197 max. daily	1/month	1/month
Chrysene	NG/L	3.8 avg. monthly/ 6.37 max. daily	120 avg. monthly/ 196 max. daily	1/month	1/month
Benzo(K) Fluoranthene	NG/L	3.8 Avg. monthly/ 8.02 max. daily	12 avg. monthly/ 19 max. daily	1/month	1/month

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[101] 33 U.S.C. § 1342(o); W. Va. Code R. § 47-10-6.3.j.1.

[102] 33 U.S.C. § 1342(o)(2)(B)(i).

Table 1. Pollutants with Less Stringent Effluent Limitations in the Draft Permit as compared to the 2020 Permit.

Empire's Application does not meet any of the exception criteria necessary to relax permit standards. Empire does not include any new information from the time of initial issuance that would justify a weakening or elimination of effluent limitations. Further, as explained above, the antidegradation analysis WVDEP conducted for the Application is inadequate and cannot provide a basis for weakening effluent limitations under 33 U.S.C. § 1342(o)(1).

VI. Conclusion

For the reasons stated herein, Empire's Application is inadequate and the Draft Permit violates the Clean Water Act and West Virginia water pollution control laws. Accordingly, WVDEP must deny Empire's Application and refrain from any further permit review until Empire has submitted a complete application that accurately describes the site and its potential discharges.

Sincerely,

Megan M. Hunter*
mhunter@earthjustice.org
James Yskamp
jyskamp@earthjustice.org
Earthjustice
*not licensed to practice in West Virginia

Andrew C. Earley
aearley@fairshake-els.org
Fair Shake Environmental Legal Services

Counsel for West Virginia Citizen Action Group

The following groups join in this comment through the duly authorized representatives below:

Jennie Smith, Executive Director
WV Rivers Coalition
Jsmith@wvrivers.org

Warren Hilsbos, Community Liaison
Ohio Valley Environmental Advocates

Oveadvocates@gmail.com

Cheryl Johncox, Regional Coordinator
People Over Petro Coalition
Cheryl@peopleoverpetro.org

Martec Washington, Community Organizer
Black Appalachian Coalition
Martec@blackappalachiancoalition.org

Exhibit 1

STATE OF WEST VIRGINIA

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER AND WASTE MANAGEMENT
BASIS FOR LIMITATIONS

Empire Trimodal Terminal, LLC
WV0023281
November 2025

BACKGROUND INFORMATION

Empire Trimodal Terminal, LLC owns the site previously operated as a sinter plant in Moundsville, West Virginia. The facility shut down all manufacturing operations and decommissioned the facility in 1999. The property occupies approximately 130 acres and currently provides railroad and tank truck access to various operations including third party operations including materials screening, metallurgical coke storage, new pipe storage and a railroad tanker to tank truck transfer operation. The untreated storm water and ground water collection/disposal system remains in operation at the site and is covered by this permit

Facility	Outlet	Description	Receiving Stream	7Q10	Trout	303(d)
Empire Trimodal Terminal, LLC	001	Storm Water/Ground Water	Ohio River MP 69.7	5,880 cfs	No	No

The Ohio River (Upper North) at MP 69.7 is included in the approved 2016 303(d) list of impairments for dioxin and bacteria. These are not parameters of concern for this permit.

COMPLIANCE ASSESSMENT:

This facility has not had an inspection since 2019. The SWPPP submitted with the application has not been updated since 2016. The DEP Groundwater Department reviewed the Groundwater Protection Plan (GPP) and this has been updated and resubmitted with the application.

OUTLET 001

A hardness value of 104 mg/l was utilized in the evaluation of reasonable potential for certain metals. Stream background data was obtained from ORSANCO from the New Cumberland (MP 54.4) and Pike Island (84.2) monitoring stations from the time period of 2021 – 2024. A reasonable potential analysis was performed utilizing the available background data and discharge data from DMRs in conjunction with default mixing zone values of 3 (ZID), 10 (CMZ) and 30 (HHCMZ). The permittee did not have reasonable potential to exceed water quality criteria at the end of pipe for barium, beryllium, and manganese. The permittee had reasonable potential to exceed water quality criteria at the end of pipe, but not at the edge of the default mixing zone for aluminum, chloride, copper, hexavalent chromium, iron, and lead. Continued monitoring is imposed for these parameters.

The permittee had reasonable potential to exceed water quality criteria at the end of pipe and at the edge of the default mixing zone for cadmium and mercury. Therefore, effluent limitations are imposed for those parameters.

No stream background was available for benzo(a) anthracene, benzo(a) pyrene, benzo(b) fluoranthene, benzo(k) fluoranthene, chrysene, dibenzo(a,h) anthracene, indeno(1,2,3-cd) pyrene, and vanadium; therefore, no mixing zone could be granted. There was reasonable potential to exceed water quality criteria at the end of pipe for benzo(a) anthracene, benzo(a) pyrene, benzo(b) fluoranthene, benzo(k) fluoranthene, chrysene, dibenzo(a,h) anthracene, and indeno(1,2,3-cd) pyrene. Therefore, effluent limitations are imposed for those parameters.

West Virginia does not currently have numeric water quality criteria prescribed for vanadium. The agency believes it is necessary to evaluate the necessity of water quality-based effluent limits for vandium at Outlet 001 due to its presence in discharges from this outlet. EPA Region III has recognized 0.18 mg/l as the risk-based criteria (RBC) for tap water and 1/10 of a 96-hour LC50 of 0.2 mg/l for vanadium for daphnia magna (TOXNET). The agency therefore used these values as a Category A (Human Health) and the B1, B4 (freshwater) acute aquatic water quality criteria to evaluate if there is reasonable potential to cause or contribute to a violation of the State's narrative water quality criteria. Using these criteria, there was no reasonable potential to exceed the criteria at the end of pipe.

ANTIDEGREADATION:

The outlet identified in this permit is an existing outlet. Tier 1 protection is provided for the uses specified in Title 47, Series 2, Section 6 for Outlet No. 001 for all parameters of concern.

FINAL EFFLUENT LIMITATIONS SUMMARY
Outlet No. 001 - Discharges to Ohio River MP 69.7

Parameter	Mass Limits		Concentration Limits (mg/l)		Frequency	Rationale
	Average Monthly	Max Daily	Average Monthly	Max Daily		
Flow (MGD)	--	--	Monitor	Monitor	Monthly	BPJ
pH (Standard Units)	--	--	--	6-9	Monthly	WQS
TSS	--	--	Monitor	Monitor	Monthly	BPJ
Oil and Grease	--	--	Monitor	Monitor	Quarterly	BPJ
Aluminum, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Chloride (as Cl)	--	--	Monitor	Monitor	Quarterly	BPJ
Iron, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Cadmium, Total Recoverable	--	--	0.0014	0.0034	Monthly	WQS/Mixing
Copper, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Hexavalent Chromium	--	--	Monitor	Monitor	Quarterly	BPJ
Barium, Total	--	--	Monitor	Monitor	Quarterly	BPJ
Beryllium, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Lead, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Mercury, Total	--	--	0.068 µg/l	0.197 µg/l	Monthly	WQS/Mixing
Manganese, Total Recoverable	--	--	Monitor	Monitor	Quarterly	BPJ
Sulfate	--	--	Monitor	Monitor	Quarterly	BPJ
Vanadium, Total	--	--	Monitor	Monitor	Quarterly	BPJ
Benzo(a) Anthracene	--	--	1.2 ng/l	1.85 ng/l	Monthly	WQS
Benzo(a) Pyrene	--	--	0.12 ng/l	0.20 ng/l	Monthly	WQS
Benzo(b) Flouranthene	--	--	1.2 ng/l	2.0 ng/l	Monthly	WQS
Benzo(k) Flouranthene	--	--	12 ng/l	18.6 ng/l	Monthly	WQS
Chrysene	--	--	120 ng/l	196 ng/l	Monthly	WQS
Dibenzo(a,h) Anthracene	--	--	0.12 ng/l	0.16 ng/l	Monthly	WQS
Indeno(1,2,3-cd) Pyrene	--	--	1.2 ng/l	1.89 ng/l	Monthly	WQS

WATER QUALITY BASED EFFLUENT LIMITATIONS

v 10.4

Empire Trimodal Terminal

Outlet: 001

Stream: Upper Ohio River MP 69.7

Hardness (mg/l):	104	**Instream Waste %:**	0.01
Temperature (°C):	27	**ZID:**	3.0
pH:	7.64	**CMZ:**	10.0
Stream 1Q10 (CFS):	NA	**HH CMZ:**	30.0
Stream 7Q10 (CFS):	5880	**HHA 1/2 Mile Rule CMZ:**	30.0
Effluent Flow (MGD):	0.21		

PARAMETER	Baseline Water Quality (mg/l)	Stream Background (mg/l)	End of Pipe WQC RP	RWC WQC RP	Average Monthly Limit (mg/l)	Maximum Daily Limit (mg/l)	Tier Protection Level
Aluminum	NA	0.1970	Yes	No	Monitor	Monitor	Tier 1
Barium	NA	0.0420	No	No	Monitor	Monitor	Tier 1
Berylium	NA	0.0005000	No	No	Monitor	Monitor	Tier 1
Cadmium	NA	0.0001	Yes	Yes	0.0014	0.0034	Tier 1
Chloride	NA	29	Yes	No	Monitor	Monitor	Tier 1
Hexavalent Chromium	NA	0.0006	Yes	No	Monitor	Monitor	Tier 1
Copper	NA	0.0017	Yes	No	Monitor	Monitor	Tier 1
Iron	NA	0.3710	Yes	No	Monitor	Monitor	Tier 1
Lead	NA	0.0006	Yes	No	Monitor	Monitor	Tier 1
Manganese	NA	0.0650	No	No	Monitor	Monitor	Tier 1
Mercury	NA	0.00000136	Yes	Yes	0.00006788	0.00019695	Tier 1

Outfall discharges to Ohio River and is subject to ORSANCO Pollution Control Standards:	No
Outfall discharges to a Trout Stream:	No
Outfall discharges to a stream exempt from Human Health A Criteria:	No
Outfall discharges to a stream exempt from all Human Health Criteria:	No
Outfall discharges within 1/2 mile upstream of a public drinking water intake:	No
Outfall has limitations for at least one metal using a site specific translator:	No
Outfall has Tier 2.0 antidegradation limitations for at least one pollutant:	No

WATER QUALITY BASED EFFLUENT LIMITATIONS

v 10.4

Empire Trimodal Terminal

Outlet: 001

Stream: Upper Ohio River MP 69.7

Hardness (mg/l):	104	**Instream Waste %:**	0.01
Temperature (°C):	27	**ZID:**	1.0
pH:	7.64	**CMZ:**	1.0
Stream 1Q10 (CFS):	NA	**HH CMZ:**	1.0
Stream 7Q10 (CFS):	5880	**HHA 1/2 Mile Rule CMZ:**	1.0
Effluent Flow (MGD):	0.21		

PARAMETER	Baseline Water Quality (mg/l)	Stream Background (mg/l)	End of Pipe WQC RP	RWC WQC RP	Average Monthly Limit (mg/l)	Maximum Daily Limit (mg/l)	Tier Protection Level
Vanadium	NA	NA	No	No	Monitor	Monitor	Tier 1
Benzo(a) Anthracene	NA	NA	Yes	Yes	0.00000120	0.00000185	Tier 1
Benzo(a) Pyrene	NA	NA	Yes	Yes	0.00000012	0.00000020	Tier 1
Benzo(b) Fluoranthene	NA	NA	Yes	Yes	0.00000120	0.00000206	Tier 1
Benzo(k) Fluoranthene	NA	NA	Yes	Yes	0.00001200	0.00001863	Tier 1
Chrysene	NA	NA	Yes	Yes	0.00012000	0.00019641	Tier 1
Dibenzo(a,h) Anthracene	NA	NA	Yes	Yes	0.00000012	0.00000016	Tier 1
Indeno(1,2,3-cd) Pyrene	NA	NA	Yes	Yes	0.00000120	0.00000189	Tier 1

Outfall discharges to Ohio River and is subject to ORSANCO Pollution Control Standards:	No
Outfall discharges to a Trout Stream:	No
Outfall discharges to a stream exempt from Human Health A Criteria:	No
Outfall discharges to a stream exempt from all Human Health Criteria:	No
Outfall discharges within 1/2 mile upstream of a public drinking water intake:	No
Outfall has limitations for at least one metal using a site specific translator:	No
Outfall has Tier 2.0 antidegradation limitations for at least one pollutant:	No

Exhibit 2

west virginia department of environmental protection

Environmental Enforcement
131-A Peninsula Street
Wheeling, WV 26003
Phone: 304-238-1220

Harold D. Ward, Cabinet Secretary
dep.wv.gov

Oct 31, 2025

Empire Trimodal Terminal, LLC
Attn: Chip Fenske, VP of Operations
1400 Main Street
Follansbee, WV 26037

Certified Return Receipt Requested
Cert #9414 8118 9956 1975 4124 91

Dear Mr.Fenske,

Enclosed is the report for the reconnaissance inspection conducted at The Port of West Virginia (WV0023281) on Oct 2, 2025. A copy of this report is being forwarded to the U.S. Environmental Protection Agency, Region III and the West Virginia Department of Environmental Protection’s Division of Water and Waste Management.

Your immediate attention should be given to the deficiencies listed in the report summary. The violations noted in the report, or failure to implement corrective action to eliminate those violations, may result in enforcement action as outlined in Chapter 22, Article 11 of the West Virginia Code.

Within twenty (20) days of receipt of this letter, please advise this office in writing of your plans to bring your facility into compliance. The response should be sent to the name and address of the inspector indicated on the attached Notice of Violation(s).

If you have any questions, please contact Supervisor at (304) 238-1220.

Sincerely,

Ryan Harbison
Environmental Inspector Supervisor

enclosure
cc: Kimi Ely, Environmental Inspector, EE/WW (via e-mail)
Tonya Mather, EE/WW-CSW Enforcement Coordinator (via e-mail)

Rev. 9/17 I-Form

STATE OF WEST VIRGINIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ENVIRONMENTAL ENFORCEMENT
INDUSTRIAL FACILITY INSPECTION FORM

Facility Name: The Port of West Virginia		**Permit /Reg. #:** WV0023281	**Expiration Date:** 11/9/2025
Permittee: Empire Trimodal Terminal, LLC			
Site Representative /Title: Chip Fenske, VP of Operations			
Location: 600 Veterans Dr, Follansbee, WV 26037		**Entry Date / Time:** 10/02/2025 9:00 am	
County: Brooke Co.		**Exit Date / Time:** 10/02/2025 11:30 am	
Address /Phone: 1400 Main Street Follansbee, WV 26037	**Regular Mail:** ☐ **Certified Mail:** X	**Photos:** X	**Samples:** ☐
	Tracking # **9414 8118 9956 1975 4124 91**		

**Rating: S-Satisfactory M-Marginal U-Unsatisfactory N/A-Not Applicable N/O-Not Observed N/D-Not Determined This Visit Y-Yes N-No*

X **No Treatment** ☐ **Treatment: Sand Filter Beds**

Treatment		**Rating**	Treatment		**Rating**	Records / Operations		**Rating**
01	Pond(s)	N/A	13	Aeration	N/A	25	Solid Waste Disposal	U
02	Clarifier(s)	N/A	14	Sludge Return	N/A	26	Sludge Disposal	N/A
03	Separator(s)	N/A	15	Filtration	N/A	27	General Housekeeping	M
04	Equalization Basin	N/A	16	Carbon Filter	N/A	28	Operation and Maintenance	U
05	Neutralization	N/A	17	Air Stripping	N/A	29	Secondary Containment	U
06	Sump		18	Dissolved Air Floatation	N/A	30	SWPPP/GPP/SPCC	S
07	Chemical Feeder	N/A	19	Post Aeration	N/A	31	Sampling / Laboratory	U
08	Scum Removal	N/A	20	Sanitary Wastewater System	N/A	32	Records/Reporting	U
09	Septic Tank	N/A	21	Other: Tenates	S	33	Discharge Limitations	U
10	Holding Tank	N/A	22	Other:		34	Storm Water	N/D
11	Emergency Basin	N/A	23	Other:		35	BMPs	U
12	Impoundment(s)	N/A	24	Other:		36	Compliance Schedule	N/D
		-				37	Monitoring Wells	N/A
		-				38	Other:	-

Outlet	Marker	Design Flow	Present Flow	Appearance	Odor	TRC mg/L	pH S.U.	DO mg/L	Temp. C.	Samples
001	S	0.014485 mgd	N/O	N/D	N	N/D	N/D	N/D	N/D	N

Overall Facility Rating: Unsatisfactory

Compliance Outcome: Not Immediately Corrected

NOVs issued: 1

COMMENTS:

On October 2, 2025, WVDEP Inspector Kimi Ely conducted an inspection at Empire Trimodal Terminal (ETT)'s industrial facility, the Port of West Virginia. Inspector Ely gave notice of this inspection to Chip Fenske on September 29, 2025. Mr.Fenske was the site representative during this inspection. The Port of West Virginia is a transloading and storage facility. ETT also conducts an excavation and screening operation of iron-rich slag.

Inspector Ely found and observed the following:

21) Tenants - ETT also leases a part of the facility to FTSI, Inc. FTSI, Inc uses the property for the offloading and mixing of hydrochloric acid. Additives were observed in totes with secondary containment. Operations take place over a concrete pad. Drop-inlets on the pad are stated to lead to a sump.

USA Gypsum also utilizes this facility for the transloading of gypsum sand.

Murphy Consolidated Industries also utilizes this facility for truck parking. This lot was vacant during the inspection. Mr.Fenske explained that vehicle maintenance does not take place at this facility.

25) Solid Waste Disposal - ETT has an open dump of solid waste consisting of metal, wood, and soil onsite. The solid waste came from offsite locations.

27) General Housekeeping - Gypsum sand was observed tracked out around a dump truck.

28) Operation and Maintenance - ETT has an idle water withdrawal facility onsite.

Mr.Fenske explained that a stormwater basin leads to this sample port. This stormwater basin collects precipitation from the City of Follansbee. Due to vegetation, this basin was not located during the inspection. Mr. Fenske later sent photos of the basin. Vegetation had been cut down around the basin. Sediment and debris was present in the basin.

Screening operations were observed taking place in close proximity to the sample port of Outlet 001. A chain-link fencing covered and locked the sample port. ETT did not have any way to prevent dust or debris from entering the port.

30) SWPPP/GPP/SPCC - ETT maintains a Stormwater Protection Plan and Groundwater Protection Plan. ETT last updated them in September 2025. Employee training is completed annually. Quarterly inspections are being conducted.

FTSI, Inc. also maintains a separate SWPPP and GPP that was developed in 2015. However, Mr.Fenske stated that the ETT is working with FSTI to further develop FSTI's SWPPP and GPP.

34) Stormwater - Mr.Fenske explained that stormwater is also gathered from surrounding facilities. This site and surrounding sites have known historic contamination.

35) BMPs - Control structures were minimal. Silt socks were placed around a stormwater basin.

29) Secondary Containment - Three 500-gallon diesel tanks are used to fuel equipment. These tanks are placed in tubs. One of the tubs was not sealed properly; staining was observed around it.

31) Sampling/Laboratory - Discharge Monitoring Reports (DMRs) submitted between the reporting periods of September 2023 to August 2025 were reviewed. ETT did not analyze Total Recoverable Lead for the January 2025 reporting period. ETT utilizes Eurofins Pittsburg (State Lab ID 142) in Pittsburg, PA for laboratory analysis. ETT started to use Eurofins Pittsburgh in December 2024.

Samples for Outlet 001 are collected through a port. Flow was present inside the port.

32) Records/Reporting - ETT submitted DMRs late on 13 occasions during the reviewed reporting periods.

33) - Discharge Limitations - ETT exceeded discharge limitations a total of 93 times during the reviewed reporting periods. Polycyclic aromatic hydrocarbons (PAHs) limits were exceeded 92 times and Total Mercury 1 time. ETT has not been able to determine a correlation with the exceedances and any events.

Outlet 001 - The outlet and marker could not be located during the inspection. In the approximate area of the Outlet, no concerns were noted in the Ohio River. Mr. Fenske sent a photo of the outlet marker after the inspection.

See the included Notice of Violations#: W25-05-052-KJE *for the issues discussed above.*

Inspector: Kimi J. Ely
Kimi J. Ely

(681) 910-1362
kimi.j.ely@wv.gov
Telephone / Email

Outlet 001 DMR Exceedances - AVG. MONTHLY - September 2023 through August 2025						Degree of non-compliance		
Date	Parameter	Units	Permitted	Reported	% Exceedance			
			avg. monthly	avg. monthly		Min	Mod	Maj
12/31/2024	**Benzo (B) Fluoranthene**	NG/L	3.8	**190**	4900%	-	-	X
1/31/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**1700**	44637%	-	-	X
2/28/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**110**	2795%	-	-	X
3/31/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**150**	3847%	-	-	X
4/30/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**18**	374%	-	-	X
5/31/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**39**	926%	-	-	X
6/30/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**26**	584%	-	-	X
7/31/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**24**	532%	-	-	X
8/31/2025	**Benzo (B) Fluoranthene**	NG/L	3.8	**16**	321%	-	-	X
12/31/2024	**Benzo (K) Fluoranthene**	NG/L	3.8	**69**	1716%	-	-	X
1/31/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**490**	12795%	-	-	X
2/28/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**45**	1084%	-	-	X
3/31/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**61**	1505%	-	-	X
5/31/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**24**	532%	-	-	X
6/30/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**10**	163%	-	X	-
7/31/2025	**Benzo (K) Fluoranthene**	NG/L	3.8	**14**	268%	-	X	-
10/31/2023	**Benzo (A) Pyrene**	NG/L	3.8	**61**	1505%	-	-	X
5/31/2024	**Benzo (A) Pyrene**	NG/L	3.8	**66**	1637%	-	-	X
12/31/2024	**Benzo (A) Pyrene**	NG/L	3.8	**140**	3584%	-	-	X
1/31/2025	**Benzo (A) Pyrene**	NG/L	3.8	**650**	17005%	-	-	X
2/28/2025	**Benzo (A) Pyrene**	NG/L	3.8	**77**	1926%	-	-	X
3/31/2025	**Benzo (A) Pyrene**	NG/L	3.8	**100**	2532%	-	-	X
4/30/2025	**Benzo (A) Pyrene**	NG/L	3.8	**15**	295%	-	X	-
5/31/2025	**Benzo (A) Pyrene**	NG/L	3.8	**23**	505%	-	X	-
6/30/2025	**Benzo (A) Pyrene**	NG/L	3.8	**17**	347%	-	X	-
7/31/2025	**Benzo (A) Pyrene**	NG/L	3.8	**20**	426%	-	X	-
8/31/2025	**Benzo (A) Pyrene**	NG/L	3.8	**14**	268%	-	X	-
12/31/2024	**Chrysene**	NG/L	3.8	**120**	3058%	-	-	X
01/31/2025	**Chrysene**	NG/L	3.8	**1100**	28847%	-	-	X
02/28/2025	**Chrysene**	NG/L	3.8	**65**	1611%	-	-	X
03/31/2025	**Chrysene**	NG/L	3.8	**88**	2216%	-	-	X
04/30/2025	**Chrysene**	NG/L	3.8	**12**	216%	-	X	-
05/31/2025	**Chrysene**	NG/L	3.8	**26**	584%	-	X	-
06/30/2025	**Chrysene**	NG/L	3.8	**16**	321%	-	X	-
07/31/2025	**Chrysene**	NG/L	3.8	**15**	295%	-	X	-
08/31/2025	**Chrysene**	NG/L	3.8	**11**	189%	-	X	-
12/31/2024	**Benzo (A) Anthracene**	NG/L	3.8	**92**	2321%	-	-	X
01/31/2025	**Benzo (A) Anthracene**	NG/L	3.8	**360**	9374%	-	-	X
02/28/2025	**Benzo (A) Anthracene**	NG/L	3.8	**56**	1374%	-	-	X
03/31/2025	**Benzo (A) Anthracene**	NG/L	3.8	**61**	1505%	-	-	X
04/30/2025	**Benzo (A) Anthracene**	NG/L	3.8	**12**	216%	-	X	-
05/31/2025	**Benzo (A) Anthracene**	NG/L	3.8	**15**	295%	-	X	-
06/30/2025	**Benzo (A) Anthracene**	NG/L	3.8	**13**	242%	-	X	-
07/31/2025	**Benzo (A) Anthracene**	NG/L	3.8	**18**	374%	-	X	-
12/31/2024	**Dibenzo (A,H) Anthracene**	NG/L	3.8	**31**	716%	-	-	X

01/31/2025	**Dibenzo (A,H) Anthracene**	NG/L	3.8	**140**	3584%	-	-	X
02/28/2025	**Dibenzo (A,H) Anthracene**	NG/L	3.8	**19**	400%	-	X	-
03/31/2025	**Dibenzo (A,H) Anthracene**	NG/L	3.8	**21**	453%	-	X	-
5/31/2025	**Mercury, Total (as Hg)**	ug/l	0.061	**0.0647**	6%	X	-	-

Outlet 001 DMR Exceedances - MAX. DAILY - 9/30/2023 through 9/30/2025						Degree of non-compliance		
Date	Parameter	Units	Permitted	Reported	% Exceedance			
			max. daily	max. daily		Min	Mod	Maj
12/31/2024	**Benzo (B) Fluoranthene**	NG/L	6.52	**190**	2814%	-	-	X
1/31/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**1700**	25974%	-	-	X
2/28/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**110**	1587%	-	-	X
3/31/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**150**	2201%	-	-	X
4/30/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**18**	176%	-	X	-
5/31/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**39**	498%	-	X	-
6/30/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**26**	299%	-	X	-
7/31/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**24**	268%	-	X	-
8/31/2025	**Benzo (B) Fluoranthene**	NG/L	6.52	**16**	145%	-	X	-
12/31/2024	**Benzo (K) Fluoranthene**	NG/L	8.02	**69**	760%	-	-	X
1/31/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**490**	6010%	-	-	X
2/28/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**45**	461%	-	X	-
3/31/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**61**	661%	-	-	X
5/31/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**24**	199%	-	X	-
6/30/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**10**	25%	X	-	-
7/31/2025	**Benzo (K) Fluoranthene**	NG/L	8.02	**14**	75%	X	-	-
10/31/2023	**Benzo (A) Pyrene**	NG/L	6.25	**61**	876%	-	-	X
5/31/2024	**Benzo (A) Pyrene**	NG/L	6.25	**66**	956%	-	-	X
12/31/2024	**Benzo (A) Pyrene**	NG/L	6.25	**140**	2140%	-	-	X
1/31/2025	**Benzo (A) Pyrene**	NG/L	6.25	**650**	10300%	-	-	X
2/28/2025	**Benzo (A) Pyrene**	NG/L	6.25	**77**	1132%	-	-	X
3/31/2025	**Benzo (A) Pyrene**	NG/L	6.25	**100**	1500%	-	-	X
4/30/2025	**Benzo (A) Pyrene**	NG/L	6.25	**15**	140%	-	X	-
5/31/2025	**Benzo (A) Pyrene**	NG/L	6.25	**23**	268%	-	X	-
6/30/2025	**Benzo (A) Pyrene**	NG/L	6.25	**17**	172%	-	X	-
7/31/2025	**Benzo (A) Pyrene**	NG/L	6.25	**20**	220%	-	X	-
8/31/2025	**Benzo (A) Pyrene**	NG/L	6.25	**14**	124%	-	X	-
12/31/2024	**Chrysene**	NG/L	6.37	**120**	1784%	-	-	X
01/31/2025	**Chrysene**	NG/L	6.37	**1100**	17168%	-	-	X
02/28/2025	**Chrysene**	NG/L	6.37	**65**	920%	-	-	X
03/31/2025	**Chrysene**	NG/L	6.37	**88**	1281%	-	-	X
04/30/2025	**Chrysene**	NG/L	6.37	**12**	88%	X	-	-
05/31/2025	**Chrysene**	NG/L	6.37	**26**	308%	-	X	-
06/30/2025	**Chrysene**	NG/L	6.37	**16**	151%	-	X	-
07/31/2025	**Chrysene**	NG/L	6.37	**15**	135%	-	X	-
08/31/2025	**Chrysene**	NG/L	6.37	**11**	73%	X	-	-
12/31/2024	**Benzo (A) Anthracene**	NG/L	6.95	**92**	1224%	-	-	X
01/31/2025	**Benzo (A) Anthracene**	NG/L	6.95	**360**	5080%	-	-	X
02/28/2025	**Benzo (A) Anthracene**	NG/L	6.95	**56**	706%	-	-	X
03/31/2025	**Benzo (A) Anthracene**	NG/L	6.95	**61**	778%	-	-	X
04/30/2025	**Benzo (A) Anthracene**	NG/L	6.95	**12**	73%	X	-	-

05/31/2025	**Benzo (A) Anthracene**	NG/L	6.95	**15**	116%	-	**X**	-
06/30/2025	**Benzo (A) Anthracene**	NG/L	6.95	**13**	87%	**X**	-	-
07/31/2025	**Benzo (A) Anthracene**	NG/L	6.95	**18**	159%	-	**X**	-

Outlet 001 Totals	**Degree of non-compliance**		
	Min	**Mod**	**Maj**
	7	**35**	**51**

Photo Attachment
WV0023281 - Empire Trimodal Terminal
October 02, 2025

PA020315 - Part of the iron slag screening process

PA020318 - Track-out of gypsum sand

PA020322 - FSTI's hydrochloric acid transloading and blending location

PA020332 - Middle diesel tank without a plug for secondary containment; note staining

PA020338 - Pile of limestone for transloading

PA020345 - From the City of Follansbee's projects

PA020348 - Outlet 001 sample port

January 6, 2026

Dear Samuel Huckins:

The following is in response to your request for proof of delivery on your item with the tracking number: **9414 8118 9956 1975 4124 91**.

Item Details

Status:	Delivered, Left with Individual
Status Date / Time:	November 17, 2025, 9:41 am
Location:	FOLLANSBEE, WV 26037
Postal Product:	First-Class Mail®
Extra Services:	Certified Mail™ Return Receipt Electronic
Recipient Name:	Empire Trimodal Terminal Attn Chip Fenske

Shipment Details

Weight:	3.0oz

Recipient Signature

Signature of Recipient:	Tammy Elliott Tammy Elliott
Address of Recipient:	**1400 MAIN ST, FOLLANSBEE, WV 26037**

Note: Scanned image may reflect a different destination address due to Intended Recipient's delivery instructions on file.

Thank you for selecting the United States Postal Service® for your mailing needs. If you require additional assistance, please contact your local Post Office™ or a Postal representative at 1-800-222-1811.

Sincerely,
United States Postal Service®
475 L'Enfant Plaza SW
Washington, D.C. 20260-0004

Exhibit 3

west virginia department of environmental protection

Environmental Enforcement – Water and Waste
131-A Peninsula St.
Wheeling, WV 26003
Phone: 304-238-1220

Harold D. Ward, Cabinet Secretary
dep.wv.gov

COMPLAINT INVESTIGATION/EMERGENCY RESPONSE

Report type: Final

Complaint Received By:

Anonymous

Date and Time:

N/D

Name of Complainant:

Anonymous

Address of Complainant:

N/D

Phone Number or Email of Complainant:

N/D

Description of Complaint:

Empire Diversified Energy is storing medical waste and chemical drums at a specific location.

Date and Time Noted By Complainant:

Ongoing

Stream Affected, If Any:

N/D

Location:

600 Veterans Dr.,
Follansbee, WV 26037

Responsible Party and Address:

Empire Trimodal Terminal LLC
1400 Main Street
Follansbee, WV 26037

Investigated By:
Kimi Ely

Phone Number of Responsible Party:
304-914-4624

Date Investigated: 12/19/25

Prepared By:

Time Investigated: 9:30

Kimi Ely, Environmental Inspector

Narrative:

On arrival, WVDEP Inspector Kimi Ely and WVDEP Inspector Lucas Stan went to the area of concern, where an open dump of waste tires was observed. Inspector Ely observed no indication of medical or chemical waste being stored. Inspectors then met with Engineering VP Farley Wood. Inspectors observed a pyrolysis reactor. The reactor was not in operation. Inspectors also observed plastic beads, empty drums and overpacks and other various plastic items. These plastics are being stored there for the intended use of feedstock for pyrolysis. Inspector Ely later informed Mr.Wood of the tire dump and the Stormwater Protection Plan and the Groundwater Protection Plan needed to be updated to include plastics being stored onsite. As of January 8, 2026 tires have been collected. They are waiting on plans for proper disposal.

Compliance Evaluation:

Notice of Violation No.W25-05-063-KJE is being issued for the open dump of waste tires.

Certified tracking #9414 8118 9956 1919 1798 55

Photo Attachment
Empire Trimodal Terminal
December 19, 2025

PC190150 - Waste Tires

PC190152 - Pile of plastic items

PC190152 - Boxes of plastic beads and empty overpacks

UNITED STATES
POSTAL SERVICE

February 5, 2026

Dear Samuel Huckins:

The following is in response to your request for proof of delivery on your item with the tracking number: **9414 8118 9956 1919 1798 55**.

Item Details

Status:	Delivered, Left with Individual
Status Date / Time:	January 21, 2026, 9:09 am
Location:	FOLLANSBEE, WV 26037
Postal Product:	First-Class Mail®
Extra Services:	Certified Mail™ Return Receipt Electronic
Recipient Name:	Empire Trimodal Terminal

Shipment Details

Weight:	3.0oz

Recipient Signature

Signature of Recipient:	Tammy Elliott Tammy Elliott
Address of Recipient:	600 VETERANS DR, FOLLANSBEE, WV 26037

Note: Scanned image may reflect a different destination address due to Intended Recipient's delivery instructions on file.

Thank you for selecting the United States Postal Service® for your mailing needs. If you require additional assistance, please contact your local Post Office™ or a Postal representative at 1-800-222-1811.

Sincerely,
United States Postal Service®
475 L'Enfant Plaza SW
Washington, D.C. 20260-0004

Exhibit 4

Review of water quality data at Outfall 001 at the Empire Trimodal Terminal, LLC facility in Follansbee, West Virginia

Meghan Betcher
Kasey Osborne

February 20, 2026

911 Greenbag Road
Morgantown, WV 26508
downstreamstrategies.com

Downstream Strategies
Ideas that sustain.

1. INTRODUCTION

In January 2026, the West Virginia Department of Environmental Protection (WVDEP) issued Draft Water Pollution Control Permit WV0023281 ("permit") to Empire Trimodal Terminal, LLC to operate and maintain a disposal system and best management practices for the direct discharge of untreated stormwater and groundwater into the Ohio River in Follansbee, Brooke County, West Virginia.

Activities at this facility include recycling of iron-rich slag, metallurgical coke storage, new pipe storage, vehicle parking, railroad tanker to tanker truck transfer of hydrochloric acid, and an inland river port supporting regional freight movement. Three 500-gallon tanks containing diesel are stored onsite. Stormwater from Follansbee is piped under the site for discharge to the Ohio River. Stormwater is discharged to the Ohio River via one outfall (Outfall 001) and samples are collected at a sampling portal prior to discharge.

The draft permit includes water quality-based effluent limits (WQBELs) for cadmium, mercury, benzo (a) anthracene, benzo (b) pyrene, benzo (b) fluoranthene, benzo (k) fluoranthene, chrysene, dibenzo (a, h) anthracene, and indene (1, 2, 3-cd) pyrene. The permit also requires that the permittee monitor and report concentrations of aluminum, barium, beryllium, chloride, hexavalent chromium, copper, iron, lead, and manganese.

Discharge monitoring reports (DMRs) submitted to WVDEP by Empire Trimodal Terminal, LLC for 2024 and 2025 were reviewed. Exceedances of draft permit limits and West Virginia water quality standards during this time, impacts on human health and aquatic life, and limitations of the analytical methods to determine exceedances are discussed in the memo.

Stormwater discharged at this site has exceeded permit limits routinely in recent years, yet no stormwater treatment is proposed. Without taking action to remove pollutants from the stormwater prior to discharge, this facility will continue to violate its permit and contribute to decreased water quality in the Ohio River.

2. REVIEW OF DISCHARGE MONITORING REPORTS

Empire Trimodal Terminal, LLC is required to conduct water quality sampling and submit discharge monitoring reports (DMRs) to WVDEP monthly under its current permit. Parameters with WQBELs must be analyzed and reported monthly. Parameters with report only requirements must be analyzed and reported quarterly.

2.1 Exceedances identified

DMRs were retrieved from WVDEP's Xtender Application for years 2024 and 2025. Data reported were reviewed for exceedances of permit limitations for parameters with limitations in the draft permit. Parameters with report-only requirements were compared to West Virginia water quality standards for aquatic life and human health.

DMRs for August, October, and November 2024 indicated that no discharge was present in the sampling port, thus analytical data are not available for those months. DMRs for October, November, and December 2025 were not available in the Xtender Application so were not reviewed.

Parameters with permit limitations

Permit limits were exceeded at least 93 times between January 2024 and September 2025 at Outfall 001. Almost all exceedances were for parameters classified as polycyclic aromatic hydrocarbons (PSHs). Benzo (b) fluoranthene exceeded its limits 22 times, benzo (b) fluoranthene exceeded its limits 20 times, and benzo (a) anthracene exceeded its limits 16 times. See Table 1 and Appendix A.

Table 1: Exceedances of permit limits at Outfall 001, 2024 - 2025

Category	Parameter	Exceedances of average monthly WQBEL	Exceedances of maximum daily WQBEL	Total exceedances
Metal	Cadmium	1	0	**1**
Metal	Mercury	0	0	**0**
PAHs	Benzo (a) anthracene	8	8	**16**
PAHs	Chrysene	1	1	**2**
PAHs	Benzo (b) fluoranthene	10	10	**20**
PAHs	Benzo (k) fluoranthene	6	6	**12**
PAHs	Benzo (a) pyrene	11	11	**22**
PAHs	Dibenzo (a, h) anthracene	4	4	**8**
PAHs	Indeno (1,2,3-cd) pyrene	6	6	**12**
PAHs	**Total exceedances**	**47**	**46**	**93**

Source: WVDEP, 2024-2025. Accessed via WVDEP's Xtender Application, February 18, 2026. PAH is polycyclic aromatic hydrocarbons.

Many of the exceedances were much greater than the permit limits. For example, benzo (a) pyrene was reported at a concentration more than 3,000 times its maximum daily WQBEL and the concentration of benzo (b) fluoranthene was 825 times greater than its maximum daily WQBEL in January 2025. The concentrations of benzo (a) anthracene and indeno (1,2,3-cd) pyrene were 195 and 524 times greater than their respective maximum daily WQBELs in January 2025.

34 of 46 (74%) exceedances of the maximum daily WQBELs were more than ten times the WQBEL between December 2024 and September 2025.

Parameters with report-only requirements

Results reported on DMRs for parameters that were not subject to WQBELs were compared to relevant West Virginia water quality standards. Between January 2024 and September 2025, lead exceeded the chronic aquatic life standard four times and chloride exceeded its chronic aquatic life standard and its human health standards once. A table of report-only results is included in Appendix A.

2.2 Laboratory analyses could not detect exceedances

It is not possible to determine whether exceedances of permit limits occurred during many of the reporting periods in 2024 due to the detection levels of laboratory analyses. The analytical laboratory must determine and report the minimum detection level (MDL) for each parameter for each analysis completed. If a parameter is not detected at that detection level, it does not mean that the parameter is not present in the sample. Rather, it means that it is not present at the MDL concentration and could be present at a concentration below the MDL. Permittees must report non-detect results as less than the MDL on DMRs. If the MDL is greater than the WQBEL, it is not possible to determine if the parameter is present in the sample at a concentration exceeding the WQBEL.

Between January 2024 and September 2024, 47 of 56 (84%) analyses for PAH parameters were not able to detect contaminants at concentrations small enough to determine if there were exceedances of WQBELs. If MDLs were below the WQBELS, it is likely that additional exceedances of WQBELS for the hydrocarbons would have been identified. Non-detect results where the MDL is greater than the WQBEL are highlighted in Appendix A.

3. HEALTH IMPACTS OF CONTAMINANTS

Most exceedances of WQBELs identified in DMRs for the Empire Trimodal Terminal were for parameters classified as polycyclic aromatic hydrocarbons (PAHs). PAHs are a class of chemicals that are produced through the burning of coal, oil, gas, wood, and garbage. Anthropogenic sources of PAHs in the environment include burning of gasoline, asphalt, coke and aluminum production, and vehicle exhaust. Once in the environment, PAHs tend to be persistent. (ATSDR, 1995; CDC, 2009; and Patel et al., 2020)

Not all PAHs have the same health effects; however, many PAHs are mutagenic, carcinogenic, teratogenic, and immunotoxic to humans and animals. Impacts of chronic exposure to PAHs include decreased immune function, cataracts, kidney and liver damage, and skin irritation. (ATSDR, 1995; CDC, 2009; and Patel et al., 2020)

Metals limited at the Empire Trimodal Terminal include cadmium and mercury, both of which are known to cause kidney damage. (USEPA, 2026)

4. CONCLUSION

The review of DMR data for the Empire Trimodal Terminal facility's Outfall 001 indicates that exceedances of WQBELs for multiple PAHs have occurred routinely throughout 2025. Given the inability of the analytical laboratory to detect contaminants at concentrations at or below the WQBELs for six of seven limited PAHs in 2024, it is not possible to determine if exceedances occurred during that year for these parameters. Many of the exceedances of WQBELs for PAHs that occurred in 2025 were not just slightly over the WQBELS, they exceeded the permit limits by more than ten times the limit frequently and over 3,000 times the limit in one sample.

Currently, the stormwater at the Empire Trimodal Terminal facility does not undergo any treatment prior to discharge to the Ohio River. If stormwater treatment measures are not implemented, the facility will continue to release stormwater containing pollutants in exceedance of permitted concentrations. PAHs and cadmium and mercury have known impacts to human health and aquatic life. Without implementation of controls, these contaminants will likely continue to be discharged to the Ohio River in concentrations exceeding limits imposed by the draft permit, thus decreasing water quality and posing harm to human health and aquatic species.

5. REFERENCES

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United States Environmental Protection Agency (USEPA). 2026. National Primary Drinking Water Regulations. Accessed online at: https://www.epa.gov/ground-water-and drinking water/national-primary-drinking-water-regulations#Organics. Accessed February 19.

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APPENDIX A: WATER QUALITY DATA REPORTED IN DMRS FOR EMPIRE TRIMODAL TERMINAL, LLC

▨	Non-detect but MDL exceeds WQBEL
🟥	Exceeds WQBEL

WQBEL – Average monthly				**2024**											
Parameter	**Unit**	**Avg. monthly**	**Max daily**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mercury	ug/L	0.06788	0.19695	0.008	0.0102	0.00657	0.00404	0.0647	0.0045	0.00903	-	<0.00337	-	-	0.0078
Benzo (a) Anthracene	ng/L	1.2	1.85	<74	<72	<74	<72	<74	<74	<74	-	<65	-	-	92
Chrysene	ng/L	120	196.41	<79	<78	<80	<78	<79	<79	<80	-	<73	-	-	120
Benzo (b) Fluoranthene	ng/L	1.2	2.06	<95	<93	<96	<93	<95	<95	<96	-	<71	-	-	190
Benzo (k) Fluoranthene	ng/L	12	18.63	<86	<85	<87	<85	<86	<86	<87	-	<68	-	-	69
Benzo (a) Pyrene	ng/L	0.12	0.2	<52	<51	<52	<51	66	<52	<52	-	<63	-	-	140
Dibenzo (a,h) Anthracene	ng/L	0.12	0.16	<71	<69	<71	<69	<71	<71	<71	-	<72	-	-	31
Indeno (1,2,3-cd) Pyrene	ng/L	1.2	1.89	<83	<82	<84	<82	<83	<83	<84	-	<72	-	-	140
Cadmium	mg/L	0.0014	0.0034	-	-	<0.0018	-	-	0.0017	-	-	0.00049	-	-	0.0003

WQBEL – Max daily				**2024**											
Parameter	**Unit**	**Avg. monthly**	**Max daily**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mercury	ug/L	0.06788	0.19695	0.008	0.0102	0.00657	0.00404	0.0647	0.0045	0.00903	-	<0.00337	-	-	0.0078
Benzo (a) Anthracene	ng/L	1.2	1.85	<74	<72	<74	<72	<74	<74	<74	-	<65	-	-	92
Chrysene	ng/L	120	196.41	<79	<78	<80	<78	<79	<79	<80	-	<73	-	-	120
Benzo (b) Fluoranthene	ng/L	1.2	2.06	<95	<93	<96	<93	<95	<95	<96	-	<71	-	-	190
Benzo (k) Fluoranthene	ng/L	12	18.63	<86	<85	<87	<85	<86	<86	<87	-	<68	-	-	69
Benzo (a) Pyrene	ng/L	0.12	0.2	<52	<51	<52	<51	66	<52	<52	-	<63	-	-	140
Dibenzo (a,h) Anthracene	ng/L	0.12	0.16	<71	<69	<71	<69	<71	<71	<71	-	<72	-	-	31
Indeno (1,2,3-cd) Pyrene	ng/L	1.2	1.89	<83	<82	<84	<82	<83	<83	<84	-	<72	-	-	140
Cadmium	mg/L	0.0014	0.0034	-	-	<0.0018	-	-	0.0017	-	-	0.00049	-	-	0.0003

Data source: Discharge monitoring reports submitted to WVDEP by Empire Trimodal Terminal, accessed via WVDEP’s Xtender Application.

Note: Non-detect results are reported as < minimum detection limit (MDL). ug/L = micrograms per liter, ng/L = nanograms per liter, mg/L = milligrams per liter.

