Water Management and Stewardship in Midstream, Downstream, and Delivery Operations in the Oil and Gas Industry

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Executive Summary

The oil and gas industry has significant connections to the water environment. Water is beneficially used, consumed, generated, reused, recycled, and disposed of over the life cycle of an oil and gas resource. The degree and impact of these connections vary with the nature and location of the resource and the methods of extracting and converting that resource into valuable end products.

This report uses the oil and gas (petroleum) life cycle represented in Figure ES.1 as an organizing framework for explanation and discussion. As depicted in Figure ES.1, the scope of this study is focused on the midstream, downstream, and delivery components of the oil and gas life cycle. Upstream components of the life cycle will be addressed in a future report.

This study describes water use, management, and stewardship practices, the existing regulatory framework, quantitative water footprint information, and comparison of water use to other industry and societal uses.

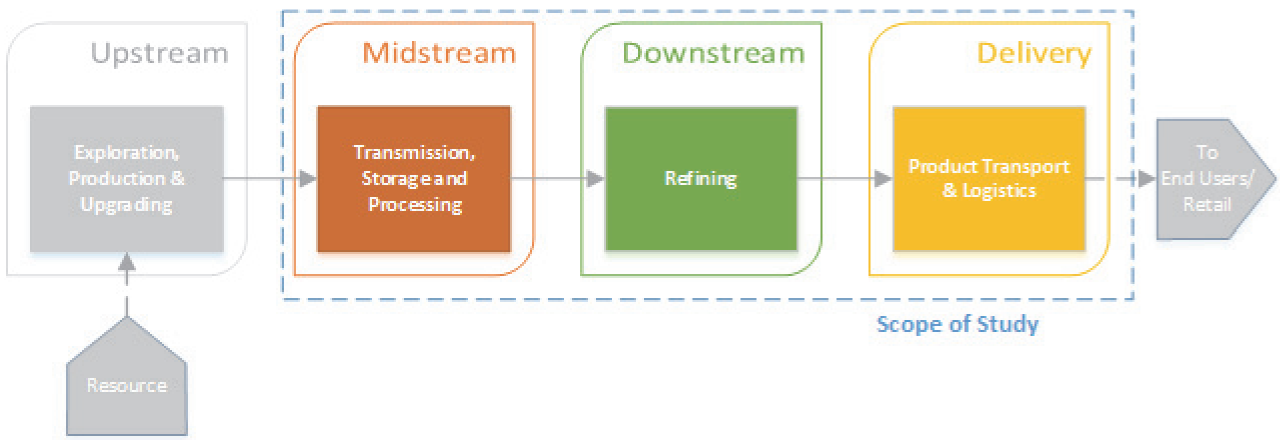

Figure ES.1—Petroleum Life Cycle and Scope of Study

Water Use

Water is used throughout the midstream, downstream, and delivery phases of the oil and gas life cycle. The most significant of these uses, however, is for oil refining. The raw material of the petroleum refining industry is petroleum material such as crude oil. Petroleum refineries process this raw material into a wide variety of petroleum products, including gasoline, fuel oil, jet fuel, heating oils and gases, and petrochemicals. Petroleum refining includes a wide range of physical separation and chemical reaction processes.

Water use in gas processing, oil and gas transmission (midstream) and oil and gas delivery phases is negligible compared to the amount of water required for oil refining. Therefore, this section focuses on water use in oil refining.

In petroleum refineries, water is vital for many applications including crude desalting, scrubbing, cooling, steam production, utility water, fire protection, and more. Refineries depend on uninterrupted and sustainable water supplies to maintain production and safety.

Refineries also generate wastewaters which are typically reused or discharged to the environment (mainly fresh and marine water bodies) after the appropriate level of treatment to meet regulated discharge limits. These limits vary from one location to another. In ecologically sensitive areas, a higher degree of effluent treatment may be required to allow discharge into the environment.

Figure ES.2 illustrates the water use and management in a typical refinery. Water inputs to a refinery come from a variety of sources including fresh, saline, and brackish surface water, groundwater, public water supplies, rainwater, and water contained within the crude oil. Much of the water used within a refinery can be reused, sometimes with and sometimes without treatment. Water outputs from the refinery process include losses to atmosphere, clean stormwater, utility blowdown, discharge of treated first flush stormwater and wastewaters, and water treatment residuals.

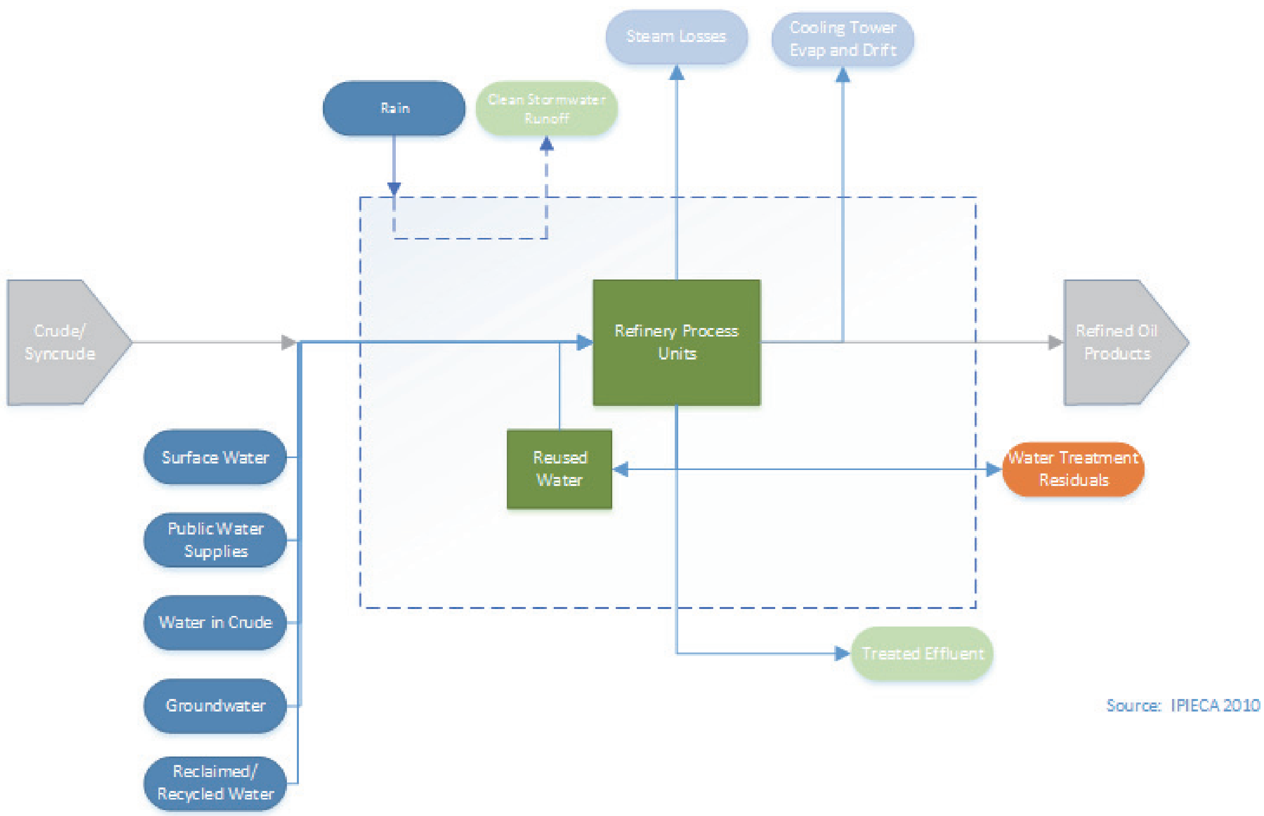

Figure ES.2—Water Use and Management Simplified Schematic in a Typical Refinery (with Closed Circuit Cooling) Water System

Losses to atmosphere are considered "consumptive" losses in that they represent a net loss of water within the refinery. However, losses to atmosphere allow for the reincorporation of that water into the hydrologic cycle where it will ultimately be available for reuse.

Water is used throughout the refinery for many different purposes and each purpose has its own set of water quality requirements. For some uses (such as cooling water, fire water, and utility water), lower quality brackish and saline sources, and reused refinery or municipal treatment plant effluent can be used, thereby reducing the overall fresh water demand for the facility. Other uses require a higher water quality. Table ES.1 provides a summary of the types of water uses within a refinery, the typical water sources for those uses, and specific water quality needs.

Regulatory Framework

Many different federal, state, and local regulations pertain to water use in oil refining, although the regulation with the most direct and significant impact on water management is the Clean Water Act (CWA), including the CWA's National Pollutant Discharge Elimination System (NPDES) program. In many states, the U.S. Environmental Protection Agency (USEPA) has delegated authority for implementation of the NPDES program. The NPDES permitting program encompasses all discharges from a facility, including both wastewater and stormwater. One key regulation pertaining to water management in oil refining is USEPA's Effluent Limitation Guidelines (ELGs) for the petroleum refining industry. In addition, the regulatory framework for water discharges from refineries includes water quality-based effluent limits (WQBELs) that allow flexibility for local regulators to set customized permit limits based on the characteristics and uses of the receiving stream. The more stringent requirement of technology-based effluent limits and WQBELs will be used in determining the permit limits for oil refineries.

Industry-led Water Stewardship Activities

Through industry-leading organizations and stakeholder partnerships, the oil and gas industry has been taking action to improve water stewardship and sustainability practices, including in the area of oil refining which is most relevant to this report. Key organizations leading these efforts include the American Petroleum Institute (API), the International Petroleum Industry Environmental Conservation Association (IPIECA), the Petroleum Environmental Research Forum (PERF), and the World Business Council for Sustainable Development (WBCSD). Examples of activities conducted through these organizations include development of guidance on sustainability reporting and water management for oil and gas activities, and documentation of best practices and strategies for water use minimization in refineries.

Water Footprint

As noted above, the water footprint for oil refining dominates all other water uses for oil and gas within the midstream, downstream and delivery phases of the life cycle. Water consumed in the refining process is the water lost to atmosphere through evaporation from steam heating and evaporative cooling processes. Through evaporation, this water is returned to the hydrologic cycle. The remainder of the water used is treated and reused or discharged to surface water, thereby also returning to the hydrologic cycle. The estimated consumptive water use for oil refining is between 5 and 9 gallons per million British thermal units of energy generated by combustion of the refined oil product (gal/MMBtus). Consumptive water use for all other activities in midstream, downstream (such as gas processing), and delivery phases of the oil and gas life cycle is 1 gal/MMBtu or less.

Comparison of Oil and Gas Industry Water Use

Conventional petroleum-based fuels historically have had a relatively minor impact on the overall water resources of the United States. According to King and Webber (King and Webber 2008), conventional petroleum gasoline consumes between 7 and 14 gallons of water per 100 miles driven, and conventional petroleum diesel consumes between 5 and 11 gallons of water per 100 miles. King and Webber (King and Webber 2008) stated that, “In general, fuels more directly derived from fossil fuels are less water intensive than those derived either indirectly from fossil fuels, or directly from biomass.”

The latest nationwide water use estimation by the U.S. Geological Survey (USGS, 2009) presented 2005 water withdrawals in the United States for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together accounted for less than 10 % of total water withdrawals. Notable withdrawal statistics include the following:

- Thermoelectric-power withdrawals account for 49 % of total water use, 41 % of total freshwater withdrawals, and 53 % of fresh surface water withdrawals for all categories.

- Irrigation withdrawals represented 37 %of total freshwater withdrawals and 62 % of total freshwater withdrawals for all categories excluding thermoelectric power.

- Public supply represented about 13 % of total freshwater withdrawals, and 21 % of all withdrawals, excluding thermoelectric power.

Industrial withdrawals represented about 4 % of total withdrawals and about 9 % of total withdrawals for all categories excluding thermoelectric power. Petroleum refining was included in the industrial category. Compared with other water use sectors, the oil and gas industry uses less water than the thermo-electric power industry, agricultural irrigation, biofuels for energy production, and public water supply.

The industry's beneficial use, management and stewardship of its water resources results in significant societal benefits. The oil and gas industry provides good jobs for many Americans and contributes significantly to the Gross Domestic Product (GDP) of the United States. Each direct job in the oil and natural gas industry supported approximately 2.8 jobs elsewhere in the U.S. economy in 2011. Counting direct, indirect, and induced impacts, the industry's total impact on labor income was $598 billion, or 6.3 % of national total in 2011. The industry's total impact on the U.S. GDP was $1.2 trillion, accounting for 8.0 % of the national total in 2011 (PricewaterhouseCoopers, 2013).

Key Take-aways

— Water is an increasingly important global environmental and social issue. Stewardship of this key resource in the transport, refining, and delivery of refined fuels to consumers, like all commercial and industrial enterprises, is gaining new focus. Water is essential for the safe operation of fuels production and transport; it plays a key role in protecting employees and assets.

— The oil and gas industry is using its practical and technological expertise to explore ways to decrease demands on scarce freshwater supplies and encourage procedures to conserve, recycle and reuse water. In some cases, the industry has found ways to use reclaimed wastewater or low quality water in the industrial process - utilizing less fresh water ((WBMWD) n.d.).

— Water withdrawal and discharge in oil refining operations is regulated by numerous federal, state, and local regulations, the most prominent of which are the CWA and associated permitting program and the national discharge standards for all oil refineries. In addition, regulators have the ability to establish water quality based effluent limits in permits that can be customized to specific conditions to protect the local receiving stream.

— Stormwater management and stormwater runoff water quality from oil and gas operations are also highly regulated as is the proactive prevention and protection from spills that could impact surface water and groundwater quality. The industry is also reducing its impact by monitoring and reporting discharges. Through continually improving the storage, handling and transportation of all products our operations are further reducing the possibility of marine or groundwater contamination (IPIECA 2010).

— In midstream, downstream, and delivery phases of the oil and gas life cycle, water use in oil refining dominates all other activities with respect to quantity of water used. Oil refining requires the consumptive use of water in the range of 5 to 9 gal/MMBtu. This consumed water is the water that is lost to atmosphere through evaporation and will ultimately rejoin the hydrologic cycle for future use. The remainder of the water used in oil refining is treated and discharged consistent with regulatory and water quality obligations.

