NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Marcellus Shale Water Treatment at a WWTP

Reference Flow: 1 kg of Flowback Water to Delivered to WWTP

Brief Description: This unit process models the transport of water from a Marcellus Shale well to a WWTP (wastewater treatment plant) and subsequent treatment to remove water pollutants.

Section I: Meta Data

Geographical Coverage: United States **Region:** Northeast, U.S.

Year Data Best Represents: 2011

Process Type: Waste Treatment (WT)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: All Relevant Flows Captured

Flows Aggregated in Data Set:

☒ Process ☒ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☒ Greenhouse Gases	☒ Criteria Air Pollutants	☐ Other
Releases to Water:	☒ Inorganic Emissions	☒ Organic Emissions	☐ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

dist_WWTP	*[km] Distance by truck from NG well to WWTP (wastewater treatment plant).*

Tracked Input Flows:

Diesel_use_mass	Diesel Combustion, Mobile Sources, Truck [Refinery products]
Flowback Water to WWTP	[kg] *Mass of wastewater input (Reference flow)*
Power	[kWh] *Electricity used by wastewater treatment plant*

Tracked Output Flows:

none

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_MarcellusWaterQuality_WWTP_2011.03.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with transport and treatment of flowback water from a natural gas well in the Marcellus Shale. The inputs to this unit process include flowback water, electricity, and diesel. (Electricity is used to power the water treatment plant and diesel is used by a tanker truck that transports flowback water from the Marcellus Shale natural gas well site to a wastewater treatment plant.) The calculations presented for this unit process are based on the reference flow of 1 kg of wastewater from a Marcellus Shale gas well, as described below and shown in **Figure 1**.

This unit process is used under Life Cycle (LC) Stage #1 in support of the extraction of Marcellus Shale natural gas. This unit process is combined with other relevant equipment for LC Stage #1 in a separate operations assembly process, DF_Stage1_O_Assembly_Natural_Gas _2011.02.doc. The assembly process quantifies the relevant flows and emissions associated with each portion of the natural gas extraction profile being modeled, in order to complete extraction and in-field processing of 1 kg of natural gas.

Boundary and Description

This unit process provides a summary of relevant input and output flows associated with transport and treatment of flowback water from a natural gas well in the Marcellus Shale. The inputs to this unit process include flowback water and diesel used by a tanker truck that transports flowback water from the Marcellus Shale natural gas well site to a wastewater treatment plant. The calculations presented for this unit process are based on the reference flow of 1 kg of wastewater from a Marcellus Shale gas well. The quantity of electricity consumed by the WWTP plant is accounted for in this unit process, but the upstream emissions from electricity generation are accounted for by upstream unit processes.

Flowback water is generally of poor quality, and typically has elevated loads of total suspended solids, total dissolved solids, nitrogen, ammonia, and total organic carbon, among other constituents (Hayes, 2009). In many regions, low quality flowback waters and other produced waters are disposed of via deep well injection. However, the

geologic formations that underlie most of the Marcellus Shale region are not amenable to deep well injection. Therefore, for Marcellus Shale, other disposal methods must be utilized for flowback waters. Water having sufficient quality (i.e., without very high levels of total dissolved solids levels or other pollutants) may be conveyed to a municipal wastewater treatment facility, treated via the facility's process, and discharged to surface waters. This process requires approximately 1,700 kWh per million gallons per day of wastewater that is treated (Lampman 2008). However, the municipal wastewater treatment process is only partially effective at treating flowback water pollutants, and provides zero benefit in terms of reduction of mass loadings for ionic constituents, including salts and other dissolved solids.

Figure 1 provides an overview of the boundary of this unit process. Within the boundary of this unit process, water is transported by a truck and water is purified by a WWTP. This unit process is combined with other natural gas extraction unit processes in a natural gas operations assembly unit process.