WQBEL – Average monthly				2025											
Parameter	**Unit**	**Avg. monthly**	**Max daily**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mercury	ug/L	0.06788	0.19695	0.021	0.0051	0.0084	0.0068	0.0075	0.0097	0.01	0.014	0.0057	-	-	-
Benzo (a) Anthracene	ng/L	1.2	1.85	360	56	61	12	15	13	18	<9.3	<9.4	-	-	-
Chrysene	ng/L	120	196.41	1,100	65	88	12	26	16	15	11	12	-	-	-
Benzo (b) Fluoranthene	ng/L	1.2	2.06	1,700	45	150	18	39	26	24	16	21	-	-	-
Benzo (k) Fluoranthene	ng/L	12	18.63	490	45	61	<9.4	24	10	14	<9.3	<9.4	-	-	-
Benzo (a) Pyrene	ng/L	0.12	0.2	650	77	100	15	23	17	20	14	11	-	-	-
Dibenzo (a,h) Anthracene	ng/L	0.12	0.16	140	19	21	<19	<19	<19	<19	<19	<19	-	-	-
Indeno (1,2,3-cd) Pyrene	ng/L	1.2	1.89	990	75	94	<19	29	<19	24	<19	<19	-	-	-
Cadmium	mg/L	0.0014	0.0034	-	-	0.00026	-	-	0.00021	-	-	0.00039	-	-	-

WQBEL – Max daily				2025											
Parameter	**Unit**	**Avg. monthly**	**Max daily**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mercury	ug/L	0.06788	0.19695	0.021	0.0051	0.0084	0.0068	0.0075	0.0097	0.01	0.014	0.0057	-	-	-
Benzo (a) Anthracene	ng/L	1.2	1.85	360	56	61	12	15	13	18	<9.3	<9.4	-	-	-
Chrysene	ng/L	120	196.41	1,100	65	88	12	26	16	15	11	12	-	-	-
Benzo (b) Fluoranthene	ng/L	1.2	2.06	1,700	45	150	18	39	26	24	16	21	-	-	-
Benzo (k) Fluoranthene	ng/L	12	18.63	490	45	61	<9.4	24	10	14	<9.3	<9.4	-	-	-
Benzo (a) Pyrene	ng/L	0.12	0.2	650	77	100	15	23	17	20	14	11	-	-	-
Dibenzo (a,h) Anthracene	ng/L	0.12	0.16	140	19	21	<19	<19	<19	<19	<19	<19	-	-	-
Indeno (1,2,3-cd) Pyrene	ng/L	1.2	1.89	990	75	94	<19	29	<19	24	<19	<19	-	-	-
Cadmium	mg/L	0.0014	0.0034	-	-	0.00026	-	-	0.00021	-	-	0.00039	-	-	-

Data source: Discharge monitoring reports submitted to WVDEP by Empire Trimodal Terminal, accessed via WVDEP's Xtender Application.

Note: Non-detect results are reported as < minimum detection limit (MDL). ug/L = micrograms per liter, ng/L = nanograms per liter, mg/L = milligrams per liter.

Report only							2024											
Parameter	**Unit**	**Aquatic Life - B1/B4, Acute**	**Aquatic Life - B1/B4, Chronic**	**Human Health - C**	**Human Health - A**	**Comparison value**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Lead	mg/L	0.085825	0.003344	NA	0.05	0.003344475	<0.0029	0.005	<0.0034	<0.0034	<0.0034	0.0034	0.004	-	<0.0034	-	-	0.001
Aluminum	mg/L	0.75	0.75	NA	NA	0.75	-	-	0.36	-	-	0.2	-	-	0.27	-	-	0.1
Barium	mg/L	NA	NA	NA	1	1	-	-	0.056	-	-	0.047	-	-	0.054	-	-	0.038
Beryllium	mg/L	0.13	NA		0.004	0.004	-	-	<0.00029	-	-	<0.00029	-	-	<0.00029	-	-	<.00012
Chloride	mg/L	860	230	250	250	230	-	-	192	-	-	173	-	-	335	-	-	0.2
Copper	mg/L	0.014526	0.009647	NA	1	0.009647	-	-	<0.0037	-	-	0.0045	-	-	0.0045	-	-	0.0027
Hexavalent Chromium	mg/L	0.016	0.011	NA	0.05	0.011	-	-	<0.0054	-	-	<0.0054	-	-	<0.0054	-	-	0.00051
Iron	mg/L	NA	1.5	NA	1.5	1.5	-	-	0.51	-	-	0.53	-	-	0.75	-	-	0.34
Manganese	mg/L	NA	NA	NA	1	1	-	-	0.041	-	-	0.15	-	-	0.32	-	-	0.12
Vanadium	mg/L	0.1032	NA	NA	NA	0.1032	-	-	0.0062	-	-	0.0085	-	-	0.0092	-	-	0.0026
Sulfate	mg/L	NA	NA	NA	NA	NA	-	-	257	-	-	307	-	-	334	-	-	0.2
Oil and grease	mg/L	NA	NA	NA	NA	NA	-	-	5.1	-	-	<1.8	-	-	<1.8	-	-	7.3

Report only							2025											
Parameter	**Unit**	**Aquatic Life - B1/B4, Acute**	**Aquatic Life - B1/B4, Chronic**	**Human Health - C**	**Human Health - A**	**Comparison value**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Lead	mg/L	0.085825	0.003344	NA	0.05	0.003344475	-	0.008	0.00085	0.00048	0.00069	0.0014	0.00045	0.00076	0.00078	-	-	-
Aluminum	mg/L	0.75	0.75	NA	NA	0.75	-	-	0.086	-	-	0.16	-	-	0.057	-	-	-
Barium	mg/L	NA	NA	NA	1	1	-	-	0.042	-	-	0.047	-	-	0.044	-	-	-
Beryllium	mg/L	0.13	NA		0.004	0.004	-	-	<.00012	-	-	<0.0005	-	-	<.00012	-	-	-
Chloride	mg/L	860	230	250	250	230	-	-	150	-	-	150	-	-	-	-	-	-
Copper	mg/L	0.014526	0.009647	NA	1	0.009647	-	-	0.0016	-	-	0.0026	-	-	0.0028	-	-	-
Hexavalent Chromium	mg/L	0.016	0.011	NA	0.05	0.011	-	-	0.003	-	-	0.0043	-	-	0.0068	-	-	-
Iron	mg/L	NA	1.5	NA	1.5	1.5	-	-	0.37	-	-	0.49	-	-	-	-	-	-
Manganese	mg/L	NA	NA	NA	1	1	-	-	0.16	-	-	0.16	-	-	0.13	-	-	-
Vanadium	mg/L	0.1032	NA	NA	NA	0.1032	-	-	0.0052	-	-	0.005	-	-	0.0059	-	-	-
Sulfate	mg/L	NA	NA	NA	NA	NA	-	-	380	-	-	380	-	-	390	-	-	-
Oil and grease	mg/L	NA	NA	NA	NA	NA	-	-	4.9	-	-	<4.9	-	-	<1.4	-	-	-

Data source: Discharge monitoring reports submitted to WVDEP by Empire Trimodal Terminal, accessed via WVDEP's Xtender Application.

Note: Non-detect results are reported as < minimum detection limit (MDL). The comparison value is equal to the most stringent of the West Virginia water quality standards. ug/L = micrograms per liter, ng/L = nanograms per liter, mg/L = milligrams per liter.

Exhibit 5

west virginia department of environmental protection

Environmental Enforcement
131-A Peninsula St.
Wheeling, WV 26003
Phone: 304-238-1220

Harold Ward, Cabinet Secretary
www.wvdep.org

Oct 31, 2025

Empire Trimodal Terminal
Attn: Chip Fenske, VP of Operations
1400 Main Street
Follansbee, WV 26037

NOTICE OF VIOLATION

RE:NOV#:W25-05-052-KJE
Cert #: 9414 8118 9956 1975 4124 91

Dear Mr.Fenske,

On Oct 2, 2025, West Virginia Department of Environmental Protection (WVDEP) personnel conducted an inspection at your property located in Brooke County, WV. During the course of this inspection, the following Permit, WV Legislative Rule and WV State Code violations were observed and documented:

A. Section A.001 - Discharge Limitations and Monitoring Requirements
    a. Empire Trimodal Terminal exceeded discharge limitations a total of 93 times from September 2023 to August 2025.
    b. Empire Trimodal Terminal failed to monitor an effluent characteristic, i.e. Total Recoverable Lead was not analyzed during the January 2025 reporting period.

B. Section C.5 - The required DMRs shall be received by the agency no later than 25 days following the end of the reporting period.
    a. Empire Trimodal Terminal failed to submit DMRs on time 13 times.

C. Appendix.II.1 - The permittee shall at all times properly operate and maintain all facilities.

a. Empire Trimodal Terminal failed to properly maintain a stormwater basin, i.e. Sediment and debris was present in the basin.
b. Empire Trimodal Terminal failed to have any way to prevent dust or debris from entering Outlet 001 sample port.
c. Empire Trimodal Terminal failed to implement adequate control structures.

D. WV Legislative Rule 47-58-4.7.4 - Drums containing materials that have the potential to contaminate groundwater shall be stored so that spills and leaks are contained.
   a. a. Empire Trimodal Terminal failed to provide proper secondary containment for diesel tanks.

E. WV State Code 22-15-10(a) - Open dumps are prohibited and it is unlawful for any landowner to allow an open dump to exist on the landowner's property.
   a. Empire Trimodal Terminal allowed open dumps consisting of metal, wood, and soil to exist onsite.

In order to address these violations, you are requested to respond, in writing, within twenty (20) days of receipt of this Notice of Violation. This response should include remedial measures that will fully abate the above-mentioned violation. Please direct this response to Kimi Ely, at WVDEP, Environmental Enforcement, 601 57th Street SE, Charleston, WV 25604-2345 Submit a PDF of this response via email to Kimi Ely at kimi.j.ely@wv.gov Should you have any questions or comments, you may contact me at (681) 910-1362 between the hours of 8:00 a.m. and 4:00 p.m., Monday through Friday. Be advised that violation(s) of your WV/NPDES Permit, Legislative Rules and/or the WV Code may result in enforcement action(s) being initiated by WVDEP.

Respectfully,

Kimi J. Ely

Kimi Ely
Environmental Inspector

cc: Tonya Mather, Environmental Inspector Supervisor, EE/WW (via e-mail)

Revised 12/2015

Exhibit 6

STATE OF WEST VIRGINIA

Department of Environmental Protection

Environmental Enforcement

NOTICE OF VIOLATION

Violation No. **W25-05-063-KJE**

To the Operator or Agent of:

Facility Name: **The Port of West Virginia** Permit No. **WV0023281**

Permittee or Individual **Empire Trimodal Terminal**

Located at or near **600 Veterans Dr., Follansbee, WV 26037** in **Brooke** County

Representative **Farley Wood** Date **Dec 19, 2025** Time **10:00 am**

Address / phone number **304-914-4624**

Whereas, an inspection of the above named operation by the undersigned, duly authorized agent of the Secretary, at which the following described condition or practice exists, in violation of Chapter **22**,

Article **15**, Section(s) **10(a)** of the Code of West Virginia and/or Section(s) _____ of the Rules and Regulations and/or Section(s)_____ of the Permit referenced above promulgated thereunder in that you:

Empire Trimodal Terminal created, contributed, or operated or allowed an open dump to exist on the landowner's property

allowed an open dump to exist on your property. An open dump of waste tires was observed.

Within **20** days provide a written response to the inspector named below, at the address indicated, detailing the actions taken to abate this violation.

Received by:

Signature

Title

Kimi Ely

Kimi Ely
Duly Authorized Agent / Inspector

(681) 910-1362
Telephone

kimi.j.ely@wv.gov
E-mail

Send Response to the Inspector at the address indicated below:

WV Department of Environmental Protection

Environmental Enforcement / WW

kimi.j.ely@wv.gov

Exhibit 7

Appalachian Mountain Advocates

West Virginia
Post Office Box 507
Lewisburg, WV 24901
(304) 645-9006

Virginia
415 Seventh Street NE
Charlottesville, VA 22902
(434) 529-6787

www.appalmad.org

December 28, 2023

C. Scott Ewusiak, President
Empire Trimodal Terminal, LLC
1400 Main St
Follansbee, WV 26037

Frank Rosso, President
Empire Diversified Energy, Inc.
2760 SE 13th Ct
Pompano Beach, FL 33062

By Certified Mail – Return Receipt Requested

Re: 60-Day Notice of Intent to File Citizen Suit under the Clean Water Act for Violations of WV/NPDES Permit No. WV0023281 by Empire Trimodal Terminal, LLC (dba The Port of West Virginia)

Dear Messrs. Ewusiak and Rosso:

West Virginia Rivers Coalition, in accordance with section 505(b)(1) of the Clean Water Act ("CWA"), 33 U.S.C. § 1365(b)(1) and 40 C.F.R. Part 135, hereby notifies you that Empire Trimodal Terminal, LLC ("Empire") has violated and continues to violate "effluent standard[s] or limitation[s]" under Section 505(a)(1)(A) of the CWA, 33 U.S.C. § 1365(a)(1)(A) and (f)(6), by failing to comply with the terms and conditions of its WV/NPDES Permit No. WV0023281 issued by the West Virginia Department of Environmental Protection ("WVDEP") for its facility in Follansbee, West Virginia. If, within sixty days of the postmark of this letter, Empire does not bring its discharges and its monitoring and reporting thereof into full compliance with the CWA, West Virginia Rivers Coalition intends to file a citizens' suit against Empire seeking civil penalties for the ongoing violations and for an injunction compelling it to come into compliance with the CWA.

Background

Empire's discharges are regulated under WV/NPDES Permit No. WV0023281. The WVDEP issued that permit on March 9, 2016, with an effective date of May 1, 2016. The permit was set to expire on March 8, 2021, but WVDEP reissued WV/NPDES Permit No. WV0023281 on November 10, 2020. The November 10, 2020 permit is the operative permit, which became effective on January 1, 2021, and will expire on November 9, 2025.

Empire is a wholly owned subsidiary of Empire Diversified Energy, Inc. ("Empire Diversified"). WV/NPDES Permit No. WV0023281 was originally issued to a prior operator—Trimodal Terminal, L.P. Empire Diversified, however, has had a majority stake in Trimodal Terminal since May 30, 2019. Empire then acquired Trimodal Terminal per the terms of a November 25, 2020 purchase agreement. WV/NPDES Permit No. WV0023281 was officially transferred to Empire on May 12, 2022, according to a completed WVDEP Form WRD 10-64N. That transfer form also indicated that the "[n]ew Permittee/Owner accepts all environmental liability and responsibility (past, present, and future) for this facility and permit." The operator of this facility has remained constant despite ownership changes—Scott Ewusiak was the owner and operator of Trimodal Terminal, and he is the current president of Empire.

Empire discharges wastewater from one outlet—Outlet 001. Outlet 001 discharges untreated stormwater and groundwater into the Ohio River near River Mile 69.7. Among other parameters, Empire has permit limits for total mercury, as well as the following polycyclic aromatic hydrocarbons parameters ("PAH parameters"): benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Section C.13 of the permit prescribes the specific EPA Test Method Number and method detection levels Empire must use for its monitoring and reporting of several parameters, including the PAH parameters. According to Section C.13, Empire must use EPA Test Method No. 610 for all of the PAH parameters. Further, Section C.13 requires Empire to ensure that its effluent is analyzed using the following method detection levels:

- benzo(a)anthracene: 0.01 μg/l
- benzo(b)fluoranthene: 0.018 μg/l
- benzo(k)fluoranthene: 0.017 μg/l
- benzo(a)pyrene: 0.02 μg/l
- dibenzo(a,h)anthracene: 0.03 μg/l
- indeno(1,2,3-cd)pyrene: 0.04 μg/l

However, this permit condition allows the permittee to use a different EPA Approved Test Method, so long as that different method has a *lower* method detection level.

The prior operator was granted a two-year compliance schedule for the PAH parameters in a prior CWA permit but did not come into compliance by the end of the compliance schedule. WVDEP issued a notice of violation to the prior operator Trimodal Terminal regarding non-compliance with the PAH parameters on March 19, 2019. WVDEP also issued Administrative Order # 9928 to the prior operator on November 9, 2020, for the operator's failure to comply with the permit's prescribed testing methods for the PAH parameters as required by Section C.13 of the

CWA permit. WVDEP took no further action regarding those violations, and the operative permit includes final numeric effluent limits for the PAH parameters without any schedules of compliance and without any changes to the prescribed testing methods for PAH parameters.

CWA Violations

Empire is in ongoing violation of its CWA permit in at least two ways. First, as evidenced in the chart below, it has violated its numeric effluent limits for the PAH parameters and total mercury.

Violation #	Date	Outlet	Parameter	Type	Permit Limit	Reported Concentration	Units	% Over Limit
1	Jun-19	001	Dibenzo (A,H) Anthracene	Avg Monthly	3.8	70	NG/L	1742
2	Jun-19	001	Dibenzo (A,H) Anthracene	Max Daily	8	70	NG/L	775
3	Jun-19	001	Indeno (1,2,3-Cd) Pyrene	Avg Monthly	3.8	83	NG/L	2084
4	Jun-19	001	Indeno (1,2,3-Cd) Pyrene	Max Daily	10.2	83	NG/L	714
5	Sep-20	001	Indeno (1,2,3-Cd) Pyrene	Avg Monthly	3.8	95	NG/L	2400
6	Sep-20	001	Indeno (1,2,3-Cd) Pyrene	Max Daily	10.2	95	NG/L	831
7	Apr-21	001	Benzo (B) Fluoranthene	Avg Monthly	3.8	120	NG/L	3058
8	Apr-21	001	Benzo (B) Fluoranthene	Max Daily	6.52	120	NG/L	1740
9	Apr-21	001	Benzo(A)Pyrene	Avg Monthly	3.8	56	NG/L	1374
10	Apr-21	001	Benzo(A)Pyrene	Max Daily	6.25	56	NG/L	796
11	May-22	001	Benzo (B) Fluoranthene	Avg Monthly	3.8	26	NG/L	584
12	May-22	001	Benzo (B) Fluoranthene	Max Daily	6.52	26	NG/L	299
13	May-22	001	Benzo(A)Pyrene	Avg Monthly	3.8	14	NG/L	268
14	May-22	001	Benzo(A)Pyrene	Max Daily	6.25	14	NG/L	124
15	Sep-22	001	Benzo(A)Anthracene	Avg Monthly	3.8	72	NG/L	1795
16	Sep-22	001	Benzo(A)Anthracene	Max Daily	6.95	72	NG/L	936
17	Oct-22	001	Total Mercury	Avg Monthly	0.061	0.42	ug/l	589
18	Oct-22	001	Total Mercury	Max Daily	0.18	0.42	ug/l	133
19	Jun-23	001	Total Mercury	Avg Monthly	0.061	0.0737	ug/l	21

20	Jun-23	001	Benzo(A)Anthracene	Avg Monthly	3.8	600	NG/L	15689
21	Jun-23	001	Benzo(A)Anthracene	Max Daily	6.95	600	NG/L	8533
22	Jun-23	001	Benzo (B) Fluoranthene	Avg Monthly	3.8	1100	NG/L	28847
23	Jun-23	001	Benzo (B) Fluoranthene	Max Daily	6.52	1100	NG/L	16771
24	Jun-23	001	Benzo (K) Fluoranthene	Avg Monthly	3.8	340	NG/L	8847
25	Jun-23	001	Benzo (K) Fluoranthene	Max Daily	8.02	340	NG/L	4139
26	Jun-23	001	Benzo(A)Pyrene	Avg Monthly	3.8	760	NG/L	19900
27	Jun-23	001	Benzo(A)Pyrene	Max Daily	6.25	760	NG/L	12060
28	Jun-23	001	Dibenzo (A,H) Anthracene	Avg Monthly	3.8	130	NG/L	3321
29	Jun-23	001	Dibenzo (A,H) Anthracene	Max Daily	7.54	130	NG/L	1624
30	Jun-23	001	Indeno (1,2,3-Cd) Pyrene	Avg Monthly	3.8	400	NG/L	10426
31	Jun-23	001	Indeno (1,2,3-Cd) Pyrene	Max Daily	6.86	400	NG/L	5731
32	Aug-23	001	Total Mercury	Avg Monthly	0.061	0.0979	ug/l	60
33	Oct-23	001	Benzo(A)Pyrene	Avg Monthly	3.8	61	NG/L	1505
34	Oct-23	001	Benzo(A)Pyrene	Max Daily	6.25	61	NG/L	876

Empire's PAH violations are particularly concerning because of the second way Empire is consistently violating WV/NPDES Permit No. WV0023281: its failure to use the prescribed analytical methods.

Instead of employing the test method prescribed by the permit for PAH parameters—EPA Test Method No. 610—Empire has been using EPA Test Method 625.1 (as did the prior operator after Empire Diversified acquired a majority stake in the facility but before Empire took ownership). That violates Section C.13 of Empire's CWA permit, which specifically requires Empire to use EPA Test Method No. 610 for the PAH parameters "unless the permittee desires to use an EPA Approved Test Method with a listed lower method detection level." The permit limits for the PAH parameters are very low, measured in nanograms per liter (NG/L), and EPA Test Method No. 610 is a sensitive test with a method detection limits closer to the permit limits, allowing for more accurate monitoring of permit compliance. Because EPA Test Method No. 625.1 does not have lower method detection limits for the PAH parameters than Method No. 610, it is not a permissible substitute test method under Section C.13 of Empire's permit.

In fact, EPA Test Method No. 625.1 has method detective levels much higher than Method No. 610. For example, for the parameter benzo(a)anthracene, EPA Test Method No. 610 has a method detection level of 0.01 µg/L (which converts to 10 NG/L), whereas EPA Test Method No. 625.1 has a method detection level of 0.075 µg/L (which converts to 75 NG/L) for that parameter. Because benzo(a)anthracene has an average monthly permit limit of 3.8 NG/L and max daily limit of 6.95 NG/L, using the more sensitive test method—the one prescribed by the permit—is critical for detection of violations near the permit limit. Using Test Method No. 625.1 for benzo(a)anthracene allows Empire to discharge more than 18 times the limit without detection of an average monthly violation, whereas Test Method No. 610 would allow violations only 2.6 times higher to escape detection. As shown in the below chart, the same problems are true for the other PAH parameters:

Parameter	**Monthly Limit**	**Max Daily Limit**	**MDL for EPA Test Method No. 610**	**MDL for EPA Test Method No. 625.1**
benzo(a)anthracene	3.8 NG/L	6.95 NG/L	10 NG/L	75 NG/L
benzo(b)fluoranthene	3.8 NG/L	6.52 NG/L	18 NG/L	97 NG/L
benzo(k)fluoranthene	3.8 NG/L	8.02 NG/L	17 NG/L	88 NG/L
benzo(a)pyrene	3.8 NG/L	6.25 NG/L	20 NG/L	53 NG/L
dibenzo(a,h)anthracene	3.8 NG/L	7.54 NG/L	40 NG/L	72 NG/L
indeno(1,2,3-cd)pyrene	3.8 NG/L	6.86 NG/L	40 NG/L	85 NG/L

Because Empire has reported violations for the PAH parameters using even the incorrect and less sensitive test method, Empire has likely failed to detect and report additional violations of the PAH parameters because of its failure to comply with Section C.13 of its permit. Empire's violations of Section C.13 of its permit began in at least June of 2019, and continued each month through November 2023 (the latest discharge monitoring report available at the time this letter was sent). Each time Empire failed to use the correct test method, it violated Section C.13 of its permit. This amounts to at least 324 violations of Section C.13 (based on one violation per parameter per month).

Empire Diversified—Empire's parent company—has had a majority ownership stake in the prior operator since May 30, 2019. The WVDEP transfer form also indicated that the new operator—Empire—accepted environmental responsibility for all past, current, and future environmental liability for the facility. Further, Scott Ewusiak appears to be both the former and current operator of the facility, despite ownership changes. For all of those reasons, Empire is responsible for all the violations discussed in this letter dating back to at least June 1, 2019.

The CWA authorizes citizens to sue "any person . . . who is alleged to be in violation of . . . an effluent standard or limitation under this chapter." 33 U.S.C. § 1365(a)(1). An "effluent standard or limitation under this chapter" is defined to include "a permit or condition thereof." *Id.*

§ 1365(f)(6). Each discharge amount that exceeds permit limits is an unlawful and unpermitted discharge and, therefore, is not shielded from liability under Section 402(k) of the Clean Water Act. *Swartz v. Beach*, 229 F. Supp. 2d 1239, 1269 (D. Wyo. 2001); U.S. E.P.A. *Revised Policy Statement on Scope of Discharge Authorization and Shield Associated with NPDES Permits* at 2, n.1 (April 11, 1995) (explaining that, in a NPDES permit, "authorization is only provided to discharge such pollutants *within the limits and subject to the conditions set forth in the permit*" (emphasis added)). A person who violates a condition of a NPDES permit is therefore in violation of the CWA and subject to a citizen enforcement action under the CWA. Based on Empire's discharge monitoring reports, we believe that Empire is violating its effluent limitations for total mercury, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrenein in its permit. Additionally, Empire has failed to use the testing method prescribed by its permit and is utilizing an impermissibly high method detection level in violation of Section C.13 of its permit. If Empire does not cease its violations within 60 days, we intend to bring a citizen suit against Empire under Section 505(a)(1) of the CWA seeking civil penalties and declaratory and injunctive relief.

Conclusion

If Empire has taken any steps to eradicate the underlying cause of the violations described above, or if Empire believes that anything in this letter is inaccurate, please let us know. If Empire does not advise us of any remedial steps during the 60-day period, we will assume that no such steps have been taken and that violations are likely to continue. Additionally, we would be happy to meet with Empire or its representatives to attempt to resolve these issues within the 60-day notice period.

Sincerely,

Amanda Demmerle
Appalachian Mountain Advocates
P.O. Box 507
Lewisburg, WV 24901
(757) 650-2774
ademmerle@appalmad.org

Counsel for:

West Virginia Rivers Coalition
501 MacCorkle Ave. SE #129
Charleston, WV 25304
(304) 637-7201

cc (via certified mail):

Empire Trimodal Terminal, LLC
Registered Agent for Empire Trimodal Terminal, LLC
1400 Main Street
Follansbee, WV 26037

Carl S. Ewusiak
Registered Agent for Empire Diversified Energy Inc.
1400 Main Street
Follansbee, WV 26037

Harold Ward, Secretary
West Virginia Department of Environmental Protection
601 57th Street SE
Charleston, WV 25304

Adam Ortiz
Regional Administrator
U.S. Environmental Protection Agency Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Michael Regan
Administrator
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20004

Exhibit 8

WV0023281

COMPREHENSIVE GW PROTECTION PLAN

6/1995

COMPREHENSIVE GROUNDWATER PROTECTION PLAN WHEELING-PITTSBURGH STEEL CORP. STEUBENVILLE EAST COKE AND SINTER PLANTS

June 1995

Prepared for

Wheeling-Pittsburgh Steel Corporation
1134 Market Street
Wheeling, West Virginia

Prepared by

Geraghty & Miller, Inc.
26 South Main Street, 2nd Floor
Washington, PA 15301

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1.0 INTRODUCTION

1.1 PURPOSE

On June 1, 1994, the Legislature of the State of West Virginia enacted the Groundwater Protection Act, or GPA (Code of State Regulations Title 47, Series 58; 47 CSR 58). The purpose of the GPA is to establish a series of practices that protect groundwater resources. The practices must be followed by owners or operators of facilities subject to pertinent sections of Chapter 20-5M-1 of the West Virginia Code and regulation by the West Virginia Division Environmental Protection's (WVDEP) Office of Waste Management or Office of Water Resources.

Section 4.11 of the GPA establishes the requirement for each industrial establishment to develop and maintain on-file a groundwater protection plan (GPP) for each individual facility. This GPP has been prepared for the Wheeling-Pittsburgh Steel Corporation (WPSC) Steubenville East Coke and Sinter Plants.

This GPP has the full approval and total support of the management of WPSC, who will ensure that the necessary resources are committed to implement this plan.

1.2 FACILITY DESCRIPTION

The Steubenville East Coke and Sinter Plant (East Plant) is located approximately one mile north of Follansbee, Brooke County, West Virginia on West Virginia Route 2. The plant occupies approximately 121 acres along the eastern bank of the Ohio River. The plant is bordered to the west by Koppers Industries, Inc. and the Ohio River, to the south by the City of Follansbee and Wheeling-Nisshin Steel, and to the north by Mahan Run. West Virginia Route

2 serves as the eastern boundary for operating portions of the East Plant. WPSC owns and uses property east of Route 2 for employee parking. An inactive sludge drying bed is also located east of Route 2 and is awaiting closure approval from the WVDEP.

Past and current operations performed at the East Plant include the production of metallurgical-grade coke, coke gas byproducts (light oil, ammonium sulfate, fuel gas, coal tar, commercial-grade sulfuric acid) and sinter (the recovery of iron from miscellaneous plant byproducts and raw materials).

2.0 SUMMARY OF FACILITY OPERATIONS AND POTENTIAL FOR RELEASES TO GROUNDWATER

The East Plant is comprised of the following four principal operations/process areas that may potentially contribute facility-related constituents to the subsurface:

- Four coke batteries and associated coal and coke storage areas.
- Byproducts plant and product storage areas.
- Wastewater treatment plant.
- Sinter plant and associated storage areas.

A brief description of the principal plant operations, and the potential for each operation to contribute to groundwater contamination is provided below.

2.1 COKE BATTERIES AND ASSOCIATED COAL AND COKE STORAGE AREAS

2.1.1 Coke Batteries

Coal is converted to metallurgical-grade coke in four batteries, which are comprised of 224 ovens (see Figure 1). The coke batteries are heated using a fuel gas obtained from the byproducts plant. Coke oven gas that is driven off during the coking process is cooled with a spray of recycled flushing liquor, and is and routed via overhead pipelines to the byproducts plant for further processing. The coke is removed from the batteries, cooled (quenched) with water, and is used for iron production at the Steubenville North and South plants, or is sold.

The coking process is self-contained, and presents limited potential for groundwater contamination. Leaks that may occur in the coke oven gas transfer and recycled flushing liquor lines are the potential sources of facility-related constituents to the subsurface.

2.1.2 Coal & Coke Storage Areas

Coal to be used in the coking operation is barged to the East Plant, and is stored in two open pits which occupy approximately 14 acres (see Figure 1). The eastern sidewall and floor of the north and south coal pits are constructed of concrete. The western sidewalls consist of concrete cribbing. An earthen berm serves as the partition between the two pits. Precipitation runoff in the north pit is collected in a stormwater collection sump and is pumped to the wastewater treatment plant. Coke that cannot be immediately used is placed in the southern portion of the coal pit, or is temporarily stockpiled in an open storage area (see Figure 1). The coke storage stockpile occupies approximately 6 acres.

The infiltration of precipitation that passes through, and comes into contact with the coal and coke stockpiles represents an active source of facility-related constituents to groundwater.

Because of the nature of the coal and coke storage operations, a Variance from Groundwater Standards (Variance) under Title 47, Series 57 of the Code of State Regulations has been requested for the coal and coke storage areas. The Variance request is discussed in Section 6.5.

2.2 BYPRODUCTS PLANT

The combined coke oven gas/flushing liquor stream is processed in the byproducts plant (see Figure 1). Several processes are used to purify and isolate components of coke oven gas stream. Process flows are transferred between process units via a combination of underground and above-ground pipelines. A brief description of the processes located in the byproducts plant is provided below.

The mixture of coal tar and flushing liquor is routed to five decanters. Liquid consisting of water and coal tar (flushing liquor) is separated and is stored for further processing or reuse in three, above-ground storage tanks. Decanter tar sludge is a listed hazardous waste (K087) that is recycled in the coking process. Because it is recycled, decanter tar sludge is exempt from hazardous waste regulations. The sludge is collected in sludge boxes (hoppers) and is returned as feed to the coking process. Excess ammonia liquor (flushing liquor) from tank storage is routed through an ammonia still to remove ammonia. The ammonia still discharge is routed to the wastewater treatment plant.

Coke oven gas passes from the primary coolers through direct (contact) gas exhausters to the hydrogen sulfide scrubbers for removal of hydrogen sulfide. Hydrogen sulfide is converted in the acid plant to sulfuric acid. Coke oven gas is then passed through the saturators to form solid ammonium sulfate. Solid ammonium sulfate is stored in an enclosed building.

Coke oven gas passes from the saturator units to the final coolers and then to the light oil recovery process. Benzene, toluene, and xylenes (BTX, or light oil) are removed from the coke oven gas by spraying oil (wash oil) into the coke oven gas stream in two direct spray scrubbers. Light oil containing BTX is separated from the wash oil, purified and is stored in an above-ground storage tank. Virgin wash oil is stored in one above-ground tank for reuse. The remaining gas is used to fuel the coke battery furnaces and various downstream users.

Spent noncontact cooling water and uncontaminated stormwater are routed into a dedicated sewer for discharge to the Ohio River under WPSC's National Pollution Discharge Elimination System (NPDES) permit. Process water is isolated at the source then pumped to the coke plant wastewater treatment facility. Small quantities of contaminated water and stormwater are discharged to an underground stormwater sewer. The stormwater sewer discharges to a collection sump equipped with an oil skimmer. Stormwater is pumped to storage then subsequently discharged to the wastewater treatment plant for processing.

Potential sources of coke oven gas constituents to the environment include leaks in transfer pipelines, pumps, process units, or storage tanks. Leakage from wastewater sumps, above-ground piping and transfer pumps also are potential sources of contaminated wastewater to the subsurface. Groundwater infiltration into the underground stormwater sewer beneath the byproducts plant has been documented. Groundwater infiltration effectively prevents the discharge of contaminated wastewater from the stormwater sewer to the subsurface.

2.3 COKE PLANT WASTEWATER TREATMENT PLANT

Process wastewater and runoff collected from the stormwater sewer is pumped to the East Plant wastewater treatment facility (see Figure 1). Wastewater is temporarily stored in three, 750,000 gallon above-ground storage tanks, then is routed to two above-ground biological treatment basins. Discharge from the biological treatment basins is then clarified, filtered, and routed through granular activated carbon (Terminal Treatment System) and is discharged through WPSC's NPDES-permitted outfall.

Wastewater treatment is performed in above-ground tanks and vessels. Wastewater is conveyed between treatment units via a combination of above-ground and underground piping. Potential sources of facility-related constituents to the environment from the wastewater treatment system include the spillage of water treatment chemicals (polymers, defoamers, caustic soda, phosphoric and sulfuric acids) or leaks from treatment units. Because the wastewater treatment system is situated almost entirely above-ground, the potential for unidentified releases of wastewater is low.

2.4 SINTER PLANT

Iron ore, limestone, and process residues are combined and heated at the sinter plant to produce a high-iron sinter that is used for iron production. Iron ore, limestone, residuals, sand, and sinter are stockpiled in open storage areas located west of the sinter plant (see Figure 1).

Scrubber water from the air pollution control system is recycled. Blowdown from the air pollution control systems is routed to the sinter plant wastewater treatment system for clarification and pH adjustment. Sinter plant wastewater treatment sludges are returned to the sintering process as feedstock. Sinter plant wastewater treatment sludges contain small amounts of lead and zinc, which could be released to the environment through spillage. Diesel fuel also may be released via spillage during equipment refueling operations or through leaks in the storage/dispensing system.

3.0 SITE HYDROGEOLOGY AND GROUNDWATER QUALITY

General hydrogeologic information provided below was obtained from the March 1994 "RCRA Facility Investigation/Corrective Measures Study" report prepared by ICF-Kaiser Engineers for the Koppers Industries, Inc., (KII) Follansbee facility. Site-specific data was obtained during the installation of monitoring wells in the vicinity of the coal and coke storage areas to support the preparation of the Request of Variance from Groundwater Standards, and geotechnical borings installed for construction projects.

The unconsolidated deposits beneath the East Plant consist of surficial steel slag and miscellaneous soil fill, a fine-textured sandy to silty clay unit, and subjacent (underlying) sand and gravel deposits.

Surficial fill beneath the East Plant is comprised of sand to cobble-sized steel slag, with lesser amounts of brick, cinder, and soil. The fill ranges from about 12 feet in thickness beneath the Byproducts Plant to 28 feet in thickness beneath the coke storage stockpile.

Beneath the surficial fill exists a naturally occurring, silty and sandy clay alluvium. The low-permeability alluvium ranges in thickness from approximately 22 feet near the coal/coke storage pits to the north, to about 35 feet beneath the coke storage stockpile.

Extending from the base of the sandy clay to the top of bedrock are deposits of stratified sands and gravels that aggraded the Ohio River Valley during the retreat of the Pleistocene-age glaciers. The glacial deposits are comprised of a poorly sorted, medium to coarse sand and gravel that coarsens somewhat with depth. At some locations, the sand and gravel is overlain by a silty sand, which comprises the upper portion of the glacial deposits in these areas. The glacial deposits range up to approximately 40 feet in total thickness beneath the East Plant (ICF Kaiser, 1994).

Bedrock encountered beneath the adjacent Koppers Industries Inc, site consists predominantly of relatively soft claystone with varying concentrations of silt and, to a lesser extent, fine-grained silty sandstone. Thin lenses of shale, limestone, and coal exist throughout the claystone and sandstone (ICF Kaiser, 1994).

Groundwater exists beneath the site and former impoundment area as a perched-water body within the lower portion of the fill (the perched zone), in the glacial deposits (the Ohio River Valley alluvial aquifer), and in the bedrock system. Laterally extensive perched zones develop where infiltrating water accumulates within relatively permeable fill materials above the clayey alluvium. The alluvium, with a reported permeability of 3.1×10^{-6} to 5.8×10^{-8} centimeters per second (cm/sec) restricts the downward infiltration of groundwater, creating perched zones in the overlying fill (ICF Kaiser, 1994). Perched zones exist beneath the East Plant coal/coke storage pits, the southern coke stockpile area, and beneath the Byproducts Plant.

Unconsolidated deposits comprising the alluvial aquifer include the silty sand unit (where present), and the underlying sand and gravel outwash deposits. Groundwater elevations measured in existing monitoring wells indicate that the alluvial aquifer exists under confined (artesian) conditions, with the piezometric surface of the alluvial aquifer lying within the silty clay alluvium. Groundwater within both the upper and lower portions of the alluvial aquifer generally flows toward, and discharges to the Ohio River. Because the alluvial aquifer is in hydraulic communication with the Ohio River, groundwater levels fluctuate in response to river stage. Under high-flow conditions, hydraulic gradients in the aquifer may reverse, resulting in the recharge of river water to the alluvial aquifer.

The alluvial aquifer is prolific, with calculated hydraulic conductivities and transmissivities of approximately 8 x 10^{-3} cm/sec, and 6,700 gallons per day per square foot (ICF Kaiser, 1994). WPSC formerly operated up to 15 tubular wells situated along the Ohio River for plant use. Well 15, which is situated in the southern portion of the East Plant is operated by International Mill Services (IMS), a contractor of WPSC, and used to control sinter moisture content. Well 15 is pumped at a rate of 20,000 gallons per day. The influence of Well 15 on groundwater flow is not known, but is anticipated to be insignificant.

Groundwater within the bedrock system generally flows towards the Ohio River. Fluid-level data indicate that the bedrock system exists under artesian conditions, with a consistent upward gradient between the bedrock system and the overlying alluvial aquifer. The calculated permeability of the bedrock unit range from impermeable to 1 x 10^{-2} cm/sec (ICF Kaiser, 1994)."

Water-quality data have been obtained from two surface-water sampling locations and five monitoring wells installed across the alluvial aquifer and upper portion of the bedrock system. Results of laboratory analyses are summarized in Tables 1 through 3. The data presented in Table 3 were collected during the RFI being performed at the adjacent KII facility.

4.0 EAST PLANT OPERATING PROCEDURES

WPSC has implemented standard operating procedures (SOPs) at the East Plant that are designed to prevent the release of facility-related constituents to the environment. SOPs which focus on the prevention of releases and protection of groundwater resources are summarized in the following sections. Procedures to be used in the event of releases to the environment are detailed in the East Plant Spill Prevention, Countermeasures, and Contingency (SPCC) plan, Hazardous Waste Generator Contingency Plan (HWGCP), Best Management Practices (BMP) plan, and Oil Pollution Act (OPA-90 plan.

4.1 PLANT PROCESSES AND PRODUCTION UNITS

Each of the East Plant's principal production units are visually inspected on a daily, weekly, and/or monthly basis. Material handling areas, processes, and storage areas are to be continuously monitored by operations, supervisory, and maintenance personnel throughout each shift. Visual inspections of active process units are to be performed at the start of each shift by operations personnel. Tanks, pipelines, valves, pumps, and pipeline/process unit fittings are to be checked for leaks, deterioration, or structural failure during each shift inspection. Abnormalities are to be addressed by operations personnel (if possible), documented, and reported to the appropriate supervisor using verbal or written reports. Process system components to be installed as replacement units will meet the requirements outlined in the GPA.

The Byproducts Supervisor or lead (hourly staff with limited management responsibilities) conducts formal weekly inspections of the decanters and biological treatment system. Weekly inspection reports are to be prepared and stored in the coke plant files.

Above-ground storage tanks and ancillary equipment are to be inspected by the Byproducts Supervisor on a monthly basis. Results of the inspections are to be recorded on "Declaration of Inspection" and "Secondary Containment Structure Inspection" reports (see Appendix A). Completed inspection reports are to be stored in the coke plant files.

Notification and response procedures to be employed in the event of a release from production or storage units are provided in the SPCC plan, and are summarized in Section 4.10.

4.2 PRODUCT AND WASTE MATERIAL HANDLING

4.2.1 Chemical Transfers

Chemical transfers are performed at designated locations. Prior to transferring material, the supervisor or lead is to approve the location and evaluate the potential for groundwater contamination, and to take any actions deemed necessary to prevent groundwater contamination. The loading/unloading of tank trucks and railcars is to be performed only in areas designated for chemical transfers. Transfer operations are to be continuously monitored by East Plant personnel and the truck driver (if applicable). Whenever possible, chemical transfers are to be performed on designated spill containment pads, or paved areas with appropriate spill controls. To prevent releases from entering the stormwater sewer, the sewer inlet adjacent to the caustic and acid tank reloading area is equipped with a shutoff valve. In the event of a spill, the valve is to be closed to permit recovery of the spilled material.

A procedure for the loading/unloading of tank trucks has been developed as part of the SPCC plan. This procedure is outlined below:

- Prior to loading/unloading, WPSC operations personnel will identify the appropriate tank and check the fluid level within the tank.
- The tank truck will be parked in the designated chemical transfer area, and the trailer will be secured using brakes and wheel chocks.
- Connections between the tank truck and tank will be performed in the following order:
    - The transfer hose will be attached to the tank.

  - The transfer hose will be attached to the tank trailer.
  - The valve at the receiving tank will be opened.
  - The valve at the tank to be unloaded will be opened.

- The truck driver will remain with the vehicle during the transfer.

- Upon completion of delivery, the valve on the receiving tank will first be closed, then the discharge valve will be closed.

- The transfer hose will be disconnected from the tank, and allowed to drain into a drip pan or similar unit. The hose will be disconnected from the tank trailer only after all fluid is drained from the hose.

Whenever possible, bulk materials are to be purchased in reusable containers which reduce or eliminate the need for the transfer of materials between permanent and temporary containers. Portable, secondary containment is to be used (where applicable) in conjunction with reusable containers to contain any spillage during fluid transfers.

4.2.2 Waste Handling

Decanter tar sludge and related sludge accumulated in other portions of the byproducts plant is collected in portable sludge boxes. The sludge is transported in the sludge boxes to the sludge processing area near Batteries 1, 2, and 3. Sludge spilled during the filling or transport of the sludge boxes, and any affected soil is to be collected and returned to the recycling process or placed in a lined rolloff box for proper disposal. The Environmental Control Department representative is to be immediately notified when spillage of decanter sludge or other waste material occurs.

Baghouse dust collected from Batteries 1, 2, and 3 is sent to the sinter plant for use as feedstock to the sintering process. Boilerhouse baghouse dust is collected in rolloff containers and is landfilled. Coke plant wastewater treatment plant sludge is filter-pressed, and is landfilled.

4.2.3 Drum Handling

The use of drums to store, dispense, and transport materials within the East Plant is to be avoided. Where possible bulk materials are to be purchased in portable containers or similar bulk systems to minimize the need for fluid transfers.

Full and empty drums are to be stored in designated storage areas that are situated in low-traffic or secure portions of the East Plant. Empty drums will be collected once per month and crushed or transferred to a drum recycler for reuse. Immediately upon being identified, damaged drums will be emptied of their contents, and the drum will be destroyed. Drum labelling will be performed in accordance with the OSHA Hazard Communication standard.

Drums are to be stored on pallets equipped with secondary containment to collect potential spillage during drum and fluid transfer. Fluids are to be dispensed from drums using non-drip type dispensers or pumps. In the event of a spill, the Environmental Control Department representative is to be contacted. Every effort should be made to contain and collect the spill. Spill cleanup equipment is maintained by the East Plant Hazmat team.

4.3 EQUIPMENT DECONTAMINATION AND CLEANING OPERATIONS

It is the policy of WPSC to perform process unit and equipment decontamination on containment pads or other spill control structures to prevent the release of facility-related constituents to the subsurface. The decontamination and/or cleaning of process vessels, pipelines, pumps, etc., is to be restricted to the containment pads on which the units are located. If decontamination cannot be performed over an existing containment pad and the unit can be relocated, decontamination is to be performed at the decontamination pad located at the north of the coal pits. If the unit cannot be relocated, the ground surface in the area to be potentially affected by the decontamination procedure is to be lined with plastic, and sloped to collect any spillage of decontamination fluids.

Recyclable decontamination fluid is to be routed to the byproducts plant for recycling. Spent cleaning fluids and chemicals that cannot be treated or recycled are to be handled in accordance with Federal and State regulations. The Environmental Control Department representative is to be notified prior to the generation of fluids during decontamination or other maintenance-related operations.

4.4 PROCEDURES FOR NEW CONSTRUCTION OPERATIONS

WPSC maintains a strict supervision and approval procedure for all new construction, repairs, or other activities performed by outside Contractors. All construction activities are to be authorized by area supervisors, and monitored on a daily basis by a plant engineer designated by WPSC. Construction to be performed within process areas and other high-risk activities may require continuous monitoring by WPSC supervisory personnel to reduce the potential for damage to adjacent equipment.

If excavated soil is not contaminated, the soil may be used as backfill. Soil excavated from areas in which contamination is possible is to be stored in lined rolloff boxes, analyzed, and disposed of according to applicable regulations. Soil will be placed in lined rolloff boxes pending the receipt of laboratory characterization analyses. Fluids pumped from excavations are to be routed to the wastewater treatment plant based on management and Environmental Control approval. Fluids that cannot be treated or recycled are to be stored in secure, portable storage containers approved by WPSC pending arrangements for proper disposal. All soil and liquid waste handling and disposal activities are to be coordinated with the Environmental Control Department representative. The Environmental Control Department representative is to be notified prior to the generation of soil or water as part of any construction activities.

4.5 PLANT MAINTENANCE ACTIVITIES

Maintenance on equipment is performed in accordance with manufacturer's recommendations when necessary repairs are identified during routine inspections by plant personnel and on an as-needed basis to maintain operations. Most equipment is maintained during periodic scheduled shutdowns or changeovers. Rotating elements of exhausters and other equipment are checked on a routine basis. Critical process units and pumps are located on concrete pads to contain potential releases. Repair or maintenance activities that may result in the release of coke oven gas constituents or other potentially hazardous materials are to be performed on the containment pads in a fashion that will confine any potential release to the pad.