— The latest nationwide water use estimation by USGS (Maupin 2014) estimated water withdrawals in the United States for 2010 for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together accounted for less than 10 % of total water withdrawals. Industrial withdrawals represented about 4 % of total withdrawals. Petroleum refining was included in the industrial category. Compared to other water use sectors, the oil and gas industry uses less water than the thermo-electric power industry, agricultural irrigation, biofuels for energy production, and public water supply.

— The oil and gas industry has actively participated in establishing global standards for measuring and reporting water stewardship performance for all industries and routinely and voluntarily reports individual company performance through such avenues as annual stockholder and corporate responsibility reports and industry organization data collection and reporting efforts (such as IPIECA water use reports).

— With further sharing and implementation of best practices and increased use of alternative water sources for refinery water demands (such as reusing treated municipal wastewater for cooling and other operational purposes), the industry trend of declining water requirements for refining is expected to continue. The industry continues to make significant capital investments in equipment and each day operates significant assets to treat wastewater, maintain water quality, and protect the environment.

— Several key industry organizations, including API, IPIECA, PERF, and WBCSD have been and continue to be instrumental in providing leadership and sharing best practices across the industry to improve water use and sustainability.

Water Management and Stewardship in Midstream, Downstream, and Delivery Operations in the Oil and Gas Industry

1 Scope and Objectives

The oil and gas industry has significant connections to the water environment. Water is beneficially used, consumed, generated, reused, recycled, and disposed of over the life cycle of an oil and gas resource. The degree and impact of these connections vary with the nature and location of the resource and the methods of extracting and converting that resource into valuable end products.

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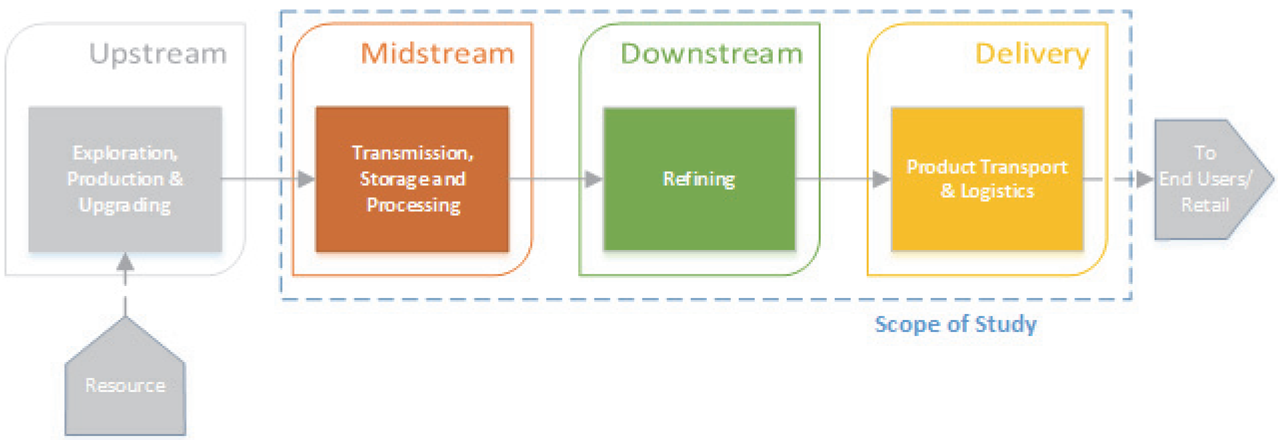


Figure 1—Petroleum Life Cycle and Scope of Study

This study is intended to inform stakeholders about how the oil and gas industry uses water in the petroleum life cycle (midstream, downstream, and delivery phases) and the different industry-led and regulatory practices employed to conserve and protect water resources. Specifically, within its scope, the study:

— describes water use in each life cycle stage;

— describes water management and stewardship practices employed by the industry, including when these practices may and may not be feasible;

— describes the existing regulatory framework governing the oil and gas industry and its use, management, and protection of water resources and the environment;

— provides a quantitative summary of the water footprint for typical operations;

— illustrates oil and gas industry water use in context with other industry and societal uses.

This study provides stakeholders with a more thorough understanding of oil and gas industry water management and stewardship in midstream, downstream, and delivery operations. The study does not endeavor to address other media such as air emissions or residual streams.

2 Abbreviations and Acronyms

API	American Petroleum Institute
bgd	billion gallons per day
CAA	Clean Air Act
CDP	Formerly known as the Carbon Disclosure Project; in 2013, CDP rebranded its name to the abbreviation only
COGCC	Colorado Oil and Gas Conservation Commission
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DOT	U.S. Department of Transportation
EA	environmental assessment
EIS	environmental impact statement
ELG	Effluent Limitation Guideline
ESA	Endangered Species Act
gal/MMBtu	gallons per million British thermal units
GAO	U.S. Government Accountability Office
GCD	groundwater conservation district
GDP	Gross Domestic Product
GEMI	Global Environmental Management Initiative
GTL	gas-to-liquids
GWPC	Ground Water Protection Council
H_2S	hydrogen sulfide
HCA	high-consequence area
IAOGP	International Association of Oil and Gas Professionals
IPIECA	International Petroleum Industry Environmental Conservation Association
MACT	maximum achievable control technology
NEPA	National Environmental Policy Act of 1969
NETL	National Energy Technology Laboratory
NGL	natural gas liquids
NPDES	National Pollutant Discharge Elimination System
OPA	Oil Pollution Act
PERF	Petroleum Environmental Research Forum
POTW	publicly owned treatment works
SDWA	Safe Drinking Water Act
SPCC	spill prevention, control, and countermeasures
SPE	Society of Petroleum Engineers
TDS	total dissolved solids
TMDL	total maximum daily load
TSS	total suspended solids
TWDB	Texas Water Development Board

UIC	Underground Injection Control
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WBCSD	World Business Council for Sustainable Development
WQBEL	water quality-based effluent limit

3 Water Use

3.1 General

This section expands on the simplified representation in Figure 1 to describe how water management varies through midstream, downstream, and delivery phases, and depending on the type of resource. A composite diagram comparing activities for each resource is included in Appendix A.

Water stewardship is an ethic embodying responsible planning and management of water resources. Industry water stewardship practices related to specific water use, and when these practices may or may not be feasible, are described in this section. For the purpose of this report, the following definitions are used.

— **Use.** Refers to water that is withdrawn for a specific purpose (in this case, midstream, downstream, and delivery operations within the oil and gas industry). Water use includes both self-supplied withdrawals and deliveries from public supply. More broadly, water use pertains to the interaction of humans with and influence on the hydrologic cycle (Kenny et al. 2009).

— **Consumptive Use.**Consumptive use precludes the subsequent withdrawal for another use, at least temporarily, because it represents that fraction of water that is removed from availability due to evaporation, transpiration, or incorporation into products or crop, or consumed by livestock or humans (Maupin 2014).

— **Generate.** A small amount of water is contained within the extracted oil and gas and is separated from the oil and gas during midstream and downstream processing. This is the water that is referred to as being “generated” during oil and gas processing.

— **Reuse or Recycle.** Water from an industrial or commercial process that is not disposed of, but beneficially used again in the same or another process (IPIECA, API, and OGP 2010). For the purposes of this report, the terms reuse and recycle are synonymous and will be used interchangeably.

— **Disposal.** Final discharge or placement, on site or off site, of wastewater under proper process and authority with no intention to retrieve (IPIECA, API, and OGP 2010).

— **Management.** Sustainable water management can be defined as water resource management that meets the needs of present and future generations (USEPA 2012).

3.2 Midstream

Midstream activities vary between oil, whether from regular crude or synthetic crude, and gas. Midstream generally comprises the following operations:

— terminals;

— transmission (can include pipeline construction and expansion; hydrostatic testing of new and existing lines for both oil and gas; and transportation via truck, rail, and tanker);

— processing.

Asset ownership and custody transfer of the resource often govern what specific midstream activities are involved. Subcategories of midstream oil and gas activities are depicted in Figure 2.

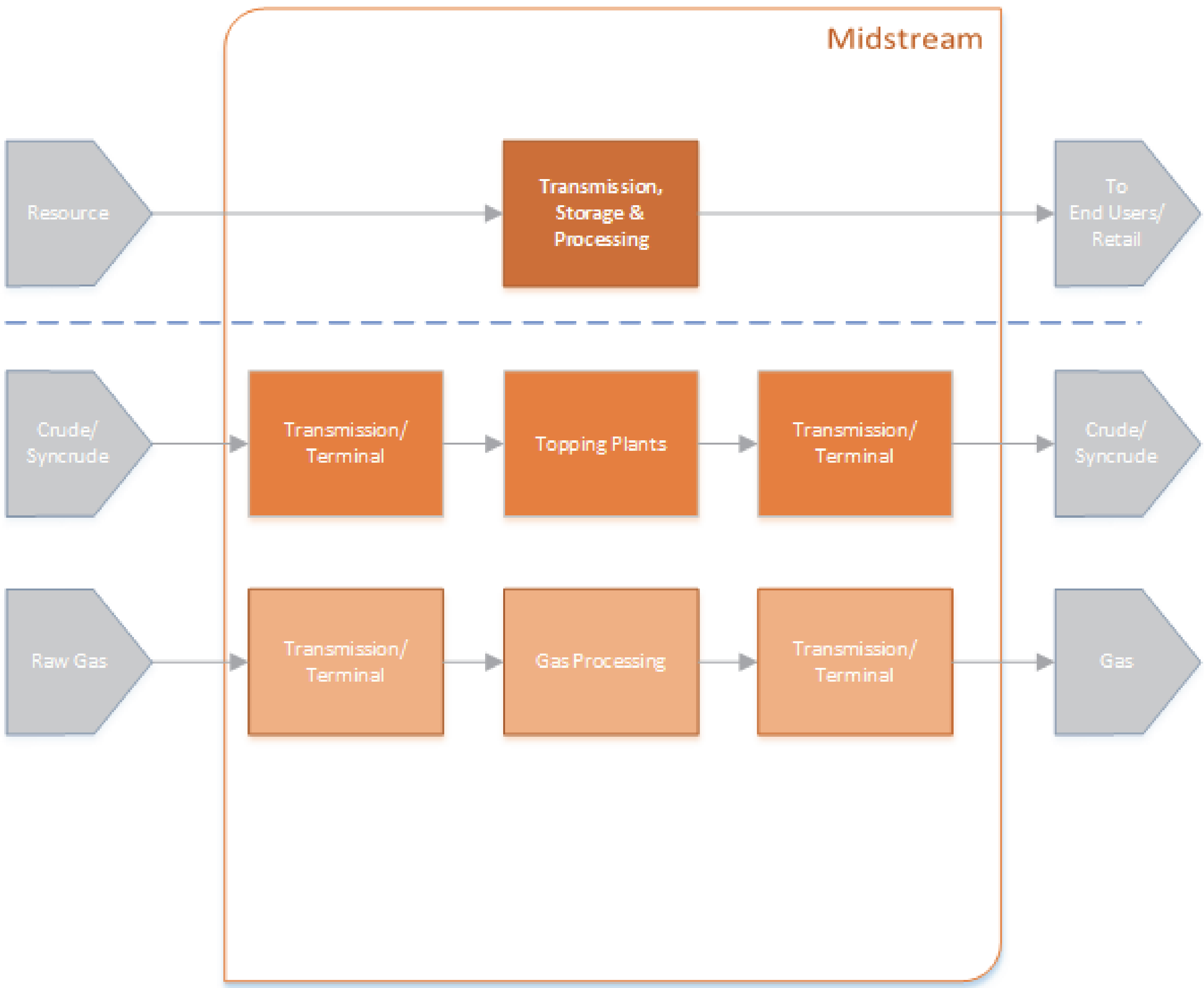


Figure 2—Midstream Activities by Petroleum Resource Type

3.2.1 Oil

Conventional, unconventional, and heavy oil/oil sands are all handled similarly in midstream, downstream, and delivery phases of the life cycle. Midstream oil activities primarily consist of transmission pipelines. The pipelines are used to convey crude oil from the source to oil refineries for processing. Some water is used in the construction of pipelines, although a relatively small amount. Once pipelines are constructed, hydrostatic testing is conducted to check for leaks in the system. To conduct this testing, pipelines must be completely filled with water. When hydrostatic testing is complete, the water is stored and tested to assess water quality. The test water is typically of sufficient quality for discharge to sewer or for direct land application. Test water of lower quality is managed through treatment or disposal.

Midstream oil activities can also include midstream oil terminals designed to reduce the water content of the crude prior to transmission to the refinery. These terminals are sometimes located at a midstream location and sometimes located within the refinery limits as part of downstream activities. In midstream terminals, oil is pumped into tanks where the oil and water phases can separate into distinct layers. The water is then bled off the tanks and the crude is transferred to conveyance pipelines for transmission to the refinery. This process is a net producer of oily water, which can be treated and reused or returned to the hydrologic cycle.

Figure 3 depicts the typical water balance within a midstream oil terminal.