Figure 1: Unit Process Scope and Boundary

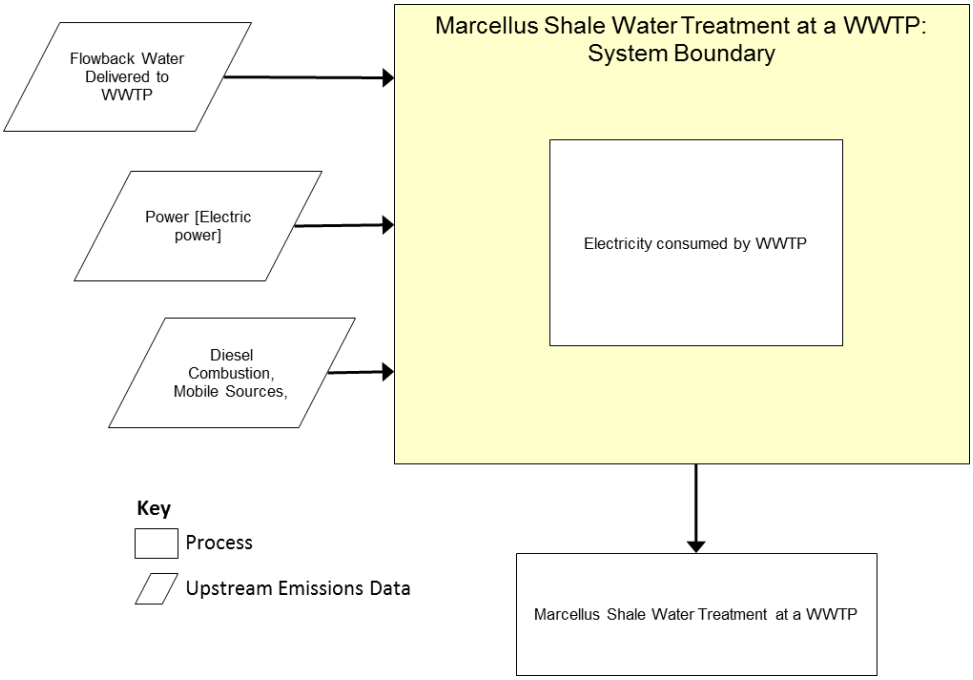

Table 1 summarizes water sources related to the treatment of Marcellus Shale flowback water at a wastewater treatment plant. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Default Parameters for Unit Process Waste Water WWTP

Flow Name	Value	Units	Reference
Transportation distance from well to WWTP (waste water treatment plant)	100	km	study assumption
WWTP electricity use	4.49E-04	kWh/kg water	Lampman 2008
Total suspended solids in flowback water	1.224E-04	kg/kg	Hayes 2009
Total dissolved solids in flowback water	7.851E-02	kg/kg	Hayes 2009
Nitrous oxide emissions from WWTP	1.38E-06	kg/kg water	Ahn 2010
Methane emissions from WWTP	3.70E-06	kg/kg water	IPCC 2006
Carbon dioxide emissions from WWTP	3.39E-04	kg/kg water	IPCC 2006

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units	DQI
Inputs			
Diesel Combustion, Mobile Sources, Truck [Refinery products]	**2.416E-03**	**kg**	2,2
Flowback Water to WWTP [Intermediate Product]	**1.000E+00**	**kg**	2,2
Power [Electric power]	**4.491E-04**	**kWh**	1,2
Outputs			
Treated Flowback Water, Effluent from WWTP	1.000E+00	kg	2,2
Carbon dioxide [Inorganic emissions to air]	3.391E-04	kg	2,2
Methane [Organic emissions to air (group VOC)]	3.700E-06	kg	2,2
Nitrous oxide (laughing gas) [Inorganic emissions to air]	1.377E-06	kg	2,2
Total Suspended Solids [Inorganic emissions to water]	1.224E-04	kg	2,2
Total Dissolved Solids [Inorganic emissions to water]	7.851E-02	kg	2,2
Total Kjeldahl Nitrogen [Inorganic emissions to water]	9.246E-05	kg	2,2
Total ammonia [Inorganic emissions to water]	8.253E-05	kg	2,2
Total biochemical oxygen demand [Organic emissions to water]	1.218E-04	kg	2,2
Total organic carbon [Organic emissions to water]	5.768E-05	kg	2,2
Total dissolved organic carbon [Organic emissions to water]	9.890E-05	kg	2,2
Oil and Grease [Organic emissions to water]	4.960E-06	kg	2,2
Bromide [Inorganic emissions to water]	5.001E-04	kg	2,2
Sulfite [Inorganic emissions to water]	1.888E-05	kg	2,2
Total Phosphorous [Inorganic emissions to water]	1.223E-06	kg	2,2

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows for bolded values were added during the modeling process using GaBi modeling software, as shown in **Figure 1**.

Inventory items not included are assumed to be zero based on best engineering judgment or assumed to be zero because no data was available to categorize them for this unit process at the time of its creation.

Embedded Unit Processes

None.

References

Ahn 2010 — Ahn, Joon Hoo. (2010). *N_2O emissions from activated sludge processes, 2008-2009: results of a national monitoring survey in the United States.*

Colorado School of Mines 2009	Colorado School of Mines . (2009). *An Integrated Framework for Treatment and Management of Produced Water.* http://aqwatec.mines.edu/produced_water/treat/docs/Tech_Assessment_PW_Treatment_Tech.pdf (Accessed February 21, 2011)
Hayes 2009	Hayes, Thomas. (2009). *Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas.*
IPCC 2006	Intergovernmental Panel on Climate Change (IPCC). (2006). IPCC NGGIP. http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_ft.php (Accessed February 21, 2011)
Lampman 2008	Lampman, G.. (2008). *NYSERDA and Strategic Energy Management at Municipal Wastewater Treatment Facilities.* http://www.nywea.org/clearwaters/08-1-spring/04-NYSERDA.pdf (Accessed February 21, 2011)
Wang 1999	Wang, M. (1999). GREET 1, Version 1.8d.1. http://greet.es.anl.gov/ (Accessed January 6, 2011)

Section III: Document Control Information

Date Created:	October 19, 2011
Point of Contact:	Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV
Revision History:	
9JUNE2014	Cell reference was corrected in the calculation of total N_2O emissions.
28DECEMBER2014	Updated to reflect combustion removal. Diesel combustion is now an input to this process. Added inventory item level DQI data to the data summary tab.

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