When repair or maintenance activities that may result in a release cannot be performed on a containment pad or at the equipment decontamination area, measures are to be taken to contain the release of process materials or potentially hazardous constituents. Spill containment measures include the use of plastic liners with earthen dikes to contain released materials, use of chemical absorbents and neutralizing agents, and the use of rolloff containers for containment and disposal of debris and other wastes. Any maintenance or repair activity that may result in the major release of process materials, potentially hazardous waste, or coke oven gas constituents to the ground surface is to be coordinated with the Environmental Control Department representative (or his designee) and the Hazmat Emergency Response Team prior to startup of the work. Lockout/tagout procedures are to be employed during all maintenance activities.

To reduce future maintenance requirements and the potential for releases, WPSC has implemented a replacement program for product transfer pumps. Conventional product transfer pumps which are scheduled for replacement are being replaced with magnetic drive, zero leakage pumps which do not require mechanical seals.

Soil that is excavated during maintenance or repair activities is to be considered hazardous, and handled in accordance with the procedure described in Section 4.4.

4.6 PROCESS AND WASTEWATER PIPELINES

Above-ground pipelines conveying potentially hazardous materials and process flows will be inspected on a daily, weekly, and monthly basis, as described in Section 4.1. In addition to the routine system inspections, valves, pumps, connections, process vessels and pipelines will inspected on an semiannual basis for benzene emissions under NESHAPS. Repairs and spill cleanup are performed as soon as possible after identification. The underground tar transfer line that is used to pump tar from the East Plant to the KII facility will be pressure tested immediately prior to each use.

Pipeline leaks are to be reported to the appropriate supervisor immediately following discovery. An Environmental Control representative will, in turn, be contacted by Coke Plant management or supervisory personnel. Pipeline leaks will be repaired by trained maintenance personnel using clamp patches, plugs, or other appropriate devices. Where possible, the pipeline will be taken out of service in order to effect repairs. Appropriate personal protective equipment will be utilized at all times. Material released from the pipeline will be contained and removed as soon as possible.

In the event of a release of any material from a pipeline, the Environmental Control Department representative is to be immediately notified. Remediation of the release is to be performed in accordance with the procedures outlined in WPSC's SPCC plan, and HWGC Plan.

Provisions and guidelines for new pipeline installations are discussed in Section 4.8.

4.7 SUMPS AND TANKS

Above-ground storage tanks and sumps currently in operation at the East Plant are listed in Table 4. Tanks number 1 through 9 in Table 4 are located within secondary containment which meets or exceeds the requirements of the GPA. WPSC is currently reviewing the status of ASTs and sumps that do not meet the requirements of the GPA. ASTs and sumps not meeting these requirements will be brought up to standard in accordance with a schedule for upgrading (to be developed), or will be included in a request for a waiver from requirements under the GPA. The tank inspection and spill response programs currently in place at the East Plant will provide for the protection of groundwater resources pending the implementation of system upgrades.

Section 4.8 of the GPA is interpreted to address above-ground storage tanks, underground storage tanks and process sumps. Based upon this interpretation, process vessels and running tanks are not included in Table 4, or in the AST and sump renovation program outlined above. Above-ground process vessels and "running" tanks that are associated with plant processes are monitored and inspected as described below and in Section 4.1.

4.7.1 <u>Tank Management</u>

A discussion of coal tar-based product storage tanks, USTs, and established monitoring procedures at the East Plant is provided in WPSC's SPCC Plan. As outlined in Section 4.1, ASTs, secondary containments and process tanks are inspected on a daily, weekly, and/or monthly basis. Process and storage tanks, ancillary equipment and containment areas are to be checked for leaks, deterioration, or structural failure during each shift by operations personnel. Abnormalities are to be documented, and reported to area supervisory personnel. Rainwater collected in secondary containment areas is to be inspected for the presence of product or other contamination prior to discharge from the containment area. Contaminated rainwater is to be routed to the wastewater treatment plant.

Biological treatment system storage and treatment tanks are inspected on a weekly basis by the Byproducts Supervisor. Weekly inspection reports are prepared and filed with the East Plant SPCC plan in the coke plant files (see Appendix A).

Above-ground storage tanks and ancillary equipment are inspected by the Byproducts Supervisor or lead on a monthly basis. Results of the inspections are recorded on "Declaration of Inspection" and "Secondary Containment Structure Inspection" reports (see Appendix A). Completed inspection reports are stored in the coke plant files. Many process tanks and ASTs are equipped with fluid monitoring devices and/or high level alarms, to prevent overfilling.

USTs are used for the storage and dispensing of diesel fuel (one, 20,000 gallon tank) and gasoline (one, 6,000 gallon tank). Product levels in the USTs are to be measured, recorded, and reconciled on a daily basis. UST gauging records are to be maintained at the coke plant mechanical offices. Anomalies in the measurements are to be reported to Environmental Control Department representative, or his designee. UST integrity (tightness) testing is to be performed annually by an outside contractor. Both USTs are scheduled for removal in mid-1995. The USTs will be replaced with new ASTs that meet the requirements of the GPA.

4.7.2 Wastewater and Process Sumps

Sumps which receive uncontaminated water (once-through cooling water, recirculating cooling water, barometric condenser sumps) are constructed of reinforced concrete. The byproducts plant interceptor sump is constructed of reinforced concrete and has a synthetic lining. The acid recirculation sumps are constructed of reinforced concrete and contain a fiberglass lining.

Sumps which receive flows containing benzene (light oil condensate sump and decanter sump) are fitted with covers to minimize the release of benzene. The sumps are inspected on an annual basis in accordance with requirements under NESHAPS.

In addition to inspections performed under NESHAPS, sumps are to be inspected during changeover periods and other periods when process systems are not operating, and when suspicion of potential releases from the sump exist. Sump inspections are to be performed by maintenance personnel, or by contractors specializing in tank/sump inspections. Results of the inspection are to be stored in the coke plant files.

As outlined in Section 4.7.1, WPSC is conducting a review of sump usage and construction at the East Plant. A timetable for improvements to existing sumps will be incorporated in this GPP.

4.8 NEW EQUIPMENT DESIGN AND REVIEW

Equipment to be installed as upgrades to existing systems, or for new processes undergo a thorough review process prior to installation. Engineering and Environmental Control representatives meet on a routine basis to discuss current and future projects. The director of Environmental Control has direct input in the approval process for engineering projects which have an impact on the environment. Environmental responsibilities are often outlined in Purchase Orders issued for outside services. Environmental Control, plant operations, and engineering representatives all remain active participants throughout many engineering projects. Representatives of the WPSC Environmental Control Department have been included on many project review teams to provide input on potential impacts of the project on groundwater and surface water, and applicable state and Federal environmental regulations.

4.9 DEICING OPERATIONS AND USE OF WASTE MATERIALS

Waste materials generated by plant processes or other East Plant activities are not to be used under any circumstances for deicing, as backfill, or for any other use without the written authorization of the Environmental Control Department representative. Excavated soil handling procedures are described in Section 4.4. The reuse of any plant-related waste material must be in accordance with applicable Federal and state environmental regulations.

4.10 EMPLOYEE TRAINING

Provisions for employee training on the handling of potentially hazardous substances are outlined in the East Plant BMP, HWGCP and SPCC plans. Training for employees who may be involved in the production, handling, or storage of potentially hazardous substances will consist of the following:

- Periodic (at least annually) review of Material Safety Data Sheets for potentially hazardous substances.
- Periodic (at least annually) review of the East Plant GPP, HWGCP, BMP and SPCC plans.
- At a minimum, an annual review of Standard Operating Procedures for the respective substances handled by each employee, including the provisions of this Plan.
- The role that each employee plays, and their responsibilities in the prevention of groundwater contamination through implementation of the GPP, HWGCP, BMP, and SPCC plans.

Each new or reassigned employee will be instructed on the information outlined above. In addition to job startup and routine training, environmental incidents and associated response actions will be critiqued with all involved employees as soon as possible after an incident is addressed. Records of employee training will be maintained in the East Plant superintendent's office.

5.0 PLAN IMPLEMENTATION, COMPLIANCE AND NOTIFICATION PROCEDURES

5.1 PLAN IMPLEMENTATION

The East Plant Environmental Control Department representative is responsible for the coordination, implementation and maintenance of the GPP (GPP Administrator). Provisions of the GPP may be delegated to others by the GPP Administrator. Operations and maintenance management staff will be responsible for implementing the provisions and personnel training outlined above in each department, with the support of the GPP Administrator.

5.2 COMPLIANCE INSPECTIONS

Inspections to be performed on process units, storage areas, and other plant-related activities are outlined in Sections 4.1 and 4.7. Adherence to the provisions of the GPP will be monitored through the quarterly inspection of pertinent records by the WPSC Environmental Control Department representative. The inspection will include, but not be limited to a review of the following:

- Routine plant inspection reports.
- Employee training documentation.
- Records of environmental incidences and responses.
- UST gauging records.

The Environmental Control Department representative also will conduct a quarterly inspection of the plant to ensure that the provisions of the GPP described in the previous sections are being implemented. Results of the records review and plant inspection will be documented and submitted to the plant superintendent and Environmental Control department, who will review and, if necessary, ensure compliance with the GPP.

Actions to be performed in response to the results of compliance inspections, or other improvements at the East Plant will be incorporated under Section 6.0 of the GPP by the GPP Administrator. Changes to Section 6.0 will include revised dates for project startup.

5.3 RELEASE NOTIFICATION PROCEDURES

Procedures to be employed by East Plant personnel in the event of a release are described in the SPCC plan, and are summarized below. All personnel are to consider any release of oil, or other plant-related material to be a major spill.

Upon discovery of a spill, immediately inform the Byproduct Production Foreman or lead at extension 5604 or 5657. The Byproduct Production Foreman or lead will serve as the interim On-Scene Coordinator. The Byproduct Production Foreman or lead will notify appropriate individuals, and will initiate remedial activities.

The Byproduct Production Foreman will be responsible for ensuring that the spill is reported to the Environmental Control Department for proper notification of appropriate Federal, state, and local regulatory agencies. A report detailing the spill occurrence and size, cause of spill, constituent released, time and date of release, remedial actions taken, and measures to prevent a future release will be promptly prepared (within one day) by appropriate personnel and submitted to the Environmental Control Department.

Detailed procedures to be followed when addressing releases, and a list of emergency response equipment maintained at the East Plant is provided in the SPCC plan or other appropriate plans.

6.0 PROPOSED FUTURE ACTIVITIES AND IMPLEMENTATION SCHEDULE

WPSC is currently implementing a program of plant improvements directed towards the protection of groundwater through spill containment and runoff control. Critical areas are being reviewed and evaluated for future improvements that may include, but are not limited to paving, secondary containment, etc. A schedule for implementation of future improvements to process and materials handling areas is being developed and will be incorporated in this GPP.

7.0 OTHER ACTIVITIES OR PROGRAMS PERTINENT TO THE PROTECTION OF GROUNDWATER

Several programs implemented by, and permits issued for the WPSC East Plant directly influence the release of constituents to groundwater, or are relevant to groundwater-related issues. Provided below is a brief summary of activities pertinent to the protection of groundwater.

7.1 NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT NO. WV0004499

WPSC discharges treated wastewater to the Ohio River under NPDES Permit Number WV0004499. The permit is currently undergoing reissuance. Revisions to the draft permit are undergoing review and comment by WPSC.

7.2 SPILL PREVENTION CONTROL AND COUNTERMEASURE (SPCC) PLAN

The East Plant SPCC plan addresses the prevention of, and response to the release of petroleum-based product from plant storage tanks and processes, as required under the Code of Federal Regulations, Title 40, Part 112 (40 CFR 112). The SPCC plan establishes spill prevention measures, emergency response teams, and the chain of command to be employed in the event of an oil spill at the East Plant. Provisions for employee training, disposal of recovered product and waste materials, and inspection of plant processes and tanks also are described in the SPCC plan. By establishing requirements for employee training, system inspections, and remedial response capabilities, the SPCC plan serves to prevent and if necessary, control releases to groundwater and surface water.

7.3 HAZARDOUS WASTE GENERATOR CONTINGENCY (HWGC) PLAN

The HWGC plan provides WPSC personnel with information necessary to effectively respond to emergencies related to hazardous wastes generated at the East Plant. As with the SPCC plan, the HWGC plan establishes employee notification and response procedures to be used in the event of a release of hazardous material, an internal chain of command, and the requirement for an emergency response team.

7.4 BEST MANAGEMENT PRACTICES (BMP)

The BMP plan addresses the handling, production, and storage of potentially hazardous materials at the East Plant. The BMP plan presents an inventory of potentially hazardous substances in use at the East Plant, reporting and notification procedures to be used in the event of a release, establishes provisions for employee training, and provides for preventive maintenance, housekeeping, and response to releases of potentially hazardous substances to the ground surface.

7.5 REQUEST FOR VARIANCE FROM GROUNDWATER STANDARDS (VARIANCE)

On June 1, 1995, WPSC submitted a Request for Variance from Groundwater Standards to the WVDEP. The Variance addresses the operation of the coal and coke storage pits, and the coke stockpile area. A Variance permits the operation of a source or class of sources of contaminants that by their nature cannot be conducted or operated in compliance with existing groundwater quality standards, within parameters to be established by the petitioner and the WVDEP. If granted, the Variance will permit the operation of the coal and coke storage areas within guidelines established in the Request for Variance. Periodic groundwater monitoring of the coal and coke storage areas will be performed in accordance with pertinent sections of the GPA.

7.6 COAL PIT DEWATERING CONSENT DECREE

During April of 1984, WPSC and the Koppers Company, Inc., entered into a Consent Decree with the former West Virginia Division of Natural Resources and the U.S. Environmental Protection Agency, which addressed the occurrence of phenol and other contaminants in water collected from WPSC's coal and coke pits. Seepage of perched groundwater originating beneath the Koppers plant into the pits was identified as the source of phenol in the coal pit runoff.

Under the Consent Decree, Koppers is required to operate three perched-zone recovery wells and one interception trench to prevent the discharge of perched water into the coal pits. WPSC collects and pumps runoff from the coal and coke pits to the East Plant wastewater treatment facility for treatment.

7.7 BYPRODUCTS PLANT RECOVERY WELLS

To address the presence of separate-phase hydrocarbons in the perched groundwater beneath the benzol production area of the byproducts plant, WPSC installed and operates two, total fluids recovery wells. The recovery wells are constructed of slotted, corrugated galvanized pipe. Separate-phase hydrocarbons and perched groundwater produced by the two wells are pumped to the byproducts recovery units, which then blow down to the wastewater treatment plant.

Table
Results of Analyses for Inorganic Constituents
Coal and Coke Storage Area Runoff and Groundwater
Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia.

Parameter	Units	Detection Limit	CP-1 4/11/95	CP-2 4/11/95	VA-1 4/11/95	VA-2 4/12/95	VA-3 4/12/95	VA-3 Duplicate 4/12/95	R-210 4/12/95	Groundwater Protection Standard
Cyanide (total)	mg/L	0.005	0.006	0.012	0.011	0.056	0.010	0.013	0.006	0.2
Fluoride	mg/L	0.10	1.1	1.0	0.43	0.23	0.18	0.21	0.21	4.0
Nitrite	mg/L	0.010	0.13	0.10	0.013	0.017	0.036	0.036	0.017	1.0
Nitrate-Nitrite	mg/L	0.10	1.4	0.26	ND	ND	0.38	0.51	ND	10.0
<u>Dissolved Metals</u>										
Barium	mg/L	0.02	0.028	0.040	0.50	0.047	0.082	0.082	0.043	2.0
Beryllium	mg/L	0.002	0.004	0.006	0.004	0.007	0.008	0.007	0.004	0.004
Cadmium	mg/L	0.005	0.006	0.019	0.037	0.008	ND	ND	ND	0.005
Chromium	mg/L	0.01	ND	ND	ND	0.014	ND	0.010	ND	0.10
Mercury	mg/L	0.0002	ND	ND	ND	ND	ND	0.0002	ND	0.002
Nickel	mg/L	0.04	ND	ND	ND	0.20	0.11	0.12	ND	0.10
Lead	mg/L	0.015	ND	ND	ND	ND	ND	0.028	ND	0.015
Antimony	mg/L	0.006	0.021	ND	0.007	0.007	0.007	ND	0.012	0.006
Selenium	mg/L	0.05	ND	ND	ND	ND	ND	ND	ND	0.05
Thallium	mg/L	0.002	ND	ND	ND	ND	ND	ND	ND	0.002
<u>Total Metals</u>										
Barium	mg/L	0.02	0.039	0.12	0.51	0.23	0.65	0.64	0.10	2.0
Beryllium	mg/L	0.002	0.004	0.006	0.004	0.009	0.011	0.010	0.004	0.004
Cadmium	mg/L	0.005	ND	ND	0.016	0.007	0.018	0.018	ND	0.005
Chromium	mg/L	0.01	ND	ND	ND	0.048	0.067	0.063	ND	0.10
Mercury	mg/L	0.0002	ND	0.0002	ND	0.0003	0.003	0.0004	ND	0.002
Nickel	mg/L	0.04	ND	0.045	ND	0.23	0.19	0.18	ND	0.10
Lead	mg/L	0.015	ND	ND	ND	0.039	0.038	0.042	ND	0.015
Antimony	mg/L	0.006	ND	ND	ND	ND	ND	ND	ND	0.006
Selenium	mg/L	0.05	ND	ND	ND	ND	ND	ND	ND	0.05
Thallium	mg/L	0.002	ND	ND	ND	ND	ND	ND	ND	0.002

Analyses were performed by Antech, Ltd., of Export, Pennsylvnaia using USEPA-approved procedures.
CP-1: North coal pit collection sump.
CP-2: Surface-water accumulation in southern coal/coke pit, adjacent to stockpiled coke.
VA: Downgradient alluvial aquifer monitoring well.
R-210: Upgradient alluvial aquifer monitoring well.
ND: Not detected.

Table 2.
Results of Analyses for Organic Constituents
Coal and Coke Storage Area Runoff and Groundwater

Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia.

Parameter	Units	Detection Limit	CP-1 4/11/95	CP-2 4/11/95	VA-1 4/11/95	VA-2 4/12/95	VA-3 4/12/95	VA-3 Duplicate 4/12/95	R-210 4/12/95	Groundwater Protection Standard
Benzene	mg/L	0.005	ND	ND	ND	ND	ND	ND	0.013	0.005
Toluene	mg/L	0.005	ND	ND	ND	ND	ND	ND	0.0052	1.0
Ethylbenzene	mg/L	0.005	ND	ND	ND	ND	ND	ND	0.0099	0.70
Xylenes	mg/L	0.005	ND	ND	ND	ND	ND	ND	0.011	10.0
Benzo(a)pyrene	mg/L	0.00002	0.0016	0.000055	ND	ND	ND	ND	ND	0.0002

Notes:
Analyses were performed by Antech, Ltd., of Export, Pennsylvania using SW-846 Method 8240 for benzene, toluene, ethylbenzene, and xylenes and high-pressure liquid chromatography (HPLC, EPA-600/4-82-057) for benzo(a)pyrene.
Benzo(a)pyrene analyses were performed after USEPA sample holding time of seven days. Samples extracted 10 days after collection.
CP-1: North coal pit collection sump.
CP-2: Surface-water accumulation in southern coal/coke pit, adjacent to stockpiled coke.
VA: Downgradient alluvial aquifer monitoring well.
R-210: Upgradient alluvial aquifer monitoring well.
ND: Not detected.

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Table 3.

Results of Analyses for Priority Pollutant Metals and General Parameters

Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia

			SAMPLE IDENTIFICATION				
PARAMETER	ANALYTICAL METHOD	UNITS	R-210 10/5/93	R310 (10/5/93)	R-210 Duplicate (10/5/93)	Field Blank (10/5/93)	Method Blank (10/5/93)
Cyanide (Total)	9012(1)	mg/L	<0.010	0.020	0.030	<0.010	<0.010
Total Organic Carbon	9060(1)	mg/L	9.9	<1.0	8.8	2.1	<1.0
Metals:							
Silver (Dissolved)	6010(1)	μg/L	<10	<10	<10	<10	<10
Silver (Total)	6010(1)	μg/L	<10	<10	<10	<10	<10
Arsenic (Dissolved)	7060(1)	μg/L	3.0	4.0	2.0	<1.0	<1.0
Arsenic (Total)	7060(1)	μg/L	3.0	6.0	2.0	<1.0	<1.0
Beryllium (Dissolved)	6010(1)	μg/L	<2.0	<2.0	<2.0	<2.0	<2.0
Beryllium (Total)	6010(1)	μg/L	2.0	<2.0	<2.0	<2.0	<2.0
Cadmium (Dissolved)	6010(1)	μg/L	<5.0	<5.0	<5.0	<5.0	<5.0
Cadmium (Total)	6010(1)	μg/L	<5.0	<5.0	<5.0	<5.0	<5.0
Chromium (Dissolved)	6010(1)	μg/L	<10	<10	<10	<10	<10
Chromium (Total)	6010(1)	μg/L	<10	14	13	<10	<10
Copper (Dissolved)	6010(1)	μg/L	<10	<10	<10	<10	<10
Copper (Total)	6010(1)	μg/L	15	<10	18	<10	<10
Mercury (Dissolved)	7470(1)	μg/L	<0.20	0.20	<0.20	<0.20	<0.20
Mercury (Total)	7470(1)	μg/L	<0.20	0.20	<0.20	<0.20	<0.20
Nickel (Dissolved)	6010(1)	μg/L	<40	<40	<40	<40	<40
Nickel (Total)	6010(1)	μg/L	<40	<40	<40	<40	<40
Lead (Dissolved)	6010(1)	μg/L	<100	<100	<100	<100	<100
Lead (Total)	6010(1)	μg/L	<100	<100	<100	<100	<100
Antimony (Dissolved)	6010(1)	μg/L	<100	<100	<100	<100	<100
Antimony (Total)	6010(1)	μg/L	<100	<100	<100	<100	<100
Selenium (Dissolved)	7740(1)	μg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium (Total)	7740(1)	μg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Thallium (Dissolved)	7841(1)	μg/L	<4.0	<4.0	<4.0	<4.0	<4.0
Thallium (Total)	7841(1)	μg/L	<4.0	<4.0	<4.0	<4.0	<4.0
Zinc (Dissolved)	6010(1)	μg/L	13	13	11	18	<10
Zinc (Total)	6010(1)	μg/L	67	58	140	25	<10

(1) U.S. Environmental Protection Agency, 1987. Test Methods for Evaluating Solid waste, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.

(2) USEPA MCL: USEPA Maximum Contaminant Levels for drinking water.

Adapted from Antech, Ltd.

WPS\PA0196.002\TABLE-3A.WK1

Table 3. (continued)

Results of Analyses for Volatile Organic Compounds
SW-846 Method 8010/8020(1)

Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia

			SAMPLE IDENTIFICATION					
PARAMETER	CAS(2) NUMBER	UNITS	R-210 (10/5/93)	R-310 (10/5/93)	R-210 Duplicate (10/5/93)	Field Blank (10/5/93)	Trip Blank (10/5/93)	Method Blank (10/5/93)
Benzene	71-45-2	µg/L	21	<5.0	21	<5.0	<5.0	<5.0
Benzyl chloride	100-44-7	µg/L	<10	<10	<10	<10	<10	<10
Bromodichloromethane	75-27-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bromobenzene	108-86-1	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bromoform	75-25-2	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Carbon tetrachloride	56-23-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chlorobenzene	108-90-7	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chlorodibromomethane	124-48-1	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroethane	75-00-3	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
2-Chloroethyl vinyl ether	110-75-8	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1-Chlorohexane	544-10-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloromethane	74-87-3	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroform	67-66-3	µg/L	<5.0	<5.0	<5.0	8.0	<5.0	<5.0
2-Chlorotoluene	95-49-8	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Dibromomethane	74-95-3	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichlorobenzene	95-50-1	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,3-Dichlorobenzene	541-78-1	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,4-Dichlorobenzene	106-46-7	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Dichlorodifluoromethane	75-71-8	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethane	75-34-3	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloroethane	107-06-2	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethene	75-35-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
trans-1,2-Dichloroethene	156-60-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloropropane	78-87-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
cis-1,3-Dichloropropene	10061-01-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
trans-1,3-Dichloropropene	10061-02-6	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ethylbenzene	100-41-4	µg/L	13	<5.0	13	<5.0	<5.0	<5.0
Methylene chloride	75-09-2	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,1,2-Tetrachloroethane	630-20-6	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,2,2-Tetrachloroethane	79-34-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Tetrachloroethene	127-18-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Toluene	108-88-3	µg/L	21	<5.0	21	<5.0	<5.0	<5.0
Trichlorofluoromethane	75-69-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2,3-Trichloropropane	96-18-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,1-Trichloroethane	71-55-6	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,2-Trichloroethane	78-00-5	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Trichloroethane	78-01-6	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Vinyl chloride	75-01-4	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Xylenes (Total)	1330-20-7	µg/L	33	<5.0	35	<5.0	<5.0	<5.0

(1) U.S. Environmental Protection Agency, 1987, Test Methods for Evaluating Solid Waste, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.

(2) CAS - Chemical Abstracts Services.

(3) USEPA MCL: USEPA Maximum Contaminant Levels for drinking water.

Adapted from Antech, Ltd.

Table 3. (continued)

Results of Analyses for Polynuclear Aromatic Hydrocarbons
SW-846 Method 8310(1)

Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia

			SAMPLE IDENTIFICATION				
PARAMETER	CAS(2) NUMBER	UNITS	R-210 (10/5/93)	R-310 (10/5/93)	R-210 Duplicate (10/5/93)	Field Blank (10/5/93)	Method Blank (10/5/93)
Acenaphthene	83-32-9	µg/L	80	<10	90	<10	<10
Acenaphthylene	208-96-8	µg/L	<10	<10	<10	<10	<10
Anthracene	120-12-7	µg/L	<10	<10	<10	<10	<10
Benzo(a)pyrene	50-32-8	µg/L	<10	<10	<10	<10	<10
Benzo(a)anthracene	56-55-3	µg/L	<10	<10	<10	<10	<10
Benzo(b)fluoranthene	205-99-2	µg/L	<10	<10	<10	<10	<10
Benzo(ghi)perylene	191-24-2	µg/L	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	207-08-9	µg/L	<10	<10	<10	<10	<10
Chrysene	218-01-9	µg/L	<10	<10	<10	<10	<10
Dibenz(a,h)anthracene	53-70-3	µg/L	<10	<10	<10	<10	<10
Fluoranthene	206-44-0	µg/L	44	<10	48	<10	<10
Indeno(1,2,3-cd)pyrene	86-73-7	µg/L	<10	<10	<10	<10	<10
Napthalene	193-39-5	µg/L	1000	<10	1100	<10	<10
Phenanthrene	85-01-8	µg/L	42	<10	48	<10	<10
Pyrene	129-00-0	µg/L	<10	<10	<10	<10	<10

(1) U.S. Environmental Protection Agency, 1987. Test Methods for Evaluating Solid waste, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.

(2) CAS = Chemical Abstracts Services

Adapted from Antech, Ltd.

WPS\PA0196.002\TABLE-3C.WK1

Table 3. (continued)

Results of Analysis for Acid Extractable Compounds
SW-846 Method 8040(1)

Wheeling-Pittsburgh Steel Corporation
Follansbee, West Virginia

			SAMPLE IDENTIFICATION				
PARAMETER	CAS(2) NUMBER	UNITS	R-210 (10/5/93)	R-310 (10/5/93)	R-210 Duplicate (10/5/93)	Field Blank (10/5/93)	Method Blank (10/5/93)
2-Chlorophenol	95-57-8	µg/L	<20	<10	<20	<10	<10
2,3-Dichlorophenol	120-83-2	µg/L	<20	<10	<20	<10	<10
2,4-Dimethylphenol	105-67-9	µg/L	<20	<10	<20	<10	<10
4,6-Dinitro-o-cresol	534-52-1	µg/L	<100	<50	<100	<50	<50
2,4-Dinitrophenol	51-28-5	µg/L	<100	<50	<100	<50	<50
2-Nitrophenol	88-75-5	µg/L	<20	<10	<20	<10	<10
4-Nitrophenol	100-02-7	µg/L	<40	<10	<20	<10	<10
p-Chloro-m-cresol	59-50-7	µg/L	300	<10	500	<10	<10
Pentachlorophenol	87-88-5	µg/L	<20	<10	<20	<10	<10
2,4,6-Trichlorophenol	88-06-2	µg/L	64	<10	110	<10	<10

(1) U.S. Environmental Protection Agency, 1987. Test Methods for Evaluating Solid Waste, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.
(2) CAS = Chemical Abstracts Services
Adapted from Antech, Ltd.

WPS\PA0196.002\TABLE-3D.WK1

Table 4.

GROUND WATER PROTECTION PLAN TANK LISTING

GWP #	TANK IDENTIFICATION	TANK LOCATION	CAPACITY (GAL)	SECONDARY CONTAINMENT	PRIORITY
1	COAL SPRAY OIL	S. END #8 BATTERY	20,000	YES	
2	COAL SPRAY OIL	S. END #8 BATTERY	20,000	YES	
3	TAR TANK #13	S. END BY-PRODUCTS	230,000	YES	
4	TAR TANK #2	S. END BY-PRODUCTS	230,000	YES	
5	AMMONIA LIQUOR TANK #1	S. END BY-PRODUCTS	120,000	YES	
6	AMMONIA LIQUOR TANK #2	S. END BY-PRODUCTS	259,000	YES	
7	AMMONIA LIQUOR TANK #2B	S. END BY-PRODUCTS	259,000	YES	
8	MUCK TANK	N. END BY-PRODUCTS	22,000	YES	
9	LIGHT OIL	N. END BY-PRODUCTS	600,000	YES	
10	WASH OIL	N. END BY-PRODUCTS	20,000		
11	FUEL GAS CONDENSATE	S. END #8 BATTERY			
12	Q-COTE 6879	S. END #8 BATTERY	5,000		
13	HYDRAULIC OIL	S. END #8 BATTERY			
14	FUEL GAS CONDENSATE	N. END #8 BATTERY			
15	20% CAUSTIC SODA	PUSHING EMISSIONS			
16	HYDRAULIC OIL	N. END #8 BATTERY			
17	WASTE OIL	#6 BATTERY WALL			
18	WASTE HYDRAULIC OIL	#6 BATTERY WALL			
19	Q-COTE 6879	S. END #3 BATTERY	2,500		
20	U.F. DOOR SEALANT	S. END #3 BATTERY	2,000		
21	HYDRAULIC OIL	S. END #3 BATTERY			
22	FUEL GAS CONDENSATE	S. END #3 BATTERY			
23	U.F. DOOR SEALANT	S. END #3 BATTERY	2,000		
24	Q-COTE 6879	N. END #1 BATTERY	2,000		
25	S.T. DOOR SEALANT	N. END #1 BATTERY	4,000		
26	HYDRAULIC OIL	N. END #1 BATTERY			
27	FUEL GAS CONDENSATE	N. END #1 BATTERY			
28	20% CAUSTIC SODA	BIO PLANT	10,000		
29	PHOSPHORIC ACID	BIO PLANT	10,000		
30	C-E TANK 301	BIO PLANT	750,000		
31	C-E TANK 302	BIO PLANT	750,000		
32	C-E TANK 303	BIO PLANT	750,000		
33	BETZ 3F27	SOUTH OF HOLDER			
34	BETZ FERRAMEEN 716	#1 SATURATOR			
35	CHEMLINK 1750	SERVICE WATER BLD.			
36	L. O. DAY TANK	BTX PLANT	20,000		
37	BETZ FERRAMEEN 716	PRECIPITATOR BLD.			
38	BETZ 3F27	W. SIDE ENGINE ROOM			
39	STORM WATER TANK	COAL HANDLING	500,000		

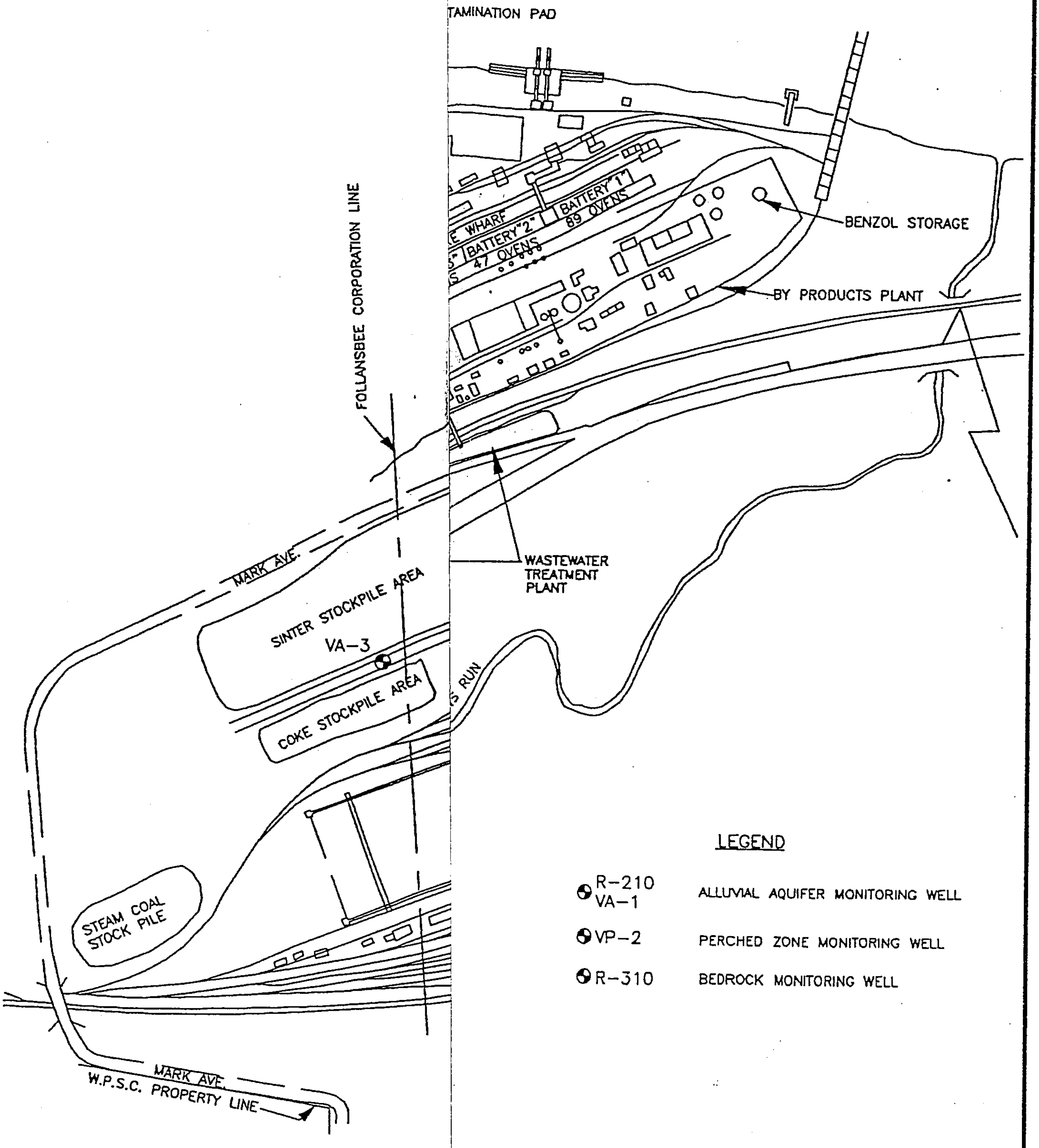
GROUND WATER PROTECTION PLAN TANK LISTING

GWP #	TANK IDENTIFICATION	TANK LOCATION	CAPACITY (GAL)	SECONDARY CONTAINMENT	PRIORITY
40	SULFURIC ACID	S. SIDE PHENOL BLD.			
41	SULFURIC ACID	S. SIDE PHENOL BLD.			
42	SULFURIC ACID	S. SIDE PHENOL BLD.			
43	50% CAUSTIC SODA	S. END ACID PLANT	20,000		
44	50% CAUSTIC SODA	S. END ACID PLANT	20,000		
45	WASH OIL CIRC.	W. SIDE LIGHT OIL BLD.			
46	WASH OIL DECANTER	W. SIDE LIGHT OIL BLD.			
47	OLD MUCK TANK	W. SIDE LIGHT OIL BLD.			
48	BETZ FERRAMEEN 716	E. SIDE BOILERHOUSE			
49	BETZ SULFITE L	E. SIDE BOILERHOUSE			
50	BETZ BALANCED POLY	E. SIDE BOILERHOUSE			
51	FUEL GAS CONDENSATE	W.SIDE OF BRIDGE	5,000		
52	FUEL GAS CONDENSATE	E. SIDE OF BRIDGE	500		
53	20% CAUSTIC SODA	SINTER PLANT			
54	FERRAMEEN 5K9	BYPRODUCTS AREA	2,000		
55	FERRAMEEN 3F27	BYPRODUCTS AREA	1,000		
56	FERRAMEEN 718	BYPRODUCTS AREA	2,000		

GROUND WATER PROTECTION PLAN SUMP LISTING

	SUMP IDENTIFICATION	SUMP LOCATION	CAPACITY (GAL)	PRIORITY
1	DECANTER SUMP	N. SIDE #4 DECANTER		
2	DETARRER SUMP	S.W. OF #2 SATURATOR		
3	INTERCEPTOR SUMP	S. SIDE OF L.O. BLD.		
4	LIGHT OIL SUMP	WSAC TANK PAD		
5	SATURATOR SUMP	S. SIDE #2 SATURATOR		
6	PHENOL SUMP	TAR TANK CONTAINMENT		
7	DIRECT COOLER SUMP	N. SIDE DIRECT COOLER		
8	NEUTRALIZATION SUMP	S. END ACID PLANT		
9	TAR/OIL SUMP	W. SIDE C-E TANKS		
10	#8 QUENCHER SUMP	S.END #8 BATTERY		
11	#1-2-3 QUENCHER SUMP	N.END #1 BATTERY		

DWG DATE: 25MAY95 | PRJCT NO.: PA0196.001 | FILE: WH-PITT | DRAWING: WPS-ST.DWG | CHECKED: T. RATVASKY | APPROVED: T. RATVASKY | DRAFTER: B. HERRMANN



LE EAST COKE PLANT
ES AND OPERATION AREAS

SBURGH STEEL CORPORATION
SBEE, WEST VIRGINIA

FIGURE
1

APPENDIX A

INSPECTION REPORT FORMS

WHEELING-PITTSBURGH STEEL CORPORATION
STEUBENVILLE EAST PLANT
SECONDARY CONTAINMENT STRUCTURE INSPECTION REPORT

SECONDARY CONTAINMENT STRUCTURE INSPECTION REPORT		
LOCATION		
CONDITION	YES	NO
1.0 Verify that the bypass valve(s) on the storage tank(s) are closed during the precipitation event.		
2.0 Inspect the standing water within the secondary containment structure for visible signs of contamination–(oil and/or oily by-products).		
3.0 Verify that the bypass valve is opened and resealed.		
4.0 Verify that the equipment used to transfer the contaminated liquid and/or residual solids are properly decontaminated and/or deposed of.		
5.0 Record the approximate amount of water drained from the secondary containment structure and its' final destination. Amount, Liquid:____________Solid:___________ Point of Discharge:		
COMMENTS–(Rework):		
INSPECTION DATE:		
SUPERVISOR/INSPECTOR: DATE:		
SUPERINTENDENT–(APPROVAL): DATE:		

WHEELING-PITTSBURGH STEEL CORPORATION

MONTHLY
DECLARATION OF INSPECTION

(a) TANK:		**DATE:**	
(b) LOCATION:			
(c) INSPECTION CHECK LIST:	**YES (X)**	**NO (X)**	**N/A (X)**
1. Are there any signs of tank foundation deterioration or undue settlement?			
2. Does the tank supporting structure indicate any signs of fatigue or deterioration of structural members on above ground tanks?			
3. Due to atmospheric conditions, weather, etc., are there any signs of corrosion or deterioration of the storage tank shell and shell connections?			
4. Are there adequate pipe supports to prevent any possible failure in the pipe system?			
5. Are all drain valves and any other valves that will permit direct outward flow of the tank's contents to the surface securely closed and capped when in non-operating and non-standby status?			
6. Is the starter control on all oil pumps locked in the "Off" position or located at a site accessible only to authorized personnel when the pumps are in a non-operating or non-standby status?			
7. Is the facility lighting adequate for operation during the hours of darkness as well as for the detection of a possible spill?			

WHEELING-PITTSBURGH STEEL CORPORATION

MONTHLY
DECLARATION OF INSPECTION
(Continued)

(c) INSPECTION CHECK LIST:	YES (X)	NO (X)	N/A (X)
8. Have all flange joints, valve glands and bodies, drip pans, pipeline supports, pump and pump packing, been examined as to the general condition of all items as well as possible system leaks?			
9. Does the oil handling flexible unloading hose show signs of deterioration or weakness?			
10. Are there adequate "No Smoking" signs posted at the facility?			
11. Are the phone numbers posted and maintained at the facility of personnel to be contacted in the event of a spill?			
12. Is the general condition of the site such that there is no accumulation of oil or residue at the facility?			

Comments:____

I have personally inspected this facility and have found the general conditions as designated (X) above.

SUPERVISOR OR INSPECTOR: **TITLE:**	**DATE:**	**TIME:**
DEPARTMENT SUPERINTENDENT:	**DATE:**	

Exhibit 9

Technical Factsheet on: POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

List of Contaminants

As part of the Drinking Water and Health pages, this fact sheet is part of a larger publication:
National Primary Drinking Water Regulations

Drinking Water Standards
MCLG: zero mg/L
Mcl: 0.0002 mg/L
HAL(child): none

Health Effects Summary

Acute: EPA has found polycyclic aromatic hydrocarbons (PAHs) similar to benzo(a)pyrene to potentially cause the following health effects from acute exposures at levels above the MCL: red blood cell damage, leading to anemia; suppressed immune system.

Drinking water levels which are considered "safe" for short-term exposures have not been established at this time.

Chronic: Benzo(a)pyrene has the potential to cause the following health effects from long-term exposures at levels above the MCL: developmental and reproductive effects.

Cancer: There is some evidence that benzo(a)pyrene has the potential to cause cancer from a lifetime exposure at levels above the MCL.

Usage Patterns

Benzo(a)pyrene is one of a group of compounds called polycyclic aromatic hydrocarbons (PAHs), or polynuclear aromatic hydrocarbons (PNAs). They are not produced or used commercially but are ubiquitous in that they are formed as a result of incomplete combustion of organic materials.

Release Patterns

PAHs are found in exhaust from motor vehicles and other gasoline and diesel engines, emission from coal-, oil-, and wood-burning stoves and furnaces, cigarette smoke; general soot and smoke of industrial, municipal, and domestic origin, and cooked foods, especially charcoal-broiled; in incinerators, coke ovens, and asphalt processing and use.

There are two major sources of PAHs in drinking water: 1) contamination of raw water supplies from natural and man-made sources, and 2) leachate from coal tar and asphalt linings in water storage tanks and distribution lines. PAHs in raw water will tend to adsorb to any particulate matter and be removed by filtration before reaching the tap.

PAHs in tap water will mainly be due to the presence of PAH-containing materials in water storage and distribution systems. Though few data are available for estimating the potential for PAH release to water from these materials, there are reports that levels can reach 0.01 mg/L with optimum leaching conditions.

Environmental Fate

Released benzo(a)pyrene is largely associated with particulate matter, soils, and sediments. Although environmental concentrations are highest near sources, its presence in places distant from primary sources indicates that it is reasonably stable in the atmosphere and capable of long distance transport.

When released to air it may be subject to direct photolysis, although adsorption to particulates apparently can retard this process. It may also be removed by reaction with ozone (half-life 37 min) and NO2 (half-life 7 days), and an estimated half-life for reaction with photochemically produced hydroxyl radicals is 21.49 hr.

If released to water, it will be expected to adsorb very strongly to sediments and particulate matter. It will not hydrolyze. It has been shown to be susceptible to significant metabolism by microorganisms in some natural waters without use as carbon or energy source, but in most waters and in sediments it is stable towards biodegradation. BaP will be expected to undergo significant photodegradation near the surface of waters. Evaporation may be significant with a predicted half-life of 43 days. However, adsorption to sediments and particulates may significantly retard biodegradation, photodegradation, and evaporation.

If released to soil it will be expected to adsorb very strongly and will not be expected to leach to the groundwater. However, its presence in some groundwater samples indicates that it can be transported there by some mechanism. It will not hydrolyze, and evaporation from soils and surfaces is not expected to be significant. Biodegradation tests in soils have resulted in a wide range of reported half-lives: 2 days to 1.9 yr. Based on these values and the apparent lack of a significant competing fate process, biodegradation may be an important process in soils.

Benzo(a)pyrene is expected to bioconcentrate in aquatic organisms that can not metabolize it. Reported BCFs include: Oysters, 3000; Rainbow trout, 920; Bluegills, 2,657; zooplankton, 1000 to 13,000. The presence of humic acid in solution has been shown to decrease bioconcentration. Those organisms which lack a metabolic detoxification enzyme system, tend to accumulate polycyclic aromatic hydrocarbons. For example, BCFs have been found to be very low (<1) for mudsuckers, sculpins and sand dabs.

Human exposure will be from inhalation of contaminated air and consumption of contaminated food and water. Especially high exposure will occur through the smoking of cigarettes and the ingestion of certain foods (eg smoked and charcoal broiled meats and fish).

Chemical/ Physical Properties

CAS Number: 50-32-8

Color/ Form/Odor: Pale yellow needlelike crystals, faintly aromatic

M.P.: 179-179.3 C B.P.: >360 C

Vapor Pressure: >1 mm Hg at 20 C

Density/Spec. Grav.: 1.35 at 15 C

Octanol/Water Partition (Kow): Log Kow = 6.04

Solubility: 0.0038 mg/L of water at 25 C; very low solubility in water

Soil sorption coefficient: Log Koc =6.6 to 6.8; very low mobility in soil

Odor/Taste Thresholds: N/A

Bioconcentration Factor: BCFs range from <1 to 2675 in fish; expected to bioconcentrate in aquatic organisms which are unable to metabolize it.

Henry's Law Coefficient: N/A; volatilization not significant

Trade Names/Synonyms: 3,4-Benz(a)pyrene; BaP; BP

Other Regulatory Information

Monitoring For Ground/Surface Water Sources:

Initial Frequency- 4 quarterly samples every 3 years
Repeat Frequency- If no detections during initial round:
    2 quarterly per year if serving >3300 persons;
    1 sample per 3 years for smaller systems
Triggers - Return to Initial Freq. if detect at > 0.00002 mg/L

Analysis:

Reference Source	**Method Numbers**
EPA 600/4-88-039	525.1; 550; 550.1

Treatment- Best Available Technologies:
Granular Activated Charcoal

For Additional Information:

EPA can provide further regulatory and other general information:
EPA Safe Drinking Water Hotline - 800/426-4791

Other sources of toxicological and environmental fate data include:
Toxic Substance Control Act Information Line - 202/554-1404
Toxics Release Inventory, National Library of Medicine - 301/496-6531
Agency for Toxic Substances and Disease Registry - 404/639-6000

Exhibit 10

Pace Analytical Services, LLC
1638 Roseytown Road - Suites 2,3,4
Greensburg, PA 15601
(724)850-5600

January 08, 2024

Mr. Chip Fenske
Empire Diversified Energy, Inc
1400 Main Street
Follansbee, WV 26037

RE: Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

Dear Mr. Fenske:

Enclosed are the analytical results for sample(s) received by the laboratory on December 28, 2023. The results relate only to the samples included in this report. Results reported herein conform to the applicable TNI/NELAC Standards and the laboratory's Quality Manual, where applicable, unless otherwise noted in the body of the report.