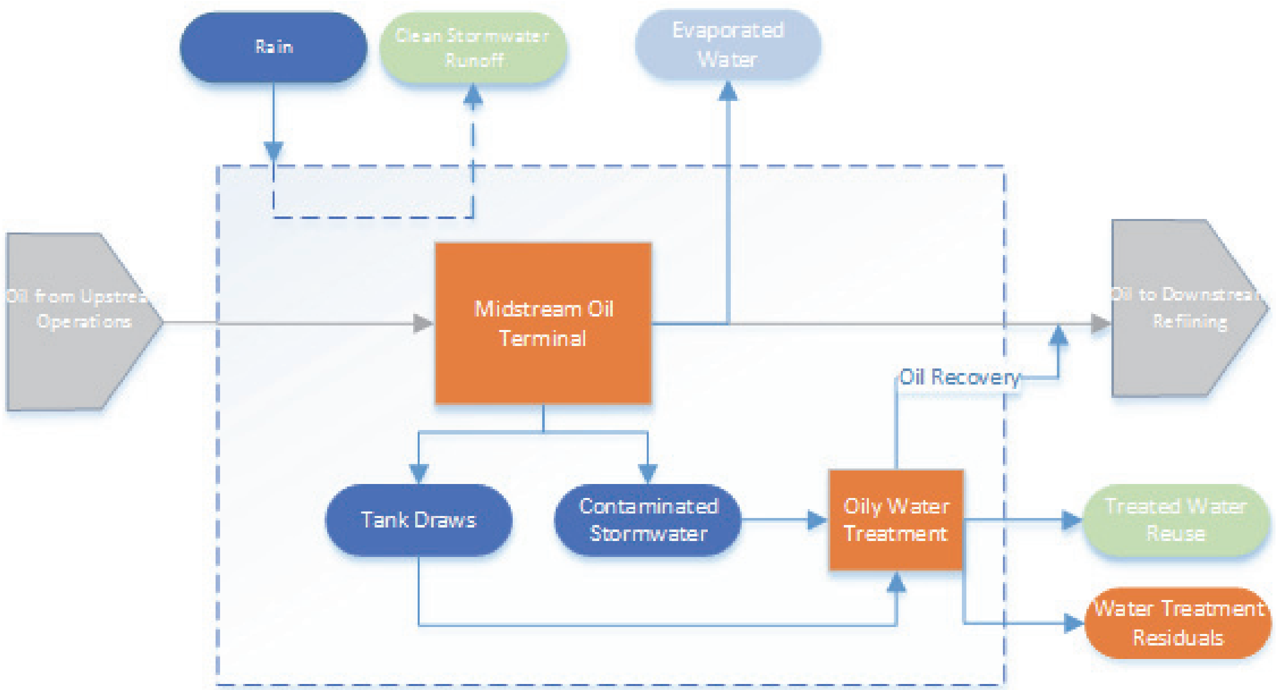


Figure 3—Typical Water Use and Management in Midstream Oil Terminal Operations

Topping plants, sometimes referred to as topping refineries, are also considered a midstream activity. Topping plants are simple refineries that include atmospheric distillation towers, but do not include more complex refining processes such as reforming, catalytic cracking, and coking. They are generally small in size. Topping plants separate the crude oil into its major constituents, which include liquefied petroleum gases, gasoline blending stocks, and distillate fuels (jet and diesel fuels and heating oils). These products from the topping plants can then be conveyed to and further refined in more complex refineries. Water is used in topping plants as cooling water and in water-cooled heat exchangers.

Industry water management and stewardship activities applied to midstream oil terminals include the treatment and reuse of oily water and recovery of oil from oily water streams.

3.2.2 Natural Gas

By the midstream point in the natural gas life cycle, gas from conventional, unconventional, offshore, and onshore sources are handled similarly. The processing of natural gas for sale to end users is an activity that, depending on location and proximity of gas processing facilities to the well field, is sometimes classified as an upstream activity and sometimes classified as a midstream activity. A minimal level of processing to remove water and corrosive agents (hydrogen sulfide and carbon dioxide) is always part of the upstream process, but it is the removal of additional impurities and separation of the natural gas liquids (NGLs) that can be either an upstream or midstream process. Regardless of the point within the gas life cycle gas processing occurs, the process is the same, as is the water balance around the process.

Gas processing includes removal of additional impurities such as trace metals and metalloids, and separation of NGLs, which include propane, butane, ethane, among others, for recovery and sale. Little water is used in gas processing and the process is a net water producer, meaning that more water comes out of the process than is put in due to the inherent water content of the gas. Typical water use in natural gas processing is illustrated in Figure 4.

Industry water management and stewardship activities applied to gas processing include the reuse of condensed water within gas processing facilities.

Aside from processing, the other key element of midstream natural gas activities is transmission. The transmission of gas from one region to another is accomplished through a complex system of low pressure, small diameter gathering pipelines that convey produced gas to the gas plant (gathering lines), the interstate pipeline system, and the distribution system. The interstate pipelines are high pressure lines, typically operating at pressures of between 200 and 1,500 pounds per square inch (psi). This high pressure reduces the volume of the natural gas being transported and also propels natural gas through the pipeline (naturalgas.org n.d.). Compressor stations are located periodically along the interstate pipelines to ensure that the gas remains at the desired pressure. At the compressor station, the gas is compressed either by a turbine, motor, or engine. The compressor stations also include systems to capture any liquids or other unwanted particles from the natural gas in the pipeline.

Very little water is used in midstream natural gas activities and gas processing is a net water generator.

3.3 Downstream

Downstream activities vary between oil, whether from regular crude or synthetic crude, and gas. Downstream generally comprises following activities.

- Oil Refining
- Gas Refining
- Ethane Separation and Ethane Cracking
- Gas-to-liquids (GTL)
- Liquefied Natural Gas (LNG)

Subcategories of downstream oil and gas activities are depicted in Figure 5. Downstream activities for all oil resources (onshore, offshore, unconventional, oil sands, heavy oil) consist of oil refining processes. Oil refining processes will vary based on the specific type of oil to be refined, products to be produced, anticipated throughput, and other factors; however, the general uses of water throughout the process are the same. The raw material of the petroleum refining industry is petroleum material such as crude oil. Petroleum refineries process this raw material into

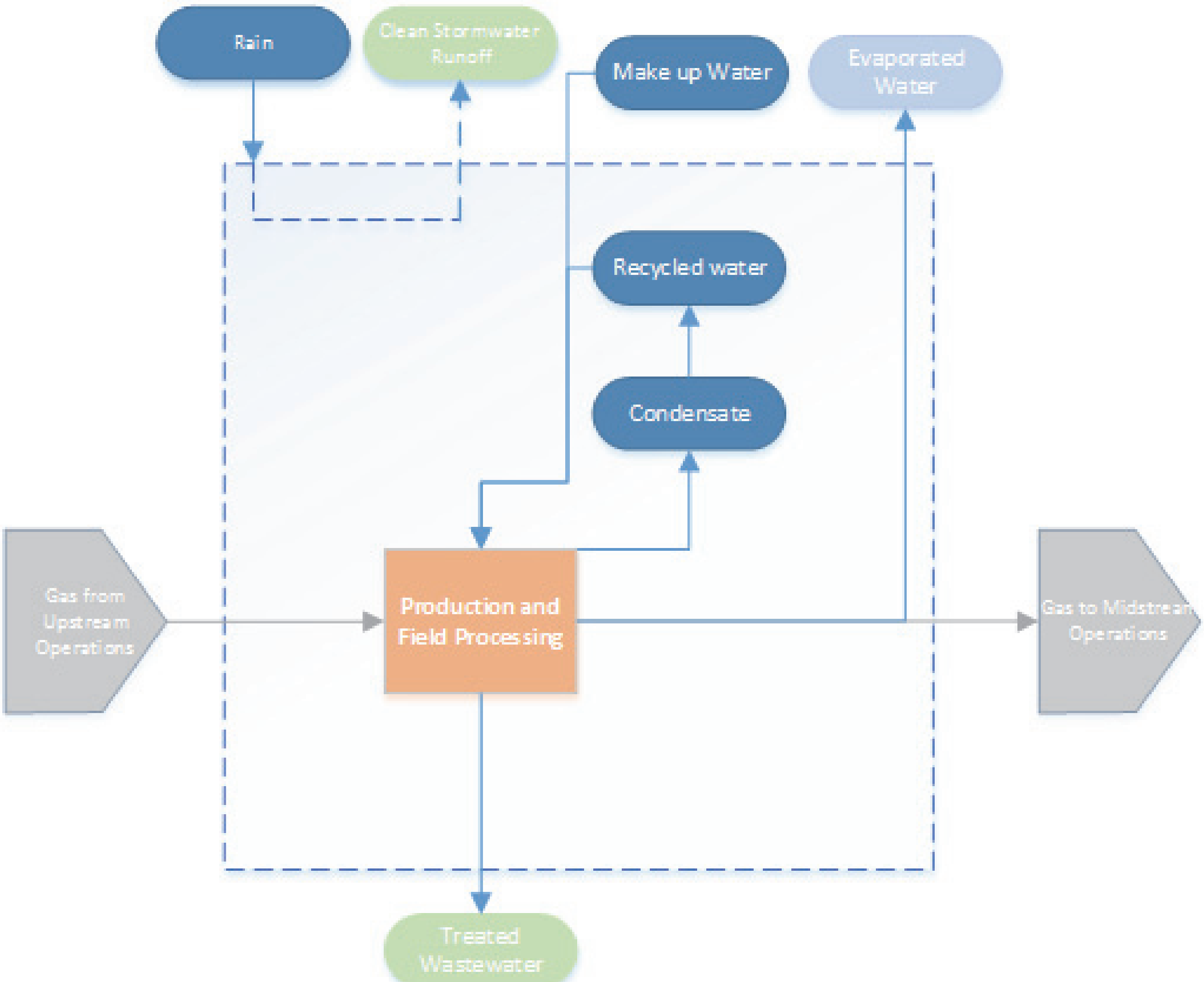


Figure 4—Typical Water Use and Management in Midstream Gas Processing Operations

a wide variety of petroleum products, including gasoline, fuel oil, jet fuel, heating oils and gases, and petrochemicals. Petroleum refining includes a wide variety of physical separation and chemical reaction processes.

Downstream activities for gas resources can consist of one of three options, depending on the end use for the resource. Extracted and purified gas can be either directly conveyed to the point of sale, liquefied (LNG process) to reduce volume prior to transportation, or refined to separate ethane for ethane cracking or to produce liquid petroleum products, such as gasoline (GTL process). Each of these downstream activities is further described in the subsections below.

3.3.1 Oil Refining

In petroleum refineries, water is vital for many applications including crude washing; cooling; steam production for various contact and non-contact processes, including pre-heating, steam stripping, vacuum generation, and other processes; fire protection; and more. Dependence on uninterrupted and sustainable water supplies is therefore critical to maintaining production and safety.

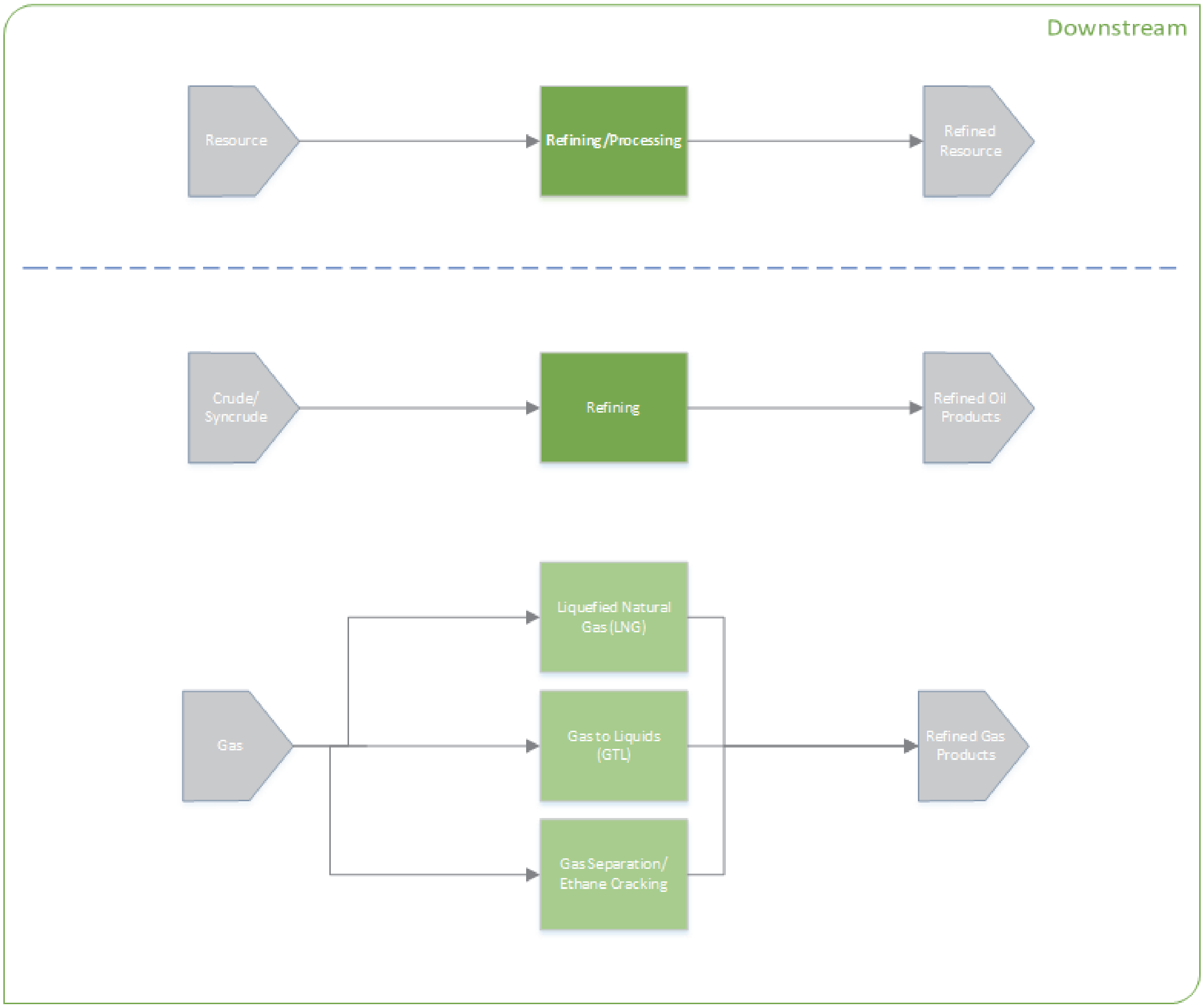


Figure 5—Downstream Activities by Petroleum Resource Type

Refineries also generate wastewaters, which are typically discharged to the environment (mainly fresh and marine water bodies) after the appropriate level of treatment to meet regulated discharge limits. These limits vary from one location to another. In ecologically sensitive areas, a higher degree of effluent treatment may be required to allow discharge into the environment.