Some analyses were subcontracted outside of the Pace Network. The test report from the external subcontractor is attached to this report in its entirety.

The test results provided in this final report were generated by each of the following laboratories within the Pace Network:

- Pace Analytical Services - Beaver
- Pace Analytical Services - Greensburg

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Theresa A. Wilson
theresa.wilson@pacelabs.com
(724)850-5600
Project Manager

Enclosures

cc: Leah Mistick, Environmental Standards, Inc.
Ms. Katie Pugh, Terrace Consulting Services, LLC
Ms. Lydia Work, Environmental Standards, Inc.

CERTIFICATIONS

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

Pace Analytical Services Pennsylvania

1638 Roseytown Rd Suites 2,3&4, Greensburg, PA 15601
ANAB DOD-ELAP Rad Accreditation #: L2417
ANABISO/IEC 17025:2017 Rad Cert#: L24170
Alabama Certification #: 41590
Arizona Certification #: AZ0734
Arkansas Certification
California Certification #: 2950
Colorado Certification #: PA01547
Connecticut Certification #: PH-0694
EPA Region 4 DW Rad
Florida/TNI Certification #: E87683
Georgia Certification #: C040
Guam Certification
Hawaii Certification
Idaho Certification
Illinois Certification
Indiana Certification
Iowa Certification #: 391
Kansas Certification #: E-10358
Kentucky Certification #: KY90133
KY WW Permit #: KY0098221
KY WW Permit #: KY0000221
Louisiana DHH/TNI Certification #: LA010
Louisiana DEQ/TNI Certification #: 04086
Maine Certification #: 2023021
Maryland Certification #: 308
Massachusetts Certification #: M-PA1457
Michigan/PADEP Certification #: 9991
Missouri Certification #: 235
Montana Certification #: Cert0082
Nebraska Certification #: NE-OS-29-14
Nevada Certification #: PA014572023-03
New Hampshire/TNI Certification #: 297622
New Jersey/TNI Certification #: PA051
New Mexico Certification #: PA01457
New York/TNI Certification #: 10888
North Carolina Certification #: 42706
North Dakota Certification #: R-190
Ohio EPA Rad Approval: #41249
Oregon/TNI Certification #: PA200002-015
Pennsylvania/TNI Certification #: 65-00282
Puerto Rico Certification #: PA01457
Rhode Island Certification #: 65-00282
South Dakota Certification
Tennessee Certification #: TN02867
Texas/TNI Certification #: T104704188-22-18
Utah/TNI Certification #: PA014572223-14
USDA Soil Permit #: 525-23-67-77263
Vermont Dept. of Health: ID# VT-0282
Virgin Island/PADEP Certification
Virginia/VELAP Certification #: 460198
Washington Certification #: C868
West Virginia DEP Certification #: 143
West Virginia DHHR Certification #: 9964C
Wisconsin Approve List for Rad

Pace Analytical Services Beaver

225 Industrial Park Road, Beaver, WV 25813
Virginia VELAP 460148
West Virginia DEP 060
West Virginia DHHR 00412CM
North Carolina DEQ 466
Kentucky Wastewater Certification KY90039
Pennsylvania DEP 68-00839

SAMPLE SUMMARY

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

Lab ID	Sample ID	Matrix	Date Collected	Date Received
30650140001	**Outfall 001 Grab**	Water	12/27/23 15:40	12/28/23 15:20
30650140002	**Grab Field Blank**	Water	12/27/23 15:40	12/28/23 15:20
30650140003	**Outfall 001 Comp**	Water	12/27/23 15:40	12/28/23 15:20

SAMPLE ANALYTE COUNT

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
30650140001	**Outfall 001 Grab**	EPA 1631E	DDL	1	PASI-BV
		SM 4500H+B-2011	BDU	1	PASI-PA
30650140002	**Grab Field Blank**	EPA 1631E	DDL	1	PASI-BV
30650140003	**Outfall 001 Comp**	EPA 200.7	MFC	1	PASI-BV
		SM 2540D-2015	BM1	1	PASI-PA

PASI-BV = Pace Analytical Services - Beaver
PASI-PA = Pace Analytical Services - Greensburg

ANALYTICAL RESULTS

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

Sample: Outfall 001 Grab **Lab ID: 30650140001** Collected: 12/27/23 15:40 Received: 12/28/23 15:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
BVR 1631E Mercury, Low Level	Analytical Method: EPA 1631E Preparation Method: EPA 1631E Pace Analytical Services - Beaver								
Mercury	**33.2**	ng/L	2.5	2.1	1	01/02/24 15:30	01/03/24 13:42	7439-97-6	
4500H+ pH, Electrometric	Analytical Method: SM 4500H+B-2011 Pace Analytical Services - Greensburg								
pH at 25 Degrees C	**8.1**	Std. Units	2.0	2.0	1		12/29/23 15:08		H3,H6

Sample: Grab Field Blank **Lab ID: 30650140002** Collected: 12/27/23 15:40 Received: 12/28/23 15:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
BVR 1631E Mercury, Low Level	Analytical Method: EPA 1631E Preparation Method: EPA 1631E Pace Analytical Services - Beaver								
Mercury	**<0.42**	ng/L	0.50	0.42	1	01/02/24 15:30	01/03/24 13:50	7439-97-6	

Sample: Outfall 001 Comp **Lab ID: 30650140003** Collected: 12/27/23 15:40 Received: 12/28/23 15:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
BVR 200.7 Metals Total	Analytical Method: EPA 200.7 Preparation Method: EPA 200.2 Pace Analytical Services - Beaver								
Lead	**<2.9**	ug/L	10.0	2.9	1	01/02/24 08:33	01/02/24 19:13	7439-92-1	
2540D Total Suspended Solids	Analytical Method: SM 2540D-2015 Pace Analytical Services - Greensburg								
Total Suspended Solids	**11.0**	mg/L	4.0	4.0	1		01/03/24 10:04		PL

QUALITY CONTROL DATA

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

QC Batch: 639641
QC Batch Method: EPA 1631E
Analysis Method: EPA 1631E
Analysis Description: BVR 1631E Mercury
Laboratory: Pace Analytical Services - Beaver
Associated Lab Samples: 30650140001, 30650140002

METHOD BLANK: 3118415 Matrix: Water
Associated Lab Samples: 30650140001, 30650140002

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Mercury	ng/L	<0.42	0.50	0.42	01/03/24 11:24	

METHOD BLANK: 3118416 Matrix: Water
Associated Lab Samples: 30650140001, 30650140002

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Mercury	ng/L	<0.42	0.50	0.42	01/03/24 11:32	

METHOD BLANK: 3118417 Matrix: Water
Associated Lab Samples: 30650140001, 30650140002

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Mercury	ng/L	<0.42	0.50	0.42	01/03/24 11:40	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 3118418 3118419

Parameter	Units	30649409001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Mercury	ng/L	ND	5	5	5.24	5.46	96	100	71-125	4	24	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 3118420 3118421

Parameter	Units	30649989001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Mercury	ng/L	1.29	5	5	5.67	5.88	88	92	71-125	4	24	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

QC Batch: 639442
QC Batch Method: EPA 200.2
Analysis Method: EPA 200.7
Analysis Description: BVR 200.7 Metals, Total
Laboratory: Pace Analytical Services - Beaver

Associated Lab Samples: 30650140003

METHOD BLANK: 3117708 Matrix: Water
Associated Lab Samples: 30650140003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Lead	ug/L	<2.9	10.0	2.9	01/02/24 18:29	

LABORATORY CONTROL SAMPLE: 3117709

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Lead	ug/L	2000	2070	103	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 3117725 3117726

Parameter	Units	30650473001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Lead	ug/L	ND	2000	2000	2100	2050	105	103	70-130	2	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 3117727 3117728

Parameter	Units	30650231002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Lead	ug/L	ND	2000	2000	2040	2040	102	102	70-130	0	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project:	Trimodal Terminal Monthly
Pace Project No.:	30650140

QC Batch:	639728	Analysis Method:	SM 2540D-2015
QC Batch Method:	SM 2540D-2015	Analysis Description:	2540D Total Suspended Solids
		Laboratory:	Pace Analytical Services - Greensburg

Associated Lab Samples: 30650140003

METHOD BLANK: 3118984 Matrix: Water

Associated Lab Samples: 30650140003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Suspended Solids	mg/L	<4.0	4.0	4.0	01/03/24 10:04	

LABORATORY CONTROL SAMPLE: 3118985

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Suspended Solids	mg/L	100	81.0	81	80-120	

SAMPLE DUPLICATE: 3118986

Parameter	Units	30650077001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Suspended Solids	mg/L	ND	<4.0		5	PL

SAMPLE DUPLICATE: 3118987

Parameter	Units	30650104002 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Suspended Solids	mg/L	ND	<4.0		5	PL

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Trimodal Terminal Monthly
Pace Project No.: 30650140

QC Batch: 639306
QC Batch Method: SM 4500H+B-2011
Analysis Method: SM 4500H+B-2011
Analysis Description: 4500H+B pH
Laboratory: Pace Analytical Services - Greensburg

Associated Lab Samples: 30650140001

SAMPLE DUPLICATE: 3117061

Parameter	Units	30650175001 Result	Dup Result	RPD	Max RPD	Qualifiers
pH at 25 Degrees C	Std. Units	7.6	7.7	1	10	H3,H6

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	Trimodal Terminal Monthly
Pace Project No.:	30650140

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Reported results are not rounded until the final step prior to reporting. Therefore, calculated parameters that are typically reported as "Total" may vary slightly from the sum of the reported component parameters.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

WORKORDER QUALIFIERS

WO: 30650140

[1]	(Greensburg, PA) - Revision 1 - This report replaces the 01/08/2024 report. This project was revised on 01/08/2024 to add in the sub report.

ANALYTE QUALIFIERS

H3	Sample was received or analysis requested beyond the recognized method holding time.
H6	Analysis initiated outside of the 15 minute EPA required holding time.
PL	The minimum mass of dried residue of 2.5 mg could not be obtained using the routine sample volume of 100 mL.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	Trimodal Terminal Monthly
Pace Project No.:	30650140

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
30650140001	**Outfall 001 Grab**	EPA 1631E	639641	EPA 1631E	639842
30650140002	**Grab Field Blank**	EPA 1631E	639641	EPA 1631E	639842
30650140003	**Outfall 001 Comp**	EPA 200.2	639442	EPA 200.7	639651
30650140003	**Outfall 001 Comp**	SM 2540D-2015	639728		
30650140001	**Outfall 001 Grab**	SM 4500H+B-2011	639306		

Pace®

Pace® Location Requested (City/State):
Pace Analytical Pittsburgh
1638 Roseytown Road, Suites 2,3,4
Greensburg, PA 15601

CHAIN-OF-CUSTODY Analytical Request Document

Chain-of-Custody is a LEGAL DOCUMENT - Complete all relevant fields

LAB USE ONLY- Affix Workorder/Login Label Here

WO# : 30650140

30650140

Company Name:	Empire Trimodal Terminal, LLC	Contact/Report To:	Chip Fenske
Street Address:	1400 Main Street, Follansbee, WV 26037	Phone #:	(740)434-3779
		E-Mail:	cfenske@empirede.com
		Cc E-Mail:	
Customer Project #:		Invoice To:	Chip Fenske
Project Name:	Trimodal Terminal Monthly	Invoice E-Mail:	cfenske@empirede.com
Site Collection Info/Facility ID (as applicable):		Purchase Order # (if applicable):	
		Quote #:	

Time Zone Collected: [ ] AK [ ] PT [ ] MT [ ] CT [ ] ET

County / State origin of sample(s): West Virginia

Data Deliverables: [ ] Level II [ ] Level III [ ] Level IV [ ] EQUIS [ ] Other

Regulatory Program (DW, RCRA, etc.) as applicable:

Rush (Pre-approval required): [ ] 2 Day [ ] 3 day [ ] 5 day [ ] Other

DW PWSID # or WW Permit # as applicable:

Date Results Requested:

Field Filtered (if applicable): [ ] Yes [ ] No

Analysis:

* Matrix Codes (Insert in Matrix box below): Drinking Water (DW), Ground Water (GW), Waste Water (WW), Product (P), Soil/Solid (SS), Oil (OL), Wipe (WP), Tissue (TS), Bioassay (B), Vapor (V), Other (OT), Surface Water (SW),Sediment (SED), Sludge (SL), Caulk

Specify Container Size **: 3, 3, 3, 3, 1

Identify Container Preservative Type***: 1, 1, 4, 2, 1

**Container Size: (1) 1L, (2) 500mL, (3) 250mL, (4) 125mL, (5) 100mL, (6) 40mL vial, (7) EnCore, (8) TerraCore, (9) Other

*** Preservative Types: (1) None, (2) HNO3, (3) H2SO4, (4) HCl, (5) NaOH, (6) Zn Acetate, (7) NaHSO4, (8) Sod. Thiosulfate, (9) Ascorbic Acid, (10) MeOH, (11) Other

Analysis Requested

Lab Use Only:
Proj. Mgr: Samantha Bayura
AcctNum / Client ID:
Table #:
Profile / Template: 13656
Prelog / Bottle Ord. ID: EZ 3002076

Customer Sample ID	Matrix *	Comp / Grab	Collected (or Composite Start) Date	Collected Time	Composite End Date	Composite End Time	Res. CL2	Number & Type of Containers Plastic	Number & Type of Containers Glass	2540D Total Suspended Solids	4500H+ pH, Electrometric	BVR 1631E Mercury, Low Level	BVR 200.7 Metals Total	LL SVOC 625	Sample Comment	Preservation non-conformance identified for sample.
Outfall 001 Grab	WT	G	12-27-23	1540				1	2		X	X				
Outfall 001 Comp	WT	C	12-27-23	1440	12-27-23	1540		2	3	X			X	X		

Received by Pace Beaver
Therm ID 9 Corr Factor +/- .0
Receipt Temp .8
Corrected Temp .8
Correct Preservation [✓ Y] N

Customer Remarks / Special Conditions / Possible Hazards: 35gpm

Collected By:
Printed Name: Katie Wood
Signature:

Additional Instructions from Pace®:

# Coolers:	Thermometer ID:	Correction Factor (°C):	Obs. Temp. (°C)	Corrected Temp. (°C)
1	14	-0.2	4.0	3.8

Relinquished by/Company: (Signature)	Date/Time:	Received by/Company: (Signature)	Date/Time:
	12-28-23 700	Pace 12-28-23	12:00
	12-28-23 14:00		12-28-23 1400
	12-28-23 1520	Lucy Brum Pace	12-28-23 1520
	12-28-23 2300	Nicely's Del. Service	12-28-23 2300

Tracking Number:

Delivered by: [ ] In- Person ☒ Courier [ ] FedEX [ ] UPS [ ] Other

Page: 1 of 1

Submitting a sample via this chain of custody constitutes acknowledgment and acceptance of the Pace® Terms and Conditions found at https://www.pacelabs.com/resource-library/resource/pace-terms-and-conditions/

ENV-FRM-CORQ-0019_v01_082123 ©

Nicely's Del. Service 12-29-23

CWilan 12-29-23 0000

Pace ANALYTICAL SERVICES

DC#_Title: ENV-FRM-GBUR-0088 v06_Samp
Pittsburgh

Effective Date: 09/20/2023

WO#: 30650140
PM: SMB Due Date: 01/15/24
CLIENT: TRIMODAL

Client Name: Empire Trimodal Terminal

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☐ Client ☐ Commercial ☒ Pace ☐ Other
Tracking Number: Drop-Off

Initial / Date
Examined By: LB 122823
Labeled By: LB 122823
Temped By: LB 122823

Custody Seal on Cooler/Box Present: ☐ Yes ☒ No **Seals Intact:** ☐ Yes ☒ No
Thermometer Used: 19 **Type of Ice:** [✓ Wet] Blue None
Cooler Temperature: Observed Temp 4.0 °C Correction Factor: -0.2 °C Final Temp: 3.8 °C
Temp should be above freezing to 6°C

pH paper Lot# 1001632
D.P.D. Residual Chlorine Lot # 042V33HKK

Comments:	Yes	No	NA	
Chain of Custody Present	X			1.
Chain of Custody Filled Out:	X			2.
-Were client corrections present on COC		X		
Chain of Custody Relinquished	X			3.
Sampler Name & Signature on COC:	X			4.
Sample Labels match COC:	X			5. Labels on AG1U 2/3 and 3/3 difficult to read. Marker rubbed off.
-Includes date/time/ID Matrix: WT				
Samples Arrived within Hold Time:	X			6.
Short Hold Time Analysis (<72hr remaining):		X		7.
Rush Turn Around Time Requested:		X		8.
Sufficient Volume:	X			9.
Correct Containers Used:	X			10.
-Pace Containers Used	X			
Containers Intact:	X			11.
Orthophosphate field filtered:			X	12.
Hex Cr Aqueous samples field filtered:			X	13.
Organic Samples checked for dechlorination	X			14:
Filtered volume received for dissolved tests:			X	15:
All containers checked for preservation:		X		16.
exceptions: VOA, coliform, TOC, O&G, Phenolics, Radon, non-aqueous matrix				LL Mercury
All containers meet method preservation requirements:	X			Initial when completed LB Date/Time of Preservation Lot# of added Preservative
8260C/D: Headspace in VOA Vials (> 6mm)			X	17.
624.1: Headspace in VOA Vials (0mm)			X	18.
Trip Blank Present:			X	Trip blank custody seal present? YES or NO
Rad Samples Screened <.05 mrem/hr.	X			Initial when completed LB Date: 122823 Survey Meter SN: 25014286

Comments:

Note: For NC compliance samples with discrepancies, a copy of this form must be sent to the DEHNR Certification office.
PM Review is documented electronically in LIMS through the SRF Review schedule in the Workorder Edit Screen.

Pace Container Order #3002076

samantha.bayura@pacelabs.com

PLEASE RETURN THIS COPY WITH COC

Addresses

	Order By :	**Ship To :**	**Return To:**
Company	Terrace Consulting Services, LLC	Terrace Consulting Services, LLC	Greensburg, PA (Pace Analytical
Contact	Pugh, Katie	Pugh, Katie	Samantha Bayura
Email	kpugh1045@gmail.com	kpugh1045@gmail.com	samantha.bayura@pacelabs.com
Address	14 Lorraine Terrace	14 Lorraine Terrace	1638 Roseytown Road
Address 2			Suites 2,3,4
City	Wheeling	Wheeling	Greensburg
State	WV	WV	PA
Zip	26003	26003	15601
Phone	(304)650-2804	(304)650-2804	(724)850-5622

Info

Project Name Trimodal Terminal Monthly
Due Date 12/04/2023
Profile 13656
Quote
Project Manager Bayura, Samantha
Return Date
Carrier Pace Courier
Location WV

Return Shipping Labels

Return Label Type
☐ No Shipper
☐ With Shipper

Bottle Labels

☐ Blank
☐ Pre-Printed No Sample IDs
☒ Pre-Printed With Sample IDs

Bottles

☐ Boxed Cases
☐ Individually Wrapped
☐ Grouped By Sample ID/Matrix

Trip Blanks

☐ Include Trip Blanks

COC Options

☐ Number of Blanks
☒ Pre-Printed

Misc

☐ Sampling Instructions
☐ Custody Seal
☐ Temp. Blanks
☒ Coolers
☐ Syringes
☐ Extra Bubble Wrap
☐ Short Hold/Rush Stickers
☐ DI Water
☐ USDA Regulated Soils
☐ Dry Weight

# of Samp	Matrix	Analysis	Qty / Samp	Container	Total	# of QC	Lot #	Notes
1	WT	1L SVOC 625	1	1L amber glass unpreserved	1	2	100923-1DDN	2 Extra for lab MS/MSD
1	WT	2540D Total Suspended Solids	1	1L plastic unpreserved	1		081423-2EEV	
1	WT	BVR 1631E Mercury, Low Level	1	250mL clear glass HCl	1		0230401H	send blank
1	WT	BVR 200.7 Metals Total	1	250mL plastic HNO3	1		100923-2EIZ	
1	WT	4500H+ pH, Electrometric	1	250mL plastic unpreserved	1		061223-2EIY	

WO# : 30650140

PM: SMB
Due Date: 01/15/24
CLIENT: TRIMODAL

Hazard Shipping Placard In Place : N/A

*Sample receiving hours are typically 8am-5pm, but may differ by location. Please check with your Pace Project Manager.

*Pace Analytical reserves the right to return hazardous, toxic, or radioactive samples to you.

*Pace Analytical reserves the right to charge for unused bottles, as well as cost associated with sample storage/disposal.

*Payment term are net 30 days.

*Please include the proposal number on the chain of custody to ensure proper billing.

LAB USE:

Ship Date : 12/04/2023
Prepared By: David F
Verified By:

CLIENT USE (Optional):

Date Rec'd:
Received By:

Sample Notes :

1
2
3
4
5
6
7
8
9
10
11
12
13

ANALYTICAL REPORT

PREPARED FOR

Attn: Ms. Samantha Bayura
Pace Analytical Services LLC
1638 Roseytown Road
Suites 2,3, and 4
Greensburg, Pennsylvania 15601

Generated 1/8/2024 6:19:49 AM

JOB DESCRIPTION

PAH Analyses

JOB NUMBER

180-167574-1

Eurofins Pittsburgh
301 Alpha Drive
RIDC Park
Pittsburgh PA 15238

See page two for job notes and contact information.

Job Notes

This report may not be reproduced except in full, and with written approval from the laboratory. The results relate only to the samples tested. For questions please contact the Project Manager at the e-mail address or telephone number listed on this page.

PA Lab ID: 02-00416

The test results in this report relate only to the samples as received by the laboratory and will meet all requirements of the methodology, with any exceptions noted. This report shall not be reproduced except in full, without the express written approval of the laboratory. All questions should be directed to the Eurofins Pittsburgh Project Manager.

Authorization

Generated
1/8/2024 6:19:49 AM

Authorized for release by
Sarah Steadman, Project Manager
sarah.steadman@et.eurofinsus.com
(412)963-7058

Table of Contents

Case Narrative

Job ID: 180-167574-1 Eurofins Pittsburgh

Job Narrative
180-167574-1

Analytical test results meet all requirements of the associated regulatory program listed on the Accreditation/Certification Summary Page unless otherwise noted under the individual analysis. Data qualifiers are applied to indicate exceptions. Noncompliant quality control (QC) is further explained in narrative comments.

- Matrix QC may not be reported if insufficient sample or site-specific QC samples were not submitted. In these situations, to demonstrate precision and accuracy at a batch level, a LCS/LCSD may be performed, unless otherwise specified in the method.
- Surrogate and/or isotope dilution analyte recoveries (if applicable) which are outside of the QC window are confirmed unless attributed to a dilution or otherwise noted in the narrative.

Regulated compliance samples (e.g. SDWA, NPDES) must comply with the associated agency requirements/permits.

Receipt
The sample was received on 1/3/2024 9:45 AM. Unless otherwise noted below, the sample arrived in good condition, and, where required, properly preserved and on ice. The temperature of the cooler at receipt time was 0.7°C

GC/MS Semi VOA
Method 625.1_LL_PREC: Received limited quantity, insufficient amount for MSD.

(180-167574-B-1 MS)

No additional analytical or quality issues were noted, other than those described above or in the Definitions/ Glossary page.

Definitions/Glossary

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CFU	Colony Forming Unit
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MCL	EPA recommended "Maximum Contaminant Level"
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
MPN	Most Probable Number
MQL	Method Quantitation Limit
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
NEG	Negative / Absent
POS	Positive / Present
PQL	Practical Quantitation Limit
PRES	Presumptive
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)
TNTC	Too Numerous To Count

Accreditation/Certification Summary

Laboratory: Eurofins Pittsburgh

The accreditations/certifications listed below are applicable to this report.

Authority	Program	Identification Number	Expiration Date
Pennsylvania	NELAP	02-00416	04-30-24
West Virginia DEP	State	142	01-31-24

Sample Summary

Client: Pace Analytical Services LLC
Project/Site: PAH Analyses

Job ID: 180-167574-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
180-167574-1	OUTFALL 001 COMP	Water	12/27/23 15:40	01/03/24 09:45

Method Summary

Client: Pace Analytical Services LLC
Project/Site: PAH Analyses

Job ID: 180-167574-1

Method	Method Description	Protocol	Laboratory
EPA 625.1	Semivolatile Organic Compounds (GC/MS)	40 CFR 761	EET PIT
625	Liquid-Liquid Extraction	EPA	EET PIT

Protocol References:

40 CFR 761 = Toxic Substances Control Act (TSCA)
EPA = US Environmental Protection Agency

Laboratory References:

EET PIT = Eurofins Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

Lab Chronicle

Client: Pace Analytical Services LLC
Job ID: 180-167574-1
Project/Site: PAH Analyses

Client Sample ID: OUTFALL 001 COMP

Lab Sample ID: 180-167574-1

Date Collected: 12/27/23 15:40
Matrix: Water
Date Received: 01/03/24 09:45

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	625			1000 mL	1.0 mL	455959	01/03/24 13:39	BJT	EET PIT
Total/NA	Analysis	EPA 625.1		1	1 mL	1 mL	456193	01/05/24 19:22	VVP	EET PIT
	Instrument ID:	CH733								

Laboratory References:

EET PIT = Eurofins Pittsburgh, 301 Alpha Drive, RIDC Park, Pittsburgh, PA 15238, TEL (412)963-7058

Analyst References:

Lab: EET PIT
    Batch Type: Prep
        BJT = Bill Trout
    Batch Type: Analysis
        VVP = Vincent Piccolino

Client Sample ID: OUTFALL 001 COMP

Lab Sample ID: 180-167574-1

Date Collected: 12/27/23 15:40

Matrix: Water

Date Received: 01/03/24 09:45

Method: 40 CFR 761 EPA 625.1 - Semivolatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzo[a]anthracene	ND		0.19	0.075	ug/L		01/03/24 13:39	01/05/24 19:22	1
Benzo[a]pyrene	ND		0.19	0.053	ug/L		01/03/24 13:39	01/05/24 19:22	1
Benzo[b]fluoranthene	ND		0.19	0.097	ug/L		01/03/24 13:39	01/05/24 19:22	1
Benzo[k]fluoranthene	ND		0.19	0.088	ug/L		01/03/24 13:39	01/05/24 19:22	1
Chrysene	ND		0.19	0.081	ug/L		01/03/24 13:39	01/05/24 19:22	1
Dibenz(a,h)anthracene	ND		0.19	0.072	ug/L		01/03/24 13:39	01/05/24 19:22	1
Indeno[1,2,3-cd]pyrene	ND		0.19	0.085	ug/L		01/03/24 13:39	01/05/24 19:22	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
2-Fluorobiphenyl (Surr)	*70*		*47 - 107*	*01/03/24 13:39*	*01/05/24 19:22*	*1*
2-Fluorophenol (Surr)	*72*		*35 - 109*	*01/03/24 13:39*	*01/05/24 19:22*	*1*
Nitrobenzene-d5 (Surr)	*68*		*47 - 110*	*01/03/24 13:39*	*01/05/24 19:22*	*1*
Phenol-d5 (Surr)	*69*		*37 - 110*	*01/03/24 13:39*	*01/05/24 19:22*	*1*
Terphenyl-d14 (Surr)	*70*		*32 - 115*	*01/03/24 13:39*	*01/05/24 19:22*	*1*
2,4,6-Tribromophenol (Surr)	*83*		*32 - 127*	*01/03/24 13:39*	*01/05/24 19:22*	*1*

QC Sample Results

Client: Pace Analytical Services LLC　　Job ID: 180-167574-1
Project/Site: PAH Analyses

Method: EPA 625.1 - Semivolatile Organic Compounds (GC/MS)

Lab Sample ID: MB 180-455959/1-A　　**Client Sample ID: Method Blank**
Matrix: Water　　**Prep Type: Total/NA**
Analysis Batch: 456193　　**Prep Batch: 455959**

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Benzo[a]anthracene	ND		0.19	0.075	ug/L		01/03/24 13:39	01/05/24 14:40	1
Benzo[a]pyrene	ND		0.19	0.053	ug/L		01/03/24 13:39	01/05/24 14:40	1
Benzo[b]fluoranthene	ND		0.19	0.097	ug/L		01/03/24 13:39	01/05/24 14:40	1
Benzo[k]fluoranthene	ND		0.19	0.088	ug/L		01/03/24 13:39	01/05/24 14:40	1
Chrysene	ND		0.19	0.081	ug/L		01/03/24 13:39	01/05/24 14:40	1
Dibenz(a,h)anthracene	ND		0.19	0.072	ug/L		01/03/24 13:39	01/05/24 14:40	1
Indeno[1,2,3-cd]pyrene	ND		0.19	0.085	ug/L		01/03/24 13:39	01/05/24 14:40	1

Surrogate	*MB %Recovery*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
2-Fluorobiphenyl (Surr)	*76*		*47 - 107*	*01/03/24 13:39*	*01/05/24 14:40*	*1*
2-Fluorophenol (Surr)	*76*		*35 - 109*	*01/03/24 13:39*	*01/05/24 14:40*	*1*
Nitrobenzene-d5 (Surr)	*70*		*47 - 110*	*01/03/24 13:39*	*01/05/24 14:40*	*1*
Phenol-d5 (Surr)	*72*		*37 - 110*	*01/03/24 13:39*	*01/05/24 14:40*	*1*
Terphenyl-d14 (Surr)	*77*		*32 - 115*	*01/03/24 13:39*	*01/05/24 14:40*	*1*
2,4,6-Tribromophenol (Surr)	*72*		*32 - 127*	*01/03/24 13:39*	*01/05/24 14:40*	*1*

Lab Sample ID: LCS 180-455959/2-A　　**Client Sample ID: Lab Control Sample**
Matrix: Water　　**Prep Type: Total/NA**
Analysis Batch: 456193　　**Prep Batch: 455959**

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec Limits
Benzo[a]anthracene	10.0	7.25		ug/L		72	33 - 143
Benzo[a]pyrene	10.0	6.87		ug/L		69	17 - 150
Benzo[b]fluoranthene	10.0	6.52		ug/L		65	24 - 150
Benzo[k]fluoranthene	10.0	6.94		ug/L		69	11 - 150
Chrysene	10.0	7.24		ug/L		72	17 - 150
Dibenz(a,h)anthracene	10.0	7.31		ug/L		73	10 - 150
Indeno[1,2,3-cd]pyrene	10.0	7.19		ug/L		72	10 - 150

Surrogate	*LCS %Recovery*	*LCS Qualifier*	*Limits*
2-Fluorobiphenyl (Surr)	*69*		*47 - 107*
2-Fluorophenol (Surr)	*72*		*35 - 109*
Nitrobenzene-d5 (Surr)	*68*		*47 - 110*
Phenol-d5 (Surr)	*71*		*37 - 110*
Terphenyl-d14 (Surr)	*59*		*32 - 115*
2,4,6-Tribromophenol (Surr)	*84*		*32 - 127*

Lab Sample ID: 180-167574-1 MS　　**Client Sample ID: OUTFALL 001 COMP**
Matrix: Water　　**Prep Type: Total/NA**
Analysis Batch: 456193　　**Prep Batch: 455959**

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec Limits
Benzo[a]anthracene	ND		9.62	7.06		ug/L		73	33 - 143
Benzo[a]pyrene	ND		9.62	6.79		ug/L		71	17 - 163
Benzo[b]fluoranthene	ND		9.62	6.42		ug/L		67	24 - 159
Benzo[k]fluoranthene	ND		9.62	6.56		ug/L		68	11 - 162
Chrysene	ND		9.62	7.08		ug/L		74	17 - 168
Dibenz(a,h)anthracene	ND		9.62	7.30		ug/L		76	10 - 170

QC Sample Results

Client: Pace Analytical Services LLC
Project/Site: PAH Analyses

Job ID: 180-167574-1

Method: EPA 625.1 - Semivolatile Organic Compounds (GC/MS) (Continued)

Lab Sample ID: 180-167574-1 MS
Matrix: Water
Analysis Batch: 456193

Client Sample ID: OUTFALL 001 COMP
Prep Type: Total/NA
Prep Batch: 455959

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec Limits
Indeno[1,2,3-cd]pyrene	ND		9.62	7.28		ug/L		76	10 - 170

Surrogate	*MS %Recovery*	*MS Qualifier*	*Limits*
2-Fluorobiphenyl (Surr)	*67*		*47 - 107*
2-Fluorophenol (Surr)	*64*		*35 - 109*
Nitrobenzene-d5 (Surr)	*65*		*47 - 110*
Phenol-d5 (Surr)	*64*		*37 - 110*
Terphenyl-d14 (Surr)	*56*		*32 - 115*
2,4,6-Tribromophenol (Surr)	*83*		*32 - 127*

QC Association Summary

Client: Pace Analytical Services LLC
Project/Site: PAH Analyses

Job ID: 180-167574-1

GC/MS Semi VOA

Prep Batch: 455959

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-167574-1	OUTFALL 001 COMP	Total/NA	Water	625	
MB 180-455959/1-A	Method Blank	Total/NA	Water	625	
LCS 180-455959/2-A	Lab Control Sample	Total/NA	Water	625	
180-167574-1 MS	OUTFALL 001 COMP	Total/NA	Water	625	

Analysis Batch: 456193

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
180-167574-1	OUTFALL 001 COMP	Total/NA	Water	EPA 625.1	455959
MB 180-455959/1-A	Method Blank	Total/NA	Water	EPA 625.1	455959
LCS 180-455959/2-A	Lab Control Sample	Total/NA	Water	EPA 625.1	455959
180-167574-1 MS	OUTFALL 001 COMP	Total/NA	Water	EPA 625.1	455959

Chain of Custody

PASI Pittsburgh Laboratory

Pace®

Workorder: 30650140 **Workorder Name:** Trimodal Terminal Monthly **Results Requested By:** 1/15/2024

Report / Invoice To	**Subcontract To**
Samantha Bayura Pace Analytical Pittsburgh 1638 Roseytown Road Suites 2,3,4 Greensburg, PA 15601 Phone (724)850-5622 Email: samantha.bayura@pacelabs.com	Eurofins-Pittsburgh 301 Alpha Drive Pittsburgh, PA 15238 P.O. 30650140

Send Invoice To: **invoices@pacelabs.coupahost.com**
State of Sample Origin: WV

C2
-0.7 1.4
#17
PM
CT:0.7

					Preserved Containers					**Requested Analysis**												
Item	**Sample ID**	**Collect Date/Time**	**Lab ID**	**Matrix**	Unpreserved					625 LL SVOC see list below												**LAB USE ONLY**
1	Outfall 001 Comp	12/27/2023 15:40	30650140003	Water						X												
2																						
3																						
4																						
5																						

Transfers	**Released By**	**Date/Time**	**Received By**	**Date/Time**
1		1/3/24 0945	EPitHNE	01/03/24 0945
2				
3				

Comments

625 LL - Benzo(A)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene

Cooler Temperature on Receipt °C **Custody Seal Y or N** **Received on Ice Y or N** **Samples Intact Y or N**

180-167574 Chain of Custody

Login Sample Receipt Checklist

Client: Pace Analytical Services LLC

Job Number: 180-167574-1

Login Number: 167574

List Source: Eurofins Pittsburgh

List Number: 1

Creator: Abernathy, Eric L

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Exhibit 11

FOLLANSBEE HOOVERSON HEIGHTS
WV3300512
Consumer Confidence Report – 2025
Covering Calendar Year – 2024

This brochure is a snapshot of the quality of the water that we provided last year. Included are the details about where your water comes from, what it contains, and how it compares to Environmental Protection Agency (EPA) and state standards. We are committed to providing you with information because informed customers are our best allies. If you would like to observe the decision-making process that affects drinking water quality or if you have any questions, comments or suggestions, please attend any regularly scheduled water board meeting held on the third Thursday of each month at 6:00 p.m. in the Council Chambers or call DAVID A. VELEGOL, JR. at 304-527-1330.

Your water comes from Surface water:

Source Name	Source Water Type
INTAKE OHIO RIVER	Surface water
WELL #1	Ground water
WELL #2	Ground water
WELL #3	Ground water

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as those with cancer undergoing chemotherapy, people who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. EPA/CDC guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline (800-426-4791).

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the EPA's Safe Drinking Water Hotline (800-426-4791).

The sources of drinking water (both tap water and bottled water) included rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in sources water before we treat it include:
Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, livestock operations and wildlife.
Inorganic contaminants, such as salts and metals, which can be naturally-occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming.
Pesticides and herbicides, which may come from a variety of sources such as storm water run-off, agriculture, and residential users.
Radioactive contaminants, which can be naturally occurring or the result of mining activity.
Organic contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and also come from gas stations, urban storm water run-off, and septic systems.

In order to ensure that tap water is safe to drink, EPA prescribes regulation which limits the amount of certain contaminants in water provided by public water systems. We treat our water according to EPA's regulations. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health.

Our water system has an estimated population of 4970 and is required to test a minimum of 6 sample(s) per month in accordance with the Total Coliform Rule for microbiological contaminants. Coliform bacteria are usually harmless, but their presence in water can be an indication of disease-causing bacteria. When coliform bacteria are found, special follow-up tests are done to determine if harmful bacteria are present in the water supply. If this limit is exceeded, the water supplier must notify the public.

Water Quality Data

The following tables list all of the drinking water contaminants which were detected during the 2024 calendar year. The presence of these contaminants does not necessarily indicate the water poses a health risk. Unless noted, the data presented in this table is from the testing done January 1- December 31, 2024. The state requires us to monitor for certain contaminants less than once per year because the concentrations of these contaminants are not expected to vary significantly from year to year. Some of the data, though representative of the water quality, is more than one year old.

Terms & Abbreviations

Maximum Contaminant Level Goal (MCLG): the “Goal” is the level of a contaminant in drinking water below which there is no known or expected risk to human health. MCLGs allow for a margin of safety.
Maximum Contaminant Level (MCL): the “Maximum Allowed” is the highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.
Secondary Maximum Contaminant Level (SMCL): recommended level for a contaminant that is not regulated and has no MCL.
Action Level (AL): the concentration of a contaminant that, if exceeded, triggers treatment or other requirements.
Treatment Technique (TT): a required process intended to reduce levels of a contaminant in drinking water.
Maximum Residual Disinfectant Level (MRDL): the highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
Non-Detects (ND): lab analysis indicates that the contaminant is not present.
Parts per Million (ppm): or milligrams per liter (mg/L)
Parts per Billion (ppb): or micrograms per liter (µg/L)
Picocuries per Liter (pCi/L): a measure of the radioactivity in water.
Millirems per Year (mrem/yr): measure of radiation absorbed by the body.
Monitoring Period Average (MPA): An average of sample results obtained during a defined time frame, common examples of monitoring periods are monthly, quarterly and yearly.
Nephelometric Turbidity Unit (NTU): a measure of the clarity of water. Turbidity in excess of 5 NTU is just noticeable to the average person. Turbidity is not regulated for groundwater systems.
Running Annual Average (RAA): an average of sample results obtained over the most current 12 months and used to determine compliance with MCLs.
Locational Running Annual Average (LRAA): Average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

Testing Results for: FOLLANSBEE HOOVERSON HEIGHTS

Regulated Contaminants	Collection Date	Highest Value	Range (low/high)	Unit	MCL	MCLG	Typical Source
ANTIMONY, TOTAL	8/6/2024	0.085	0.085	ppb	6	6	Discharge from petroleum refineries; fire retardants; ceramics; electronics;solder
BARIUM	8/6/2024	0.054	0.054	ppm	2	2	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits
CHROMIUM	8/6/2024	0.86	0.86	ppb	100	100	Discharge from steel and pulp mills; Erosion of natural deposits
FLUORIDE	8/6/2024	0.5	0.5	ppm	4	4	Erosion of natural deposits; Water additive which promotes strong teeth; Discharge from fertilizer and aluminum factories
NITRATE	8/6/2024	0.74	0.74	ppm	10	10	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits
NITRATE-NITRITE	3/1/2022	1.1	1.1	ppm	10	10	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits
SELENIUM	8/6/2024	1.2	1.2	ppb	50	50	Discharge from petroleum and metal refineries; Erosion of natural deposits; Discharge from mines

Disinfection Byproducts	Sample Point	Collection Date	Highest LRAA Value	Range (low/high)	Unit	MCL	MCLG	Typical Source
TOTAL HALOACETIC ACIDS (HAA5)	3305 TENT CHURCH ROAD	2024	35	29 - 44	ppb	60	0	By-product of drinking water disinfection
TOTAL HALOACETIC ACIDS (HAA5)	727 MORTON HILL ROAD	2024	33	23 - 37	ppb	60	0	By-product of drinking water disinfection
TTHM	3305 TENT CHURCH ROAD	2024	55	33 - 61	ppb	80	0	By-product of drinking water chlorination
TTHM	727 MORTON HILL ROAD	2024	53	27 - 60	ppb	80	0	By-product of drinking water chlorination

Lead and Copper	**Monitoring Period**	**90TH Percentile**	**Range (low/high)**	**Unit**	**AL**	**Sites Over AL**	**Typical Source**
COPPER, FREE	2022 - 2024	0.175	0.0125 - 0.257	ppm	1.3	0	Corrosion of household plumbing systems; Erosion of natural deposits; Leaching from wood preservatives
LEAD	2022 - 2024	1.5	0.093 - 4.8	ppb	15	0	Corrosion of household plumbing systems; Erosion of natural deposits

There is no safe level of lead in drinking water. Exposure to lead in drinking water can cause serious health effects in all age groups, especially pregnant people, infants (both formula-fed and breastfed), and young children. Some of the health effects to infants and children include decreases in IQ and attention span. Lead exposure can also result in new or worsened learning and behavior problems. The children of people who are exposed to lead before or during pregnancy may be at increased risk of these harmful health effects. Adults have increased risks of heart disease, high blood pressure, kidney or nervous system problems. Contact your health care provider for more information about your risks.

Lead can cause serious health effects in people of all ages, especially pregnant people, infants (both formula-fed and breastfed), and young children. Lead in drinking water is primarily from materials and parts used in service lines and in home plumbing. FOLLANSBEE HOOVERSON HEIGHTS is responsible for providing high quality drinking water and removing lead pipes but cannot control the variety of materials used in the plumbing in your home. Because lead levels may vary over time, lead exposure is possible even when your tap sampling results do not detect lead at one point in time. You can help protect yourself and your family by identifying and removing lead materials within your home plumbing and taking steps to reduce your family's risk. Using a filter, certified by an American National Standards Institute accredited certifier to reduce lead, is effective in reducing lead exposures. Follow the instructions provided with the filter to ensure the filter is used properly. Use only cold water for drinking, cooking, and making baby formula. Boiling water does not remove lead from water. Before using tap water for drinking, cooking, or making baby formula, flush your pipes for several minutes. You can do this by running your tap, taking a shower, doing laundry or a load of dishes. If you have a lead service line or galvanized requiring replacement service line, you may need to flush your pipes for a longer period. If you are concerned about lead in your water and wish to have your water tested, contact FOLLANSBEE HOOVERSON HEIGHTS and DAVID A. VELEGOL, JR. at 304-527-1330. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available at https://www.epa.gov/safewater/lead.

FOLLANSBEE HOOVERSON HEIGHTS completed lead tap sampling in 2022 - 2024 the results are available for review and can be accessed by emailing Sam Mazzone@follansbeewater@gmail.com.

FOLLANSBEE HOOVERSON HEIGHTS has prepared a service line inventory identifying service line materials throughout the water distribution supply. The most up to date inventory is located at thecityoffollansbee.com. By November 1, 2027, our water system must develop an updated initial inventory, known as the “baseline inventory” and it must include each service line and identified connector that is connected to the public water distribution system.

Our water system identified ***[unknown]*** service lines in our inventory. Due to this identification our water system must create a service line replacement plan by November 1, 2027.

If you have any questions about our inventory or if you would like information about our service line replacement plan, please contact DAVID A. VELEGOL, JR. at 304-527-1330.

Chlorine/Chloramines Maximum Disinfection Level	**MPA**	**MPA Units**	**RAA**	**RAA Units**
11/1/2024 - 11/30/2024	1.40000	MG/L	1.30000	MG/L

AVAILABILITY OF MONITORING DATA FOR UNREGULATED CONTAMINANTS

Our water system has sampled for a series of unregulated contaminants. Unregulated contaminants are those that do not yet have a drinking water standard set by the US Environmental Protection Agency (EPA). The purpose of monitoring for these contaminants is to help EPA decide whether the contaminants should have a standard. As our customers, you have a right to know that this data is available.

If you are interested in examining the results, please contact: *[Contact Name] at [Phone Number].*

Total Organic Carbon Lowest Month for Removal	**Collection Date**	**Highest Value**	**Range**	**Unit**	**TT**	**Typical Source**
CARBON, TOTAL	3/12/2024	4	0 - 4	MG/L	0	Naturally present in the environment

Analyte	Facility	Highest Value	Unit of Measure	Month Occurred
Turbidity	TREATMENT PLANT	0.4	NTU	September

Radiological Contaminants	Collection Date	Highest Value	Range	Unit	MCL	MCLG	Typical Source
COMBINED RADIUM (-226 & -228)	8/1/2023	4.2	4.2	pCi/L	5	0	Erosion of natural deposits
RADIUM-226	8/1/2023	2.1	2.1	pCi/L	0	0	Erosion of natural deposits

Secondary Contaminants-Non Health Based Contaminants- No Federal Maximum Contaminant Level (MCL) Established.	Collection Date	Highest Value	Range (low/high)	Unit	SMCL
NICKEL	8/6/2024	0.00097	0.00097	MG/L	0.1
SODIUM	8/6/2024	44.1	44.1	MG/L	1000

During the 2024 calendar year, we had the below noted violation(s) of drinking water regulations.

Compliance Period	Analyte	Comments
1/1/2023 - 3/31/2023	PUBLIC NOTICE	Failed to issue public notice or failed to provide a copy of the notice and certification to the state. (Samples were taken in the wrong month of the quarter.)
4/1/2023 - 6/30/2023	PUBLIC NOTICE	Failed to issue public notice or failed to provide a copy of the notice and certification to the state. (Samples were taken in the wrong month of the quarter.)

Coliforms are bacteria that are naturally present in the environment and are used as an indicator that other, potentially harmful waterborne pathogens may be present, or that a potential pathway exists through which contamination may enter the drinking water distribution system. We found coliforms, indicating the need to look for potential problems in water treatment or distribution. When this occurs, we are required to conduct assessment(s) to identify and correct any problems that were found during these assessments.

There are no additional required health effects notices.

There are no additional required health effects violation notices.

Your CCR is available at https://thecityoffollansbee.com/wp-content/uploads/2025/05/2025-CCR_FOLLANSBEE-HOOVERSON-HEIGHTS-WV3300512.pdf. To receive a paper copy in the mail, please contact us at the phone number above.

Exhibit 12

State of West Virginia
Source Water Assessment and Protection Program
Source Water Assessment Report

Follansbee Hooverson Heights
Brooke County
PWSID WV3300512

Prepared by:

West Virginia Department of Health and Human Resources
Bureau for Public Health
Office of Environmental Health Services
Source Water Protection Unit

August 2012

TABLE OF CONTENTS

GROUND WATER PUBLIC SUPPLY SYSTEMS
SOURCE WATER ASSESSMENT AND PROTECTION (SWAP) PROGRAM REPORT

Prepared by: West Virginia Department of Health and Human Resources (WVDHHR), SWAP Program

INTRODUCTION

What is the Purpose of this Report?

The Source Water Assessment and Protection (SWAP) Program of the West Virginia Bureau for Public Health (BPH) is completing assessments of the contamination threats to all public water sources (private wells are not involved in this effort). This concept of source water protection is a preventative approach and complements the effort of proper treatment and disinfection by the individual water supply systems. This assessment is one step in a multilevel approach to ensure a safe future supply of water by understanding what potential threats exist.

This Source Water Assessment Public Summary is to provide information to support local and state efforts to protect public drinking water source and to maintain a safe and dependable water supply for the protection of human health by preventing contamination. The costs of these preventative measures will rarely exceed the cost of remediating a public water supply once it is contaminated.

The emphasis of this assessment is on “source” water rather than the “tap” water. Information on tap water quality is available in the Consumer Confidence Report, which can be obtained from your local water supplier.

This report identifies the significant potential contaminant sources that could threaten source(s) water quality. Your susceptibility ranking does not imply poor water quality. Actual water quality is best reflected by results of regular water tests. Please refer to Table 1 for an informational summary of your public water supply.

The Follansbee Hooverson Heights is located in the town of Hooverson Heights, West Virginia. Source locations, PCS inventories, and activity status are based on data and information collected during a field review conducted by WVDHHR personnel on June 19, 2012. A delineation and assessment is provided for the each source well.

Table 1 Public Water Supply Information

PWS Name	Follansbee Hooverson Heights
Address	P.O. Box 606
City, State, Zip	Follansbee, West Virginia 26037
PWSID#	WV3300512
County	Brooke County
System Type	Community Water System

What is my Well's Source Water Protection Area?

A well(s) source water protection area (SWPA) is the land around the well where protection activities should be focused. The SWPA is the area that is likely contributing water to the well. Please refer to Figure 1 for your SWPA.

What is SWAP?

The SWAP, established under the Safe Drinking Water Act, requires every state to:

- Delineate the area from which a public water supply system receives its water;
- Inventory land uses within the recharge areas of all public water supplies;
- Assess the susceptibility of drinking water sources to contamination from these land uses;
- Publicize the results to provide support for improved protection of sources.

The WVDHHR SWAP will complete all of these components of a source water assessment.

What is Susceptibility?

Susceptibility is a measure of your well field's potential to become contaminated by land uses and activities within the SWPA. The purpose of a susceptibility analysis is to provide an overview to actions a public water system may take to further reduce the susceptibility to their drinking water supply. Because public water supply wells have been constructed in various hydrologic settings and have a range of potentially significant contaminant sources, best professional judgment has been used in determining the susceptibility of each public water system to contamination. The possibility of a release from potential contaminant sources is greatly reduced if Best Management Practices (BMP's) are used. The susceptibility determination for your well did not take into account whether BMP's are being used.

Susceptibility of drinking water does not mean a customer will drink contaminated water. Water suppliers protect drinking water by monitoring and treating water supplies, and using BMP's and source water protection measures to ensure that safe water is delivered to the tap.

How Was my Well's Susceptibility Determined?

Your well field’s susceptibility is based on the following parameters:

- Review of the hydrologic setting (ease of contamination transport through each materials present in the local hydrologic setting);
- Review of the physical integrity of the well(s);
- Review of available ground water quality data;
- Characterization of the potential significant contaminant sources identified in the SWPA;
- Integration of this information to identify the greatest threats to the source water and suggestions of appropriate protection strategies or activities.

Table 2 Source of Your Drinking Water - Hydrogeologic Setting

Well Name	Geologic Setting/Sensitivity
Well 1	Alluvial Valleys Areas – High Sensitivity
Well 2, Inactive	Alluvial Valleys Areas – High Sensitivity
Well 3	Alluvial Valleys Areas – High Sensitivity
Well 4	Alluvial Valleys Areas – High Sensitivity

The Follansbee Hooverson Heights water system serves a population of approximately 5702 people. The supply is from a three out of four source wells and an intake from the Ohio River. Total raw water production is approximately 180,000 GPD for the wells. The source well is located in the Alluvial Valleys province/ area of West Virginia.

The Alluvial Valleys province/ area consist of geological recent flood plains of the larger rivers. These flood plains contain unconfined, fine to coarse grained, slightly silty alluvium.

The estimated land area (approximately 637 acres) that may contribute water to the wells is depicted in the attached map (Figure 1) as the Source Water Protection Area. This is generally based on water use for a five year period with consideration given to influencing hydrogeologic factors. However, in karst areas, source water and contaminant sources may originate from greater distances than encompassed by this interim delineation.

Table 3 Physical Integrity of Well

Well Name	Source Integrity
Well 1	Unknown Construction
Well 2, Inactive	Unknown Construction
Well 3	Unknown Construction
Well 4	Unknown Construction

Wells may vary in their construction characteristics and in the geologic rock types in which they occur. The lack of an effective grout and sanitary seals are avenues by which contaminants from nearby surface water bodies or overland runoff can percolate to wells.

Table 4 Water Quality and Water Treatment Information

Well Name	Results
Well 1	Meets Standards
Well 2	Inactive
Well 3	Meets Standards
Well 4	Meets Standards

The Ground Water Under the Direct Influence (GWUDI) assessment evaluates contaminants that may enter the water drawn directly from the well. The Follansbee Hooverson Heights Wells have not been tested for GWUDI due to already being treated as surface water. The water from the 3 pumping wells is mixed with surface water before treatment. GWUDI testing is not required.

EVALUATION OF SIGNIFICANT POTENTIAL SOURCES OF CONTAMINATION

The inventory for Follansbee Hooverson Heights consists of approximately 14 significant Potential Contaminant Sources (PCS) of which 4 are considered higher threats to ground water. Please refer to Table 5 for a listing of identified PCSs and Figure 1 for their locations within the SWPA. Regulated facilities and activities are listed in Table 5 (if present within the SWPA). Their locations are displayed on the map but they are not sequentially numbered.

Some PCSs that are located outside of the SWPA may be included for information purposes. Water supply wells are not identified on the map for security reasons. Some facilities are not located on the SWPA map as they occur over broad geographic areas (agricultural fields, highways, and railroad right-of-ways).

Each significant potential source of contamination has been analyzed and prioritized (low, moderate, and high, unless otherwise noted) relative to its potential to impact the water supply. It is important to note that the links between the PCS and the primary contaminant types are not intended to be comprehensive, but only those commonly associated with the PCS. Any potential source may have one or more types of contaminants associated with the chemicals indicated. Threat rankings are a combination of the perceived risk of the release of a contaminant from a land use area, the migration route of the contaminant to the well and the relative public health risk of the contaminant itself. The risk rankings are based on the general nature of their activities and the contaminants associated with them, not on facility specific information, such as management practices. This ranking does not take into consideration any unforeseen releases or the dynamics of new PCS's within the delineated SWPA.

A detailed risk assessment of PCS's was beyond the scope of what could be accomplished with available resources and data. A detailed risk analysis is more meaningful when prepared by local decision makers as the bridge from assessment work to protection strategies.

Table 5 Potential Contaminant Sources

Sequential No.	Map Code	PCS Name	PCS Category	Associated Chemicals	Threat to GW
1	I-44	Follansbee Steel Terne – TCS	Industrial	ND	Moderate
2	I-44	Wheeling – Nisshin Plant (WN), Regulated	Industrial	ND	Moderate
3	M-29	City of Follansbee WTP	Municipal	MP, D	Low
4	I-27	Sheet Metal Specialty	Industrial	ALL	Low
5	I-44	Storage Building	Industrial	ND	Low
6	I-44	Hooverson Heights WTP	Industrial	ND	Low
7	C-18	BP Gas Station	Commercial	PH, M, VOC, SOC	High
8	C-18	Former Sunoco Gas Station	Commercial	PH, M, VOC, SOC	High
9	I-44	West Virginia Energy, Inc.	Industrial	ND	Moderate
10	C-15	Mullenbach Funeral Home	Commercial	M, MP, SOC, HM, VOC	Moderate
11	C-7	RPR Preowned Auto's	Commercial	PH, VOC	High
12	C-3	A&J Exhaust Auto Repair	Commercial	PH, M, VOC, HM, SOC	Moderate
	M-7	Highway (WV-2)	Municipal	PH, VOC, M	Moderate
	R-4	Residential (single family homes)	Residential	VOC, SOC, NN	High

Index to Associated Chemicals is as follows:

MP	Microbiological Pathogens: Total/Fecal Coliform, Viruses, Protozoa
NN	Nitrate/Nitrite
VOC	Volatile Organic Compounds
HM	Heavy Metals
M	Metals
SOC	Synthetic Organic Compounds
T	Turbidity
TO	Taste and Odor precursors
R	Radionuclides
PH	Petroleum Hydrocarbons
D	Disinfection byproducts
ND	Not Determined

Based on this summarized narrative and susceptibility review for each well, the overall susceptibility for all the wells the Follansbee Hooverson Heights indicates a High susceptibility to the identified potential sources of contamination.

For this susceptibility analysis, the State combined the inventory results with other relevant information to decide how likely a water supply may become contaminated by the identified potential sources of contamination. This step makes the assessments useful for communities, since it provides information that local decision-makers use to prioritize approaches for protecting the drinking water supply. It does not mean that these wells are currently contaminated or that these wells are going to be contaminated in the near future, but the potential does exist.

RECOMMENDATION FOR YOUR SOURCE WATER ASSESSMENT AND PROTECTION ACTIVITIES

The following list provides specific recommendations for your source water assessment and protection activities.

- An aquifer protection management program should be developed for the well. Preferably, the protection plan should be developed for the entire SWPA with the cooperation of neighboring towns, county, and state agencies. It is recommended that protection and management efforts should focus on obtaining additional information on the sources present to evaluate their risk.

- Plan for and complete the proper abandonment of all inactive supply wells.

- Reduce existing chronic threats by obtaining further detailed information concerning Leaking Underground Storage Tanks (LUST's) or other Underground Storage Tanks (UST's) within the SWPA that are now in service or were in the past. This information should include the type of leak detection and corrosion protection currently being used at the facility.

- Investigate what types of preventative pollution measures are being conducted by the industrial or commercial facilities located within the SWPA. Some facilities may already have developed their Groundwater Protection Plan (GPP) for their facility.

- Inspect the SWPA regularly.

- Implement Land Use Planning tools to influence future developments within the SWPA. One way to accomplish this is to join forces with the county to adopt a zoning ordinance that would govern certain uses that are considered high threats to ground water.

- Provide maps of the SWPA to the County Planning Commission or other appropriate county agency to make them aware of the location of proposed development in relation to the water supply source.

- Establish funds to purchase land banks of critical areas (e.g. around sinkholes, wells, springs) to preserve the areas from future development.

- Support and encourage the implementation of Best Management Practices for agricultural areas including grazing lands, crop production farms, and orchards. In addition, support information can be provided to residents and commercial users to encourage the reduction in over use of common pesticides and fertilizers.

- Implement systems for regular collection of hazardous waste from residents. For example, the Eastern Panhandle Soil Conservation District and the Berkeley County Solid Waste Authority has helped organize amnesty days in the past where residents could bring in all types of hazardous wastes without threat of punishment.

- Encourage and implement public education about your water supply regarding its susceptibility to contamination and ways to protect. This could come in the form of brochures containing information and advice about ground water and the local terrain. For example, the Berkeley County Health Department has an on-going educational program that is presented to all fourth graders in the county.

- Support and encourage the identification of contamination incidents by citizens.

- Include information regarding contamination and source water protection in mailings to homeowners, including non-emergency contact information. Reduce the amount of septic systems in use by extension of the public sewer system or other approved systems.

NEXT STEP:

The next step in source water protection planning is to prepare or update a Source Water Protection Plan (SWPP) plan. The SWPP plan incorporates this source water delineation and assessment report and the following additional sections:

Contingency Planning

A contingency plan documents the system's planned response to interruption of the source water.

Alternative Sources

Information pertaining to alternative water sources focusing on long-term source replacement should the system be required to develop a new source of water due to contamination (or other reasons). This section outlines the most likely sources that can be utilized.

Management Planning

Management planning is the most important element of SWAP. The management plan identifies specific activities that will be pursued by the system to protect their water resources. The system will benefit by taking a proactive approach to source water protection in their source water protection area. It is anticipated that most of the management effort will focus on coordination with government agencies and periodic surveys of the watersheds. It may be necessary to conduct a limited number of special studies to determine actual risk and consequences for selected contaminant sources. This information may be needed before decisions can be made on management activities.

NEED ADDITIONAL INFORMATION?

To obtain additional information and/or links, visit the WVDHHP Web site at http://www.wvdhhr.org/oehs/eed/swap/ or call the SWAP Program at 304-558-2981.

***Disclaimer - The coverage presented in this program are under constant revision as new sites or facilities are added. They may not contain all the potential or existing sites or facilities. The West Virginia Bureau for Public Health is not responsible for the use or interpretation of this information.**

Maps contained in this source water assessment report are provided as a public service by the West Virginia Bureau for Public Health. The Bureau makes no representation regarding completeness or accuracy of the data presented thereon. Efforts are made to verify and update the data used to generate the maps. However, with data sets of this size and nature, eliminating all errors is difficult. Thus, the user assumes total responsibility for verification.

Please report any inaccuracies on either the map or inventory by calling the SWAP Program at 304-558-2981.

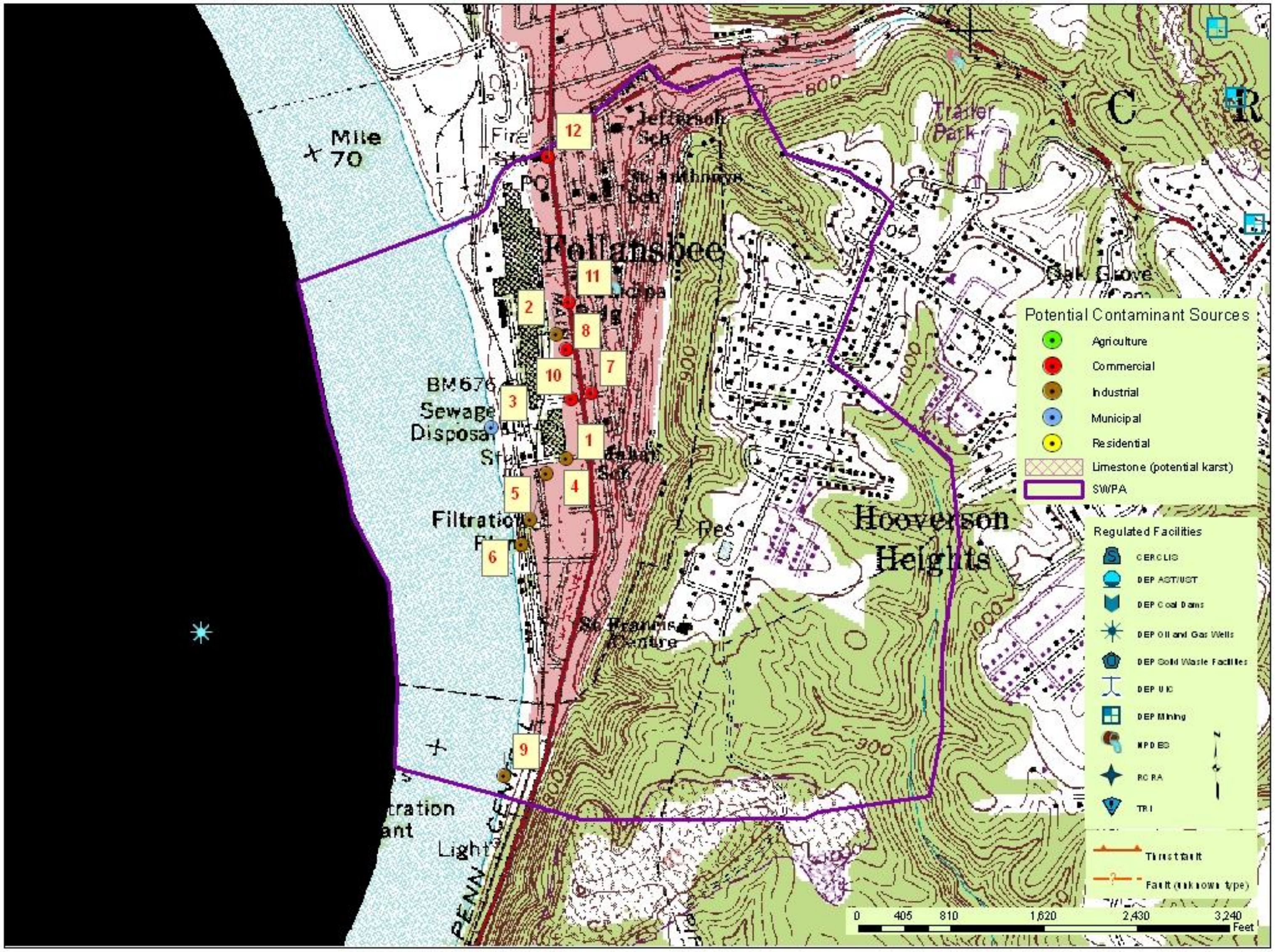


Figure 1: Source Water Protection Area

GLOSSARY OF TERMS

Alluvium - Sediments deposited by moving rivers.

Aquifer - A formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield sufficient, economical quantities of water to wells and springs.

Conjunctive Delineation – In cases where a “ground water” source is designated as Ground Water Under the Direct Influence (GWUDI), an additional delineation in addition to the five (5) year time of travel/recharge delineation for ground water will be completed. The additional delineation will account for stream segments outside of the ground water delineation in cases where the area of surface influence is known or reasonably suspected. It should be noted in karst situations particularly, the surface link is not always an adjacent stream, but could come from a stream miles away. In these cases a conjunctive delineation may not always be performed.

Contamination - The addition to water of any substance or property preventing the use of reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing, washing, recreation, and cooling

Flood Plain - Any land area susceptible to inundation by floodwater from any source.

GWUDI or "Ground Water Under the Direct Influence" - is defined by the EPA as water beneath the surface of the ground with either a significant occurrence of insects or other macro organisms, algae, or large diameter pathogens such as Giardia lambia or Cryptosporidium or other water characteristic such as turbidity, temperature, pH or conductivity.

Hydrogeologic Setting - Evaluates the sensitivity of an aquifer. The likelihood of a contaminant reaching a well or spring is a function of the ground water flows patterns, the rate of flow, the distance to the source and the hydraulic characteristics of the contaminant. The technical factors include the well(s) pumping rate and spring flow, the direction, slope and elevation of the water table, transmissivity and storativity characteristics of the aquifer, overlaying material and recharge rate for ground water systems.

100-year Flood Plain - The area adjoining a river, stream, or water course covered by water in the event of a 100 year flood.

100 -year Flood - The flood having a one percent chance of being equaled or exceeded in magnitude in any given year. Contrary to popular belief it is not a flood occurring once every 100 years.

Karst - A term denoting a formation containing soluble rocks, underground solution passages, sinkholes and springs.

Infiltration - The process of, or fluids, entering the soil and recharging aquifers rather than becoming runoff.

Maximum Contaminant Level (MCL) - Defined as the maximum permissible level of a contaminant in water, which is delivered to any user of a public water system.

Physical Integrity of the Well or Spring - This analysis evaluates and reviews the integrity of the well or spring structures needed to protect the water source from a potential contaminant source(s). It is recognized that protective well construction characteristics can prevent the occurrence of contamination even in the presence of potentially significant contaminant sources. The design and construction of a well should include casing without cracks; tight joints between lengths of casing; adequate grout between the casing and bore hole and location (floodplain or flooding area). A spring must be protected with “shoe box” type lid enclosure that is screened and locked to prevent unauthorized entry. Surface water runoff diversion and land use of the recharge area are paramount elements to evaluate. These features provide reasonable assurance that contaminants will not enter the well or spring through any pathway, and allow operators to focus on the potential for contaminants to migrate through the aquifer and enter into the well(s) or spring. However, even a well(s) and springs constructed to the most exacting standards may lose structural integrity with time. Maintenance records of remedial improvements also will be reviewed in evaluation of integrity.

Potential Contaminant Source (PCS) - A facility or container or route of travel that could release a sufficient amount of a harmful contaminant that upon entering an aquifer or surface stream could contaminate it past the level of human health concerns.

Public Water System - is any water system or water supply which regularly supplies or offers to supply, piped water to the public for human consumption, if serving at least an average of twenty-five (25) individuals per day for at least sixty (60) days per year, or which has at least fifteen (15) service connections.

Recharge - Water entering the upper end of a groundwater flow system.

Remediation - The removal of contaminants from soil and/or ground water.

Sensitivity of the Source Water Protection Area (SWPA) - refers to the hydrologic or hydrogeologic characteristics that affect the transport of the contaminant from a source of contamination to a well or intake.

Source Water Assessment and Protection (SWAP) Program - The program established by the 1996 Amendments to the Safe Drinking Water Act (SDWA) which expanded the initial Wellhead Protection Program to all public drinking water supply systems including surface water systems. This program is to assess, preserve, and protect the source waters which are used to supply water for public drinking water supply systems and to provide a long term availability of an abundant supply of safe water in sufficient quantity for present and future citizens of the State. This program also enables the water supply owners, consumers, and others to initiate and promote actions to protect their drinking water supplies with the developed information.

Source Water Protection Area (SWPA) - refers to the area delineated by the State for a public water system, or including numerous public water systems, whether the source is ground water, surface water or both, as part of the West Virginia SWAP approved by the EPA under section 1453 of the Safe Drinking Water Act.

Susceptibility - The likelihood that a release from a PCS would contaminate and render unusable a drinking water supply such as aquifers or surface steams.

Unconfined Aquifer - An aquifer over which there is no confining layer.

Water quality - Available data will be evaluated to help direct protection activities. If the water quality impact is known, evaluating the source(s) present may help to determine the origin of the contamination and where immediate protection efforts should be focused

Well(s) - refers to ground water intakes including the well structure (i.e., casing, etc) and wellhead.

Wellhead Protection Area (WHPA) - The surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or well field. This area is delineated by the State for ground water source public water systems. The former Wellhead Protection Program (WHPP) is now part of the Source Water Assessment and Protection (SWAP) Program.

Exhibit 13

Prepared in cooperation with the West Virginia Department of Health and Human Resources, Bureau for Public Health

Water-Quality Indicators of Surface-Water-Influenced Groundwater Supplies in the Ohio River Alluvial Aquifer of West Virginia

Scientific Investigations Report 2023–5139

U.S. Department of the Interior
U.S. Geological Survey

Cover. Looking north from the Fort Boreman Scenic Overlook at the confluence of the Ohio River and Little Kanawha River near Parkersburg, West Virginia. Photograph by Matthew Kearns, U.S. Geological Survey.

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Contents

Figures

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F–32)/1.8.

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Activities for radioactive constituents in water are given in picocuries per liter (pCi/L).

Results for measurements of stable isotopes of an element (with symbol E) in water, solids, and dissolved constituents commonly are expressed as the relative difference in the ratio of the number of the less abundant isotope (iE) to the number of the more abundant isotope of a sample with respect to a measurement standard.

Abbreviations

~	approximately
^{14}C	carbon-14
$\delta^{13}C$	delta carbon-13
$^{3}He_{trit}$	tritiogenic helium-3
$^{4}He_{rad}$	radiogenic helium-4
^{3}H	tritium
Ar	argon
CBE	charge-balance error
DIC	dissolved inorganic carbon
DOC	dissolved organic carbon
EA	entrapped air
EPA	U.S. Environmental Protection Agency
GWUDI	groundwater under direct influence
HA	health advisory
HACA	hierarchical agglomerative cluster analysis
KM	Kaplan-Meier
Kr	krypton
LC	line-conditioned
MCL	maximum-contaminant level
N	nitrogen
N_2	nitrogen gas
Ne	neon
NGT	noble gas recharge temperature
permil	parts per thousand
PFAS	per- and polyfluoroalkyl substances
PCA	principal components analysis
R/R_a	the helium isotopic ratio of the sample to that of the atmosphere
RPD	relative percentage difference
SMCL	secondary maximum-contaminant level
SVOC	semi-volatile organic compound

SIMPROF	similarity profile
SF_6	sulfur hexafluoride
SWIG	surface-water-influenced groundwater supply
TDS	total dissolved solids
TU	tritium units
USGS	U.S. Geological Survey
VOC	volatile organic compounds
X	xenon

Water-Quality Indicators of Surface-Water-Influenced Groundwater Supplies in the Ohio River Alluvial Aquifer of West Virginia

By Mitchell A. McAdoo and Gregory T. Connock

Abstract

The U.S. Geological Survey, in cooperation with the West Virginia Department of Health and Human Resources, studied surface-water-influenced groundwater supplies in the Ohio River alluvial aquifer of West Virginia for the purpose of understanding the influence of surface water on groundwater chemistry. Public groundwater supplies obtained from these aquifers receive substantial recharge from surface-water sources and are highly susceptible to degradation from water-soluble contaminants. Water samples were collected from 4 sites in the Ohio River and 23 groundwater wells in the alluvial aquifer from June 2019 to January 2020. Surface-water influence was assessed through characterization of groundwater quality, determination of recharge sources, estimation of groundwater age, and estimation of the fraction of Ohio River water entering groundwater pumped by wells in the alluvial aquifers.

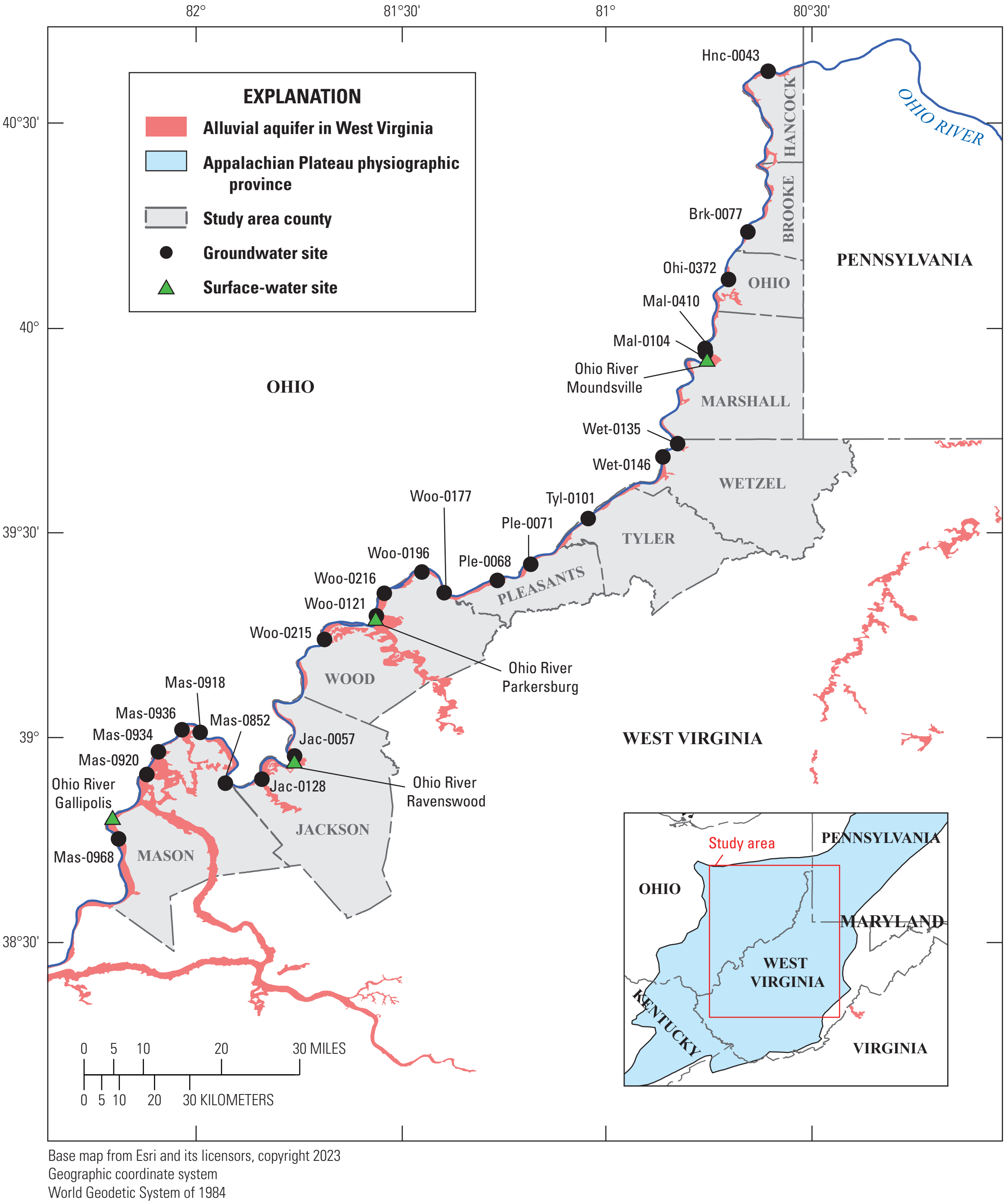
Hydrogeochemical processes controlling solute concentrations in the Ohio River alluvial aquifer were evaluated with multivariate statistical analysis and identified to be primarily controlled by redox processes, input from sources of salinity, and carbonate dissolution. Meteoric recharge from the Ohio River and precipitation on the alluvium are the main sources of water entering the aquifer. The age of groundwater in the system was determined to be primarily from a modern source. Groundwater samples from every well included in this study had detections for at least one geochemical indicator of surface-water influence, and every well was determined to be susceptible and vulnerable to contamination from surface sources.

Results from binary mixing models and inverse geochemical models showed that sulfate, silica, and bicarbonate concentrations predict the fraction of Ohio River water entering alluvial wells for preliminary determination of surface-water influence when compared to fractions predicted using a numerical groundwater-flow model. In the absence of extensive analytes and geochemical or groundwater modeling capabilities, preliminary assessment of the fraction of Ohio River water entering groundwater wells in the Ohio River alluvium can be estimated for most sites using a linear relation between the equivalent ratio of bicarbonate to sulfate and the fraction of water computed by the average of the three geochemical models presented in this report. This approximation of the fraction of Ohio River water, coupled with information on the hydrogeological framework and geochemical indicators of surface-water influence, may be sufficient for preliminary assessment of surface-water influence in the absence of more detailed site information or reaction-transport models.

Introduction

Alluvial aquifers along the Ohio River in West Virginia (fig. 1) represent a substantial groundwater resource for public, domestic, agricultural, and industrial use (Kozar and Brown, 1995; Bader and others, 1997). Despite a small areal extent limited to the Ohio River Valley floodplains, these alluvial aquifers have been estimated to contain more than 50-billion gallons of groundwater (Bader and others, 1997). This exceptional storage capacity derives from favorable aquifer properties related to the heterogenous lithology of the alluvium produced by shifting depositional regimes over time. In general, glacial outwash deposits of medium- to coarse-grained sediments ranging from sand to gravel are overlain by finer-grained fluvial deposits ranging from clay to gravel (Deutsch and others, 1966; Simard, 1989), creating a highly productive, predominantly unconfined, aquifer of variable thickness (Carlston and Graeff 1956; Bader and others, 1997). Compared to the sedimentary bedrock aquifers, the unconsolidated alluvial aquifers produce the greatest yields in West Virginia (Puente, 1985) because of the high transmissivities and specific capacities inherent to the alluvium (Kozar and Mathes, 2001).

Precipitation is the primary natural recharge mechanism to the Ohio River alluvial aquifer (Jeffords, 1945; Bader and others, 1997). However, induced infiltration (recharge from the pumping of wells or flooding) from the Ohio River has become an increasingly important process that can greatly exceed recharge via precipitation (Kozar and McCoy, 2004). The proximity of wells penetrating the alluvium to the Ohio River, combined with highly transmissive



Base map from Esri and its licensors, copyright 2023
Geographic coordinate system
World Geodetic System of 1984

Figure 1. Map showing the study area and sampling locations in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020. U.S. Geological Survey (USGS) site official names and shortened names are in table 1.

aquifers (Kozar and Paybins, 2016), facilitates reversal of natural hydraulic gradients from the river to the aquifer during high river stage and because of frequent pumping in dense wellfields (fig. 2; Jeffords, 1945; Kozar and McCoy, 2004). Whereas high river stage is transient, pumping water from wells is persistent (Maharjan and Donovan, 2017). Consequently, it has been shown that as much as 75 percent of water pumped from the alluvium is attributed to induced infiltration of Ohio River surface water (Kozar and McCoy, 2004), which is further supported by age-dating, water-temperature, and water-chemistry studies (Jeffords, 1945; McCoy and Kozar, 2007; Kozar and Paybins, 2016; Maharjan and Donovan, 2017). Thus, a combination of anthropogenic factors (for example, groundwater pumping), compounded by certain aquifer properties (for example, high transmissivity), has predisposed the Ohio River alluvial aquifer to qualify as a public surface-water-influenced groundwater supply (SWIG) in West Virginia.

Surface-Water-Influenced Groundwater Supply (SWIG)

A SWIG, as defined by West Virginia Code §22-30-3 (West Virginia Legislature, 2014), is “a source of water supply for a public water system which is directly drawn from an underground well, underground river or stream, underground reservoir or underground mine, and the quantity and quality of the water in that underground supply source is heavily influenced, directly or indirectly, by the quantity and quality of surface water in the immediate area.” However, this report assumes a previously published, modification of a SWIG to include “a groundwater supply that is heavily influenced by water recharging the well from adjacent rivers, streams, ponds, lakes, irrigation water, or even precipitation that pools at the surface” (Kozar and Paybins, 2016, p. 2). This definition permits the inclusion of additional sources of contamination from shallow surface processes (for example, crop irrigation) that may affect sources prone to rapid infiltration.

Determination of the intrinsic susceptibility and vulnerability is critical when assessing if an aquifer may be a SWIG (Kozar and Paybins, 2016). Intrinsic susceptibility includes factors like hydrogeologic properties that influence fluid transport in the unsaturated zone of an aquifer (Focazio and others, 2002). Vulnerability of an aquifer includes extrinsic factors like proximal contaminant sources and the ease of contaminant transport into and through an aquifer, which may be exacerbated by well construction design, active physical and chemical subsurface processes, and the intrinsic susceptibility of the aquifer (Eberts and others, 2013).

As SWIGs, portions of the Ohio River alluvial aquifer are defined by high intrinsic susceptibility and high vulnerability to nonmicrobial contaminants (for example, volatile organic compounds, nitrate). High transmissivities in the alluvium (4,800 feet squared per day; Kozar and Mathes, 2001) allow rapid infiltration of overland flow, either from precipitation or flooding, and induced infiltration directly from the Ohio River because of pumping (Kozar and Paybins, 2016). Progressive urbanization, industrialization, and agricultural development along the Ohio River has created multiple sources of contamination and removed surficial clays that retard infiltration (Ferrel, 1987). This removal simultaneously increases the intrinsic susceptibility and vulnerability of the alluvial aquifers that are a major groundwater resource in West Virginia, underlining the need to refine current [2019] delineations of SWIGs in the Ohio River alluvium.

In 2019, the U.S. Geological Survey (USGS) began a study in cooperation with the West Virginia Department of Health and Human Resources for the purpose of understanding the influence of surface water on groundwater chemistry in the alluvial aquifers bordering the Ohio River in West Virginia. The study was limited to the alluvial aquifers along

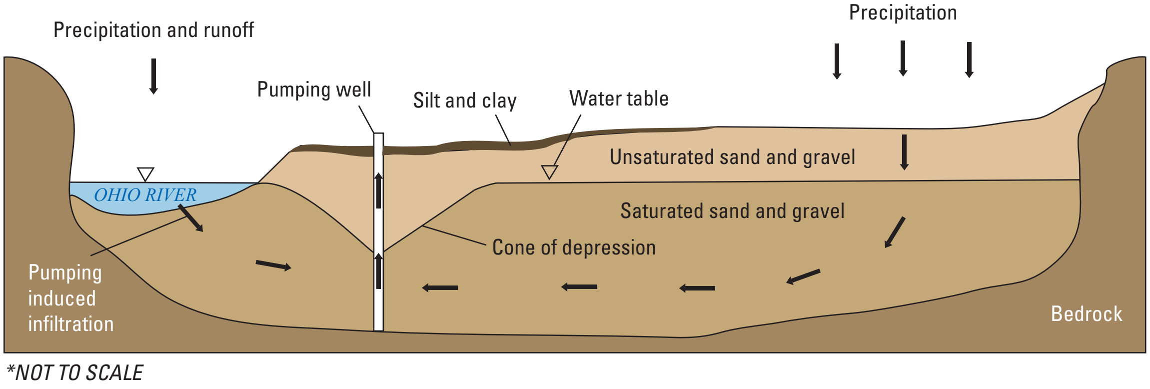


Figure 2. Representational block diagram of groundwater flow to a pumping well in the Ohio River alluvial aquifer of West Virginia. Modified from Maharjan and Donovan (2017). The inverted triangle denotes the water table.

the Ohio River in the Appalachian Plateau physiographic province of West Virginia (fig. 1) and does not include alluvial deposits of the Kanawha River or other minor tributaries. This study focused on surface-water influence in the Ohio River alluvial aquifer but not groundwater under direct influence (GWUDI) of surface water as defined by the National Primary Drinking Water Regulation (40 CFR 59570 part 141). As of 2023, no alluvial aquifers in West Virginia are classified as GWUDI, despite high intrinsic susceptibilities, because of a lack of detected pathogens (for example, virus or bacteria) and microscopic particulates in raw process water (Kozar and Paybins, 2016).

Purpose and Scope

This report describes and interprets water-quality data studied by the U.S. Geological Survey in cooperation with the West Virginia Department of Health and Human Resources to help understand the influence of surface water on groundwater chemistry in the alluvial aquifers bordering the Ohio River in West Virginia. This assessment is based on the chemical composition of surface-water samples collected from 4 sites on the Ohio River and groundwater samples collected from 23 wells in alluvial aquifers from June 2019 to January 2020. Chemical analyses of samples included major ions, dissolved organic carbon (DOC), selected man-made organic compounds, dissolved gases, tritium, and carbon-13 isotopes. Specific objectives of this study are 1) characterization of groundwater quality in relation to health-based standards and geochemical processes, 2) determination of recharge sources, 3) estimation of groundwater age, and 4) estimation of the fraction of Ohio River water entering groundwater that supplies wells in the Ohio River alluvial aquifer in the state of West Virginia. Results of multivariate analyses of water-quality samples are discussed to provide insight into geochemical processes controlling groundwater. Binary mixing models and inverse geochemical models were used to estimate the fraction of surface water in groundwater pumped by wells in the alluvial aquifer and compared to fractions estimated from previously published numerical groundwater-flow models. An improved understanding of SWIGs along the Ohio River will aid preventative efforts seeking to protect the alluvial aquifers from potential degradation associated with surface activities.

Study Area and Previous Investigations

The Ohio River alluvial aquifer in West Virginia is in the Appalachian Plateau physiographic province along the West Virginia-Ohio border (fig. 1) with alluvial sediments confined to river terraces and floodplains within the Ohio River Valley (Puente, 1985). It represents one of two major aquifer types and one of five hydrogeologic terrains (lithologies that share similar hydrogeologic properties) in the State. For context, consolidated sedimentary bedrock aquifers represent the other major aquifer type (Schwietering, 1981; Puente, 1985).

The predominantly mountainous terrain and geographic setting have a pronounced effect on climate, which is classified as temperate continental with four well-defined seasons that are locally influenced by topography (Friel and others, 1987; Battelle Memorial Institute, 2003). Average maximum and minimum temperatures from 1900 to 2016 ranged from 40 degrees Fahrenheit (°F) to 65°F, respectively. Mean precipitation, which is affected by orographic lift as atmospheric currents track eastward (Friel and others, 1987), over the same time period was 42.4 inches (Kutta and Hubbart, 2019).

The Ohio River Valley is highly developed and consists of residential, industrial, and agricultural land use. The estimated population of the 10 counties included in this study (fig.1) was 286,954 in 2022, approximately 16 percent of the State's total population (U.S. Census Bureau, 2023). Development, particularly agriculture, decreases away from the river because of rugged terrain that typifies the Appalachian Plateau physiographic province. Residential land use is a result of the Ohio River facilitating transport across the mountainous topography during settlement, which has spawned a diverse industrial presence including electric-power generation, chemical and metal manufacturing, and petroleum refinement that supports municipal growth alongside agriculture activity (Ferrel, 1987; Bader and others, 1997; Battelle Memorial Institute, 2003). Agricultural land use, which is concentrated in the Ohio River Valley, has declined by 58 percent since 1950 (Kutta and Hubbart, 2019).

Geology

The Ohio River alluvium is confined to the floodplains within the Ohio River Valley, which extends approximately (~) 280 miles along a gentle gradient between the borders of West Virginia and Ohio. Headwaters and river morphology observed today are remnants of successive Pleistocene glaciations that altered drainage dynamics and depositional sequences that formed the alluvial aquifers (Carlston, 1962). The basal alluvium, as much as 125-feet (ft) thick, comprises glaciofluvial deposits of medium- to coarse-grained gravel and sands associated with the Wisconsin glaciation. As much as 83 percent of these sediments are derived from eroded Pennsylvanian and Permian substratum consisting of cyclothem deposits of shale, limestone, coal, underclay, and sandstone (Cross and Schemel, 1956). The remaining igneous and metamorphic pebbles are classified as exogenous to local stratigraphy and consistent with the glacial outwash origin of the lower alluvial aquifers (Carlston, 1962). Alluvial fill of reworked late Pleistocene material overlies the glaciofluvial sediments and generally ranges from 20 to 30 ft in thickness, thinning downstream and toward valley walls. Deposition of the heterogenous fill, ranging from clay to gravel and defined by lenticular interbeds of variable grain size (Cross and Schemel, 1956) has formed terraces along the Ohio River (Simard, 1989) that are overlain by Holocene floodplain deposits of silts and clays (Carlston, 1962). On average, the surface sediments are ~10 ft thick and may act as a confining unit locally that produces semi-confined aquifer conditions in the alluvium (Cross and Schemel, 1956).

Hydrogeology

The high proportion of coarse-grained glacial outwash in the Ohio River alluvial aquifer provides the foundation for an excellent groundwater resource in West Virginia. Hydrologic properties of the alluvium are ideal in the context of a groundwater resource but are subject to the intrinsic spatial and stratigraphic geological heterogeneities that affect aquifer characteristics and the extent of induced infiltration from the Ohio River. Available storage-coefficient and specific-yield data (median of 0.20) support conceptual evidence that the alluvial aquifers with a median saturated thickness of 50 ft are unconfined, albeit highly variable site to site. Median depth to water is 43 ft below land surface, far deeper than the potentially confining surficial clays. Specific capacity ranges from 4 to 381 gallons per minute per foot of drawdown (median of 31.8 gallons per minute per foot) and a median transmissivity of 4,800 feet squared per day is reported, consistent with the highly productive nature of the alluvium (Bader and others, 1997; Kozar and Mathes, 2001).

The alluvium may recharge through the following processes: (1) precipitation, (2) induced infiltration because of flooding or proximity to pumping centers, (3) inflow through underlying fractured-bedrock systems, and (4) inflow through gravel deltas from tributary streams (Bader and others, 1997). The focus of this report is on the first two processes; although, the other recharge mechanisms may be important on a local scale (Mathes and others, 1997). Initial studies discounted precipitation as a major source of direct recharge to the Ohio River alluvial aquifer because of the perceived impermeability of the surficial clay or silt layer (Carlston and Graeff, 1956); however, the clay or silt layer is not spatially homogenous or omnipresent, and water-quality data suggest percolation through this layer to the coarse-grained sediments below does happen, meaning precipitation is one of the most important sources of recharge to the alluvium (Jeffords, 1945; Bader and others, 1997). The spatial extent and magnitude of precipitation as recharge is variable though, dependent on the composition of alluvial deposits. For example, the predominance of coarser sediments, such as gravel and sand, led to a fourfold increase in recharge estimations (ranging from 3 inches per year to 12 inches per year) relative to sediments mainly composed of silt and clay (Kozar and McCoy, 2004).

Induced infiltration represents another principal source of recharge, either because of flooding of the Ohio River or in response to substantial groundwater withdrawals via pumping. Hydraulic gradients are nearly always from the alluvial aquifers to the Ohio River under normal baseflow conditions (Kazmann and others, 1943). Hydraulic gradients reverse in response to river stage (Jeffords, 1945) and nearby pumping activity (Kozar and McCoy, 2004; Maharjan and Donovan, 2017), producing induced infiltration of water from the Ohio River to the adjacent alluvium. Locally, induced infiltration may be impeded by the spatially variable nature of benthic river sediments (Mathes and others, 1997), but impediment is challenging to quantify. Induced infiltration associated with transient events, such as floods, implies a minimal effect on the hydrologic budget of the alluvium; however, persistent reversals in hydraulic gradients, associated with cones of depression created by extensive pumping, may impart a large effect. Frequent use of radial collector wells (also known as "Ranney wells") that extend beneath the riverbed at pumping centers only exacerbate induced infiltration from the Ohio River. Simulations of groundwater flow in select areas of the Ohio River alluvial aquifer in West Virginia demonstrated the spatial variability of induced infiltration, which accounted for 4 to 75 percent of water pumped at various sites. Well-field density and surficial-sediment compositions were identified as potential factors controlling the magnitude of induced infiltration, with large cones of depression tied to closely spaced wells and higher percentages of fine-grained sediments in the alluvium (Kozar and McCoy, 2004).