Figure 6 illustrates the water use and management in a typical refinery. Water inputs to a refinery come from a variety of sources, including surface water, groundwater, purchased water, rainwater, and water contained within the crude oil. A large portion of the water used within a refinery can be reused, sometimes with and sometimes without treatment. Water outputs from the refinery process include losses to atmosphere, clean stormwater, utility blowdown, and the discharge of treated wastewater and residuals. Losses to atmosphere are considered “consumptive” losses in that they represent a net loss of water within the refinery. However, losses to atmosphere allow for the reincorporation of that water into the hydrologic cycle, where it will ultimately be available for reuse.

Water is used throughout the refinery for many different purposes and each purpose has its own set of water quality requirements. For some uses, such as cooling water, fire water, and utility water (used for miscellaneous washing operations such as cleaning an operating area), lower quality brackish and saline sources as well as reused refinery or municipal treatment plant effluent can be used, thereby reducing the overall fresh water footprint for the facility. The

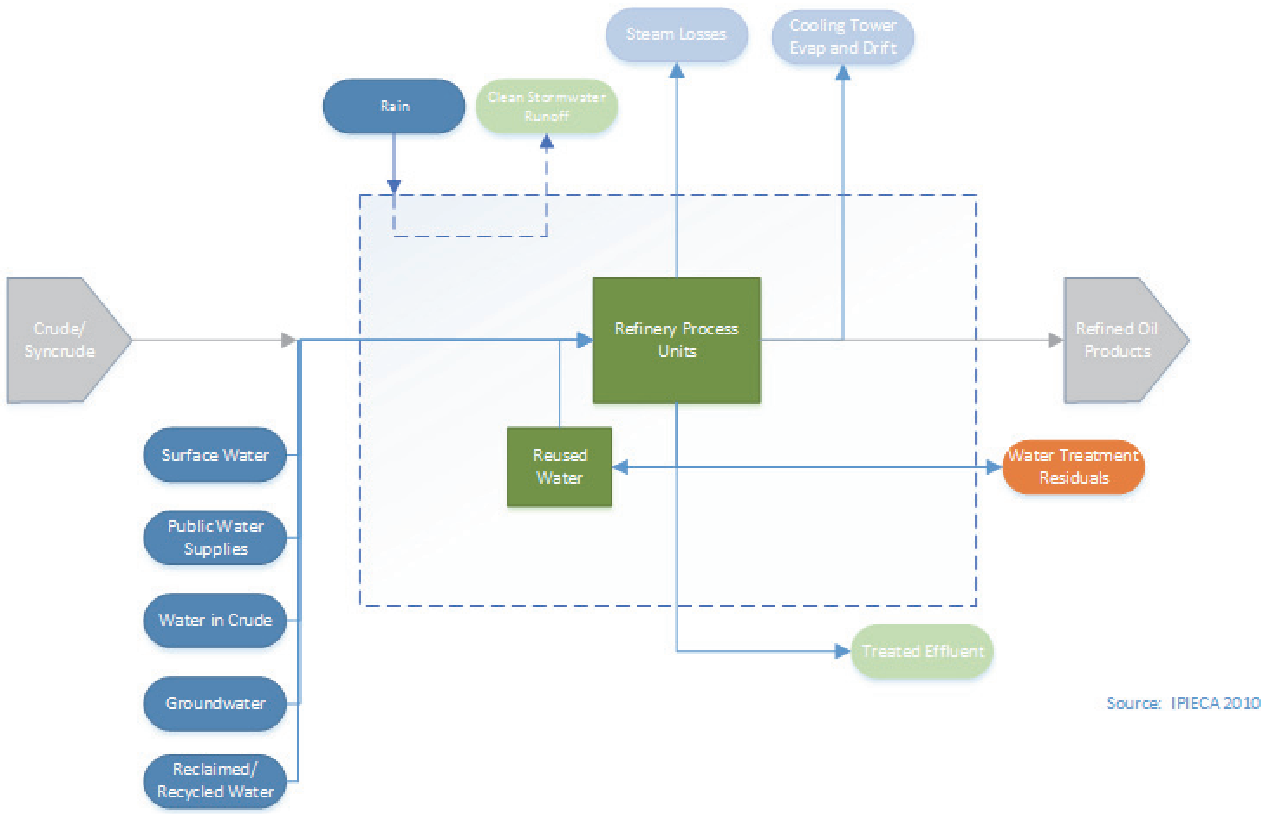


Figure 6—Water Use and Management Simplified Schematic in a Typical Refinery (with Closed Circuit Cooling) Water System

corrosive nature of these lower-quality waters normally requires the use of more expensive, corrosion resistant materials for process system components and hardware. For example, seawater cooling systems require titanium surfaces, adding significantly to the cost. Other uses require a higher water quality. Table 1 provides a summary of the types of water uses within a refinery, the typical water sources for those uses, and specific water quality needs.

Sources of wastewater within the refinery include process water, clean and contaminated stormwater, sewage, cooling water blowdown, boiler blowdown, and steam condensate (IPIECA 2010). Water management practices are used throughout the refinery to minimize the volume of wastewater discharged and maximize the reuse of water within the facility. These water management practices include the following (IPIECA 2010).

— **Stormwater Management.** Stormwater is segregated into clean and contaminated streams, depending upon which areas of the refinery the stormwater has contacted. Clean stormwater is discharged back to surface water and contaminated stormwater is sent to the wastewater treatment facility within the refinery for treatment prior to discharge. In addition to segregation, management practices include the following:

  — minimizing the process collection area through curbing or other modifications;

  — treating “first-flush” only from process areas, with subsequent runoff being sent to the non-contaminated stormwater system;

  — minimizing solids in stormwater through paving, strategic vegetation plantings, installation of green infrastructure, and sweeping of plant areas;

Table 1—Water Sources and Quality for Downstream Oil Operations

Water Use	Typical Water Sources	Water Quality Needs
Desalter Makeup	Groundwater, surface water, purchased water, reused refinery waters (Stripped sour water, vacuum tower overhead, crude tower overhead, scrubber liquids from air pollution control), recycled/reclaimed water	Low sulfide, ammonia, and total dissolved solids (TDS)
Coker quench water and cutting water	Stripped sour water, groundwater, surface water, purchased water, recycled/reclaimed water	Low total suspended solids (TSS), no biological solids, no hydrogen sulfide (H2S) or other odorous compounds
Boiler Feed Water	Treated groundwater or surface water, potable water, stormwater, treated refinery wastewater	Low hardness, chlorides, sulfates, silica, sodium, dissolved oxygen, and conductivity
Cooling Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, or in some cases brackish groundwater, seawater	For typical systems: low conductivity, alkalinity, chlorides, suspended solids. Brackish water and seawater contain higher levels of conductivity and dissolved solids than would be acceptable for use in typical refinery cooling systems due to their highly corrosive nature. If these more saline sources of water are used in cooling systems, the metallurgy of the systems normally require upgrading to more corrosion resistant materials such as titanium to prevent corrosion.
Potable Water	Municipal water supply, treated groundwater	Disinfection, meets drinking water standards
Fire Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, or in some cases brackish groundwater, seawater	Protect against corrosion; low sediment content
Utility Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, or in some cases brackish groundwater, seawater	Sediment free
Source: (IPIECA 2010)		

— covering process areas, such as truck loading and unloading pads, to reduce the amount of stormwater that comes in contact with potentially contaminated areas; and

— preventing and controlling leaks and drips from process equipment such as pumps and heat exchangers.

— **Process Wastewater Management.** Process wastewater sources include desalter effluent, sour water, spent caustic, tank water draws, maintenance liquids, coke quench water, and other miscellaneous process water streams. Water management practices are employed around each of these sources to minimize the freshwater footprint and maximize reuse.

— **Desalters.** Inorganic salts are present in crude oil as a naturally occurring emulsified solution. Desalting is typically the first unit operation in refining and is used to wash out the salt as well as to separate drilling muds that come in with the crude. Water management practices in desalting include avoiding the use of fresh water as washwater in the desalter (stripped sour water is an excellent source of recycled water that can be used as desalter washwater), operating at a pH of 6 to 7 to avoid emulsification, maintaining effective oil/water separation, and using a separate tank where solids can drop out during mud-washing operation.

Desalter water that is sent to the wastewater treatment plant may require cooling or heating to assure proper operation of the biological treatment system.

— **Sour water.** This integral utility process water stream is found throughout the refining process. The purpose of sour water is to capture impurities (hydrogen sulfide generally) for further processing to create elemental sulfur, a co-product from the manufacture of finished fuel products. Steam is used in many processes in refineries as a stripping medium in distillation and as a diluent to reduce the hydrocarbon partial pressure in catalytic cracking and other applications (IPIECA 2010). Due to the contact that the steam has had with hydrocarbons, sour water generally contains hydrogen sulfide and ammonia at levels that require treatment. Sour water is typically sent to a stripper for removal of hydrogen sulfide and ammonia. This stripped sour water is an excellent candidate for reuse within the refinery and commonly used as desalter washwater, as noted above. In some cases, the sour water can be reused directly within the refinery without stripping. Sour water management practices include segregating the sour water produced in the catalytic cracker or coker because it contains phenols and cyanides not present in other sources of sour water. The catalytic cracker sour water may be processed in a dedicated phenolic sour water stripper and the stripped sour water is used as desalter washwater. Stripped water that is sent to a wastewater treatment plant may require cooling or heating to assure proper operation of the biological treatment system.

— **Spent caustic.** Caustic is used within the refinery to extract acidic components from hydrocarbon streams. The acidic compounds are neutralized by the caustic and the resulting spent caustic solution cannot be regenerated. There are two types of spent caustic: phenolic and sulfidic. Sulfidic spent caustic can be treated in the wastewater treatment plant provided it is added in a controlled manner to avoid shocking the system. Phenolic spent caustic is typically taken to offsite treatment for beneficial recovery of the contained organic components. Spent caustic management practices include segregation of phenolic and sulfidic spent caustic, prewashing of the hydrocarbons with stripped sour water to reduce the quantity of acidic compounds, spent caustic treatment systems (wet air oxidation, neutralization), and reuse by other industries such as pulp and paper mills and cement plants where feasible.

— **Tank Draws.** Water and impurities that collect in the lower section of a storage tank require periodic removal (tank draw). Tank draws are pulled primarily from crude tanks and oil recovery tanks. Tank draws from crude tanks remove the bottom sediment and water that settles and accumulates in the bottom of these large storage tanks and prevent buildup of this material, which would result in a loss of storage capacity. Tank draws are typically sent to the wastewater treatment plant. Management practices are targeted at minimizing the amount of oil in the tank draw that is sent to the wastewater treatment plant. This is accomplished through design of piping and valves to allow proper draining of the tank, proper instrumentation for clear identification of the oil/water interface in the tank and, if necessary, close operator attention during draws to minimize the drawing of oil.

— **Coker Quench Water and Coke-cutting Water.** Water is used in the coker to provide cooling of the coke drum (quench water) and is also used in a high-pressure nozzle as a cutting fluid to cut the coke from the drum. The quench water and the coke-cutting water are reused within the coker and, when they can no longer be reused, are sent to the wastewater treatment plant.

NOTE In April 2011, Chevron's refinery in Richmond, California, was named Recycled Water Customer of the Year by the Water Reuse Association, a nonprofit organization focused on sustainable-water issues. The award honored the refinery's work on the Richmond Advanced Recycled Expansion (RARE) Water Project, a joint effort with the East Bay Municipal Utility District. The RARE Water Project facility recycles municipal wastewater into steam used in refinery operations, thereby freeing up 3.5 million gallons of freshwater per day for public use.

— **Cooling Water Management.** Three types of cooling water systems are used within the refinery: (1) once-through cooling water systems in which the water is used only once; (2) closed-loop cooling water systems in which water is circulated in a closed-loop system and absorbed heat is rejected using heat exchanger to a once-through cooling system; and (3) evaporative cooling water systems that use a recirculating loop of cooling water and rejection of acquired heat in a cooling tower by evaporation. In evaporative cooling systems, part of the circulating water is removed as blowdown to prevent the buildup of dissolved solids in the system. Cooling water blowdown is typically sent to the wastewater treatment plant for removal of accumulated hardness and solids. Management practices include minimizing oil leaks in the heat exchangers, using non-freshwater sources as cooling water (such as boiler blowdown, treated wastewater, and stormwater), and reuse of cooling tower blowdown. In addition, segregating the piping of the cooling tower blowdown from other wastewater sources and routing it directly to the secondary oil/water separation equipment due to its low oil content can greatly reduce the hydraulic loading on the primary oil/water separation unit. Effective heat exchanger and cooling tower management allows less water to be used.

— **Condensate Blowdown Management.** Condensate losses in the refinery include blowdown from the plant boiler system and steam generators and unrecovered condensate from steam traps and steam tracing. Blowdown is purged from the plant boilers for the same reason as in the cooling towers—to prevent the buildup of dissolved solids in the system. Blowdown is purged from the steam generators in order to control overheating. Management practices include maximizing the recovery of condensate, maintaining the volume of condensate blowdown to a minimum, reuse of boiler blowdown as cooling water makeup, and flashing (reducing pressure to atmospheric pressure), and cooling of blowdown prior to discharge to maintain sewer integrity and prevent heating and vaporizing of hydrocarbons that may be present.

— **Laboratory Wastewater Management.** Wastewater generated in refinery laboratories includes spent/unused hydrocarbon samples, wastewater samples, discharges from sinks and bottle washing systems in the laboratory, and any residuals from bench/lab analyses that are not managed as solid/hazardous wastes. Management practices include recycling of hydrocarbon samples to the refinery oil recovery system, disposal of wastewater samples to the wastewater treatment plant, and discharge of laboratory sinks and bottle-washing water to the wastewater treatment plant. Modern technology has allowed previous bench-scale chemistry (that may have been water-dependent) to convert to equipment methods that require smaller samples and minimal water and sorbent volumes.