Water Quality

The Ohio River Valley represents a major transportation corridor and population center in West Virginia where extensive industrial and agricultural activity has adversely affected groundwater quality in the intrinsically susceptible alluvial aquifers. Notwithstanding, water quality is generally acceptable in the Ohio River alluvial aquifer, which accounts for over 50 percent of public groundwater supplies in the State (Ferrel, 1987). Water is hard (median hardness of 220 milligrams per liter [mg/L]) and prone to elevated iron and manganese concentrations that exceed secondary maximum-contaminant levels (SMCLs). Both characteristics have been attributed to alluvium mineralogy (Carlston and Graeff, 1956; Ferrel, 1987; Bader and others, 1997). Geological features of the alluvial aquifer also indirectly affect water quality by facilitating contaminant transport associated with surface activities.

Rapid transport of surficial water into the alluvium, either from precipitation, runoff, or induced infiltration from the Ohio River, is evident by water-quality data. Contamination from agricultural and industrial activity is apparent in the form of elevated nitrogen (nitrate plus nitrite) and volatile organic compound (VOC) concentrations, respectively. Nitrogen (N) levels in the alluvial aquifers are greater than those observed in any other aquifer system across West Virginia. Of the 35 alluvial aquifer wells included in the West Virginia ambient groundwater-quality monitoring network (Chambers and others, 2012), 1 sample (11 mg/L as N) exceeded the U.S. Environmental Protection Agency (EPA) National Primary Drinking Water Regulation (40 CFR 59570 part 141) maximum-contaminant level (MCL) of 10 mg/L as N for nitrate plus nitrite, and 5 samples exhibited levels above background concentrations (5 mg/L as N). Further degradation of water quality from the pronounced industrial presence along the Ohio River is underlined by the presence of VOCs in most (60 percent) of the samples from alluvial aquifer wells (Chambers and others, 2012). For context, no other aquifer included in the ambient monitoring network had detections of VOCs in most samples. Despite the clear susceptibility of the alluvium to surface contamination, alluvial sediments do act as effective microbial biofilters that inhibit bacterial infestation (Jeffords, 1945; Chambers and others, 2012). Samples from only 1 of the 42 wells analyzed in the Ohio River alluvial aquifer had a positive detection of fecal coliform. Still, the widespread presence of surficial contaminant species, such as nitrate and VOCs, in the Ohio River alluvium signifies the susceptibility and vulnerability of this critical groundwater resource to degradative surface activities in the area.

SWIG Recognition in the Ohio River Alluvial Aquifer

The Ohio River alluvial aquifer is defined by a high intrinsic susceptibility and high vulnerability because of a combination of hydrogeologic and anthropogenic factors previously outlined in this report. Early recognition of potential induced infiltration from the Ohio River (Jeffords, 1945) has been substantiated by extensive study. Most work has centered on indirectly qualifying and quantifying how groundwater demand, fulfilled primarily by pumping centers, has altered the natural hydraulic gradients in the alluvium. Consequently, the likelihood for the Ohio River alluvial aquifer to be classified as a SWIG has dramatically increased over time.

Multiple data types indicate that surface water from the Ohio River interacts with the alluvial aquifers. Chlorofluorocarbon age dating techniques (McCoy and Kozar, 2007) and thermal covariation between water in the Ohio River and groundwater in alluvial wells (Jeffords, 1945) indicates that the groundwater in the alluvium is almost exclusively young (less than [<]60 years). Additional analysis of temperature data demonstrated a disruption of thermal stratification in alluvial aquifers proximal to high-frequency pumping centers caused by induced infiltration from the Ohio River (Maharjan and Donovan, 2017). Water-quality data from the Ohio River alluvial aquifer are congruent with water-quality in the Ohio River, with elevated nitrate and VOC concentrations attributed to surface activities (for example agriculture and industry) (Kozar and Paybins, 2016). Comparison between proximal (<1,000 ft from Ohio River) and distal (greater than [>] 1,000 ft from Ohio River) alluvial well water chemistry to Ohio River water revealed consistencies between river and groundwater in proximal wells, such as low total dissolved solids (TDS), electric conductivity (EC), alkalinity, and enriched delta carbon-13 (δ^{13}C) values of dissolved inorganic carbon (DIC), indicative of induced infiltration. Conversely, distal wells exhibited higher TDS, EC, alkalinity, and relatively depleted δ^{13}C values of DIC and were not affected by exfiltration from the Ohio River (Maharjan and Donovan, 2017). Simulations of groundwater flow in select well fields along the Ohio River not only corroborate the induced infiltration based on field data but also highlight the complexities of SWIG classification arising from the inherent heterogeneities of the alluvium (Kozar and McCoy, 2004).

Spatial and stratigraphic variability in the Ohio River alluvium precludes blanket classification as a SWIG across the entire aquifer system. The magnitude of induced infiltration is highly variable across space, contributing to 4 to 75 percent of water pumped based on numerical groundwater flow modeling of multiple well fields (Kozar and McCoy, 2004). In addition to aquifer properties (for example storage capacity, transmissivity, confinement), the proximity to pumping centers, pumping rates, cone of depression morphology, groundwater levels relative to river stage elevation, and duration of hydraulic gradient reversal collectively determine the potential for induced infiltration, and, by extension, SWIG conditions (Donovan, 2019). Thus, an updated and refined classification of possible SWIGs within the Ohio River alluvial aquifer in West Virginia is paramount to safeguard this critical groundwater resource against current [2019] and future surface contamination.

Methods of Study

Water-quality samples were collected by the USGS from 4 surface-water sites and 23 groundwater wells (fig.1; table 1) in the study area from June 2019 to January 2020. The surface-water sites were chosen with the intention of evenly distributing surface-water samples in the Ohio River across the study area. Groundwater wells were chosen for sampling with the intention of having a representative distribution of sites based on distance to the Ohio River. Distance to the Ohio River was estimated using aerial photography in a geographic information system program. Well depth below land surface values in table 1 were not surveyed and should be considered estimates.

Analytical results are documented in McAdoo, Grindle, and Grindle (2022) and the USGS National Water Information System (U.S. Geological Survey, 2023). Some data either are not available or have limited availability because of restrictions dictated by West Virginia State Law §22-26-4 and USGS policy concerning the release of sensitive water related information.

Sampling Methods

To prevent environmental contamination, samples were collected and processed inside a mobile field laboratory or a portable processing chamber assembled near the sampling location. Surface-water samples were collected by scientists on a boat at multiple stations across the Ohio River using a 1-liter Nalgene narrow mouth bottle and weighted bottle sampler. Samples were width-integrated from eight vertical stations across the river, and the vertical samples collected were poured into an 8-liter polyethylene churn splitter for sample

Table 1. Site information for 4 surface-water sites and 23 groundwater wells in West Virginia where samples were collected for the study from June 2019 to January 2020. Well-depth data from the U.S. Geological Survey National Water Information System (U.S. Geological Survey, 2023).

[The column labeled distance represents the distance estimated from the sampling location to the Ohio River. U.S. Geological Survey site numbers have not been shared for groundwater sites because they are based on sensitive information. USGS, U.S. Geological Survey; ft, feet; BLS, below land surface; OR, Ohio River; SW, surface water; —, not applicable; @, at; WV, West Virginia; GW, groundwater]

USGS site number	Site name	Shortened site name	Site type	Distance, ft	Well depth, ft BLS
395516080451501	Ohio River at Moundsville	OR Moundsville	SW	0	—
391720081334701	Ohio River @ Mile 183.0	OR Parkersburg	SW	0	—
03159600	Ohio River at Lock and Dam 22 at Ravenswood, WV	OR Ravenswood	SW	0	—
384811082121801	Ohio River at Gallipolis	OR Gallipolis	SW	0	—
Information withheld	Hnc-0043	—	GW	20	76
Information withheld	Wet-0146	—	GW	35	65
Information withheld	Woo-0121	—	GW	50	56
Information withheld	Mal-0104	—	GW	75	66
Information withheld	Mas-0934	—	GW	78	71
Information withheld	Mas-0968	—	GW	101	72
Information withheld	Woo-0215	—	GW	111	60
Information withheld	Ohi-0372	—	GW	227	90
Information withheld	Woo-0177	—	GW	240	85
Information withheld	Tyl-0101	—	GW	290	64
Information withheld	Woo-0216	—	GW	301	60
Information withheld	Wet-0135	—	GW	401	81
Information withheld	Ple-0068	—	GW	441	75
Information withheld	Mas-0918	—	GW	444	75
Information withheld	Mal-0410	—	GW	475	54
Information withheld	Brk-0077	—	GW	637	90
Information withheld	Mas-0936	—	GW	650	72
Information withheld	Mas-0852	—	GW	1,015	90
Information withheld	Jac-0128	—	GW	1,132	88
Information withheld	Ple-0071	—	GW	1,473	78
Information withheld	Mas-0920	—	GW	1,475	84
Information withheld	Jac-0057	—	GW	1,637	93
Information withheld	Woo-0196	—	GW	2,653	83

processing. A multi-parameter water-quality sonde (YSI EXO 2, Yellow Springs, Ohio) was used to measure water temperature, pH, specific conductance, dissolved oxygen, and turbidity according to procedures described in the USGS National Field Manual (U.S. Geological Survey, variously dated).

Groundwater samples were collected at public water system wells in the Ohio River alluvium. Raw-water taps, as identified by the operator at the public water system, were tested with commercially available chlorine test strips to ensure the sample point was located before the system's disinfection processes. Often located at 3/8-inch hose bibs, raw-water taps came in many configurations including lab faucets, threaded and unthreaded plumbing connections made of various metals, PVC pipes, and other plastic connections. Standard sample tubing was connected to raw-water taps using a combination of nylon connectors, stainless-steel fittings, and hose clamps to ensure an airtight connection. Sample tubing was connected to a flow-through chamber with a YSI multiparameter water-quality sonde, which was calibrated daily and measured temperature, pH, specific conductance, dissolved oxygen, and turbidity. All samples were collected at active high-production wells and did not require purging based on well volume. Field parameters were monitored for a minimum of 25 minutes and readings were recorded every 5 minutes to meet stability criteria according to the National Field Manual (U.S. Geological Survey, variously dated) and to collect enough data to calculate median values for each parameter. After field parameters were recorded, samples were collected in recommended sample containers and preserved according to lab instructions.

All samples (surface water and groundwater) were analyzed for field measurements of water quality (pH, water temperature, specific conductance, dissolved oxygen concentration, and turbidity), alkalinity, major ions, trace elements, nutrients, DOC, and per- and polyfluoroalkyl substances (PFAS; table 2). Subsets of samples at proximal wells were analyzed for microbiological indicators of fecal contamination (table 3), VOCs (table 4), semi-volatile organic compounds (SVOCs; table 5), and pesticides (table 6) to assess potential aquifer degradation from surface-water influence. Field measurements and samples for inorganic analytes, VOCs, SVOCs, DOC, and pesticides were processed using standard USGS protocols described by the USGS National Field Manual for the Collection of Water Quality Data (U.S. Geological Survey, variously dated). These protocols specified that samples collected for determination of dissolved concentrations (major ions, trace elements, nutrients, DOC) were filtered in the field through a 0.45-micron filter and, for some analyses (cations, trace elements), preserved with nitric acid.

Samples collected for determination of major inorganic element, trace element, nutrient, VOC, SVOC, and pesticide concentrations were chilled on ice and shipped overnight to the USGS National Water Quality Laboratory in Lakewood, Colorado, for analysis. Samples collected for determination of microbiological indicators of fecal contamination were chilled on ice and shipped overnight to the USGS Ohio Microbiology

Table 2. List of general water-quality characteristics, major ions, trace elements, nutrients, and per- and polyfluoroalkyl substances and associated laboratory reporting levels for analyses of 4 surface-water samples and 23 groundwater samples collected from the Ohio River and the Ohio River alluvial aquifer from June 2019 to January 2020.

[Dissolved concentrations were determined for all analytes except per- and polyfluoroalkyl (PFAS). mg/L, milligrams per liter; —, not applicable; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; ng/L, nanogram per liter; FTS, fluorotelomer sulfonate]

Constituent	Reporting level	Units
Dissolved oxygen	0.1	mg/L
pH	—	standard units
Specific conductance at 25°C	1	µS/cm
Turbidity	0.01	NTU
Alkalinity	1	mg/L as $CaCO_3$
Bicarbonate	1	mg/L
Calcium	0.022	mg/L
Magnesium	0.01	mg/L
Potassium	0.3	mg/L
Sodium	0.4	mg/L
Bromide	0.01	mg/L
Chloride	0.02	mg/L
Fluoride	0.01	mg/L
Silica	0.05	mg/L
Sulfate	0.02	mg/L
Aluminum	3	µg/L
Antimony	0.06	µg/L
Arsenic	0.1	µg/L
Barium	0.1	µg/L
Boron	5	µg/L
Beryllium	0.01	µg/L
Cadmium	0.03	µg/L
Chromium	0.5	µg/L
Cobalt	0.03	µg/L
Copper	0.4	µg/L
Iron	10	µg/L
Lead	0.02	µg/L
Lithium	0.15	µg/L
Manganese	0.4	µg/L
Molybdenum	0.05	µg/L
Nickel	0.2	µg/L
Selenium	0.05	µg/L
Silver	1	µg/L
Strontium	0.5	µg/L

Table 2. List of general water-quality characteristics, major ions, trace elements, nutrients, and per- and polyfluoroalkyl substances and associated laboratory reporting levels for analyses of 4 surface-water samples and 23 groundwater samples collected from the Ohio River and the Ohio River alluvial aquifer from June 2019 to January 2020.—Continued

[Dissolved concentrations were determined for all analytes except per- and polyfluoroalkyl (PFAS). mg/L, milligrams per liter; —, not applicable; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; CaCO$_3$, calcium carbonate; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; ng/L, nanogram per liter; FTS, fluorotelomer sulfonate]

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Constituent	Reporting level	Units
Thallium	0.04	µg/L
Vanadium	0.1	µg/L
Uranium	0.03	µg/L
Zinc	2	µg/L
Ammonia	0.01	mg/L as N
Nitrate	0.04	mg/L as N
Nitrite	0.001	mg/L as N
Total Nitrogen	0.05	mg/L
Orthophosphate	0.004	mg/L as P
Organic carbon	0.23	mg/L
4:2 FTS	3.8–9.1	ng/L
6:2 FTS	3.8–9.1	ng/L
8:2 FTS	3.8–9.1	ng/L
9Cl-PF3ONS (9-chlorohexadecafluoro-3-oxanonane-1-sulfonate)	3.8–5.6	ng/L
11Cl-PF3OUdS (11-chloroeicosafluoro-3-oxaundecane-1-sulfonate)	3.8–5.6	ng/L
ADONA (4,8-dioxa-3H-perfluorononanoate)	3.8–5.6	ng/L
HFPO-DA (perfluoro-2-propoxypropanoate)	3.8–5.6	ng/L
N-EtFOSAA (n-ethylperfluorooctanesulfonamidoacetate)	3.8–20	ng/L
N-MeFOSAA (n-methylperfluorooctanesulfonamidoacetate)	3.8–20	ng/L
PFBS (perfluorobutanesulfonate)	3.8–5.9	ng/L
PFBA (perfluorobutanoate)	3.8–9.1	ng/L
PFDS (perfluorodecanesulfonate)	3.8–5.9	ng/L
PFDA (perfluorodecanoate)	3.8–5.9	ng/L
PFDoDA (perfluorododecanoate)	3.8–5.9	ng/L
PFHpS (perfluoroheptanesulfonate)	3.8–5.9	ng/L
PFHpA (perfluoropentanoate)	3.8–5.9	ng/L
PFHxS (perfluoropentanoate)	3.8–5.9	ng/L
PFHxA (perfluorohexanoate)	3.8–5.9	ng/L
PFNS (perfluorononanesulfonate)	3.8–5.9	ng/L
PFNA (perfluorononanoate)	3.8–5.9	ng/L
PFOSA (perfluorooctanesulfonamide perfluorohexanesulfonate)	3.8–5.9	ng/L
PFOS (perfluorooctanesulfonate)	3.8–5.9	ng/L
PFOA (perfluorooctanoate)	3.8–40	ng/L
PFPeS (perfluoropentanesulfonate)	3.8–5.9	ng/L
PFPeA (perfluoropentanoate)	3.8–5.9	ng/L
PFTeDA (perfluorotetradecanoate)	3.8–5.9	ng/L
PFTrDA (perfluorotridecanoate)	3.8–5.9	ng/L
PFUnDA (perfluoroundecanoate)	3.8–5.9	ng/L

Laboratory in Columbus, Ohio. Samples for determination of PFAS concentrations were analyzed by RTI Laboratories in Livonia, Michigan, according to PFAS analysis compliant with U.S. Department of Defense Quality Systems Manual (U.S. Department of Defense, 2019).

Quality Control and Quality Assurance

Quality-assurance samples were collected to provide confidence in analytical results, identify potential sample contamination issues, and describe the magnitude of combined sample and analytical variability. Blank samples were used to determine the extent to which sampling or analytical methods may contaminate samples, which may bias analytical results. Replicate samples are used to determine the variability inherent in collection and analysis of environmental samples. Together, blank and replicate samples were used to characterize the accuracy and precision of water-quality data.

Where sufficient data were available, the ionic charge-balance error (CBE) was calculated to evaluate the electroneutrality of the water sample, identify transcription errors during field activities, and identify laboratory analytical errors. The CBE can be used to assess the accuracy and completeness of field and laboratory results for constituents contributing to sample ionic charge, which typically include the major ions (Freeze and Cherry, 1979). The CBE is calculated by the following formula:

$$CBE = \frac{\sum z\ m_c - \sum z\ m_a}{\sum z\ m_c + \sum z\ m_a} \times 100 \qquad (1)$$

where

z is the absolute value of the ionic valence,

m_c is the molality of the cation species, and

m_a is the molality of the anion species.

The CBE has a positive value when the sum of cations exceeds the sum of anions but a negative value when the sum of anions is greater than the sum of cations. Calculated CBEs are rarely zero and values as much as 10 percent are typically considered acceptable; however, CBEs may exceed this threshold for waters with low-ionic strength (specific conductance <100 µS/cm) or in acidic waters (Fritz, 1994). Analysis of quality-assurance data showed that no sites had a CBE greater than 10 percent for this study and concentrations of replicate sample pairs differed by small amounts, typically less than 15 percent of the relative percent difference (RPD). Constituents with higher RPD were usually constituents at low concentration at or below the method detection limit. Analytical or sampling variability was considered minimal as a result.

A combination of equipment blanks and field blanks was used to identify and quantify potential sources of contamination. An equipment blank consists of a volume of water of known quality that is processed through the sampling equipment in a laboratory environment. A field blank consists of a volume of water processed through the sampling equipment under the same field conditions in which the samples were processed. Equipment blanks were run through two sets of sampling equipment prior to environmental sampling. One equipment blank had detections above the laboratory reporting level for cobalt, copper, and zinc. That set of sampling equipment was discarded and not used for environmental samples.

Table 3. Microbiological indicators of fecal contamination and associated laboratory reporting levels for analyses of 18 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.

[MPN, most probable number; DSTM, defined substrate test method; cfu, colony-forming unit; —, not applicable]

Constituent	Reporting level	Unit
Escherichia coli	1	MPN per 100 milliliters
Total coliforms, DSTM	1	MPN per 100 milliliters
Enterococci	1	cfu per 100 milliliters
Coliphage, F-specific	—	presence or absence
Coliphage, somatic	—	presence or absence

Variability for a replicate sample pair was quantified by calculating the RPD of the samples. The RPD was calculated using the following formula:

$$RPD = \left(\frac{|R_1 - R_2|}{\left(\frac{R_1 + R_2}{2} \right)} \right) \times 100 \qquad (2)$$

where

R_1 is the concentration of the analyte in the first replicate sample, and

R_2 is the concentration of the analyte in the second replicate sample.

Statistical Analysis

Both univariate and multivariate statistical methods were used to ascertain significant constituent variations and distributions impacting water quality and water-quality dispersal throughout the study area. Statistical analyses were computed, and graphics created, using the R statistical computing environment, version 3.5.3 (R Core Team, 2022). Nonparametric techniques were used for computing descriptive and multivariate statistics from water-quality data that were censored at multiple levels. Censored values are water-quality results that are reported as less than a laboratory reporting level.

Table 4. Volatile organic compounds and associated laboratory reporting levels for analyses of 19 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.

[µg/L, micrograms per liter]

Constituent	Reporting level, in µg/L
1,2,3,4-Tetrahydronaphthalene	0.08
1,2-Dichloropropane	0.004
Chloropicrin	0.2
2-Ethoxyethyl acetate	5.4
Trichloromethane	0.03
trans-1,3-Dichloropropene	0.1
Hexane	0.068
1,2-Dibromo-3-chloropropane	0.02
1,3-Dioxolane	0.38
Bromomethane	0.2
1,4-Dioxane	0.2
1,3-Butadiene	0.08
1-Butanol	0.8
1,1,1,2-Tetrachloroethane	0.04
1,2,4-Trimethylbenzene	0.032
n-Pentanal	0.054
1-Octanol	1.8
1-Chloro-1,1-difluoroethane	0.08
4-Methyl-2-pentanol	0.2
cis-1,3-Dichloropropene	0.1
1,1,1-Trichloroethane	0.03
Dichlorofluoromethane	0.05
Bromochloromethane	0.06
m-Xylene plus p-xylene	0.08
1,1-Dichloro-2-propanone	0.24
1,2-Dibromoethane	0.004
Chloromethane	0.2
Nitrobenzene	1.4
tert-Butyl alcohol	0.24
Chlorodifluoromethane	0.04
Tribromomethane	0.14
1,1-Dichloroethane	0.044
Tetrachloroethene	0.058
2-Methylpropyl acetate	0.028
Methyl acetate	0.14
Acetonitrile	0.8
Styrene	0.042
Methyl tert-butyl ether	0.01
Butane	0.08
Isophorone	2.4
Ethylbenzene	0.036

Table 4—continued. Volatile organic compounds and associated laboratory reporting levels for analyses of 19 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.—Continued

[µg/L, micrograms per liter]

Constituent	Reporting level, in µg/L
Dimethoxymethane	0.044
Naphthalene	0.26
Carbon disulfide	0.1
n-Pentane	0.066
Dibromochloromethane	0.12
1,1-Difluoroethane	0.025
2,6-Dimethyl-4-heptanone	0.032
Tetrachloromethane	0.06
1,2-Dichloro-1,1,2,2-tetrafluoroethane	0.03
Benzene	0.026
1-Methoxy-4-(2-propenyl) benzene	0.4
alpha-Terpineol	2
1,1-Dichloroethene	0.025
Isopropyl acetate	0.01
Ethyl acetate	0.06
Toluene	0.2
2,2-Dichloro-1,1,1-trifluoroethane	0.025
n-Propylbenzene	0.036
Chlorobenzene	0.026
Butanal	0.38
trans-1,2-Dichloroethene	0.025
5-Methyl-2-hexanone	0.022
1,1,2-Trichloroethane	0.046
trans-Crotonaldehyde	2.6
Bromodichloromethane	0.034
N-Nitrosodiethylamine	5.2
Trichloroethene	0.074
sec-Butylbenzene	0.034
1,2,4-Trichlorobenzene	0.08
Vinyl chloride	0.06
Dichloromethane	0.04
1,2-Dichloroethane	0.08
1,2-Dichlorobenzene	0.028
Methyl tert-butyl ether	0.01
2-Nitropropane	0.12
1,4-Dichlorobenzene	0.026
1,2,3-Trichloropropane	0.006
cis-1,2-Dichloroethene	0.019
2-Propen-1-ol	7.8
o-Xylene	0.032

Table 5. Semi-volatile organic compounds and associated laboratory reporting levels for analyses of 13 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.

[µg/L, micrograms per liter]

Constituent	Reporting level, in µg/L
Hexachlorobutadiene	0.06
Hexachlorobenzene	0.1
4-Bromophenyl phenyl ether	0.06
2,4,6-Trichlorophenol	0.1
2,4-Dinitrotoluene	0.2
2-Chlorophenol	0.06
1,2,4-Trichlorobenzene	0.08
9H-Fluorene	0.06
Bis(2-chloroethoxy)methane	0.04
Anthracene	0.1
Acenaphthylene	0.1
Di-n-octyl phthalate	2
2-Nitrophenol	0.2
Dibenzo[a,h]anthracene	0.2
1,2-Dichlorobenzene	0.028
Benzo[ghi]perylene	0.2
N-Nitrosodimethylamine (NDMA)	0.2
N-Nitrosodi-n-propylamine	0.1
1,2-Diphenylhydrazine	0.2
Phenol	0.32
1,3-Dichlorobenzene	0.06
Nitrobenzene	1.4
Isophorone	2.4
Hexachloroethane	0.1
Fluoranthene	0.1
Benzo[b]fluoranthene	0.1
Bis(2-ethylhexyl) phthalate	1
2,4-Dichlorophenol	0.1
Phenanthrene	0.04
4-Chloro-3-methylphenol	0.1
Indeno[1,2,3-cd]pyrene	0.2
Hexachlorocyclopentadiene	0.2
Benzyl n-butyl phthalate	1.8
Bis(2-chloroisopropyl) ether	0.1
Benzo[k]fluoranthene	0.1
4-Chlorophenyl phenyl ether	0.06
2,6-Dinitrotoluene	0.4
2,4-Dinitrophenol	4
1,4-Dichlorobenzene	0.026
Pyrene	0.1
Dimethyl phthalate	0.2
Diethyl phthalate	0.62
Chrysene	0.1
Di-n-butyl phthalate	1
Pentachlorophenol	0.6
2-Methyl-4,6-dinitrophenol	2
4-Nitrophenol	0.52
Benzo[a]pyrene	0.1
Acenaphthene	0.1
Naphthalene	0.26
2-Chloronaphthalene	0.06
N-Nitrosodiphenylamine	0.28
Bis(2-chloroethyl) ether	0.1
2,4-Dimethylphenol	0.1
Benzo[a]anthracene	0.26

Prior to multivariate and summary statistical analyses, censored data were recoded to u-scores with the codeU function in the USGS smwrQW package (Lorenz, 2018). The u-score is the sum of the sign of the differences between each value and all other values and is equivalent to the rank but scaled so the median is equal to zero. Using u-scores allows for the computation of multivariate relations without requiring censoring at the highest reporting limit and retains information at multiple reporting limits. When a column of data has only one censoring level, the u-scores are the same as ordinal methods of ranking for one reporting limit (Helsel, 2012).

Summary Statistics for Censored Data

The nonparametric Kaplan-Meier (KM) and robust regression on order statistics models were used for estimation of summary statistics for censored data following the methods described by Ryberg (2006) and Helsel (2012). When a sample had from 50 to 80 percent censored values, the robust regression on order statistics model was used. The robust regression on order statistics model was used for this range of censoring because of its ability to make accurate estimates and handle multiple censoring levels with fewer than 50 observations. When less than 50 percent of the data were censored, the KM model was used to estimate the summary statistics. The KM estimate was used to account for multiple censoring levels because it does not depend on the assumption of a

Table 6. Pesticides, herbicides, and associated laboratory reporting levels for analyses of 19 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.

[ng/L, nanogram per liter]

Constituent	Reporting level, in ng/L
Imidacloprid	16
Acetochlor oxanilic acid	65
cis-Permethrin	4.2
Fluometuron	10
Linuron	5.6
Chlorimuron-ethyl	8.8
Fipronil sulfone	5.6
Methomyl	3
Methamidophos	10
2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine	8
1H-1,2,4-Triazole	22
Triclopyr	88
Propazine	3.2
2-Chloro-4-isopropylamino-6-amino-s-triazine	11
Bromoxynil	60
Diuron	10
Terbufos sulfone	25
Imazethapyr	8
Metolachlor oxanilic acid	200
4-Hydroxychlorothalonil	42
Trifloxystrobin	2.8
Simazine	7.2
trans-Permethrin	3.8
N-(3,4-Dichlorophenyl)-N'-methylurea	5
Acetochlor sulfonic acid	320
Desulfinylfipronil	5
Carbaryl	5.6
Chlorodiamino-s-triazine	50
Pyraclostrobin	2.4
Metconazole	5
2-Chloro-6-ethylamino-4-amino-s-triazine	20
Fipronil sulfide	4.2
2,4-D	62
Diflubenzuron	6
Malathion	5.4
Dechlorometolachlor	2
Hexazinone	3.6
Dicamba	800
Sulfentrazone	25
Myclobutanil	10
Halosulfuron methyl	12
Tebupirimfos	2
Propiconazole	6
2-Hydroxy-4-isopropylamino-6-amino-s-triazine	4
Dichlorvos	52
Fipronil amide	9.2
Tetraconazole	7
Terbufos sulfoxide	3
Terbufos	6.8
Methoxyfenozide	2.2
Bentazon	9
Dimethoate	5
Metalaxyl	6
Chlorpyrifos	3
Sulfometuron-methyl	5
Tebuthiuron	3
Thiobencarb	4.2
Metolachlor sulfonic acid	68
Etoxazole	4.2
Hydroxymetolachlor	2.5
Tebuconazole	15
Ethoprop	5
Diketonitrile-isoxaflutole	10
Dimethenamid	3
cis-Cyhalothric acid	500
Hydroxysimazine	120
Fipronil	4
Azoxystrobin	3
3-Phenoxybenzoic acid	61
Prometon	4
Diazinon	6.4
Acephate	10
Carbendazim	25
Propoxur	3.2
Piperonyl butoxide	25
Bromacil	10

Table 6. Pesticides, herbicides, and associated laboratory reporting levels for analyses of 19 groundwater samples collected from wells in the Ohio River alluvial aquifer from June 2019 to January 2020.—Continued

[ng/L, nanogram per liter]

Constituent	Reporting level, in ng/L
Metribuzin	20
Metolachlor	3.2
Dicrotophos	4
Oryzalin	12
Atrazine	6.8
Acetochlor	25

distributional shape with data that are censored at rates greater than 50 percent. When no values were censored, nonparametric estimates were not necessary and summary statistics were computed using standard methods.

Multivariate Statistics for Censored Water-Quality Data

Principal components analysis (PCA) and hierarchical agglomerative cluster analysis (HACA) were used to delineate groundwater hydrochemical-facies throughout the study area. Hydrochemical-facies is a term used to specify the chemical composition and hydrochemical processes in a portion of the aquifer (Back, 1966). Principal components analysis was used to identify relations among the major chemical and hydrological processes that could explain dissolved element concentrations in the water-quality dataset. Principal components analysis was computed with the principal function in the R psych package (Revelle, 2023), which first computes correlation coefficients (Spearman's rho) for the raw u-scores (ranks) and then performs a PCA on the resulting Spearman rank correlation matrix. Varimax rotation was applied to redistribute the explained variance across principal components and simplify the structure of the PCA model, which maximizes the differences in components and aids in the interpretation of results (Kachigan 1986). Water-quality variables that had missing values or were censored in more than 40 percent of the values were excluded from the PCA. Specific analytes and parameters used in the PCA for this study included dissolved oxygen, DOC, calcium, magnesium, potassium, sodium, chloride, nitrate, bicarbonate, sulfate, silica, iron, and manganese. The variable loadings from the varimax-rotated PCA were used to determine the master variables for each rotated component. Resulting loadings from the PCA and statistically significant correlations ($p<0.01$) from the correlation matrix were retained and used for further interpretation of the dataset.

Hierarchical agglomerative cluster analysis has been shown to be an effective multivariate statistical technique for the analysis of water chemistry data and has been used by previous studies (Güler and others, 2002; Ryberg, 2006) to group data based on chemical concentrations and field measurements. Specific analytes and parameters used in the HACA for this study included delta hydrogen-2 (δ^2H), delta oxygen-18 (δ^{18}O), delta carbon-13 (δ^{13}C), pH, specific conductance, dissolved oxygen, DOC, calcium, magnesium, potassium, sodium, chloride, fluoride, bicarbonate, silica, sulfate, iron, and manganese. Similarity was computed using Euclidian distance, and clusters were merged using Ward's method as described by Güler and others (2002). The agglomerative coefficient produces a numerical value between 0 and 1 and was used to assess the clustering structure (Kaufman and Rousseeuw, 1990). The similarity profile (SIMPROF) test was used to identify significant clusters ($p<0.01$; Clarke and others, 2008). Using the SIMPROF test to identify significant clusters was necessary to reduce misinterpretation of the HACA, but ultimately, the number of clusters chosen for further study was based on the study objectives, data, and results.

Geochemical Modeling and Interpretation

The surface-water influence on groundwater quality was evaluated through four methods of geochemical modeling and interpretation. Stable isotopes and groundwater age analysis was used to determine recharge sources and assess the aquifer's susceptibility to contamination from surface-water sources. Binary mixing models and geochemical inverse models were used to delineate the proportion of Ohio River water entering SWIG wells in the alluvial aquifer.

Stable Isotopes

Stable isotopes of water (δ^2H and δ^{18}O) were evaluated to determine variation in recharge sources throughout the study area by comparing measured isotopic concentrations at sampling sites to the isotopic composition reported in precipitation. Samples were compared to the local meteoric water line (LMWL) published by Smith and others (2021; $\delta^2H=7.58 \times \delta^{18}O+9.16$), which was used to represent precipitation in the Ohio River Valley. The line-conditioned excess (LC-excess; Landwehr and Coplen, 2006) was computed for groundwater samples to indicate additional evaporative fractionation relative to the LMWL. Samples with negative LC-excess values indicated the likelihood of post-precipitation evaporation, whereas positive LC-excess values indicated an input from distinct recharge sources, including higher elevations or stronger seasonal influence, with stable isotope compositions different from the assumed areal modern precipitation.

Groundwater Age Analysis

For this study, environmental tracer concentrations of dissolved gases (nitrogen and the noble gases) were used to determine recharge conditions and compute concentrations of tritiogenic helium-3 ($^3He_{trit}$) and radiogenic helium-4 ($^4He_{rad}$). Computed $^3He_{trit}$ and measured concentrations of tritium (^3H), sulfur hexafluoride (SF_6), and corrected carbon-14 (^{14}C) were used for estimating groundwater age. Delta carbon-13 ($\delta^{13}C$) was used for geochemical correction of ^{14}C in DIC. Field parameters (water temperature, pH, and alkalinity), dissolved oxygen, and the inorganic and trace element chemistry were used to parameterize ^{14}C correction models, assess redox conditions, and develop conceptual models that guide interpretation of tracer concentrations.

Dissolved Gases

Nitrogen and noble gases naturally exist in the atmosphere. The heavy noble gases of neon (Ne), argon (Ar), krypton (Kr), and xenon (X) and (or) Ar and nitrogen gas (N_2) dissolved in water were interpreted through the closed-system equilibration model or the unfractionated air model (Aeschbach-Hertig and others, 2000; Aeschbach-Hertig and Solomon, 2013) for determining noble gas recharge temperature (NGT; a proxy for altitude and timing of recharge), excess air (A^e) or entrapped air (EA), and the fractionation factor (F) of the gases during recharge. The fractionation factor cannot be estimated for samples that only have Ar and N_2 analysis available. N_2 in excess of atmospheric solubility is primarily derived from denitrification. Presence of suboxic to anoxic conditions suggest possible denitrification. Excess N_2 was included as an additional dissolved gas model parameter at select sites with suboxic or anoxic redox conditions.

Helium isotopes, helium-3 (^3He) and helium-4 (^4He) were used to determine the helium isotopic ratio of the sample to that of the atmosphere (R/R_a) and the amount of helium derived from radiogenic sources ($^4He_{rad}$) and the decay of tritium ($^3He_{trit}$; Solomon 2000; Solomon and Cook 2000). Calculations of $^4He_{rad}$ and $^3He_{trit}$ assumed a terrigenic $^3He/^4He$ ratio of 2.8×10^{-8}, a value within the measured range of helium production from uranium (U)- and thorium (Th)-series decay that represents helium of mantle or crustal origin (Andrews, 1985). Following previous work (Aeschbach-Hertig and others, 2000; Manning and Solomon, 2003; Aeschbach-Hertig and Solomon, 2013) the computed recharge parameters (EA, F) were evaluated with the Dissolved Gas Modeling and Environmental Tracer Analysis Computer Program (DGMETA, Jurgens and others 2020) by minimization of the error-weighted misfits (χ^2) between measured and modeled noble gas concentrations.

Tritium

Tritium is naturally produced as a cosmogenic isotope (half-life of 12.32 years; Lucas and Unterweger, 2000) and is also produced in nuclear fission. High concentrations of ^3H were released to the atmosphere during above-ground nuclear testing from 1953 to the early 1960s. Recharge during this period has an elevated bomb-pulse ^3H signal. Water containing greater than 0.5 tritium units (TU) was interpreted here as having at least some fraction of recharge after 1953, whereas concentrations less than 0.5 TU were considered tritium-dead in accordance with the analytical uncertainty. Atmospheric ^3H concentration curve used for lumped parameter models was based on interpolation of nation-wide precipitation measurements (Michel, 1989).

Sulfur Hexafluoride

Sulfur hexafluoride is primarily sourced from industrial applications and used to evaluate the age of younger (less than 60 years [yr]) groundwater or identify a component of young water in a mixed signal. Atmospheric concentrations of SF_6 have increased since 1970 (Busenberg and Plummer, 2000) and have a long atmospheric lifetime (~3,200 yr; Land and Huff, 2010) making it a useful age tracer for young groundwater. Sulfur hexafluoride concentrations are subject to potential anthropogenic and natural contamination. For example, SF_6 is produced naturally in fluorite deposits and volcanic or hydrothermal terrains (Busenberg and Plummer, 2000). Sulfur hexafluoride concentrations were corrected for EA using the computed value from noble gas modeling as described previously and have not been corrected for the potential unsaturated zone time-lag (Cook and Solomon, 1995). Inputs for lumped parameter modeling are from the USGS Reston Groundwater Dating Laboratory (https://water.usgs.gov/lab/software/air_curve/). Throughout the study area, SF_6 inputs were assumed to be constant.

Carbon Isotopes

Carbon-14 is naturally produced as a cosmogenic isotope and is also produced in nuclear fission (Kalin, 2000). With a 5,568.3 yr half-life, ^{14}C of DIC was used to evaluate the age of pre-1950s groundwater and identify the presence of old groundwater in mixtures of differing recharge sources. Groundwtaer conditions are conducive to DIC geochemical and isotopic exchange, making ^{14}C more difficult to interpret, and available groundwater age tracers for dating of thousands of years-old waters remain meager. The graphical method of Han and others (2012) was used to estimate the isotopic compositon of the various carbon exchange reservoirs and indicated the Revised Fontes and Garnier (RFG; Han and Plummer, 2013) analytical correction model is appropriate for most samples in accounting for DIC from soil zone gas and saturated aquifer carbonates. Carbon-14 and $\delta^{13}C$ values for the soil zone gas and the aquifer carbonates were estimated from the plot and further refined by checking corrected final ^{14}C values against other tracers. Sites appropriately catured by the RFG model were corrected using the open-system model, which accounts for continued gas exchange between the atmosphere and groundwater. Model parameterization and ^{14}C correction methods are discussed in the carbon isotope analysis section of this report.

Binary Mixing Models

Mixing of Ohio River water with distal groundwater wells in the alluvium was evaluated to assess relative percentages of these end members contributing water to intermediate groundwater wells proximal to the Ohio River. The Ohio River end member was assumed to be represented by the average of all four surface-water samples. The distal-well end member consisted of the average of 4 wells located greater than 1,000 ft from the Ohio River (Mas-0852, Jac-0128, Jac-0057, Woo-0196). Although Mas-0920 and Ple-0071 are also greater than 1,000 ft from the Ohio River (table 1), they were not included in the calculation for the distal-well end member because an inverse model was needed for Mas-0920 to compare to groundwater model results reported by Kozar and McCoy (2004) and Ple-0071 was identified as possibly being influenced by an unknown surface-water source (explained in the Water-Quality Indicators of Surface-Water Influence on Groundwater Wells section).

The following two chemical constituents were used for mixing models: 1) the silica concentration of the sample, and 2) the ratio of the equivalents of bicarbonate as a percentage of anions to the equivalents of sulfate as a percentage of anions. Generally, binary mixing models use conservative chemical constituents to compute fractions of contribution from different sources. Although bicarbonate, sulfate, and silica may not be conservative at every site, fractions of the Ohio River water end member computed with binary mixing models using these constituents yielded results that significantly correlated with inverse models and groundwater models (explained in subsequent sections). Binary mixing models were calculated with the following formula:

$$C = A(x) + B(1 - x) \tag{3}$$

where

A is the average value for the distal-well end member,

x is the fraction of A,

B is the average value for Ohio River water,

$1-x$ is the fraction of Ohio River water, and

C is the value for the intermediate (proximal) well.

Solving for x

$$x = \frac{(C - B)}{(A - B)} \tag{4}$$

Geochemical Inverse Models

Where possible, geochemical inverse models (also known as mole-balance models) were calculated to estimate fractions of end member chemistries supplying wells located less than 1,000 ft from the Ohio River. Geochemical inverse models were computed using PHREEQC (Parkhurst and Appelo, 2013) to account for non-conservative analytes and mixing. PHREEQC input and output files are available as a USGS data release (McAdoo, 2024). Geochemical inverse models use sets of chemical reactions that quantitatively compensate for changes in chemical and isotopic compositions of water along a flow path and may include contributions from different sources (Parkhurst, 1997). The thermodynamic data file used for speciation and inverse model calculations was WATEQ4F (Ball and Nordstrom, 1991). Chemical constituents used for inverse models included dissolved oxygen, pH, temperature, calcium, magnesium, sodium, alkalinity (as $CaCO_3$), chloride, silica (as SiO_2), sulfate, and iron. Reactive mineral and gas phases used as sinks (precipitation) or sources (dissolution) for mole balances included calcite, dolomite, amorphous silica, halite, organic matter (CH_2O), carbon dioxide, hydrogen sulfide, goethite, amorphous ferrihydrite, pyrite, and sodium exchange with calcium and magnesium. Chemical constituents of two end members (referred to as initial solutions in the PHREEQC input file) were mixed and allowed to react with the specified list of mineral phases and uncertainty of 10 percent to produce a final solution. Inverse models may produce multiple non-unique solutions and for this study the simplest model with the minimum number of mineral phases was retained for each inverse model.

The first initial solution consisted of the average of chemical constituents for all four surface-water sites and represented the Ohio River end member. The second initial solution consisted of the average of chemical constituents for 4 wells greater than 1,000 ft from the Ohio River (Mas-0852, Jac-0128, Jac-0057, Woo-0196) and represents the distal-well end member. Although Mas-0920 and Ple-0071 are also greater than 1,000 ft from the Ohio River (table 1), they were not included in the calculation for the distal well end member because 1) an inverse model was needed for Mas-0920 to compare to groundwater-flow simulations of the amount of river water that infiltrates the aquifer and is captured by pumping wells (Kozar and McCoy, 2004), and 2) Ple-0071 was identified as possibly being influenced by an unknown surface-water source (explained in further detail in subsequent sections). The initial solutions for every inverse model were represented by the Ohio River end member and the distal-well end member as described, but the final solution for each inverse model was represented by the analytical results measured at each well located less than 1,000 ft from the Ohio River and Mas-0920 (1,475 ft from the river).

Groundwater Quality of the Ohio River Alluvial Aquifer

Groundwater quality in the Ohio River alluvial aquifer was assessed using analytical results for samples collected from 23 wells from June 2019 to January 2020. These water-quality data were described by summary statistics and compared to drinking water standards. Multivariate statistics were used to provide insight into factors affecting the groundwater quality.

Statistical Summary of Field Parameters and Analytical Results

The sites sampled for this study represent raw-water supplies. Many of these sites have additional treatment after the point sampled, so the statistical summary of results presented here characterizes source water that may not be representative of supplied drinking water. Nevertheless, these data were compared to human-health benchmarks established by EPA (Environmental Protection Agency, 2018) to describe source-water quality relative to drinking-water standards. The EPA's regulatory primary standards are established to protect human health, are mandatory for public supplies, and define the maximum-contaminant levels (MCL) or highest allowable concentrations in drinking water. Other non-regulatory EPA drinking-water guidelines used to assess this dataset include health advisories (HA) and secondary maximum-contaminant levels (SMCL). Health advisories, which are non-enforceable, provide technical information to state agencies and other public health officials on potential health effects for selected constituents that have no MCL or, in addition to the MCL. Secondary maximum-contaminant levels are listed for selected constituents that pose no known health risk but may have adverse aesthetic effects, such as staining or undesirable taste or odor.

Field Parameters and Total Dissolved Solids

Parameters used for general water-quality characterization included field measurements of pH, specific conductance, temperature, turbidity, and alkalinity (table 7). The only field measurement to have an established secondary drinking-water standard is pH. The SMCL range for pH is from 6.5 to 8.5 units. Water with pH less than 6.5 may be corrosive and could leach metals like copper or lead from plumbing. Water with a measured pH less than, greater than, or equal to 7 is acidic, basic, or neutral, respectively. The pH of groundwater measured in samples from all 23 wells ranged from 6 to 7.4, with a median of 7. Three of 23 samples (13 percent) were outside of the SMCL range, and all 3 had pH lower than 6.5.

Total dissolved solids is used as a measure of salinity, with freshwater typically having TDS concentrations less than 1,000 mg/L. Concentrations of TDS of groundwater samples from the 23 wells ranged from 195 mg/L to 727 mg/L. Only one groundwater sample had TDS concentrations that exceeded the SMCL of 500 mg/L in drinking water.

Major Ions, Nutrients, and Trace Elements

Sources of major ions in the Ohio River alluvium may include precipitation, dissolution of minerals, and constituents introduced through various anthropogenic activities, such as deicing salts and septic systems. The only major ion with an MCL is fluoride, at 4 mg/L, and no samples had fluoride concentrations that exceeded this threshold. The SMCLs have been established for two major ions, 250 mg/L SMCL for sulfate and 250 mg/L SMCL for chloride, but no sample had concentrations of these constituents that exceeded the respective standards. Although chloride concentrations did not exceed a drinking-water standard, chloride concentrations higher than 10 are likely to be above natural background levels (Davis and others, 2005). The health-based drinking-water advisory of 20 mg/L sodium established by EPA for individuals on a sodium-restricted diet was exceeded in 12 of 23 (52 percent) samples. The EPA taste-based drinking-water advisory of 30–60 mg/L sodium was exceeded in samples from 4 wells, with those concentrations ranging from 30.1 to 54.1 mg/L.

Nitrate was detected above the reporting level at all 23 sites, ranging from 0.153 to 7.18 mg/L as N, but was not measured above the MCL of 10 mg/L as N in samples from any well in the study area (table 8). Nitrite was detected above the reporting level at 10 of 23 wells (43 percent) but was not measured in samples from any well above the MCL of 1 mg/L as N. Ammonia has a HA level and taste-based drinking-water advisory of 30 mg/L, but no samples had ammonia concentrations that exceeded this threshold. Nitrate and nitrite are common nutrients that can exceed drinking-water standards in agricultural areas of West Virginia, but the occurrence of nitrate and other nutrients at concentrations approaching drinking-water standards is uncommon for non-agricultural areas of the state (Chambers and others, 2012). Nitrate is not only derived from agricultural fertilizers, both from synthetic and animal sources, but also can be derived from wastewater treatment plant effluent or septic systems.