NOTE Through a partnership with the local water municipality (the West Basin Municipal Water District) Chevron was able to use reclaimed municipal wastewater as the primary water supply for refinery operations. This partnership has made it possible to use reclaimed or recycled water for more than 80 % of the water used at the El Segundo Refinery.

Wastewater treatment systems in refineries generally include a three- or four-stage oil/water/solids/vapor primary separation process to remove free oils and oily solids, a secondary oil/water separation process to remove finer oil/sand particles and emulsified oils, an equalization stage, biological treatment for removal of soluble organics, and tertiary treatment (if necessary). The need for tertiary treatment will depend on the influent conditions and level of treatment required to achieve discharge standards, which is site-specific. Some process wastewater streams also undergo pretreatment prior to discharge to the wastewater treatment plant. For example, in some cases, desalter effluent undergoes an oil/water separation step and stripping for reduction of volatile organic compounds prior to discharge to the wastewater treatment plant.

Oil/water separation processes typically include a primary oil/water separation step such as an API–type separator in the first stage and a secondary oil/water separation step such as a dissolved gas flotation or induced gas flotation (IGF) unit in the second stage.

The equalization system is designed to minimize fluctuations in flow and composition to the biological treatment system. Equalization also allows for reduction in the size of downstream units. The equalization system is commonly placed before the biological treatment process, either upstream of the secondary oil/water separation units or, in some cases, upstream of the primary oil/water separation units.

The biological treatment process is either a suspended or attached growth system. Suspended growth processes are those in which the microorganisms are mixed with the organics in the liquid and maintained as a suspension in the liquid. The most commonly used suspended growth process in refinery wastewater systems is the activated sludge process. Other suspended growth processes used in refineries' wastewater systems include activated sludge treatment with powdered activated carbon, sequencing batch reactors, membrane bioreactors, and aerated lagoons. In attached growth processes, microorganisms are attached to an inert packing material instead of being suspended.

The packing material can be rocks, gravel, plastic, or various synthetic materials. Typical attached growth processes used in refineries include moving bed bioreactors (MBBR) and rotating biological contactors. Biological nitrification or nitrification with denitrification may also be incorporated into the biological treatment system if the refinery site is required to meet stringent ammonia or nitrogen limits.

Tertiary treatment processes can be required if stringent limits for total suspended solids (TSS), chemical oxygen demand (COD), dissolved and total metals, and trace organics must be met. Typical tertiary treatment processes include media/sand filtration, microfiltration, ultrafiltration, chemical oxidation, ion exchange, reverse osmosis, natural wetland treatment systems, and pollutant-specific treatment systems such as iron co-precipitation or ion exchange designed for selenium removal.

One wastewater management approach that can be used to optimize reuse of treated wastewater within the facility is to segregate the wastewater based on total dissolved solids (TDS) or oil content. Water low in oil would not require treatment with an API separator.

Water reuse practices within the refinery fence are discussed above. Outside the refinery fence, water reuse practices include the reuse of refinery wastewater for irrigation or export to other industries and the reuse of municipal treatment plant effluent for refinery water demands.

3.3.2 Natural Gas

Downstream activities for natural gas include the following options: (1) direct transmission for delivery to consumers (in this case, the gas has been purified to sales quality through gas processing in the upstream life cycle), (2) processing in an LNG facility, or (3) processing in GTL facility. Direct transmission consists of conveyance pipelines, for which there is very little water usage. Water use and management in LNG and GTL facilities are discussed in the subsections below.

3.3.2.1 Liquefied Natural Gas

Liquefied Natural Gas (LNG) facilities cool natural gas to -260 °F (-162 °C), changing it from a gas into a liquid that is 1/600th of its original volume (Chevron, *Liquefied Natural Gas* 2012). The gas is also treated to remove water, hydrogen sulfide, carbon dioxide, and other components that would freeze at the low temperatures at which LNG is stored or would contribute to corrosion within the LNG facility. Water is used in the liquefaction process units and in some facilities as a cooling medium.

LNG facilities use relatively little water and also produce water as part of the process. Water is produced as the water carried in the gas is separated and condensed. In some facilities this water is treated and reused or discharged. Small quantities of water are used for miscellaneous washing operations within the facility. This water is referred to as utility water.

LNG facilities have historically been built on land, although Shell is currently in the process of building the world's first floating liquefied natural gas facility. The floating liquefied natural gas is a major innovation that will allow for the generation of LNG at the offshore natural gas well.

LNG is transported from one country to another aboard specially designed LNG shipping vessels. After arriving at its destination, LNG is warmed to return it to its gaseous state and delivered to natural gas customers through local pipelines.

Relative to upstream activities, LNG processing requires little water. However, some water is used in within the LNG process as process water, potable water, fire water, and utility water. Water use in LNG operations is illustrated in Figure 7 and described in Table 2.

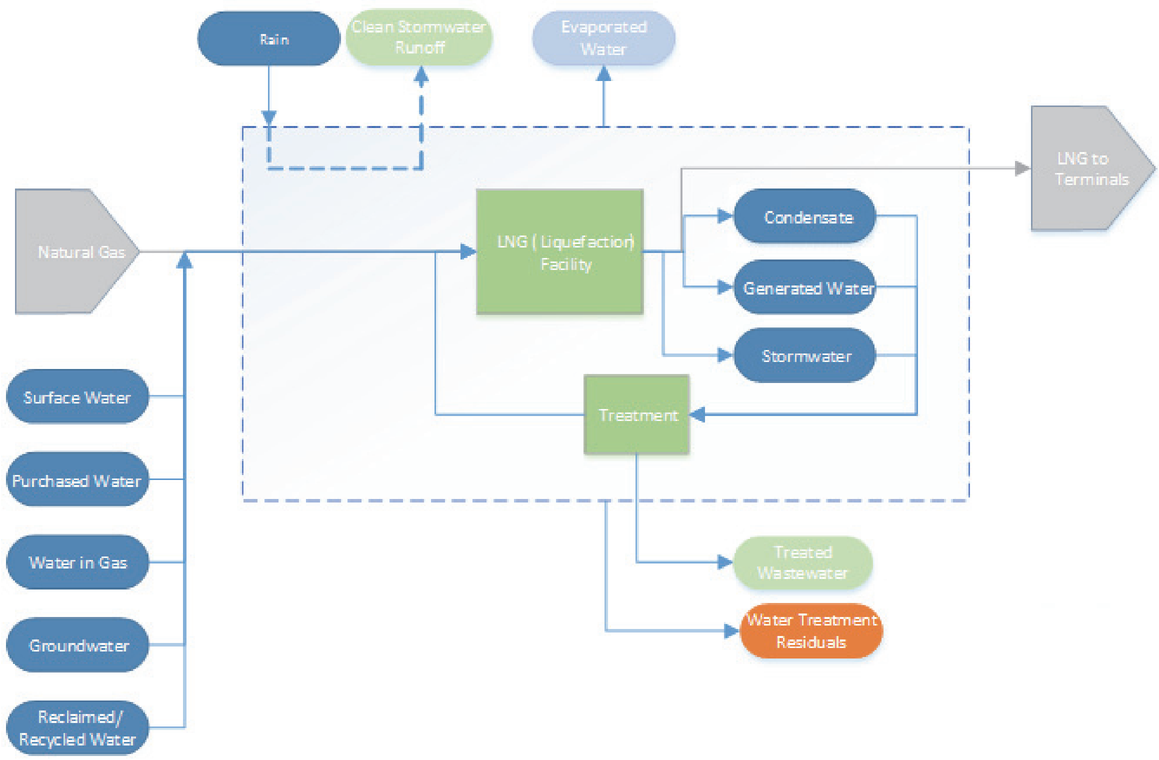


Figure 7—Water Use and Management in the Liquefied Natural Gas (LNG) Process

Table 2—Water Sources and Quality for Downstream Liquefied Natural Gas Operations

Water Use	Typical Water Sources	Water Quality Needs
Process Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, recycled/reclaimed water, boiler blowdown or, in some cases, brackish groundwater, seawater	Low conductivity, alkalinity, chlorides, suspended solids for systems with typical metallurgy. If waters with higher conductivity and chlorides are used (i.e. brackish water or seawater), the metallurgy of process systems will normally require upgrading to a more corrosion resistant material such as titanium.
Potable Water	Municipal water supply, treated groundwater	Disinfection, meets drinking water standards
Utility Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, or, in some cases, brackish groundwater, seawater	Sediment free
Fire Water	Surface water, fresh groundwater, stormwater, treated refinery wastewater, or, in some cases, brackish groundwater, seawater	Protect against corrosion; low sediment content

3.3.2.2 Gas-to-liquids

GTL is a technology that enables the production of clean-burning diesel fuel, liquid petroleum gas, and naphtha from natural gas. Natural gas has a far wider market if converted to liquid form because it is easier to transport. With the expected rise in demand for diesel, GTL technology provides an option to make a fuel with qualities that can enable significant reductions in emissions (Chevron, *Gas to Liquids* 2013).

The first step in the GTL process is to remove water, condensates, and other components such as sulfur from the gas. Natural gas liquids are then removed using distillation. Following this process, what remains of the gas is pure methane. The methane is then sent to a gasifier where, at high temperatures, the methane and oxygen are converted to a mixture of hydrogen and carbon monoxide known as synthesis gas or syngas. The syngas is then converted into long-chained waxy hydrocarbons and water through a series of chemical reactions. The long-chained waxy hydrocarbons undergo a cracking process and distillation to produce a range of GTL products such as GTL naphtha, GTL kerosene, GTL normal paraffins (used in detergents), GTL Gasoil (a diesel-type fuel), and GTL base oils.

While a number of GTL facilities exist outside the United States, to date, there have been no operating facilities in the United States. Sasol, who operates a large GTL facility in Qatar, is currently in the design phase of building a large GTL facility in Louisiana that would be the first GTL facility in the United States to produce GTL transportation fuels and other products (DuBose 2013).

The GTL process is a net producer of water and most GTL processes reuse that water within the facility. Therefore, water use within GTL facilities is not discussed further in this report.

3.4 Delivery

Subcategories of delivery activities for oil and gas products are depicted in Figure 8. The delivery phase of the life cycle generally includes terminals and storage and distribution components, although the design and operation of these activities varies for oil, gas, LNG, and GTL products. Distribution can take the form of pipelines, trucking, rail transport, or shipping by barge or commercial ship. Although there are some differences in how different types of petroleum resources are handled during these phases of the life cycle, there are also significant similarities. For that reason, this section is organized into two subsections, storage and distribution, with nuances among resource types highlighted where applicable.

3.4.1 Terminals and Storage

Once the refined oil and gas products have been transported to the market where they will be used, they can be stored for indefinite periods of time. In the case of oil, following processing at the refinery, the refined oil products are conveyed to a terminal, typically by a system of pipelines and associated aboveground breakout storage tank facilities. Terminals are comprised of above- or below-ground storage tanks that are often located near a distribution point for transmission of products through pipelines or by rail, trucks, and ships in coastal areas. Relatively little water is used as part of terminal and storage activities aside from stormwater management, tank draws to remove the water that has separated from the petroleum product and condensate, periodic hydrotesting of storage tanks and pipelines, emergency and readiness use of firefighting systems water, and small quantities of potable water for on-site services. Water use in the delivery of refined oil products to end users is illustrated in Figure 9.

In the case of natural gas, storage is generally in underground facilities that are built within depleted reservoirs, aquifers, and salt caverns. Salt caverns make particularly good storage reservoirs because of the impermeability of salt. Salt caverns are developed for use as natural gas storage reservoirs through a process called solution mining. Solution mining involves pumping freshwater into a well completed within the salt cavern, allowing the salt in the cavern formation to dissolve, and then pumping of the resulting brine solution to the surface for either salt recovery or disposal, expanding the void space. Other storage methods for natural gas (aquifers, depleted reservoirs) generally do not require water for development. The use of water in solution mining and gas storage is illustrated in Figure 10.

3.4.2 Distribution

Distribution of both refined oil products and gas to end users can be accomplished through a variety of means, including pipelines across land and underwater, tanker trucking, rail tankers, and shipping. Each of these delivery methods is described briefly in this section along with associated water use.

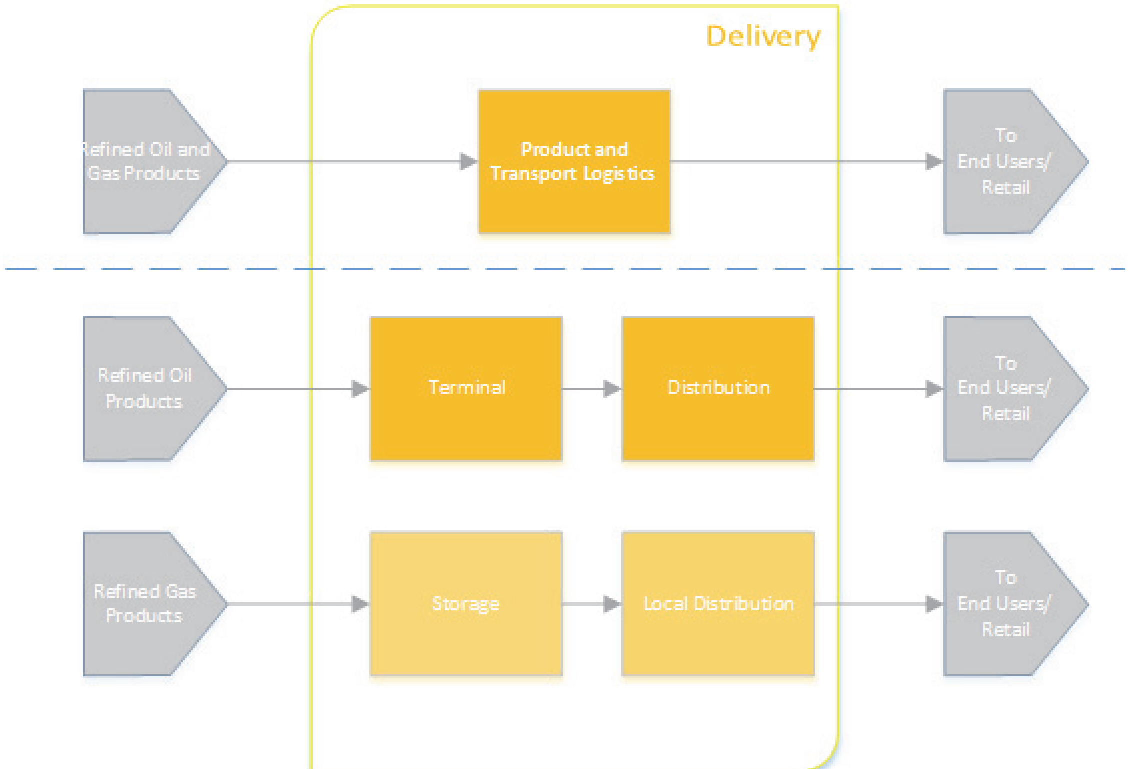


Figure 8—Delivery Activities by Petroleum Resource Type

3.4.2.1 Pipelines

For natural gas, some large industrial, commercial, and electric generation customers receive natural gas directly from high-capacity interstate and intrastate pipelines; most other users receive natural gas from their local gas utility. Local distribution generally includes the transmission of the gas from delivery points along interstate or intrastate pipelines to homes and businesses. Little to no water is used during the distribution of gas by pipeline. There are however, similar one-time usages for hydrostatic testing of pipelines as described above in 2.2.1.

For oil, pipelines are used downstream of the distribution terminals to deliver oil to end users. Little or no water is used in this process aside from that used for hydrostatic testing.

3.4.2.2 Trucking

Trucking is regularly used for the distribution of refined oil products to end users. Trucking as a means of delivery of gas to end users is generally only used in rural areas that are not served by distribution pipelines. Tanker trucks load refined oil products at terminals and transport it to end users such as industrial or commercial users, gas stations, or residential oil distributing companies. Some water is used for washing as part of trucking operations. Good management practices include recovery and reuse of wash water.

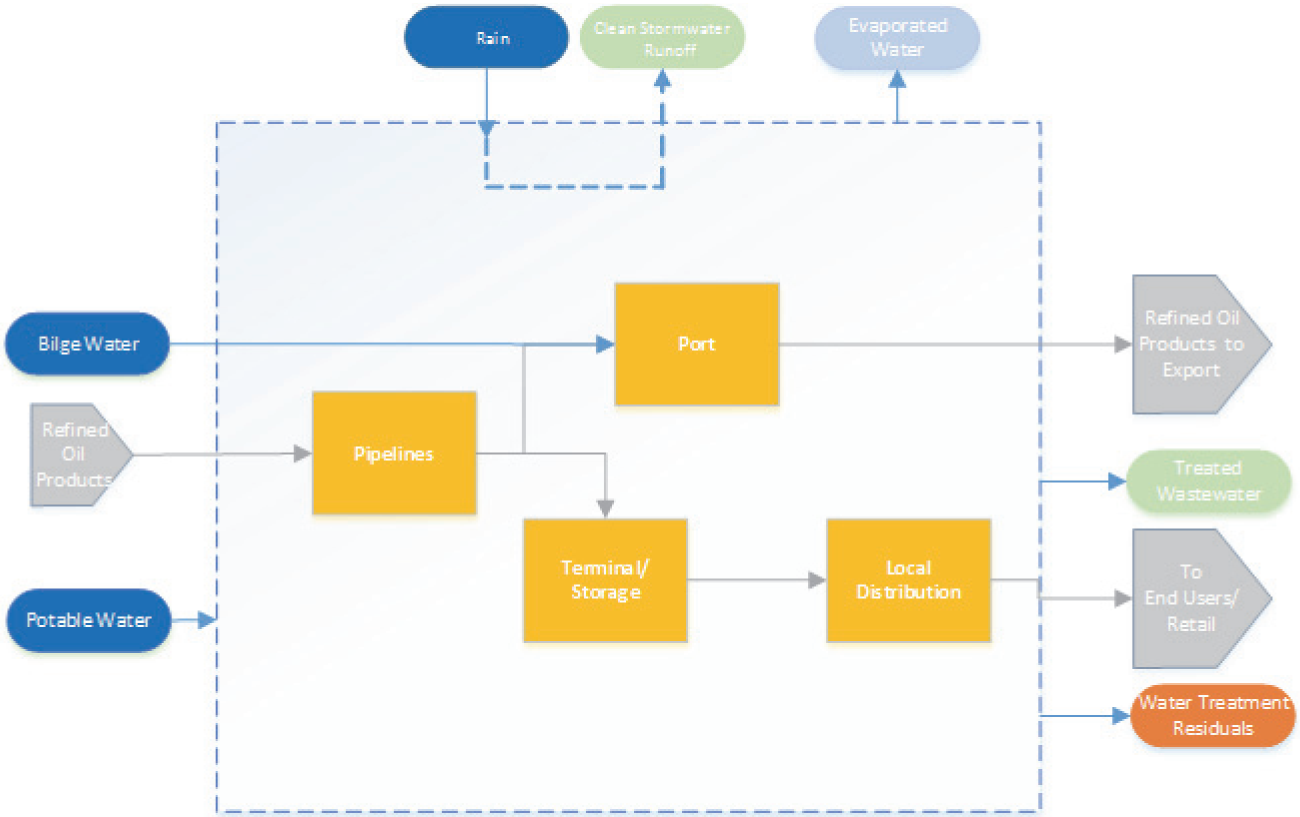


Figure 9—Water Use and Management in Delivery of Refined Oil Products to End Users

3.4.2.3 Rail Transport

Similar to trucking, rail transport via rail tankers is used for oil distribution to end users but is not used for gas transport due to the limited volumes. As with trucking, water is used primarily in rail transportation as wash water and good management practices include recovery and reuse of wash water.

3.4.2.4 Shipping

Shipping is used to deliver oil and LNG for export to other countries. Shipping could also be used to deliver GTL products in the future. LNG must be shipped aboard specially designed tankers designed to keep the product at extremely low temperatures.

Shipping of petroleum products overseas requires water for washing, potable, and sanitary use. Shipping also generates wastewater as seawater enters the ship's bilge.

4 Regulation of Water Management in Downstream, Midstream, and Delivery Operations in the Oil and Gas Industry

4.1 Activities Subject to Regulation

Midstream, downstream, and delivery operations are subject to various levels of established regulations, including those designed to manage water use/reuse, effluents to surface waters, (Table 3). Water management activities are implemented in order to meet regulatory requirements and minimize environmental impacts, especially when operating in sensitive natural environments.

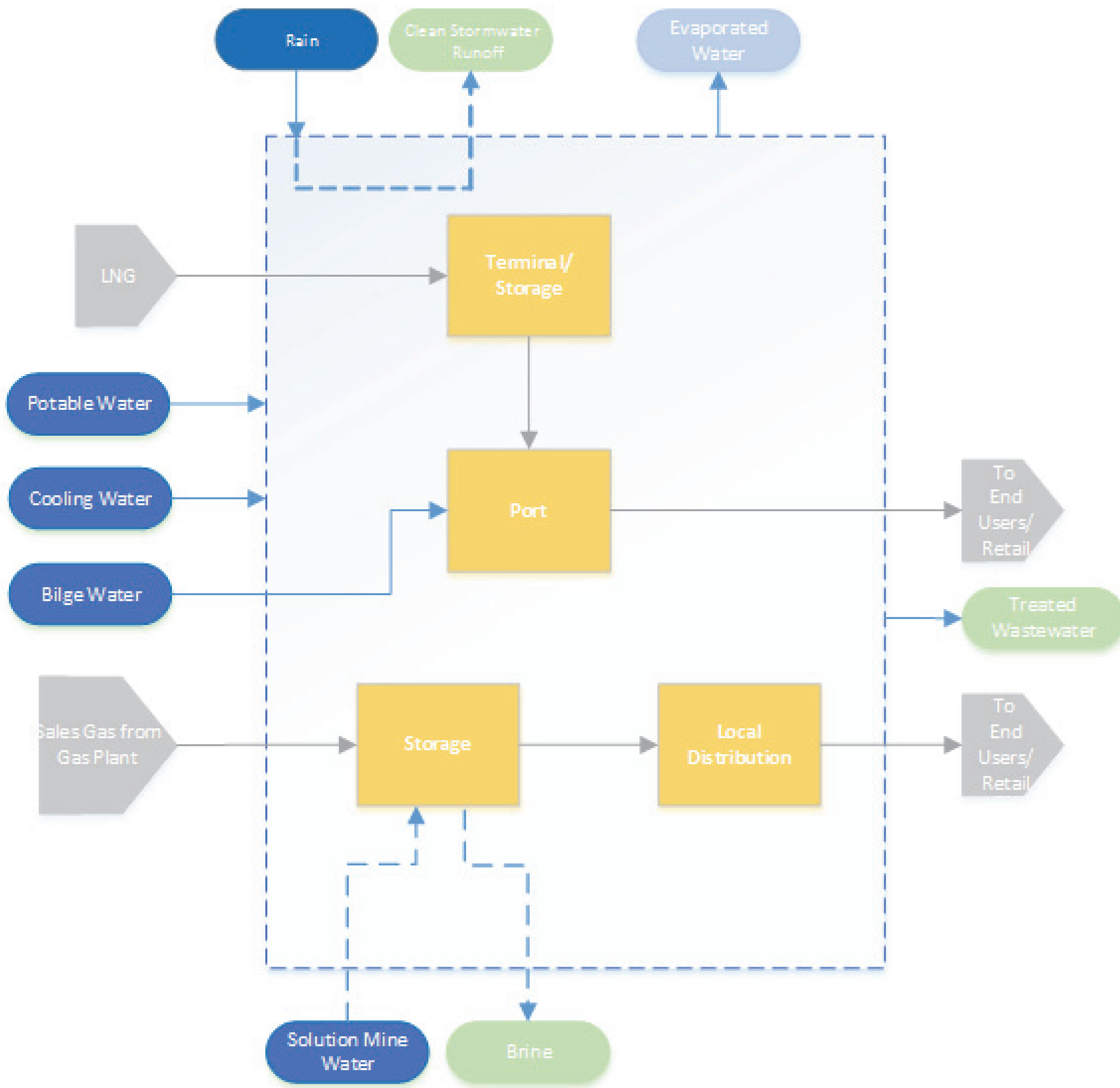


Figure 10—Water Use and Management in Delivery of Natural Gas and LNG to End Users

4.2 Delegation of Regulatory Authority in the United States

The activities by oil and gas operations are subject to three levels of applicable regulations:

1) federal level;

2) state level (including inter-state level such as river basin commission),

3) local level.

(1) Federal Level

The main federal programs in the U.S. governing water management for the oil and gas industry include the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and Oil Pollution Act (OPA), which are administered by the U.S. Environmental Protection Agency (USEPA). While the OPA established liability limits for oil spills, the Coast Guard and Maritime Transportation Act of 2006 increased the limits of liability, which is administrated through U.S.

Table 3—Examples of Applicable Water Regulations for Midstream, Downstream, and Delivery in the Oil and Gas Industry

Water in Oil and Gas Operations	Example of Applicable Regulations
Cooling Water Intake Structures	Clean Water Act Section 316(b)
Wastewater Discharge to Surface Water	Effluent Limitations Guidelines for Petroleum Refining; Clean Water Act's National Pollutant Discharge Elimination System (NPDES) Program—Water Quality Based Effluent Limits (WQBELs); Clean Water Act's NPDES Program for stormwater discharges, including general and individual permits (Storm Water Pollution Prevention Plans required as part of this program).
Wastewater Reuse from Oil and Gas Operations; Beneficial Reuse	Relevant Regulations at State Level
Oil Spills	Oil Pollution Act: (1) Spill Prevention, Control and Countermeasure (SPCC) plan; (2) National Contingency Plan for oil and hazardous substances pollution. Coast Guard and Maritime Transportation Act of 2006

Coast Guard under the Department of Homeland Security. These are described in more details in the latter part of this section.

Furthermore, under the CWA, the USEPA has the authority to regulate non-transportation-related onshore facilities. Based on a 1971 memorandum of understanding among the Secretary of the Interior, Secretary of Transportation, and the Administrator of the USEPA describing jurisdictional responsibilities for offshore facilities (including pipelines), similar authority over transportation-related onshore facilities, deepwater ports, and vessels is delegated to the U.S. Department of Transportation (DOT). Authority over other offshore facilities is delegated to the U.S. Department of the Interior.

The NTSB is an independent federal agency charged by Congress with investigating civil aviation accidents in the United States and significant accidents by other modes of transportation—railroad, highway, marine, and pipeline. This responsibility includes about 2 million miles of oil and gas pipelines and transportation of materials and products from oil and gas activities via railroad, highway, and pipe. The NTSB determines the probable cause of each accident investigated and issues safety recommendations aimed at preventing future accidents.

The Federal Energy Regulatory Commission is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. The Federal Energy Regulatory Commission also reviews proposals to build liquefied natural gas (LNG) terminals and interstate natural gas pipelines as well as licensing hydropower projects.

(2) State Level (including Interstate Level)

Each state may receive authorization from USEPA to assume primary regulatory responsibility (primacy) to implement major regulatory programs at the state level. To account for local circumstances, states granted primacy are allowed to issue state-specific regulations that can be more stringent than the federal regulations.

a) State Primacy on NPDES program

Under the CWA, states, tribes, and territories are authorized through a process that is defined by Section 402 (b) and 40 *CFR* Part 123. In brief, a state may receive authorization for one or more of the NPDES program components. If the USEPA approves the program, the state assumes permitting authority in lieu of the USEPA. All new permit applications would then be submitted to the state agency for NPDES permit issuance.

To date, more than 40 states (see map in Appendix B) have been delegated the authority by the USEPA for the state NPDES program and pre-treatment program. If a state does not receive delegation for the NPDES, the permits are written by the regional USEPA office.

b) Water Rights

Another related area of state authority is in the area of water rights. Water rights laws and regulations have evolved over time in each state to meet the particular water resource and commerce needs. The oil and gas industry has to abide by the water rights framework, regulation, and prioritization in the states in which they operate.