Concentrations of 23 trace elements, 20 of which have established drinking-water standards (MCLs, SMCL, or HAs), were analyzed at all 23 groundwater sites (table 8). Eighteen of these analytes were detected above the reporting level, with 14 analytes detected at more than 70 percent of sites, but no trace element was measured in concentrations above any established MCL. Manganese exceeded its criteria (SMCL and HA) more frequently than any other trace element. Iron was the second most frequent trace element to exceed its criteria. The SMCL of 50 micrograms per liter for manganese was exceeded in samples from 11 of 23 wells (48 percent) and the HA threshold of 300 mg/L was exceeded in 5 of 23 samples (22 percent). The SMCL of 300 mg/L for iron was exceeded in samples from 4 of 23 wells (17 percent).

Table 7. Descriptive statistics of chemical properties measured in the field and total dissolved solids and dissolved major ion concentrations measured in the laboratory for groundwater samples collected from 23 wells in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

[Human-health benchmarks from U.S. Environmental Protection Agency (2018). MCL, maximum-contaminant level; HA, health advisory; SMCL, secondary maximum-contaminant level; mg/L, milligrams per liter; —, not applicable because there is no set standard for this constituent; n.d., no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SU, standard units; NTRU, nephelometric turbidity unit; $CaCO_3$, calcium carbonate; SiO_2, silica]

Constituent	Unit	Number of samples	Above reporting level		Minimum	Median	Maximum	Exceeding standard		MCL	HA	SMCL
			Number	Percent				Number	Percent			
Dissolved oxygen	mg/L	23	23	100	0.1	1.5	8.5	—	—	—	—	—
Specific conductance	µs/cm	23	23	100	330	519	1,190	—	—	—	—	—
pH	SU	23	23	100	6	7	7.4	3	13	n.d.	n.d.	6.5–8.5
Turbidity	NTU	23	23	100	0.2	0.3	0.8	—	—	—	—	—
Alkalinity	mg/L as $CaCO_3$	23	23	100	71.6	178	331	—	—	—	—	—
Total dissolved solids	mg/L	23	23	100	195	314	727	1	1	n.d.	n.d.	500
Hardness	mg/L as $CaCO_3$	23	23	100	120	250	532	—	—	—	—	—
Calcium	mg/L	23	23	100	38.9	82.1	162	—	—	—	—	—
Magnesium	mg/L	23	23	100	5.51	10.1	30.8	—	—	—	—	—
Potassium	mg/L	23	23	100	0.96	1.81	2.75	—	—	—	—	—
Sodium	mg/L	23	23	100	4.51	20.6	54.1	12	52	—	20	n.d.
Bicarbonate	mg/L	23	23	100	87.3	216	403	—	—	—	—	—
Bromide	mg/L	23	23	100	0.024	0.05	0.388	—	—	—	—	—
Chloride	mg/L	23	23	100	8.58	32.7	116	0	0	n.d.	n.d.	250
Fluoride	mg/L	23	23	100	0.07	0.17	0.26	0	0	4	n.d.	2
Sulfate	mg/L	23	23	100	17.5	42.8	140	0	0	n.d.	n.d.	250
Silica	mg/L as SiO_2	23	23	100	9.55	14.9	25.8	—	—	—	—	—

Microbiological Indicators

Although fecal-indicator bacteria rarely cause illness, their presence in groundwater indicates the possible presence of pathogens associated with fecal contamination from sewage, agricultural activities, or surface-derived sources. Total coliforms are bacteria in animal intestines, in soils, and on vegetation. *Escherichia coli*, a coliform bacteria, is a natural inhabitant of the gastrointestinal tract of warm-blooded animals and is direct evidence of fecal contamination in source water. *Enterococci* bacteria are commonly present in the feces of warm-blooded animals. *Enterococci* are more persistent in water than coliforms and provide a different assessment of the transport of fecal contamination in groundwater than coliforms because of their unique shape and survival rate. Somatic coliphage and F-specific coliphage are viral indicators that infect and replicate in *Escherichia coli* bacteria. No sample had detections over the reporting level for any of the 5 fecal indicators analyzed at 18 sites in the aquifer (table 3).

Dissolved Organic Carbon and Anthropogenic Organic Compounds

Dissolved organic carbon was analyzed in groundwater samples from all 23 wells in the study area. Often the most common electron donor available in groundwater systems, DOC is used by microorganisms that catalyze redox processes. In alluvial aquifers, DOC concentrations have been shown to be higher near rivers, which leads to increased reduction and mobilization of manganese in shallow groundwater systems influenced by surface water (McMahon and others, 2019). Dissolved organic carbon was detected above the reporting level at all 23 sites and the median value for DOC in the aquifer was 0.81 mg/L (table 9).

Volatile organic compounds include solvents, fuel additives, and chemicals used in industrial processes that are typically characterized by exhibiting low vapor pressure. For this study, a suite of 81 VOCs was analyzed in groundwater samples from a subset of 19 wells. Only 9 of the 82 VOCs

Table 8. Descriptive statistics of nutrients and trace elements measured in the laboratory for samples collected from groundwater wells in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

[Human-health benchmarks from U.S. Environmental Protection Agency (2018). MCL, maximum-contaminant level; HA, Health Advisory; SMCL, secondary maximum-contaminant level; mg/L, milligrams per liter; N, nitrogen; <, less than; —, not applicable; P, phosphorus; µg/L, micrograms per liter]

Constituent	Unit	Number of samples	Above reporting level		Minimum	Median	Maximum	Exceeding standard		MCL	HA	SMCL
			Number	Percent				Number	Percent			
Ammonia	mg/L as N	23	16	70	0.01	0.01	0.47	0	0	—	30	—
Nitrate	mg/L as N	23	23	100	0.153	3.27	7.18	0	0	15	—	—
Nitrite	mg/L as N	23	10	43	<0.001	0.001	0.009	0	0	1	—	—
Orthophosphate	mg/L as P	23	21	91	<0.004	0.017	0.05	—	—	—	—	—
Aluminum	µg/L	23	0	0	<3	—	<6	0	0	—	—	50–200
Antimony	µg/L	23	1	4	<0.06	—	<1.2	0	0	6	—	—
Arsenic	µg/L	23	21	91	<0.1	0.25	1	0	0	15	—	—
Barium	µg/L	23	23	100	24.8	60.8	115	0	0	2,000	—	—
Boron	µg/L	23	23	100	20	56	69.1	0	0	—	7,000	—
Beryllium	µg/L	23	0	0	<0.01	—	<0.03	0	0	4	—	—
Cadmium	µg/L	23	3	13	<0.03	0.03	0.115	0	0	5	—	—
Chromium	µg/L	23	0	0	<0.5	—	<1	0	0	100	—	—
Cobalt	µg/L	23	18	78	<0.03	0.069	0.467	—	—	—	—	—
Copper	µg/L	23	18	78	<0.4	1.1	30.1	0	0	1,300	1,000	—
Iron	µg/L	23	10	43.4	<10	10	800	4	17	—	—	300
Lead	µg/L	23	21	91	<0.02	0.163	2.26	0	0	15	—	—
Lithium	µg/L	23	23	100	1.27	3.06	6.75	—	—	—	—	—
Manganese	µg/L	23	19	82	<0.4	34.3	1,740	11	48	—	300	50
Molybdenum	µg/L	23	21	91	<0.05	0.423	2.01	0	0	—	40	—
Nickel	µg/L	23	21	91	<0.2	0.46	7.4	0	0	—	100	—
Selenium	µg/L	23	21	91	<0.05	0.27	2.3	0	0	50	—	—
Silver	µg/L	23	0	0	<1	—	<2	0	0	—	—	100
Strontium	µg/L	23	23	100	107	185	658	0	0	—	4,000	—
Thallium	µg/L	23	0	0	<0.04	—	<0.08	0	0	2	—	—
Vanadium	µg/L	23	15	65	<0.1	0.12	0.38	—	—	—	—	—
Uranium	µg/L	23	20	86	<0.03	0.288	0.661	0	0	30	20	—
Zinc	µg/L	23	17	74	<2	4.1	42.6	0	0	—	2,000	5,000

were detected in these samples; however, no VOCs were detected above any established health-based thresholds (table 9). Chloroform (also known as trichloromethane) was the most frequently detected VOC, with low concentrations in 52 percent of samples. Three other VOCs that were frequently detected in the aquifer at low concentrations included 1,1,1-trichloroethane, tetrachloroethene (also known as tetrachloroethylene or PCE), and trichloroethene (also known as trichloroethylene or TCE), all of which were in 37 percent of the samples.

A suite of 55 SVOCs was analyzed in groundwater samples from a subset of 13 wells in the study area. Infrequently contaminating groundwater in West Virginia, SVOCs are anthropogenic organic compounds characterized by low vapor pressure (Chambers and others, 2012). No SVOCs were detected above the reporting level in any sample collected for this study.

A suite of 82 pesticides and herbicides was evaluated in groundwater samples from 19 wells (table 9). Only 6 of these 82 analytes were detected. The detected compounds were metolachlor sulfonic acid, 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, dechlorometolachlor, tebuthiuron, metolachlor, and atrazine. Of those, only atrazine has an established MCL, but no sample had atrazine concentrations above that MCL. Metolachlor sulfonic acid was detected most frequently of the 82 analytes, being detected in groundwater from 7 of 23 (37 percent) sampled wells. Metolachlor sulfonic

Table 9. Descriptive statistics of dissolved organic matter and organic compounds detected in samples from the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020. Human-health benchmarks from U.S. Environmental Protection Agency (2018).

[There were no secondary maximum-contaminant levels for analytes in this table. MCL, maximum-contaminant level; HA, Health Advisory; µg/L, micrograms per liter; ng/L, nanograms per liter; PFAS, per- and polyfluoroalkyl substances; VOC, volatile organic compound; —, not applicable; <, less than]

Constituent	Unit	Compound type	Number of Samples	Above reporting level		Minimum	Median	Maximum	Exceeding standard		MCL	HA
				Number	Percent				Number	Percent		
Dissolved organic carbon	µg/L	—	23	23	100	0.35	0.81	1.71	0	0	—	—
Chloroform	µg/L	VOC	19	10	52	<0.01	0.02	0.76	0	0	80	—
1,1,1-Trichloroethane	µg/L	VOC	19	7	37	<0.014	0.025	0.169	0	0	200	—
Tetrachloroethene	µg/L	VOC	19	7	37	<0.022	0.03	0.423	0	0	5	—
Trichloroethene	µg/L	VOC	19	7	37	<0.01	0.019	0.083	0	0	5	—
cis-1,2-Dichloroethene	µg/L	VOC	19	4	21	<0.016	0.019	0.035	0	0	—	—
1,2,4-Trimethylbenzene	µg/L	VOC	19	3	15	<0.016	0.025	0.058	0	0	—	—
Chlorodifluoromethane	µg/L	VOC	19	2	10	<0.04	—	0.12	0	0	—	—
1,1-Dichloroethane	µg/L	VOC	19	2	10	<0.013	—	0.078	0	0	—	—
Methyl tert-butyl ether	µg/L	VOC	19	2	10	<0.01	—	0.07	0	0	—	—
Metolachlor sulfonic acid	ng/L	Pesticide	19	7	37	<12	25.7	250	—	—	—	—
2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine	ng/L	Pesticide	19	4	21	<8	8	250	—	—	—	—
Dechlorometolachlor	ng/L	Pesticide	19	4	21	<1.42	1.42	5	—	—	—	—
Tebuthiuron	ng/L	Herbicide	19	4	21	<1.41	2.59	3.57	—	—	—	—
Metolachlor	ng/L	Herbicide	19	2	10	<1.1	—	3.3	—	—	—	—
Atrazine	ng/L	Herbicide	19	2	10	<5.03	—	10	0	0	300	—
PFBS (perfluorobutanesulfonate)	ng/L	PFAS	23	5	22	<3.8	—	24.5	0	0	—	2,000
PFBA (perfluorobutanoate)	ng/L	PFAS	23	5	22	<3.8	—	24	—	—	—	—
PFHpA (perfluoropentanoate)	ng/L	PFAS	23	2	1	<3.8	—	58.3	—	—	—	—
PFHxS (perfluorohexanesulfonate)	ng/L	PFAS	23	7	30	<3.8	—	81.4	—	—	—	—
PFHxA (perfluorohexanoate)	ng/L	PFAS	23	4	17	<3.8	—	37.1	—	—	—	—
PFNA (perfluorononanoate)	ng/L	PFAS	23	1	1	<3.8	—	8	—	—	—	—
PFOS (perfluorooctanesulfonate)	ng/L	PFAS	23	3	13	<3.8	—	97.9	3	13	—	0.02
PFOA (perfluorooctanoate)	ng/L	PFAS	23	5	22	<3.8	—	1,540	5	22	—	0.004
PFPeS (perfluoropentanesulfonate)	ng/L	PFAS	23	1	1	<3.8	—	12.4	—	—	—	—
PFPeA (perfluoropentanoate)	ng/L	PFAS	23	3	13	<3.8	—	17	—	—	—	—

acid, a commonly used herbicide, is a metabolite of metolachlor (Aga and others, 1996), which was also detected in groundwater samples from two wells.

PFAS results were evaluated in terms of concentrations that were reported above the laboratory reporting level, and 10 different PFAS were detected in the Ohio River alluvial aquifer (table 9). Other PFAS were detected below laboratory reporting levels in numerous samples and these concentrations are reported as estimated values in McAdoo, Grindle, and Grindle (2022) but are not discussed in this report. McAdoo, Connock, and Messinger (2022) generated a statewide assessment of PFAS, providing detailed information about the occurrence and distribution of PFAS in West Virginia's source water and the Ohio River alluvial aquifer.

Geochemistry of the Ohio River Alluvial Aquifer

The generalized conceptual model of flow in the Ohio River alluvial aquifer (fig. 2) assumes that recharge to the aquifer is primarily from meteoric sources. Specifically, precipitation falling on the alluvium percolates through the unsaturated zone into saturated sands and gravels, and water infiltrates from the Ohio River in areas of high pumping or during periods of high river stage (Jeffords, 1945; Mathes and others, 1997; Maharjan and Donovan, 2017).

Assessment of major ion chemistry with trilinear diagrams (fig. 3) supports this assumption of two major recharge sources because surface water and groundwater distant from the river have different chemical compositions; samples collected from surface-water sources appear to have a sulfate plus chloride dominated anion abundance, whereas the percentage of anions for wells located greater than 1,000 feet from the river has more carbonate plus bicarbonate. Differentiation of these two groups, with most intermediate wells located between these analyte abundances on trilinear diagrams, suggests that the conceptual model of two end members for recharge sources is representative of the system.

Hydrogeochemical processes controlling solute concentrations in the Ohio River alluvial aquifer were evaluated with multivariate statistical analysis of the available chemical data for the 23 wells sampled using PCA and graphical analysis. The results of the PCA (table 10) show 3 major hydrogeochemical processes—redox, salinity, and carbonate dissolution—predominantly control the geochemical system, with 73 percent of the variance explained by the first 3 components of the PCA. Twelve variables were represented in the PCA by loadings, which correlate individual variables to specific principal components. Positive loadings indicate that

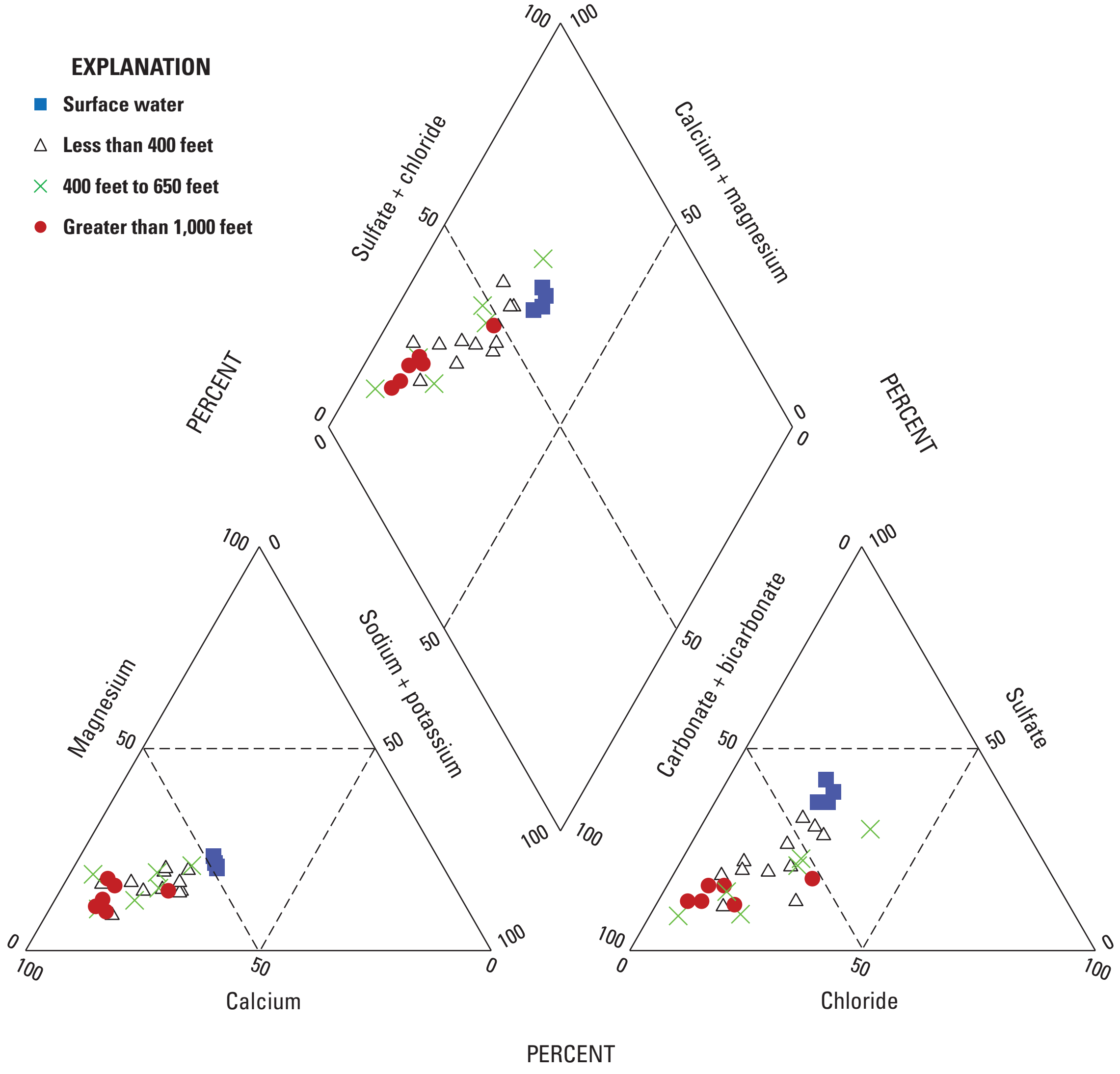

Figure 3. Trilinear diagrams showing the calcium, magnesium, sodium, potassium, sulfate, carbonate, bicarbonate, and chloride ion composition in 23 groundwater wells and 4 surface-water samples collected in the Ohio River and adjacent Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

Table 10. Distribution of eigenvector loadings and significant Spearman's correlation coefficients for the principal component analysis model.

[Communality ranges from 0 to 1 and represents the proportion of the variables variance resulting from the principal components (PC). %, percent; —, not applicable; p, probability value of statistical significance]

Variable	PC1, redox processes	PC2, salinity sources	PC3, carbonate dissolution	Communality
		Measured variables		
Manganese	[1]0.82	0.16	−0.15	0.72
Iron	[1]0.81	−0.04	0.04	0.66
Dissolved organic carbon	[1]0.81	−0.07	−0.03	0.66
Dissolved oxygen	[1]−0.79	−0.04	0.25	0.68
Nitrate	[1]−0.71	−0.29	0.38	0.73
Distance	[1]−0.44	−0.25	[1]0.53	0.54
Silica	[2]−0.43	[1]−0.54	0.35	0.6
Sodium	0.21	[1]0.88	0.02	0.82
Chloride	0.17	[1]0.85	0.07	0.75
Sulfate	0.00	[1]0.82	−0.36	0.81
Potassium	0.02	[1]0.81	0.04	0.66
Magnesium	−0.18	[1]0.73	0.22	0.62
Bicarbonate	−0.05	0.02	[1]0.96	0.93
Calcium	−0.20	0.20	[1]0.90	0.90
		Computed variables		
Eigenvalue	3.63	3.87	2.56	—
Cumulative variance %	0.26	0.54	0.72	—
Component variance %	0.26	0.28	0.18	—
Proportion explained %	0.36	0.39	0.25	—

[1] Indicates significant loadings on each component at the 99-percent confidence interval ($p<0.01$).

[2] Indicates significant loadings on each component at the 95-percent confidence interval ($p<0.05$).

as the value of one constituent increases, the value of the correlated constituent also increases; whereas, negative loadings indicate that as the value of one constituent increases, the value of the correlated constituent decreases.

Reduction and Oxidation Processes

The first principal component (PC1, table 10) is representative of ions generally controlled by redox processes, explains 26 percent of the variance, and has significant ($p<0.01$) positive loadings for manganese, iron, and DOC. Negative loadings on PC1 include dissolved oxygen, nitrate, and distance. Significant ($p<0.01$) negative loading of distance (distance of a well from the Ohio River) on PC1 indicates that wells located closer to the Ohio River have higher concentrations of manganese, iron, and DOC, but lower concentrations of dissolved oxygen and nitrate. Likewise, wells located further from the Ohio River would be expected to have higher concentrations of dissolved oxygen and nitrate, although manganese, iron, and DOC would be expected to be lower. Also, significant ($p<0.05$) negative loading of silica on PC1 indicates that silicates may dissolve more readily in wells farther from the river. As noted in the section on "Dissolved Organic Carbon and Anthropogenic Compounds," DOC is a common electron donor available in groundwater systems and is used by microorganisms that catalyze redox processes. In alluvial aquifers, DOC concentrations have been shown to be higher near rivers, which leads to increased reduction and mobilization of manganese in shallow groundwater systems influenced by surface water (McMahon and others, 2019).

Sources of Salinity

The second principal component (PC2, table 10) has significant ($p< 0.01$) positive loadings for sodium, chloride, and potassium, which are constituents commonly associated with sources of salinity and may be related to land-use or waste-disposal practices. Sources of salinity and associated constituents (sodium, chloride, potassium, bromide) have been identified using chloride to bromide ratios by several authors (Davis and others, 2005; Katz and others, 2011). Chloride to bromide mass ratios calculated with the data collected for this study ranged from 144 to 1,731 (fig. 4). Chloride to bromide mass ratios with values in this range and measured chloride concentrations from approximately 20 to 120 mg/L in samples from the 23 wells (table 2) are typical of animal waste or sewage (300–1,000 mg/L) and halite dissolution (1,000–10,000 mg/L from natural and anthropogenic salt sources), which are the probable sodium, potassium, chloride, and bromide sources to groundwater in this area (Davis and others, 2005; Mullaney and others, 2009; Katz and others, 2011).

Magnesium commonly has positive correlation with calcium and significant loading on the principal component that explains carbonate dissolution when magnesium is derived from calcium-carbonate solid-phase sources, but it has a significant ($p<0.01$) positive loading on PC2 and significant correlation with the constituents responsible for salinity. This positive loading indicates that the main source of magnesium may be from wastewater. Another possible explanation for this significant loading is that additional sodium added to the aquifer through different salinity sources may promote cation exchange of sodium with calcium or magnesium, thus magnesium concentrations may increase more through cation exchange processes rather than dissolution of magnesium-rich carbonates, such as dolomite. Calcium plus magnesium to bicarbonate molar ratios are >1 (fig. 5), indicating that there may be an abundance of magnesium or calcium that cannot be explained by carbonate dissolution alone. Sodium and chloride molar ratios plot close to 1 (fig. 5) indicating that cation exchange may not be an important process controlling magnesium concentrations and the origin of magnesium could be from several different wastewater sources.

Carbonate Dissolution

The third principal component (PC3, table 10) has significant ($p<0.01$) positive loadings for bicarbonate and calcium, which is indicative of carbonate dissolution. Significant ($p<0.01$) positive loading for the distance of a well from the Ohio River indicates that calcium and bicarbonate concentrations increase through carbonate dissolution in distal wells. This increase may be indicative of recharge from precipitation in distal wells that is more chemically aggressive than river water and capable of higher rates of carbonate mineral dissolution. The molar ratio of calcium to magnesium shows a much higher mass of calcium (fig. 6), which implies that calcite is the main carbonate mineral involved in carbonate mineral dissolution processes throughout the aquifer. The molar ratio of calcium to bicarbonate confirms this observation, that these two constituents follow a linear one-to-one

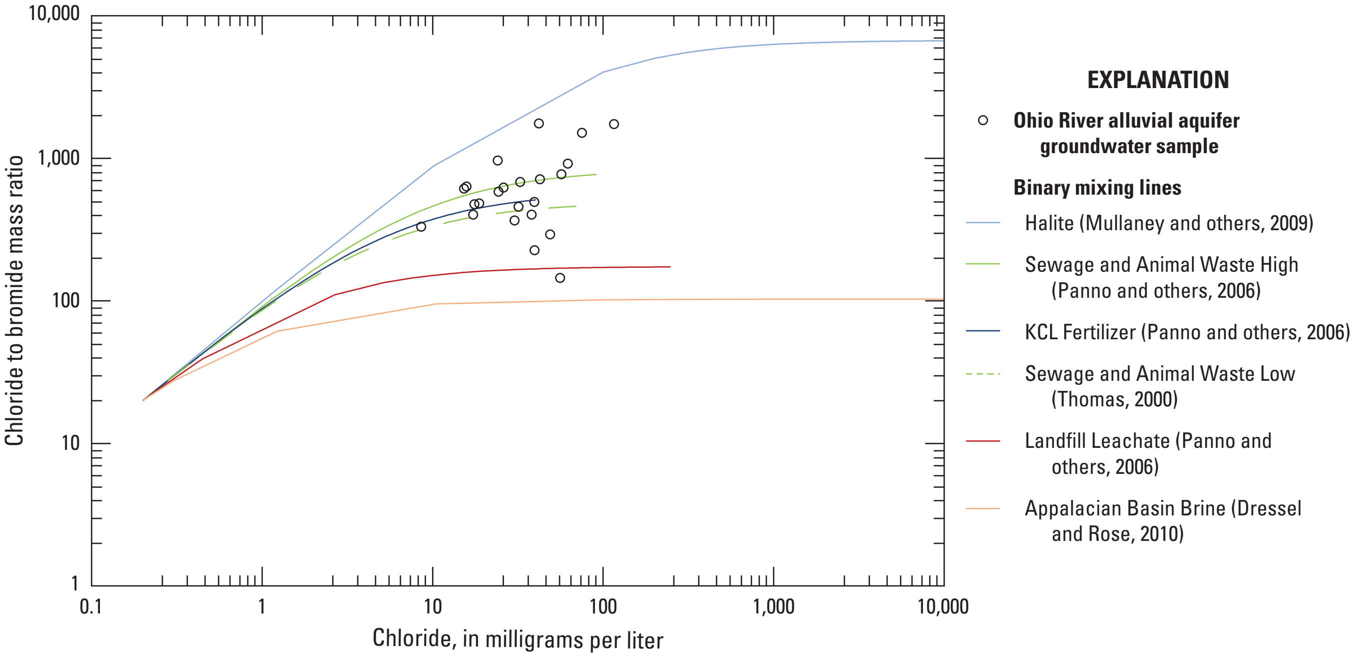

Figure 4. Scatterplot of chloride to bromide mass ratio versus chloride concentration in the 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020, in relation to the binary mixing lines of previous studies. Data are from Thomas (2000), Panno and others (2006), Dresel and Rose (2010), and Mullaney and others (2009).

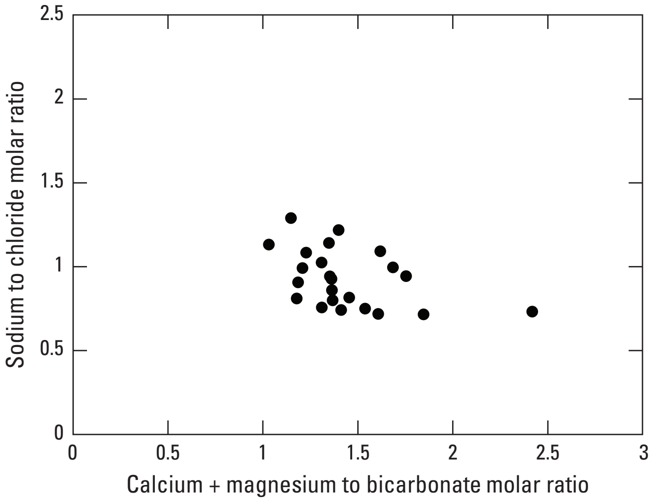

Figure 5. Scatterplot comparing the sodium to chloride mass ratio to the calcium plus magnesium to bicarbonate molar ratio calculated from the water-quality data for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

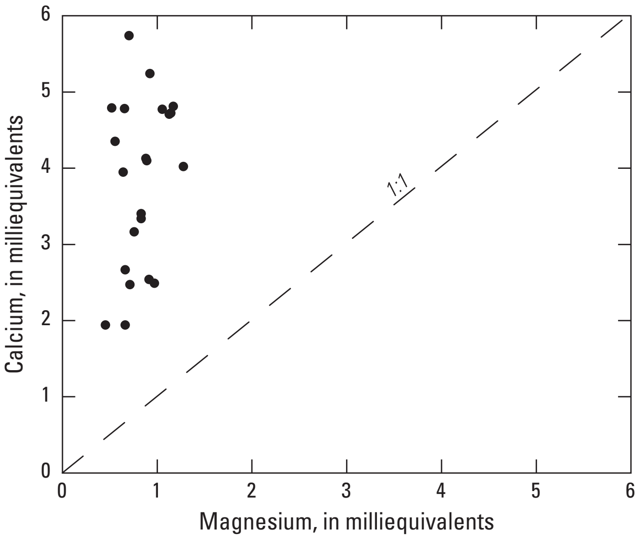

Figure 6. Scatterplot comparing the molar ratio of calcium and magnesium calculated from the water-quality data for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

relationship (fig. 7), and supports the previous assumption that magnesium may be supplied to the aquifer by originating from sources other than calcium, such as weathering magnesium-bearing minerals or through wastewater rather than carbonate dissolution.

Water-Quality Indicators of Surface-Water Influence on Groundwater Wells

Constituents related to surface water and near surface or surface sources were used as indicators to evaluate their potential influence on groundwater. A combination of isotope analysis, age-tracer analysis, binary mixing models, and geochemical inverse models were used to determine recharge sources, estimate groundwater age, and assess the influence of the Ohio River on the adjacent alluvial aquifer.

Nitrate, Pesticides, Volatile Organic Compounds, ^{3}H, and Dissolved Organic Carbon

Kozar and Paybins (2016) identified bacteria, nitrate, pesticides, volatile organic compounds, and chlorofluorocarbons as indicators of potential surface-water influence on, and vulnerability to contamination from surface or near-surface sources in, groundwater. Chlorofluorocarbons were not collected for this study but ^{3}H was used in its place to indicate infiltration of modern water and assess aquifer vulnerability to surface contamination. Additionally, DOC may indicate strong connections among groundwater and near-surface sources or surface water (Shen and others, 2015). The presence of nitrate and DOC measured in concentrations above reporting levels in all 23 groundwater samples and detections of one or more man-made organic compounds in 22 groundwater samples (tables 8, 9, and 11; McAdoo, Grindle, and Grindle (2022) indicates that the alluvial aquifer is potentially contaminated or recharged by surface or near-surface water. Although no groundwater samples had detections for any of the five microbial constituents analyzed for this study, Kozar and Paybins (2016) stated that detections of bacteria in groundwater from alluvial aquifers in West Virginia may be infrequent because of alluvial sediments acting as a large sand filter that naturally retards the movement of bacteria. However, concentrations of nitrate and DOC and detections of ^{3}H and man-made organic compounds are consistent with potential surface-water or surface-sources' influence on groundwater. Samples from 19 wells had nitrate concentrations >1 mg/L as N, samples from 9 wells had DOC concentrations >1 mg/L, samples from 18 wells had detectable ^{3}H, samples from 17 wells had detections for VOCs, and samples from 11 wells had detections for

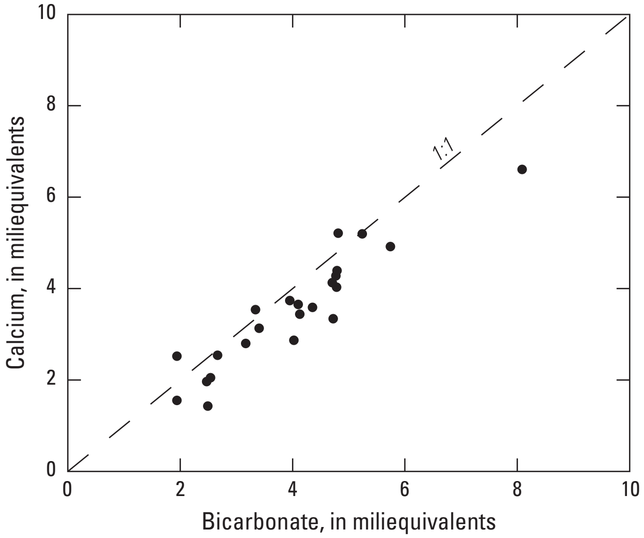

Figure 7. Scatterplot comparison of the equivalent mass of calcium and bicarbonate calculated from the water-quality data for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

pesticides (table 11). Every well sampled for this study in the Ohio River alluvial aquifer had detections for at least one of these indicators of surface-water influence.

Stable Isotope Analysis

Stable isotopes of water (δ^2H and δ^{18}O) were evaluated to determine variation in recharge sources throughout the study area by comparing measured isotopic concentrations at sampling sites (wells and river locations) to the isotopic composition reported in precipitation. Values of δ^{18}O ranged from −8.33 to −5.63 parts per thousand (permil) and values of δ^2H ranged from −54.5 to −40.0 permil (table 12). The LMWL published by Smith and others (2021; $\delta^2H=7.58 \times \delta^{18}O+9.16$) was used to represent precipitation in the Ohio River Valley. This line deviates from the global meteoric water line ($\delta^2H=8 \times \delta^{18}O+10$; Craig, 1961) and indicates enrichment of isotopes in precipitation at the local scale (fig. 8). Stable isotope data collected for this study generally follow the LMWL, indicating that recharge to the alluvial aquifer is from a meteoric source of precipitation, with the exception of one site (Mas-0918). River water samples were collected in November 2019 and the stable isotopic composition of these samples (fig. 8) may partly reflect seasonal conditions, with lighter values in cooler months.

Values for line-conditioned (LC) excess are all generally below the one standard deviation measurement uncertainty (S=1.13) except for Ohio River at Moundsville (site name shortened to OR Moundsville in this report) with a LC-excess of −1.51, and Mas-0918 with a LC excess of −6.48. Negative values of LC-excess indicate evaporative enrichment after precipitation. The reason for elevated LC-excess at OR Moundsville is unknown, but the magnitude of the departure from the LMWL is relatively small in comparison to Mas-0918. This site is within 1,000 feet of wetlands and ponds that may experience evaporation, which subsequently enriches the isotopic concentrations in groundwater recharge in that area.

Carbon Isotope Analysis

Surface-water samples had δ^{13}C values between −11.4 and −10.81 permil. Groundwater samples generally had values of δ^{13}C that were less than −13.57 permil except for Mas-0918, which had a δ^{13}C value of −11.91 permil. Mas-0918 was identified as having an LC-excess indicative of an evaporative source, likely from wetlands in the immediate area, and a bicarbonate/sulfate signature that deviated from other intermediate well samples. This high δ^{13}C value may further indicate that the groundwater entering Mas-0918 may be heavily influenced by the proximal wetlands source.

Groundwater samples generally plot to the left of the zero-age line for the open system RFG analytical model (fig. 9; Han and Plummer, 2013). The model was parameterized with values for δ^{13}C soil gas and solid carbonates of −25 permil and 2 permil, respectively, which are consistent with typical soil-zone gases and marine carbonate isotopic compositions (Clark and Fritz, 1997). The position of some samples on the figure (close to the zero-age line) indicates that the dominant controls of DIC in the study area are carbonate dissolution and open system exchange with soil CO_2, but several samples do not follow the zero-age line, which may indicate that other processes affect carbon isotope chemistry. The more fractionated δ^{13}C signal of these samples is possibly driven by organic carbon oxidation by microbial processes indicated by samples with low dissolved oxygen or high concentrations of iron or manganese. Without appropriate correction for microbial processes and carbon sources, ^{14}C has limited utility for quantification of groundwater age in samples in which controls on DIC are not accounted for.

Where possible, the final adjusted ^{14}C (table 12) for these samples was computed, resulting in a range from 100 to 133 percent modern carbon (pmC). The corrected ^{14}C values are generally consistent with other tracers and indicate that recent recharge along local flow paths is captured at these sites. Carbon-14 has limited utility for quantitative age dating of modern samples because of (1) elevated atmospheric ^{14}C (for example, >100 pmC) from above-ground nuclear testing since late 1950s and (2) high sensitivity of modern interpreted

Table 11. Water-quality indicators of surface-water influence on, or vulnerability to surface contamination of, groundwater wells as defined by Kozar and Paybins (2016). Wells listed in order of distance from the Ohio River.

[U.S. Geological Survey (USGS) site identification official names and shortened names are found in table 1. ID, identification; Micro, the number of times a microbiological constituent was detected in a sample; mg/L, milligrams per liter; N, nitrogen; DOC, dissolved organic carbon concentration; ^{3}He, helium-3; TU, tritium units; VOC, the number of times a volatile organic compound analyte was detected in a sample; Pest, the number of times a pesticide analyte was detected in a sample; ND, not detected; —, not available because no measurements were taken]

Shortened USGS site name or ID	Micro	Nitrate (mg/L as N)	DOC (mg/L)	^{3}H (TU)	VOC	Pest
OR Moundsville	—	0.71	4	—	—	—
OR Parkersburg	—	0.87	3.71	—	—	—
OR Ravenswood	—	0.89	3.6	—	—	—
OR Gallipolis	—	0.81	3.33	—	—	—
Hnc-0043	ND	3.27	0.71	16.4	3	5
Wet-0146	ND	0.15	1.71	15.7	1	1
Woo-0121	ND	0.28	1.12	20.1	3	5
Mal-0104	ND	1.35	0.91	14.2	2	2
Mas-0934	ND	5.99	0.39	3.2	1	ND
Mas-0968	ND	3.52	0.74	8.7	ND	ND
Woo-0215	ND	2.09	0.97	5.5	2	2
Ohi-0372	ND	0.28	0.81	22.9	1	1
Woo-0177	ND	0.24	1.00	29.1	1	3
Tyl-0101	ND	3.53	0.83	4.3	3	ND
Woo-0216	ND	5.1	1.13	6.5	6	1
Wet-0135	ND	5.12	0.92	5.2	4	1
Ple-0068	ND	1.56	1.19	5.3	2	ND
Mas-0918	ND	0.94	1.24	4.9	1	1
Mal-0410	ND	2.66	0.46	5.2	2	ND
Brk-0077	ND	1.98	0.60	4.8	2	ND
Mas-0936	ND	4.84	0.37	3.7	3	1
Mas-0852	—	6.18	0.35	—	—	—
Jac-0128	—	3.68	0.48	—	—	—
Ple-0071	—	3.01	0.49	—	—	—
Mas-0920	ND	3.71	0.86	3.4	5	ND
Jac-0057	—	4.73	0.53	—	—	—
Woo-0196	—	7.18	0.60	—	—	—

ages to the geochemical correction. High pmC values of ^{14}C and the presence of ^{3}H at every site indicates no, or very little, pre-1950s water in any sample collected for this study.

Groundwater Age Tracer Analysis

Measured concentrations of noble gasses were generally within 20 percent of atmospheric solubility equilibrium with Ne, Ar, Kr, and Xe exhibiting average deviations from solubility equilibrium of 20.9, 14.1, 9.2, and 6.1 percent, respectively (table 13). Dissolved noble gas data were well-fit by solubility models with statistically significant model solutions (χ^2 values less than critical value of 3.84; one-sided, one degree of freedom, 95 percent confidence). One sample (Ohi-0372) was determined to have re-equilibrated with the atmosphere because of sample container malfunction and was not used for further dissolved gas analysis. Noble gas solubility models provided a good estimate of the groundwater recharge temperature (referred to as noble gas recharge temperature; NGT) and the amount of EA for each sample. Noble gas temperatures generally group around the mean annual air temperature modeled for the study area (PRISM Climate Group, 2022). Modeled NGTs ranged from 11.0 to 13.7 °C with two outlier values of 15.1 °C and 16.9 °C at Woo-0121and Mas-0936, respectively.

Table 12. Results for isotopes and age tracers collected at 4 surface-water sites from the Ohio River and 23 groundwater wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020. Wells listed in order of distance from the Ohio River.

[U.S. Geological Survey (USGS) site identification official names and shortened names are found in table 1. ID, identification; δ^{2}H, delta hydrogen-2; ‰, permil; δ^{18}O, delta oxygen-18; LC-excess, line-conditioned excess; TU, tritium units; δ^{13}C, delta carbon-13; ^{14}C, carbon-14; pmC, precent modern carbon; OR, Ohio River; —, not available because no measurements were taken]

Shortened USGS site name or ID	δ^{2}H (‰)	δ^{18}O (‰)	LC-excess	Tritium (TU)	δ^{13}C (‰)	Corrected ^{14}C (pmC)
OR Moundsville	−49.1	−7.48	−1.56	—	−10.88	—
OR Parkersburg	−49.4	−7.63	−0.72	—	−10.9	—
OR Ravenswood	−51.6	−7.92	−0.73	—	−11.4	—
OR Gallipolis	−51	−7.88	−0.43	—	−10.81	—
Hnc-0043	−54.5	−8.33	−0.52	16.4	−15.26	102
Wet-0146	−52.5	−8.04	−0.72	15.7	−18.05	118
Woo-0121	−47.3	−7.31	−1.05	20.1	−17.33	117
Mal-0104	−49.1	−7.76	0.56	14.2	−15.32	117
Mas-0934	−44.5	−7.13	0.39	3.2	−14.16	126
Mas-0968	−44.9	−7.11	−0.17	8.7	−16.93	133
Woo-0215	−47.6	−7.55	0.47	5.5	−14.69	126
Ohi-0372	−51.7	−7.98	−0.37	22.9	−16.16	110
Woo-0177	−49.7	−7.7	−0.49	29.1	−14.62	—
Tyl-0101	−46.5	−7.38	0.28	4.3	−15.75	100
Woo-0216	−48.1	−7.39	−1.24	6.5	−16.35	—
Wet-0135	−48	−7.37	−1.30	5.2	−13.86	107
Ple-0068	−45.9	−7.25	−0.11	5.3	−19.2	—
Mas-0918	−40	−5.63	−6.48	4.9	−11.91	—
Mal-0410	−48.8	−7.56	−0.66	5.2	−14.31	123
Brk-0077	−50.3	−7.74	−0.79	4.8	−17	—
Mas-0936	−43.3	−6.82	−0.76	3.7	−21.05	—
Mas-0852	−43.5	−6.97	0.17	—	−17.7	—
Jac-0128	−44.5	−7.06	−0.15	—	−13.57	—
Ple-0071	−46.3	−7.37	0.40	—	−19.68	—
Mas-0920	−45.4	−7.14	−0.44	3.4	−14.13	104
Jac-0057	−44.8	−7.01	−0.82	—	−13.8	—
Woo-0196	−46.1	−7.25	−0.31	—	−15.18	—

The He isotopic ratio (R/R_a) indicates a possible contribution from a premodern groundwater source, with a high proportion of terrigenic helium ($^{4}He_{terr}$) observed in every sample except for Mas-0918. Four samples with R/R_a values between 0.81 and 0.73 were identified as having some $^{4}He_{terr}$, but 12 samples with R/R_a values less than 0.70 were identified as having high $^{4}He_{terr}$. The only sample in the dataset to have a R/R_a value close to 1 (indicating solubility equilibrium with the atmosphere) was Mas-0918, which was identified by stable isotope analysis as possibly being influenced by a wetland or pond source rather than representing the groundwater conditions in the rest of the aquifer. All samples in the dataset contain tritium (table 12) and are likely modern, which limits the ability to estimate the $^{4}He_{terr}$ isotopic ratio. Therefore, $^{3}He_{trit}$ could not be reliably estimated for most samples in the dataset, which reduced the number of available tracers for age determination. The source of high $^{4}He_{terr}$ in almost every sample collected for the study is not currently [2019] known but other investigators have also identified high $^{4}He_{terr}$ accumulation rates in other glacially deposited shallow alluvial aquifers (Solomon and others, 1996).