(3) Interstate Level

Where water resources issues cross multi-jurisdiction boundaries, interstate agencies may be formed to provide coordinated oversight and regulation. Examples include the Delaware River Basin Commission and the Susquehanna River Basin Commission, which regulate water resource protection, withdrawals, and discharges to these two watersheds in Delaware, Maryland, New Jersey, New York, Pennsylvania, and the District of Columbia. These commissions were established through compact legislation passed by the U.S. Congress, but function as independent administrative bodies to address regional needs.

(4) Local Level

Local jurisdictions (such as counties, cities, municipalities, and conservation districts) may also institute water management regulations based on local water resource conditions and interests. Depending on where industry operations are located, they are also required to comply with these local requirements.

The industry's water management activities are governed by a comprehensive, multi-layered framework of protective regulations that allow states and localities flexibility to address regional interests and promote effective stewardship.

4.3 U.S. Federal Regulation

The USEPA is the federal regulatory agency entrusted with protecting human health and the natural environment including air, water, and land. To meet this mission, the USEPA often works with other federal agencies, state and local governments, and Native American tribes to develop and enforce regulations under existing environmental laws.

Where national environmental standards are not met, the USEPA can issue sanctions and take other steps to assist states and tribes in reaching the desired levels of environmental quality. Environmental programs not delegated to the states are managed through the USEPA's regional offices.

4.3.1 Clean Water Act

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into waters of the United States and regulating quality standards for surface waters. Under the CWA, the USEPA has implemented pollution control programs such as setting wastewater standards for industry. The USEPA has also set water quality standards for all contaminants in surface waters.

The CWA makes it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit is obtained. The USEPA's NPDES permit program controls discharges. Point sources are discrete conveyances such as pipes or man-made ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

Under the NPDES program, there are two types of permit limits. They are technology-based effluent limitations and water quality-based effluent limitations (WQBELs), respectively. When drafting a NPDES permit, a permit writer must consider the impact of the proposed discharge on the quality of the receiving water. In such cases when a permit writer finds that technology-based effluent limitations alone will not achieve the applicable water quality standards, WQBELs will be required to meet the objectives of the CWA. Please also refer to following section regarding Effluent Limitation Guidelines (ELGs) for petroleum refining.

In addition, under the CWA, Total Maximum Daily Loads (TMDLs) are required for impaired waters, which are those waters that do not meet water quality standards, even after point sources of pollution have installed the minimum required levels of pollution-control technology. A TMDL includes a calculation of the maximum amount of a specific pollutant that a water body can receive and still meet water quality standards. TMDLs are allocated to point sources (wasteload allocation) as well as to nonpoint sources (load allocations) associated with man-made and natural background sources of pollutants. The TMDL process and associated wasteload allocation affect water quality-based NPDES permitting for refinery discharges to impaired waters. The USEPA's recommended water quality criteria are used by states when considering updates to applicable state water quality standards. Such standards provide a basis for establishing acceptable discharge limits. For example, the USEPA has been updating chloride water quality criteria for the protection of aquatic life under the CWA. Chlorides are the major component of TDS. Updating the water quality criteria for chloride will provide an updated guidance on which to issue discharge permits. A draft document for chloride water quality criteria is expected in 2016.

Under Sections 301 and 502 of the CWA, any discharge of dredged or fill materials (for example, from oil transport through pipeline) into “waters of the United States”, including wetlands, is forbidden unless authorized by a permit issued by the U.S. Army Corps of Engineers pursuant to Section 404. There are two main types of wetlands permits: general permits and individual permits. General permits change periodically, cover broad categories of activities, and require the user to comply with all stated conditions. Individual permits typically require more analysis than do the general permits and usually require much more time to prepare the application and to process the permit.

On June 29, 2015, the USEPA and U.S. Army Corps of Engineers promulgated a revision to the definition of “Waters of the United States” in the CWA, clarifying the USEPA's and the Army Corps of Engineers' federal jurisdiction under the CWA. The final rule becomes effective on August 28, 2015. This rulemaking expands federal jurisdiction based on a broad interpretation of “significant nexus”, a term used in the *Rapanos v United States* Supreme Court decision to describe a substantive impact on downstream waters. The rulemaking will increase the reach of federal permits and will have a broad impact on the regulated community, including the oil and gas industry.

4.3.2 USEPA Effluent Limitations Guidelines for “Petroleum Refining”

In October 1982, the USEPA finalized the effluent limitations guidelines, pretreatment standards, and new source performance standards for the petroleum refining point source category. The petroleum refining industry is defined by the North American Industry Classification System code 2911. The raw material of petroleum refining industry is petroleum material such as crude oil. Petroleum refineries process this raw material into a wide variety of petroleum products, including gasoline, fuel oil, jet fuel, heating oils and gases, and petrochemicals. Petroleum refining includes a wide variety of physical separation and chemical reaction processes.

In the final rule issued by the USEPA, the constituents of wastewaters were identified and established for effluent limitations guidelines and standards of performance, which include significant pollutant parameters and metallic ions commonly found in the effluents from petroleum refining industry. In addition, several distinct control and treatment technologies were identified, including both in-plant and end-of-process technologies, which are in use or capable of being used in the petroleum refining industry.

If a facility discharges wastewater to a publicly owned treatment works (POTW) or wastewater treatment plant, it will be subject to industrial pretreatment limits designed to make sure that the waste stream will not interfere with the POTW's treatment performance and cause it to violate its own discharge permit. If a facility discharges directly to a surface water body under its own NPDES permit, it will be subject to ELGs that set minimum technology-based effluent limits based on industry specific understanding of the processes, likely contaminants, and treatment strategies available to a particular industry. If technology-based effluent limits alone cannot achieve applicable ambient water quality standards for a receiving water, the permitting authority is required to establish WQBELs that are calculated to ensure that discharges do not exceed water quality standards.

In 2015, the USEPA has begun conducting a detailed study of the petroleum refining category to consider revisions to the ELG regulations. The USEPA has indicated they will solicit data and information on the discharge of metals and dioxin from petroleum refineries, including the sources of these contaminants (either in crude oil sources or in the refining process); the effects of new air pollution controls, which have the net effect of transferring airborne pollutants into wastewater discharges at refineries; and information on current and future trends in oil refining processes. The USEPA will also solicit data and information on current wastewater treatment technology performance and perform an economic assessment of the identified technologies at petroleum refineries, as well as any other information believed to be relevant to its study of this issue. This study could lead to future revisions of the ELGs for the petroleum refining category.

In July 2015, The USEPA issued the *Final 2014 Effluent Guidelines Program Plan*, which reiterated that such a study would determine if changes that the industry has experienced since the ELGs were last revised, including the use of heavier crude and wet air pollution controls, and make updates to the existing ELGs, including pretreatment standards, appropriate. The study will also investigate whether pollution prevention or wastewater treatment methods are available to reduce pollutants present in the industrial wastewater.

4.3.3 Oil Pollution Act

The Oil Pollution Act (OPA) of 1990 streamlined and strengthened the USEPA's ability to prevent and respond to catastrophic oil spills. A trust fund financed by a tax on oil is available to clean up spills when the responsible party is incapable or unwilling to do so. The OPA increased penalties for regulatory noncompliance, broadened the response and enforcement authorities of the federal government, and preserved state authority to establish law governing oil spill prevention and response.

The USEPA has published regulations for aboveground storage facilities and the Coast Guard has published regulations for oil tankers. The OPA requires oil storage facilities and vessels, including rail cars, to submit plans to the federal regulatory agency (for example, the USEPA and U.S. Coast Guard) detailing how they will respond to large discharges. Given concerns about oil spill accidents from railroad carriers, the DOT issued an emergency restriction/prohibition order on May 7, 2014. This order was issued to all railroad carriers that transport, in a single train in commerce in the United States, one million gallons or more of petroleum crude oil sourced from the Bakken shale formation (Bakken crude oil). By this order, the DOT required that each railroad carrier provide, for each state in which the carrier operates trains transporting one million gallons or more of Bakken crude oil, notification to the State Emergency Response Commission regarding the expected movement of such trains through the counties in the state. The notification shall identify each county or a particular state or commonwealth's equivalent jurisdiction (such as Louisiana parishes, Alaska boroughs, and Virginia independent cities) in the state through which the trains will operate. Similar more stringent regulations for oil by rail are under development at some states.

The OPA also requires the development of Area Contingency Plans to prepare and plan for oil spill response on a regional scale.

The OPA provided new requirements for contingency planning both by government and industry. The National Contingency Plan for oil and hazardous substances pollution has been expanded in a three-tiered approach.

a) The federal government is required to direct all public and private response efforts for certain types of spill events.

b) Area committees, which are composed of federal, state, and local government officials, must develop detailed, location-specific Area Contingency Plans.

c) Owners or operators of vessels and certain facilities that pose a serious threat to the environment must prepare their own Facility Response Plans.

An important aspect of the strategy to prevent oil spills from reaching the receiving waters is the Oil Spill Prevention, Control, and Countermeasure (SPCC) plan. Originally published in 1973 under the authority of §311 of the CWA, the Oil Pollution Prevention regulation sets forth requirements for prevention of, preparedness for, and response to oil discharges at specific non-transportation-related facilities. In 1990, the Oil Pollution Act amended the CWA to require some oil storage facilities to prepare Facility Response Plans. The USEPA has since amended the SPCC requirements of the Oil Pollution Prevention regulation to extend compliance dates and clarify and/or tailor specific regulatory requirements, including a major SPCC rule revision promulgated on December 5, 2008.

In August 2013, the USEPA revised the *SPCC Guidance for Regional Inspectors*, which is intended to assist regional inspectors in reviewing a facility's implementation of the SPCC rule. The document is designed to provide a consistent national policy on several SPCC-related issues. In the SPCC rule and associated 2013 *SPCC Guidance for Regional Inspectors,* requirements for integrity testing to identify potential leaks or failure of pipeline or container before a discharge occurs. are specified.

In particular, Chapter 7 of the 2013 *SPCC Guidance* by the USEPA refers to selected relevant industry standards that describe methods used to test the integrity of piping and pipeline at the time of installation, modification, construction, relocation, or replacement. These standards include API Standard 570 *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*, Third Edition; API Standard 1160 *Managing System Integrity for Hazardous Liquid Pipelines*; API RP 574 *Inspection Practices for Piping System Components*; API RP 1110 *Pressure Testing of Steel Pipelines for the Transportation of Gas, Petroleum Gas, Hazardous Liquids, Highly Volatile Liquids or Carbon Dioxide*; ASME Code B31.3 *Process Piping*; and ASME Code B31.4 *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*.

4.3.4 Other Federal Statutes

Insofar as new development plans or incidents could adversely impact public and environmental safety and water resource protection, other federal agencies and regulations addressing oil and gas activities include the following.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 was one of the first laws to establish a broad national framework for protecting our environment. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment.

NEPA requirements are invoked when airports, buildings, military complexes, highways, parkland purchases, and other federal activities are proposed. This may apply to the situation for oil and gas leasing on federal lands. Environmental Assessments (EAs) and Environmental Impact Statements (EISs), which are assessments of the likelihood of impacts from alternative courses of action, are required from all federal agencies.

EISs are generally prepared for projects that the proposing agency views as potentially having significant prospective environmental impacts (for example, oil and gas pipeline projects). The EIS would provide a discussion of significant environmental impacts and reasonable alternatives (including a No Action alternative), which would avoid or minimize adverse impacts or enhance the quality of the human environment. Regulatory agencies typically allow at least a 45-day comment period for draft EISs and a 30-day comment period for final EISs.

Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) was passed in 1972 in recognition of the importance of meeting the challenge of continued growth in the coastal zone. The CZMA, administered by NOAA's Office of Ocean and Coastal Resource Management, provides for management of the nation's coastal resources, including the Great Lakes, and balances economic development with environmental conservation. The objective of the CZMA is to protect the coastal environment from growing demands associated with residential, recreational, commercial, and industrial uses (such as state and federal offshore oil and gas development).

Endangered Species Act

The purpose of the Endangered Species Act (ESA) is to protect and recover imperiled species and the ecosystems on which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). The USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of the NMFS are mainly marine wildlife such as whales and anadromous fish such as salmon.

Under the ESA, species may be listed as either endangered or threatened. “Endangered” means a species is in danger of extinction throughout all or a significant portion of its range. “Threatened” means a species is likely to become endangered within the foreseeable future. All species of plants and animals, except pest insects, are eligible for listing as endangered or threatened.

Clean Air Act

The Clean Air Act (CAA) is the comprehensive federal law that regulates air emissions from stationary and mobile sources. Section 112 of the CAA addresses emissions of hazardous air pollutants. Prior to 1990, the CAA established a risk-based program under which only a few standards were developed. The 1990 CAA Amendments revised Section 112 to first require issuance of technology-based standards for major sources and certain area sources.

“Major sources” are defined as a stationary source or group of stationary sources that emit or have the potential to emit 10 tons per year or more of a hazardous air pollutant or 25 tons per year or more of a combination of hazardous air pollutants (such as major oil refineries). An “area source” is any stationary source that is not a major source. For major sources, Section 112 requires that the USEPA establish emission standards that require the maximum degree of reduction in emissions of hazardous air pollutants. These emission standards are commonly referred to as maximum achievable control technology (MACT) standards. For example, an air permit may be needed to meet permitting requirements for installation and operation of a unit to treat produced water from oil and gas operation.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) establishes preservation as a national policy and directs the federal government to provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the nation.

Preservation is defined as the protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, or engineering. The NHPA authorizes the Secretary of the Interior to expand and maintain a national register of districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology and culture, referred to as the National Register.

The 1980 amendments established guidelines for nationally significant properties, artifacts, and data documentation of historic properties, and preservation of federally owned historic sites; required designation of a Preservation Officer in each federal agency; and authorized the inclusion of historic preservation costs in project planning costs (such as for oil and gas projects). For example, it may be needed to evaluate whether the issuance of the NPDES permit by regulatory agency for produced water discharge from oil and gas operation will have an adverse effect on any listed or eligible historic properties or cultural resources under the NHPA.