Measured SF_6 concentrations were corrected for excess air and found to exceed expected concentrations from atmospheric inputs. The contamination source of excess SF_6 observed in the aquifer is not known but high concentrations of SF_6 preclude its use for groundwater age analysis. With

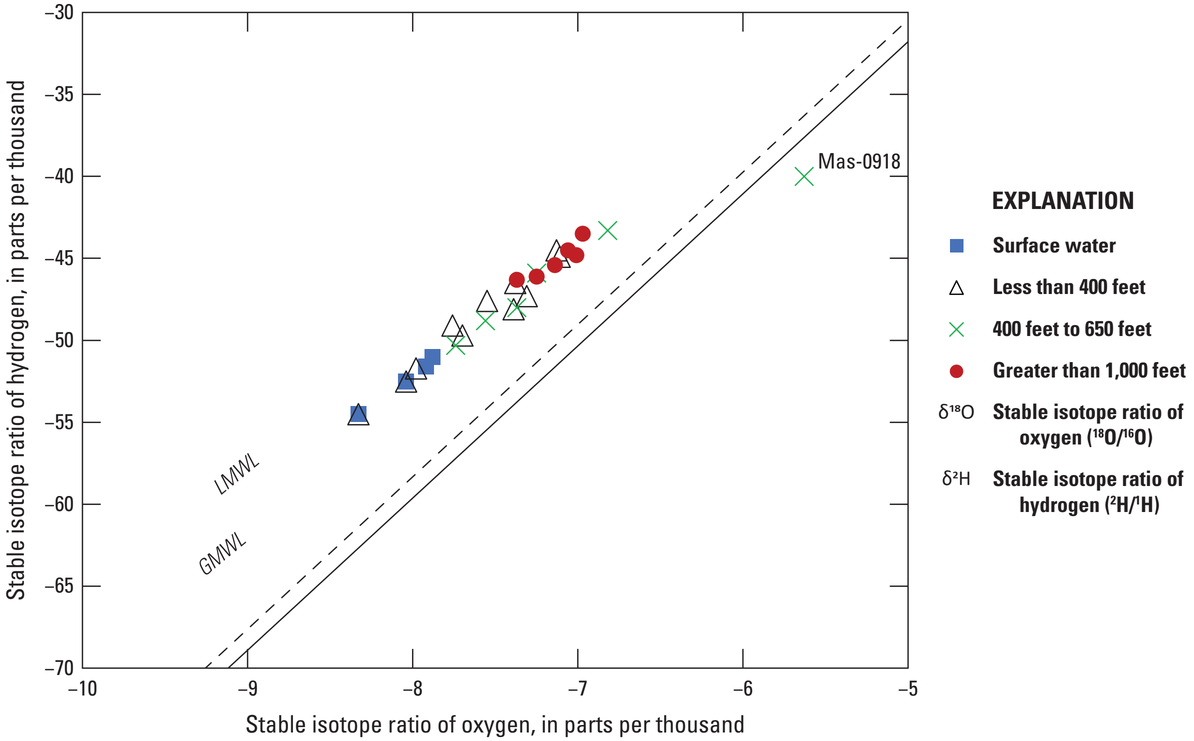

Figure 8. Scatterplot showing stable hydrogen (δ^2H) and oxygen ($\delta^{18}O$) isotope ratios in water for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020. The local meteoric water line (LMWL) is from Smith and others (2021). The global meteoric water line (GMWL) is from Craig (1961).

area-wide contamination of SF_6, ^{14}C concentrations that indicated predominantly modern recharge, and high $^4He_{terr}$ observed in most samples that limited the use of $^3He_{trit,}$ ^3H was the only modern tracer left to estimate groundwater age. At six sites, ^3H was measured above background levels (approx. 10 TU), which may be indicative of an additional non-atmospheric local source of ^3H. Bomb-pulse elevated atmospheric sources of ^3H can be distinguished from local ^3H sources based on ^{14}C, which increased in the atmosphere over the same period in response to above-ground nuclear testing. At five of the six samples with elevated ^3H concentrations (table 12), it was possible to correct ^{14}C using the RFG model. At all five sites, elevated ^3H concentrations did not correspond to elevated ^{14}C concentrations, indicating a local source of ^3H may be present.

Assessment of non-atmospheric sources of ^3H yielded possible contribution from a nuclear power plant on the Ohio River, upstream of every site in the study area. This facility regularly releases ^3H into the Ohio River at concentrations that are higher than atmospheric background levels (Paciello and others, 2019). Helium-3 was not sampled in the Ohio River for this study but 35 ^3H samples were collected in the Ohio River at a surface-water site near Newell, West Virginia (USGS 03109670) between April 17, 2002, and August 2, 2010 (U.S. Geological Survey, 2023; https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=03109670). This surface-water site is adjacent to Hnc-0043, and samples collected there had an average value for ^3H of 19 TU. This ^3H value supports the possibility of elevated ^3H in the Ohio River but without the ability to corroborate age dates across multiple tracers and the possibility of a non-atmospheric source of ^3H affecting concentrations in the aquifer, obtaining accurate estimates of groundwater age in the aquifer is not probable with these data. What can be determined from the age analysis for this study is that all water captured by wells in the Ohio River alluvial aquifer is likely from a relatively modern source.

Statistical Relations Between Ohio River Water and Groundwater Chemistry

The two major sources of recharge to the Ohio River alluvial aquifer in West Virginia are local precipitation and infiltration from the Ohio River (Jeffords, 1945). Hierarchical agglomerative cluster analysis (HACA) was used to confirm and further characterize these sources. The primary output from HACA is a dendrogram depicting the clustering structure

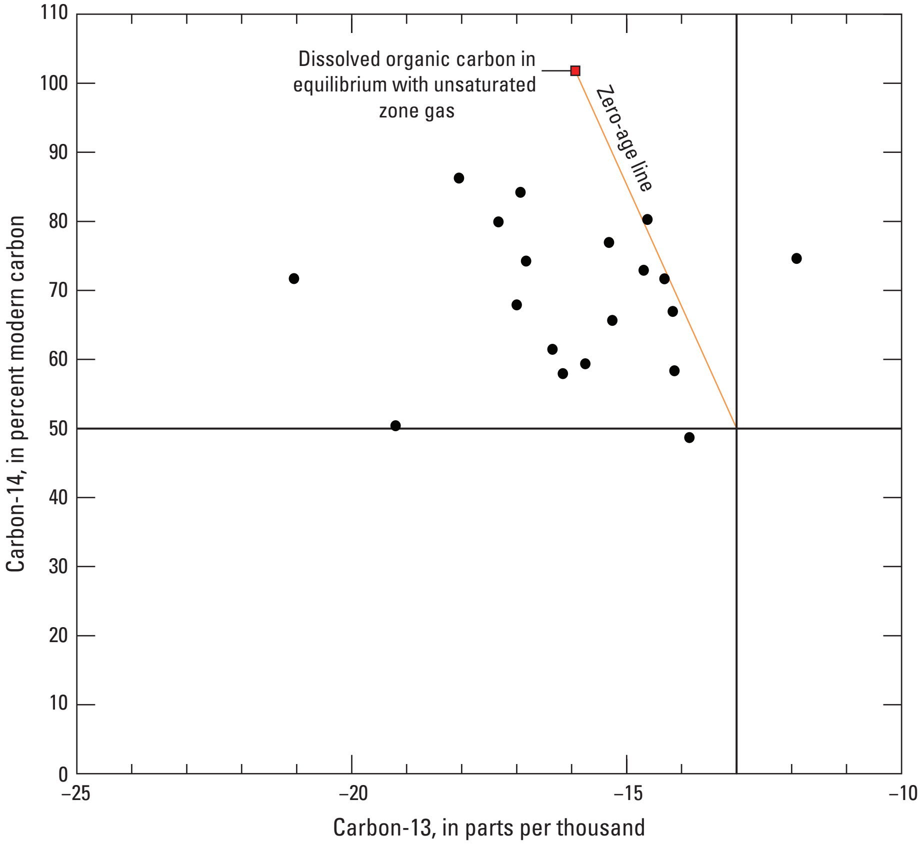

Figure 9. Scatterplot of open system revised Fonts and Garnier model for ^{14}C correction of dissolved inorganic carbon for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

of the input data (fig. 10). Individual samples are represented by vertical lines at the bottom of the figure, and the merging of similar clusters are represented by horizontal lines connecting clusters. Clusters that merge toward the bottom of the dendrogram have similar water chemistry. Clusters that do not merge until the top of the dendrogram represent groups of samples that have less similar water chemistries. Specific analytes and parameters used in the HACA for this study included δ^2H, $\delta^{18}O$, $\delta\ ^{13}C$, pH, specific conductance, dissolved oxygen, DOC, calcium, magnesium, potassium, sodium, chloride, fluoride, bicarbonate, silica, sulfate, iron, and manganese. This resulted in a HACA with 4 surface-water sites and 23 groundwater wells (table 1) that included field parameters, major ions, trace metals, and isotopes important in end-member characterization. Constituent values were converted to u-scores, and the distance matrix was computed as described in the "Methods of Study" section.

The HACA resulted in 3 clusters represented by capital letters (A, B, C). The agglomerative coefficient, a numerical value used to assess the structure of the clustering, ranges from 0 to 1, with values closer to 1 representing better cluster structure (Kaufman and Rousseeuw, 1990). The agglomerative coefficient produced was 0.77, which provides confidence in the HACA structure. The SIMPROF test was applied to the cluster analysis and identified 11 significant clusters ($p<0.01$), of which 3 clusters (A, B, C) were used for further analysis.

Cluster B includes all four surface-water samples and represents the surface-water end member of the system. Clusters C and B merge before coming together with cluster A at the final merge point in the HACA. This merge point indicates that sites in cluster C are more closely associated with surface-water sites in cluster B than other groundwater sites in cluster A. Cluster C includes 10 wells that have an average distance of 217 ft from the river and are representative of sites that may be highly influenced by Ohio River water chemistry. Cluster A includes 13 wells that have an average distance of 906 ft from the river. This cluster includes wells greater than 1,000 ft from the river and wells that may have some influence from the Ohio River water chemistry but are probably more influenced by water from the recharge area of the aquifer, as depicted in the conceptual model (fig. 2). Results indicate that two hydrochemical facies are contributing water to the SWIG

Table 13. Dissolved noble gas solubility modeling results determined using model described by Aeschbach-Hertig and others (2000) for 18 groundwater wells in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020. Wells listed in order of distance from the Ohio River. Dissolved gas data from the U.S. Geological Survey National Water Information System (U.S. Geological Survey, 2023).

[Δ, deviation of sample from solubility equilibrium with the atmosphere; χ^2, Chi-squared; elev., elevation; m, meter; NGT, noble gas temperature; °C, degrees Celsius; Ae, entrapped air; ccSTP/g, cubic centimeters per gram at standard temperature and pressure (25℃, 1 atm); F, fractionation factor; R, ratio of helium-3 to helium-4 in the sample; Ra, ratio of helium-3 to helium-4 in atmosphere; —, not available]

Site name	Δ Neon (%)	Δ Argon (%)	Δ Krypton (%)	Δ Xenon (%)	χ^2	Recharge elev. (m)	NGT (°C)	Ae (ccSTP/g)	F	R/R_a	Helium analysis comment
Hnc-0043	17.0	14.3	12.3	16.4	0.004	209	13.3	0.173	0.85	0.23	High terrigenic helium
Wet-0146	8.7	7.6	4.4	15.7	0.627	193	11.9	0.053	0.90	0.02	High terrigenic helium
Woo-0121	21.1	14.7	10.0	20.1	0.025	183	15.1	0.057	0.79	0.36	High terrigenic helium
Mal-0104	21.1	12.2	9.2	14.2	0.111	195	12.7	0.038	0.78	0.36	High terrigenic helium
Mas-0934	8.8	9.7	4.7	3.2	1.730	171	11.6	0.071	0.89	0.54	High terrigenic helium
Mas-0968	21.3	15.8	9.2	8.7	0.411	171	13.4	0.065	0.79	0.81	Terrigenic helium in sample
Woo-0215	20.9	14.5	9.9	5.5	0.087	181	11.0	0.058	0.79	0.79	Terrigenic helium in sample
Woo-0177	10.5	6.3	1.2	29.1	0.846	187	13.7	0.023	0.86	0.74	Terrigenic helium in sample
Tyl-0101	21.7	14.7	10.0	4.3	0.013	193	12.7	0.057	0.79	0.51	High terrigenic helium
Woo-0216	15.9	14.8	10.0	6.5	1.012	187	13.9	0.095	0.84	0.41	High terrigenic helium
Wet-0135	50.8	14.3	7.0	5.2	0.085	195	13.5	0.005	9.7E-05	0.39	High terrigenic helium
Ple-0068	31.6	17.1	9.6	5.3	0.106	189	11.6	0.031	0.68	0.03	High terrigenic helium
Mas-0918	9.5	8.0	3.2	4.9	0.693	183	12.3	0.066	0.90	0.97	—
Mal-0410	24.5	16.1	10.7	5.2	0.020	200	13.1	0.052	0.76	0.73	Terrigenic helium in sample
Brk-0077	16.5	15.6	9.2	4.8	1.400	204	11.6	0.089	0.83	0.01	High terrigenic helium
Mas-0936	29.9	25.9	21.7	3.7	0.670	176	16.9	0.129	0.75	0.02	High terrigenic helium
Mas-0920	26.3	15.8	10.4	3.4	0.002	180	13.4	0.040	0.74	0.50	High terrigenic helium

wells in the alluvium but the Ohio River is the most likely source contributing an increasing proportion of water to wells as distance to the river decreases.

Mixing models to estimate Ohio River Water Influence on Groundwater Chemistry

Jeffords (1945) states that analyses of major anions are adequate for use in determining the source of water recharging any well field in the Ohio River alluvium and that the greatest difference in Ohio River water and groundwater not influenced by the Ohio River is in the respective concentrations of sulfate and bicarbonate. Data collected for this study show a similar result, with anions that represent noncarbonate hardness (sulfate and chloride) comprising a higher proportion of total hardness in surface-water samples and anions that represent carbonate hardness (carbonate and bicarbonate) comprising a higher percentage of total hardness in groundwater samples greater than 1,000 ft from the river (fig. 3). Likewise, comparison of the equivalents of bicarbonate as a percentage of anions with the equivalents of sulfate as a percentage of anions (fig. 11) shows differentiation of three groups. The first group consists of surface-water samples collected in the Ohio River and is characterized by sulfate comprising over 35 percent of anion equivalents. The second group is comprised of samples greater than 1,000 ft from the Ohio River and is characterized by bicarbonate comprising over 70 percent of anion equivalents. The third group consists of samples with mixtures of Ohio River water and groundwater because they plot between the distal wells and surface water sites. Samples from three wells do not follow this general association between bicarbonate and sulfate, with the sample from Mas-0918 (444 ft from river) containing a relatively high percentage of bicarbonate compared to other wells at intermediate distances (400–650 ft) from the Ohio River, the sample from Ple-0071(1,473 ft from river) containing a low percentage of bicarbonate relative to other wells located greater than 1,000 ft from the Ohio River, and the sample Mas-0936 (650 ft from river) containing relatively more sulfate but less bicarbonate than samples from other wells at intermediate distances (400–650 ft) from the Ohio River, plotting in an area that is not indicative of surface water from the Ohio River or groundwater from more distal wells (fig. 11). These three sites may be indicative of the heterogenous nature of the Ohio River alluvial aquifer or may be supplied by an unknown source with an unidentified bicarbonate/sulfate signature.

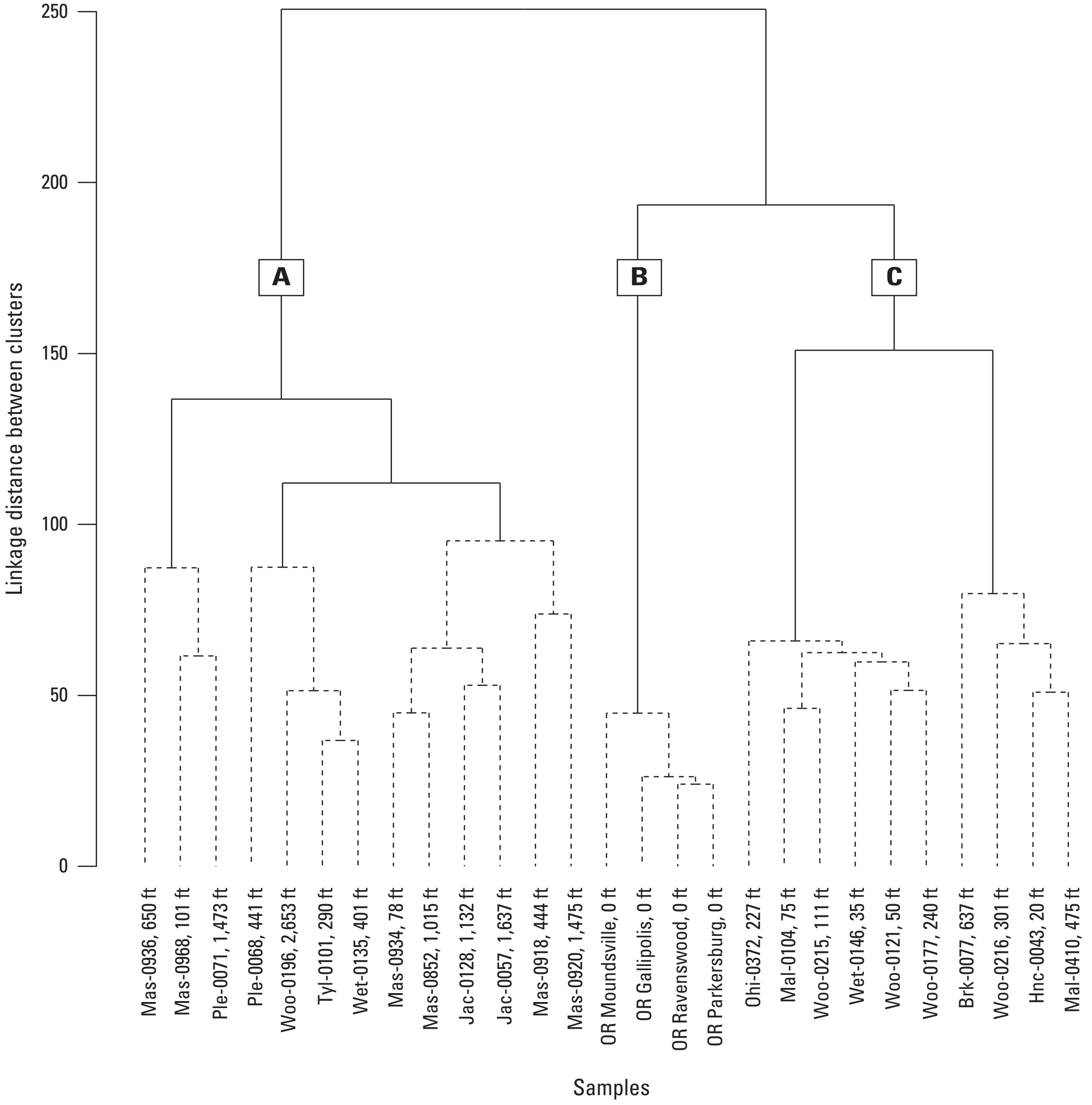

Figure 10. Dendrogram output from hierarchical agglomerative cluster analysis of water-quality data. Solid lines represent significant ($p<0.001$) clusters determined by the similarity profile test. Letters represent major clusters. Significant clusters are identified by solid lines, whereas nonsignificant clusters, according to the similarity profile test, are identified by dashed lines. Sites identified with distance from the Ohio River given in feet (ft).

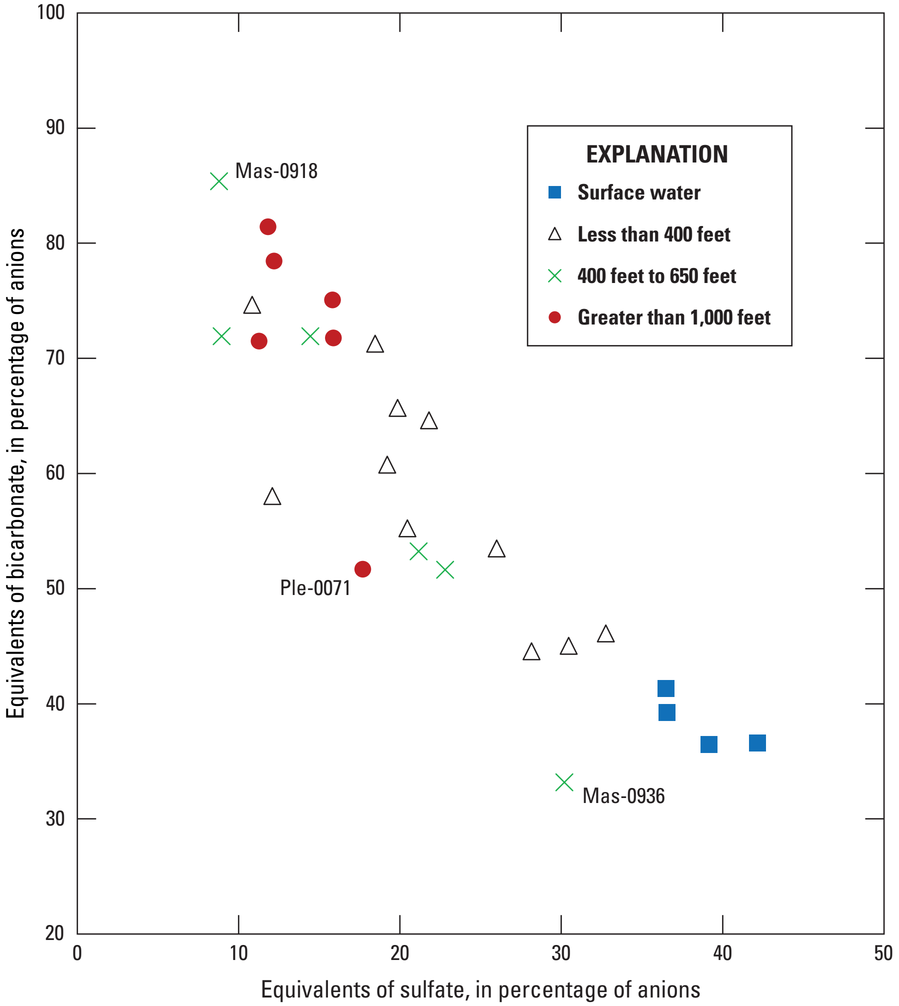

Figure 11. Scatterplot of the equivalent mass of bicarbonate and sulfate as a percentage of total anions calculated from the water-quality data for 23 wells sampled in the Ohio River alluvial aquifer, West Virginia, June 2019–January 2020.

Groundwater-flow simulations in the Ohio River alluvium by Kozar and McCoy (2004) estimated fractions of Ohio River water contribution to the groundwater system at Parkersburg, Lubeck, Glendale, and Point Pleasant, to be 0.75, 0.39, 0.72, and 0.04, respectively (table 14). The sites Parkersburg, Lubeck, Glendale, and Point Pleasant specified in Kozar and McCoy (2004) were represented in this study by Woo-0121, Woo-0215, Mal-0410, and Mas-0920, respectively. Binary-mixing models were computed with analytical data collected from this study and used as a first-order approximation for fractions of the two major recharge sources. Several analytes were considered for binary mixing, including δ^2H, δ^{18}O, and chloride, but the binary mixing model that had the most significant correlation ($r=0.97$, $p<0.03$) with groundwater modeling results was the ratio of bicarbonate equivalents as a percentage of anions to sulfate equivalents as a percentage of anions, which was shown to have a linear relation in figure 11. Silica (SiO_2) concentrations were found to have significant negative correlation ($r=-0.91$, $p<0.08$) with groundwater modeling results, showed similar behavior as bicarbonate (lower concentrations in Ohio River samples and higher concentrations in distal wells), and were also considered for simple binary mixing models (table 14). The Ohio River end member (table 14) was represented by the average of results of the four surface-water samples (table 1). The alluvial well end member was represented by the average of results for four wells greater than 1,000 ft from the Ohio River (Mas-0852, Jac-0128, Jac-0057, Woo-0196), with results from two wells excluded for the following reasons: Mas-0920 (1,475 ft from river) results were excluded because an estimate of the end member fractions for this site was needed to compare to the value reported in the groundwater-flow model, and Ple-0071

Table 14. Chemical compositions of end members representing Ohio River water and groundwater in alluvial aquifer at the greatest distance from river and of sample results from wells at various distances from the Ohio River, and estimated fraction of Ohio River water contribution to surface-water influenced wells in the Ohio River alluvial aquifer of West Virginia, June 2019–January 2020.

[OR, Ohio River; SW, surface water; GW, groundwater; —, not available; Distance, distance from the Ohio River; ft, feet; mg/L, milligrams per liter; GM, Groundwater model from Kozar and McCoy (2004); BMM, Binary Mixing Model; IM, Inverse Model; equivalent percent, equivalents as a percentage of anions]

USGS site name	GM site name	Site type	Distance, ft	Silica, mg/L as SiO2	Bicarbonate equivalent percent	Sulfate equivalent percent	GM fraction of OR end member	Silica BMM fraction of OR end member	Equivalent ratio BMM fraction of OR end member	IM fraction of OR end member	Average fraction of OR end member
OR end member	—	SW	—	5.1	38.4	38.6	—	1.00	1.00	—	—
Hnc-0043	—	GW	20	10.8	44.6	28.2	—	0.64	0.87	0.57	0.69
Wet-0146	—	GW	35	13.40	55.2	20.5	—	0.47	0.63	0.61	0.57
Woo-0121	Parkersburg	GW	50	13.60	45.1	30.4	0.75	0.46	0.90	0.67	0.68
Mal-0104	—	GW	75	11.80	60.8	19.2	—	0.57	0.53	0.40	0.50
Mas-0934	—	GW	78	18.90	71.3	18.5	—	0.12	0.38	0.23	0.24
Mas-0968	—	GW	101	22.00	64.6	21.8	—	0.00	0.54	—	0.27
Woo-0215	Lubeck	GW	111	13.90	65.7	19.8	0.39	0.44	0.50	0.37	0.44
Ohi-0372	—	GW	227	9.55	53.5	26.0	—	0.71	0.77	0.59	0.69
Woo-0177	—	GW	240	10.10	46.1	32.8	—	0.68	0.91	0.78	0.79
Tyl-0101	—	GW	290	16.20	74.6	10.8	—	0.29	0.00	0.11	0.13
Woo-0216	—	GW	301	18.90	58.1	12.1	—	0.12	0.18	0.10	0.13
Wet-0135	—	GW	401	14.50	71.9	14.4	—	0.40	0.14	0.21	0.25
Ple-0068	—	GW	441	18.30	71.9	8.9	—	0.15	0.00	—	0.08
Mas-0918	—	GW	444	14.90	85.4	8.8	—	—	—	—	—
Mal-0410	Glendale	GW	475	11.90	53.2	21.2	0.72	0.56	0.67	0.73	0.65
Brk-0077	—	GW	637	12.90	51.6	22.8	—	0.50	0.73	0.50	0.58
Mas-0936	—	GW	650	25.80	33.2	30.2	—	—	—	—	—
Mas-0920	Point Pleasant	GW	1,475	20.20	78.4	12.2	0.04	0.03	0.00	0.20	0.08
Alluvial well end member	—	GW	—	20.7	74.9	13.7	—	0.00	0.00	—	—

(1,473 ft from river) as this site was identified as possibly having a contribution from an unknown recharge source with a different bicarbonate/sulfate signature (fig. 11).

The estimated fractions of Ohio River water contribution to the groundwater system from the groundwater-flow model (Kozar and McCoy, 2004) were used to validate the results of the silica and equivalent-ratio binary mixing models. Fractions of river water in the aquifer computed using the silica binary-mixing model were significantly correlated with those determined from the groundwater-model for 4 sites (Woo-0121, Woo-0215, Mal-0410, and Mas-0920; r=0.91, p less than 0.09), with three sites showing 6 percent difference or less. The percentage of Ohio River water calculated by the silica binary mixing model for Woo-121 was 29 percent less than the percentage of Ohio River water calculated in the groundwater model results for Ohio River @ Mile 183.0 (site name shortened to OR Parkersburg in this report), which suggests that the silica binary-mixing model may not be accurate at all sites or that Woo-121 may not be representative of the Parkersburg area as simulated by the groundwater model. The percentage of Ohio River water calculated with the equivalent ratio (bicarbonate equivalent as percentage of anion equivalents to sulfate equivalent as percentage of anions equivalents) binary mixing model was significantly correlated with the percentage of Ohio River water estimated by the groundwater model at the four sites (r=0.97, p less than 0.03). Of the 4 sites, the percentage of Ohio River water for Woo-0121 was most different between these 2 models, with the equivalent ratio model results being 15 percent greater than the percentage of Ohio River water calculated in the groundwater model results for OR Parkersburg. The disparity among models in calculated results of the same site indicates that non-conservative mixing may be important at some sites where geochemical processes are not accounted for in binary mixing models.

Inverse geochemical models that met the specified uncertainty (10 percent or less) were computed for Mas-0920 and 13 of the groundwater sites located less than 1,000 ft from the river (table 14). The percentage of Ohio River water computed by inverse models was significantly correlated with the percentage of Ohio River water estimated by the groundwater model ($r=0.98$, $p<0.02$). The percentage of Ohio River water for Woo-0121, Woo-0215, and Mal-0410 calculated with the inverse model was within 8 percent of the results reported from the groundwater model. The percentage of Ohio River water for Mas-0920 was 16 percent greater than the results in the groundwater model for Point Pleasant, which indicates that the inverse model may be more accurate for sites less than 1,000 ft from the river. The average of all three geochemical models (silica binary mixing model, equivalent ratio binary mixing model, inverse model) yields the most significant correlation ($r=0.99$, $p<0.006$) with the results from the groundwater model. By using the average of all three models, all 4 sites had average results that are within 7 percent of the groundwater model results (table 14, fig. 12).

Discussion and Limitations

The broad overview and analysis presented in this report may not be appropriate for all groundwater sites in the Ohio River alluvium and site-specific information may be needed when making detailed assessments of surface-water influence on alluvial wells. Reactive transport modeling, including kinetic parameters for mineral precipitation/dissolution, may be created as more site-specific hydrological, geological, mineralogical, and geochemical data and information become available. Focused studies with well-developed reaction transport models may give a better understanding of the influence from the Ohio River on alluvial wells and can be used to confirm relevance of simple linear relationships, but without this information, the linear relation between analytes and

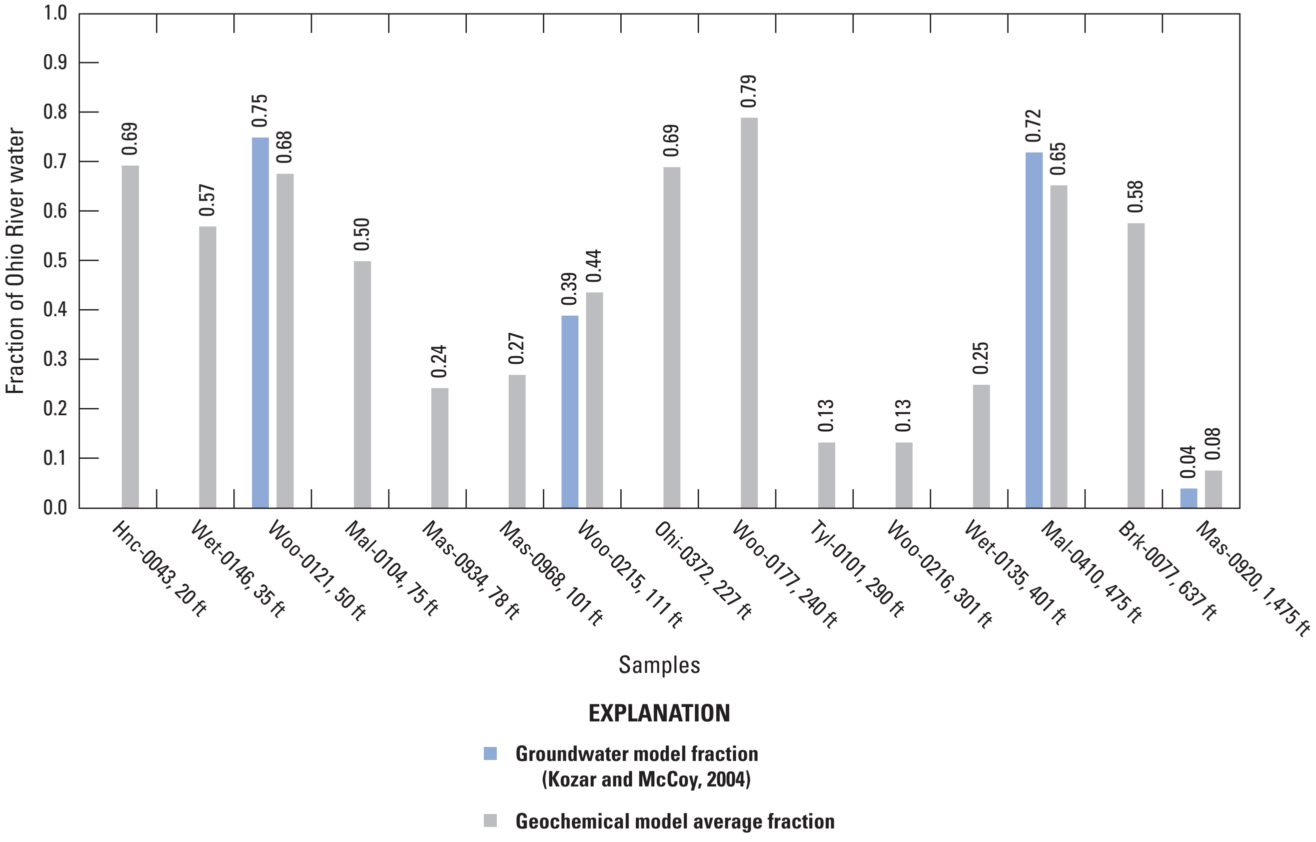

Figure 12. Bar chart showing the fraction of Ohio River water in alluvial wells in West Virginia from groundwater modeling by Kozar and McCoy (2004) and the average of three different geochemical models presented in this study. Site names followed by feet (ft) from the river.

fraction of Ohio River water presented here may be adequate for preliminary assessments of surface-water influence in the Ohio River alluvial aquifer.

The Ohio River Alluvial Aquifer is Susceptible to Contamination from Surface Water

Meteoric recharge from the Ohio River and precipitation on the alluvium and subsequent recharge through the vadose zone are the main sources of water entering the aquifer, but isotope ratios and concentrations of major ions indicate other surface-water sources may affect groundwater chemistry at individual sites (Mas-0918, Ple-0071, Mas-0936) on a local scale (fig. 8, 11). Generally, groundwater from wells located over 1,000 ft from the river, which represented the chemistry of the precipitation dominated portion of the aquifer, had a chemical signature that was different than Ohio River water (fig. 8, 10, 11), with a higher percentage of bicarbonate relative to sulfate observed in wells located closer to the Ohio River. These results are consistent with Maharjan and Donovan (2017), who observed low total dissolved solids specific conductance, alkalinity, and enriched $\delta\ ^{13}$C values of dissolved inorganic carbon, indicative of induced infiltration in proximal (less than 1,000 ft from Ohio River) groundwater wells. Also consistent with Maharjan and Donovan (2017) was the observation that distal (more than 1,000 ft from Ohio River) alluvial well water chemistry exhibited higher total dissolved solids, specific conductance, alkalinity, and relatively depleted δ^{13}C values and was not affected by exfiltration from the Ohio River.

Every well sampled for this study (distal and proximal) is intrinsically susceptible and potentially vulnerable to surface contamination. Kozar and Paybins (2016) identify bacteria, nitrate, pesticides, VOCs, and chlorofluorocarbons as indicators of surface-water influence in groundwater wells. No microbial fecal indicators were found in any groundwater sample from wells throughout the study area, indicating these sites are not likely GWUDI, but all sites sampled for this study had detections for at least one water-quality indicator of surface-water influence (table 11). These observations suggest that one tracer or parameter is not sufficient to assess surface-water-influence in the Ohio River alluvium, but when multiple constituents are included in the analysis, it is apparent that every site in the Ohio River alluvial aquifer is influenced by surface water to some extent and vulnerable to surface contamination.

Ohio River Water Influences Groundwater Chemistry in the Alluvial Aquifer

Jeffords (1945) stated that the approximate amount of river water recharging groundwater wells in the Ohio River alluvium can be determined by obtaining the percentage of bicarbonate and sulfate and comparing these with similar data on water from the Ohio River and from wells that obtain little or no recharge from the river. Likewise, results from binary mixing models and inverse models created for this study suggest that sulfate, silica, or bicarbonate concentrations adequately predict the fraction of Ohio River water entering alluvial wells for preliminary investigations of surface-water influence. These three constituents are commonly measured in water-quality analyses for regulatory purposes and are more readily available for preliminary assessment of surface-water influence than many other analytes, such as isotopes. Binary mixing models do not consider time variability of end-member signatures or the reactive nature of sulfate, bicarbonate, and silica. Nevertheless, results from binary mixing models showed significant correlation with the inverse models computed for this study and groundwater models published by Kozar and McCoy (2004). Using the average of the fraction of Ohio River water computed from the three geochemically based models (silica binary mixing model, equivalent ratio binary mixing model, and inverses models) yielded the highest correlation with fractions estimated using the groundwater-flow model (table 14).

In the absence of extensive analytes and geochemical or groundwater-flow modeling capabilities, preliminary assessment of the fraction of Ohio River water entering groundwater wells in the Ohio River alluvium may be estimated for most sites (including sites not specified in this study) using the linear relation between the equivalent ratio of bicarbonate to sulfate and the fraction of water computed by the average of the three geochemical models (fig. 13*A*, table 14). Additionally, the linear relationship of sulfate concentration with the proportion of Ohio River water computed from the average of three geochemical models (fig. 13*B*) or the linear relationship of silica concentration with the proportion of Ohio River water computed from the average of three geochemical models (fig. 13*C*) may be used to provide a preliminary assessment of the potential influence from surface water entering wells in the Ohio River alluvium, although this approach might not be sufficient for samples with high concentrations of sulfate or silica without equivalent-weight normalization. For samples with high concentrations, the equivalent ratio of bicarbonate to sulfate may yield better results for outlier sites because it normalizes the concentrations by the molecular weight and anion percentage. Although first-order calculations of the fraction of Ohio River water presented in this study may be sufficient for a broad understanding of the Ohio River alluvial aquifer or a preliminary assessment of an individual groundwater site, focused reaction-transport models or other types of biological or geochemical data could enhance understanding in localized areas.

This study indicates that the chemistry of groundwater wells in the Ohio River alluvium is influenced by recharge from the Ohio River but distance from the Ohio River was not always a good indication of the amount a SWIG site will be influenced by Ohio River water chemistry. The data and related analyses indicate that Ohio River water chemistry has more influence at some sites over 400 ft from the Ohio River

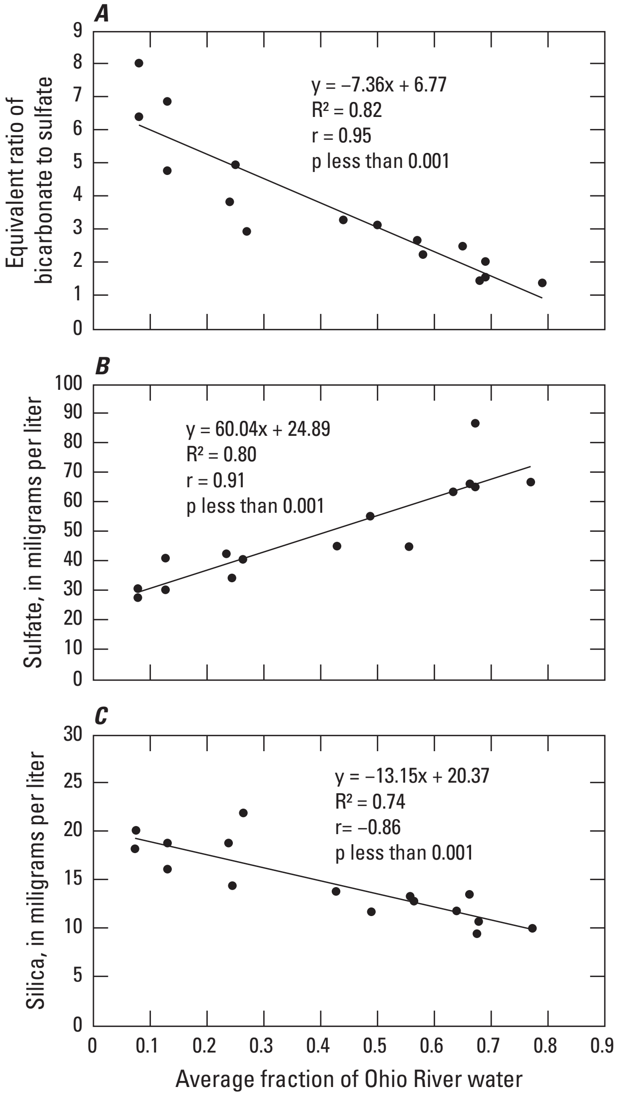

Figure 13. Graphs showing the linear relations between select parameters and the average fraction of Ohio River water entering studied groundwater wells in the Ohio River alluvial aquifer, West Virginia, computer by three geochemical models: A, equivalent ration of bicarbonate to sulfate, B, sulfate concentration, and, C, silica (as SiO_2) concentration.

(for example Mal-0410) than at some sites located less than 100 ft from the Ohio River (for example Mas-0934) and that distance from the Ohio River was not significantly correlated with the computed average fraction of Ohio River water, although models indicated the smallest fraction of river water at the well most distant from the river Mas-0920 (table 14). This general finding of inconsistent relations between distance from the river and estimated fraction of river water in groundwater indicates that influence from the Ohio River on alluvial well water chemistry may be affected by local-scale heterogeneity in alluvial sediments (permeability and mineralogy), well construction, or transient pumping by the local public water system in addition to river proximity. Pumping can induce infiltration from the river, and the analysis presented in this study could be further refined if pumping were included as a factor.

Summary

Public groundwater supplies obtained from the alluvial aquifers bordering the Ohio River in West Virginia receive substantial recharge from surface-water sources and are highly susceptible to degradation from water-soluble contaminants. Surface-water-influenced groundwater systems include any underground public-water supply that is heavily influenced by the quality of surface water in the immediate area of a well. Even though alluvial aquifers have a relatively small footprint in comparison to other aquifers in West Virginia, these sand and gravel aquifers are the primary water supply for numerous large communities along the Ohio River. Protection of public-water supplies requires an understanding of aquifer interactions with the Ohio River and tributary streams that contribute to the chemistry of groundwater from pumping wells.

Surface-water-influence on groundwater-well chemistry in the Ohio River alluvial aquifer of West Virginia was studied in cooperation with the West Virginia Department of Health and Human Resources, Bureau for Public Health. Water-quality samples were collected from 4 surface-water sites and 23 groundwater wells in the study area from June 2019 to January 2020. Comparison of results to human-health benchmarks established by U.S. Environmental Protection Agency indicated that no sites had concentrations that exceeded maximum-contaminant levels for any analyte. Manganese has a secondary maximum-contaminant level for aesthetic criterion of 50 micrograms per liter, which was exceeded in 48 percent of samples. Concentrations for manganese also exceeded the health advisory of 300 micrograms per liter, in 17 percent of samples. Sodium concentration exceeded the 20 milligrams per liter health advisory for people on a sodium-restricted diet in 52 percent of samples and iron exceeded its secondary maximum-contaminant level for aesthetic criterion of 300 micrograms per liter in 17 percent of samples.

Hydrogeochemical processes controlling solute concentrations in the Ohio River alluvial aquifer were identified to be redox processes, input from sources of salinity, and carbonate dissolution. Wells located closer to the Ohio River had higher concentrations of manganese, iron, and dissolved organic carbon but lower concentrations of dissolved oxygen and nitrate. Likewise, wells located farther from the Ohio River generally had higher concentrations of dissolved oxygen and nitrate, whereas manganese, iron, and dissolved organic carbon concentrations were lower. Sources of salinity and associated constituents (sodium, chloride, potassium, bromide) were identified using chloride/bromide ratios. Chloride to bromide mass ratios calculated with the data collected for this study ranged from 325 to 3,944 and chloride concentrations ranged from 20 to 120 milligrams per liter. These ranges are typical values for sources of salinity from halite dissolution and animal waste or sewage. Calcium and bicarbonate concentrations generally increased with the distance of a well from the Ohio River, which indicated that carbonate dissolution was an important hydrochemical process in distal wells.

Every well sampled for this study (distal and proximal to the Ohio River) had detections for at least one water-quality indicator of surface-water influence, including recent recharge. No microbial fecal indicators were found in any groundwater well throughout the study area, indicating these sites are not likely groundwater-under-direct-influence of surface water but one tracer or parameter is not sufficient to assess surface-water-influence in the Ohio River alluvium. When multiple constituents were included in the analysis, the data show that every site in the Ohio River alluvial aquifer is influenced by surface water to some extent and vulnerable to surface contamination.

Analysis of groundwater age tracers overall indicate relatively recent water, but some tracer data were not useable or indicated conflicting interpretations. Measured sulfur hexafluoride concentrations were corrected for excess air and found to exceed expected concentrations from atmospheric inputs at most sites. The He isotopic ratio indicated contribution from a premodern groundwater source, with a high proportion of terrigenic helium ($^4He_{terr}$) observed in every sample, but tritium concentrations and corrected carbon-14 values indicated that water in the Ohio River alluvium was derived exclusively from a modern source. Tritiogenic helium ($^3He_{trit}$) could not be reliably estimated for most samples in the dataset, because of the high proportion of $^4He_{terr}$, which reduced the number of available tracers for age determination. Additionally, tritium was measured above expected atmospheric background levels at six sites, which indicated the possibility of an additional non-atmospheric local source of tritium. Obtaining accurate estimates of groundwater age in the aquifer was not possible without the ability to confirm groundwater age across multiple tracers, but the age analysis for this study indicated that all water captured by wells in the Ohio River alluvial aquifer was likely from a relatively modern source (post-1950s).

Stable isotope ratios of water indicated that meteoric recharge from the Ohio River and precipitation on the alluvium are the main sources of water entering the aquifer. Groundwater wells located over 1,000 ft from the river generally had a different chemical signature than Ohio River water, with a higher percentage of bicarbonate relative to sulfate. Silica concentrations were also observed to be higher in distal wells relative to proximal wells. Because of the disparity in analyte concentrations observed in distal wells and samples collected in the Ohio River, end-member analysis considered bicarbonate, sulfate, and silica.

Results from binary mixing models and inverse models computed for this study suggest that sulfate, silica, and bicarbonate concentrations adequately predict the fraction of Ohio River water entering alluvial wells for preliminary assessments of surface-water influence. These three constituents are more commonly available for preliminary assessment of surface-water influence than other analytes such as isotopes. The fraction of Ohio River water entering groundwater wells in the Ohio River alluvium computed with binary mixing models showed significant correlation with those estimated using the inverse geochemical models for this study and using previously published groundwater-flow models of the study area. The average of the fraction of Ohio River water computed from three geochemical models yielded the highest correlation with fractions determined from groundwater-flow models compared to correlation with any single geochemical model and the groundwater-flow model.

In the absence of extensive analytes and geochemical or groundwater modeling capabilities, preliminary assessment of the fraction of Ohio River water entering groundwater supplies to wells in the Ohio River alluvium may be estimated for most sites (including sites not specified in this study) using the linear relation between the equivalent ratio of bicarbonate to sulfate and the fraction of water computed by the average of the three geochemical models presented in this report. Additionally, the linear relation of silica concentration with the proportion of Ohio River water, or the linear relationship of sulfate concentration with the proportion of Ohio River water, may also supply sufficient results to make a preliminary assessment of the potential influence from surface water entering wells in the Ohio River alluvium. This approximation of the fraction of Ohio River water, coupled with information on the hydrogeological framework and geochemical indicators of surface-water influence, may be adequate for preliminary assessment of surface-water influence until more detailed site information or reaction-transport models can be developed.

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For more information about this report, contact:

Director, Virginia and West Virginia Water Science Center
U.S. Geological Survey
1730 East Parham Road
Richmond, Virginia 23228

or visit our website at
https://www.usgs.gov/centers/virginia-and-west-virginia-water-science-center

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