The Pipeline Safety Improvement Act

The Pipeline Safety Improvement Act of 2002 mandates significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines. The law applies to natural gas transmission pipeline companies. Central to the law are the requirements it places on each pipeline operator to prepare and implement an “integrity management program”, which among other things requires operators to identify so-called “high-consequence areas” (HCAs) on their systems, conduct risk analyses of these areas, perform baseline integrity assessments of each pipeline segment, and inspect the entire pipeline system according to a prescribed schedule and using prescribed methods. The regulations define HCAs to include populated areas, areas unusually sensitive to environmental damage, and commercially navigable waterways.

Other provisions of Pipeline Safety Improvement Act include (a) participation in planned-excavation one-call notification programs; (b) increased penalties for violations of safety standards; (c) an interagency task force to expedite environmental reviews when necessary to expedite pipeline repairs; and (d) government mapping of the pipeline system and assembling pipeline operator contact information for public dissemination.

The Pipeline Inspection, Protection, Enforcement, and Safety Act

The Pipeline Inspection, Protection, Enforcement, and Safety Act of 2006 includes the following provisions: (a) minimum standards for IMPs for distribution pipelines; (b) standards for managing gas and hazardous liquid pipelines to reduce risks associated with human factors; (c) review and update of incident reporting requirements; and (c) clarification of jurisdiction between states and the DOT's Pipeline and Hazardous Materials Safety Administration for short laterals that feed industrial and electric generator consumers from interstate natural gas pipelines. The Pipeline and Hazardous Materials Safety Administration also conducts accident investigations and system-wide reviews focusing on high-risk operational or procedural problems and areas of the pipeline near sensitive environmental areas, high-density populations, or navigable waters.

A primary focus in the 2006 legislation is on preventing excavation damage to pipelines though the enhanced use and improved enforcement of state “one-call” laws that preclude excavators from digging until they contact the state one-call system to locate the underground pipe and from digging in disregard of markings. Excavators must report any damage or gas escape caused by the digging.

5 Industry-led Water Stewardship Activities

5.1 General

Water availability and the ability to manage wastewater in a cost-effective manner is a critical and growing issue for businesses around the globe, including the oil and gas industry. Water scarcity and availability affects business throughout the value chain, and the impacts from extreme weather events, drought, and sea level rise compound the already difficult scenario.

As the challenge for water availability becomes more prevalent both across the nation and the world, the risks for business disruption and increased costs for water are expected to rise. The oil and gas industry has recognized and is taking practical measures to address these challenges by innovating new methods to reduce water use and incorporate water management into business planning. Freshwater use can be reduced through re-engineering of processes for reduced water consumption, increased reuse of water within facilities, and substitution of lower-quality water where possible. These freshwater use reduction measures have a direct cost impact through added engineering and capital facilities and also impact the materials used in oil and gas facilities to prevent corrosion and scaling when lower-quality water sources are used. Water management approaches and associated costs must be planned for and therefore water issues are now an integral component of the business planning process in the oil and gas industry.

Through industry-leading associations and organizations (such as API, the International Petroleum Industry Environmental Conservation Association [IPIECA] and the Petroleum Environmental Research Forum [PERF]) and through partnerships with universities and other research institutions and stakeholders, the oil and gas industry has been taking action to improve water stewardship and sustainability practices. Examples of the industry's efforts in guidance and standards setting and other research programs related to water stewardship are provided below.

5.2 Industry Standards Related to Water

Industry-leading organizations have developed guidance, standards and manuals pertaining to water management in oil and gas operations. A few examples are given as follows.

— API and IPIECA jointly developed O*il and Gas Industry Guidance on Voluntary Sustainability Reporting* (including water metrics) in 2005. Many API and IPIECA member companies already followed this guidance in their online sustainability reporting.

— IPIECA issued *Water Management Framework* (for onshore oil and gas activities) in September 2013.

— PERF is in the process of developing *Guidance for Environmental Strategies in Refinery Waste and Wastewater Management*.

Please refer to Table 4 for more detailed descriptions.

The study will attempt to describe a higher level of thinking and strategic approaches to minimizing environmental liability and managing waste and wastewater in an integrated manner to accomplish cost-effective and environmentally friendly mitigation measures. The document will include the following: (a) current practices and lessons learned; (b) merging challenges; (c) gaps and needs; and (d) integrated management strategies for the future.

5.3 Industry-sponsored Research and Development Activity

In addition to developing industry standards and guidance, the oil and gas industry sponsored various activities and initiatives pertaining to water management. A few examples are given as follows.

— *Global Water Tool for Oil and Gas* (developed by IPIECA in association with WBCSD)

— *Local Water Tool for Oil and Gas* (developed by the Global Environmental Management Initiative (GEMI); can link with G*lobal Water Tool for Oil and Gas*)

— Ongoing projects conducted by PERF

— Numerous conferences, training, and certification programs developed by or in association with industry organizations (such as API, Society for Professional Engineers [SPE], IPIECA, IOGCC, Ground Water Protection Council [GWPC], and others)

— Numerous grants and direct collaborations with universities for water and environmental-related research

Please refer to Table 5 for more detailed descriptions.

5.4 Voluntary Reporting

Many oil and gas industry members voluntarily publish water use and management statistics and key performance metrics as part of their annual reports, as part of corporate responsibility/sustainability reporting, or on their websites. API has supported these efforts by conducting annual benchmarking studies of water usage amongst its membership since 2010. This transparent reporting of water stewardship performance may be done for public information purposes, to inform shareholders, to satisfy investors' requirements, and to comply with international reporting requirements.

Although no harmonized reporting requirement or standards exist for the oil and gas industry, they have generally adopted standards and metrics consistent with global industry, such as the Global Reporting Initiative; Dow Jones Sustainability Index (DJSI); CDP Water Program information requests; American Chemistry Council water

Table 4—Industry-developed Standards Governing Water Management and Stewardship

Standard Body	Title	Scope
API/IPIECA	*Oil and Gas Industry Guidance on Voluntary Sustainability Reporting* - 2005	API and IPIECA worked together to create a common framework for sustainability or non-financial reporting that will enable interested audiences and company stakeholders to better understand performance of oil and gas companies that operate anywhere in the world on a national, regional or international level. The development of this guidance document is part of a larger initiative aimed at helping companies and industry associations improve on the quality, scope, completeness, and consistency of reporting on issues commonly included under terms such as sustainable development, social responsibility, or corporate citizenship. This guidance is intended as a voluntary reference designed to assist oil and gas companies that are interested in reporting on their environmental, health and safety, social, and economic performance.
IPIECA	*Water Management Framework* (for onshore oil and gas activities) - September 2013	IPIECA's *Water Management Framework* has two main purposes: (1) to provide IPIECA with a structure to progress the future development of initiatives, guidelines and tools and (2) to provide high-level guidance to IPIECA members to help oil and gas companies develop their own company-specific water strategies. The framework has been developed to help the oil and gas sector respond to broader global concerns about water availability and quality to enhance the industry's efforts to achieve sustainable water management. The framework is a cyclical process of planning, implementation, evaluation, and review. It can be implemented at both the corporate and operational levels and over different phases oil and gas operations from planning to decommissioning.
IPIECA	*Petroleum Refining Water/Wastewater Use and Management* (IPIECA Operations Good Practice Series) - 2010	This manual describes typical best practices and strategies used in petroleum refineries to manage water, including ways to reduce water usage. These practices are a collection of operational, equipment, and procedural actions related to water management in a refinery.
IPIECA	*Water Resource Management in the Petroleum Industry* - 2005	This document has been prepared, on behalf of the IPIECA Strategic Issues Assessment Forum (SIAF), by a dedicated Water Task Force. The Task Force's work has included the identification of water activities and developments worldwide, solicitation of case studies on water management, and devising a workshop on water management at the IPIECA Annual Meetings. The workshop discussions helped develop these water management guidelines for the oil and gas industry.

Table 4—Industry-developed Standards Governing Water Management and Stewardship (Continued)

Standard Body	Title	Scope
IPIECA	*A Guide to Contingency Planning for Oil Spills on Water* (IPIECA Report Series - 2nd Edition) - March 2000	This contingency planning report was initially produced in 1991 in the wake of major incidents in 1989-90 and ensuing industry reviews of oil spill preparedness. This version updates the 1991 publication in the light of lessons learned from oil spills through the 1990s. Response to spills should seek to minimize the severity of the environmental and socioeconomic damage and to hasten the recovery of any damaged ecosystem. Close cooperation between industry and national administrations in contingency planning will ensure the maximum degree of coordination and understanding. When all involved parties work together, there will be the greatest likelihood of achieving the key objective of mitigating potential damage.
PERF	*Guidance for Environmental Strategies in Refinery Waste and Wastewater Management* (Ongoing)	The aim of this project is to provide advice, document good management practices, and describe innovative strategies for the management of waste and wastewater from refining operations. Many guidance documents are procedural in nature and some simply state standard technologies and practices that have been in use over more than a couple of decades. Emerging operational issues with the processing of heavier crude slates; further restrictions on contaminants such as dissolved solids, selenium, mercury, and nutrients; concerns about VOC emissions, scarcity of water supplies, and limitations on waste and wastewater disposal options present new challenges to refiners worldwide.

consumption reporting; and Bloomberg's environment, social, and governance performance metrics. The following are examples.

— Following the launch of the fourth generation (G4) *Guidelines by the Global Reporting Initiative* in May 2013, the complete sector supplement content is presented in a new format in the *Oil and Gas Sector Disclosures* document to facilitate its use in combination with the G4 guidelines. The G4 guideline for oil and gas sector includes indicators for water, effluents, and waste.

— Twenty-six and 22 energy companies responded to the CDP Water Program information request in 2013 and 2014, respectively. The majority of the respondents in 2014 reported that water poses a substantive risk to their business. In response, these energy companies are pursuing compliance with local legal requirements or company internal standards, engagement with suppliers, and engagement with policy makers. According to the 2014 CDP water report, half of the responding companies have board-level oversight and management of water issues, recognizing the importance of water to business continuity, operations, and the communities in which their operations exist. The majority of the companies have concrete water-related targets and goals. Most of the responding companies also recognize that water may present not only challenges, but also business opportunities such as improved efficiency, cost savings, and sales of new products and services.

Together, IPIECA, API, and the International Association of Oil and Gas Producers (IOGP) published *Oil and Gas Industry Guidance on Voluntary Sustainability Reporting* (IPIECA, API, and OGP 2010) to promote a consistent framework for voluntary reporting throughout the industry. This third edition of this guidance document is currently available. In 2013, IPIECA issued *Water Management Framework for Onshore Oil and Gas Activities*, which was developed to help the oil and gas sector respond to broader global concerns about water availability and quality to enhance the industry's efforts to achieve sustainable water management. Transparent and greater disclosure of water

Table 5—Examples of Industry-sponsored Research and Development Activities

Name	Summary	Link
Global Water Tool for Oil and Gas	IPIECA's Global Water Tool™ for Oil and Gas was adapted from the World Business Council on Sustainable Development's Global Water Tool and was customized for petroleum companies developed with industry input. The tool assists users in developing enterprise or portfolio level water risk assessments and risk management plans. It references water quality, water availability/scarcity, population, climate, and other water–energy nexus and relative water intensity data from vetted data resources.The tool allows oil and gas companies to map their water use and assess risks for their overall global portfolio of sites considering each part of the oil and gas value chain. The tool allows users to consider factors such as what percentage of its production volume is in water-scarce areas, how many refineries are in water-scarce areas and at greatest risks, as well as how many sites are in countries that lack access to improved water sanitation.	http://www.ipieca.org/o-g-watertool
Local Water Tool for Oil and Gas	GEMI's Local Water Tool™ for Oil and Gas is a tool customized for petroleum companies developed with industry input. The tool provides interconnectivity between global and local water risk assessments and a uniform approach between site assessments for oil and gas industry. The tool assists users in developing an operations-level water risk assessment and risk management plan that takes into account watershed-scale risks. It references water quality, water availability/scarcity, population, climate, and other water–energy nexus and relative water intensity data from vetted data resources. An option is provided in the GEMI LWT tool to enable the user to transfer specific site data from the WBCSD or IPIECA tool. The purpose and functionality of each tool are mutually supportive and the tools share the same terminology.	http://www.gemi.org/localwatertool/

metrics enables the oil and gas industry to differentiate performance between projects and enables communication of these efforts to address stakeholder concerns.

Energy companies publicly report their water and wastewater management practices, performance, and initiatives in consistence with the IPIECA, OGP, and API *Oil and Gas Industry Guidance on Voluntary Sustainability Reporting* (2015) and cross-reference the GRI reporting guidelines.

A study commissioned by GEMI and conducted by the Investor Responsibility Research Center concluded that a balanced tone and inclusion of environmental performance indicators and trends were the most important factors in establishing the credibility of such reports.

6 Oil and Gas Industry Water Footprint

6.1 General

The purpose of this section is to describe a high level water footprint for the midstream, downstream, and delivery phases of the oil and gas life cycle. Information presented in this section builds on the discussion of water uses provided in Section 3 and also supports the comparison of oil and gas industry water use to other industries in Section 7. The term water intensity is used throughout this section as a means of quantifying the water footprint in difference phases of the oil and gas life cycle. Water intensity is defined as the volume of water required as input to a process divided by the production rate from that process. In this case, the water intensity is expressed in terms of gallons per million British thermal units (gal/MMBtu), where the MMBtu reflects the energy derived from combustion of the oil or gas product.

6.2 Water Use in Midstream, Downstream, and Delivery Phases of the Oil Life Cycle

The primary use of water in these phases of the oil life cycle is for the refining of oil (downstream). Relative to water for refining, the amount of water used in midstream operations (terminals and transmission) and distribution activities is negligible. An overview of the water footprint for these phases of the oil life cycle is provided in Figure 11.

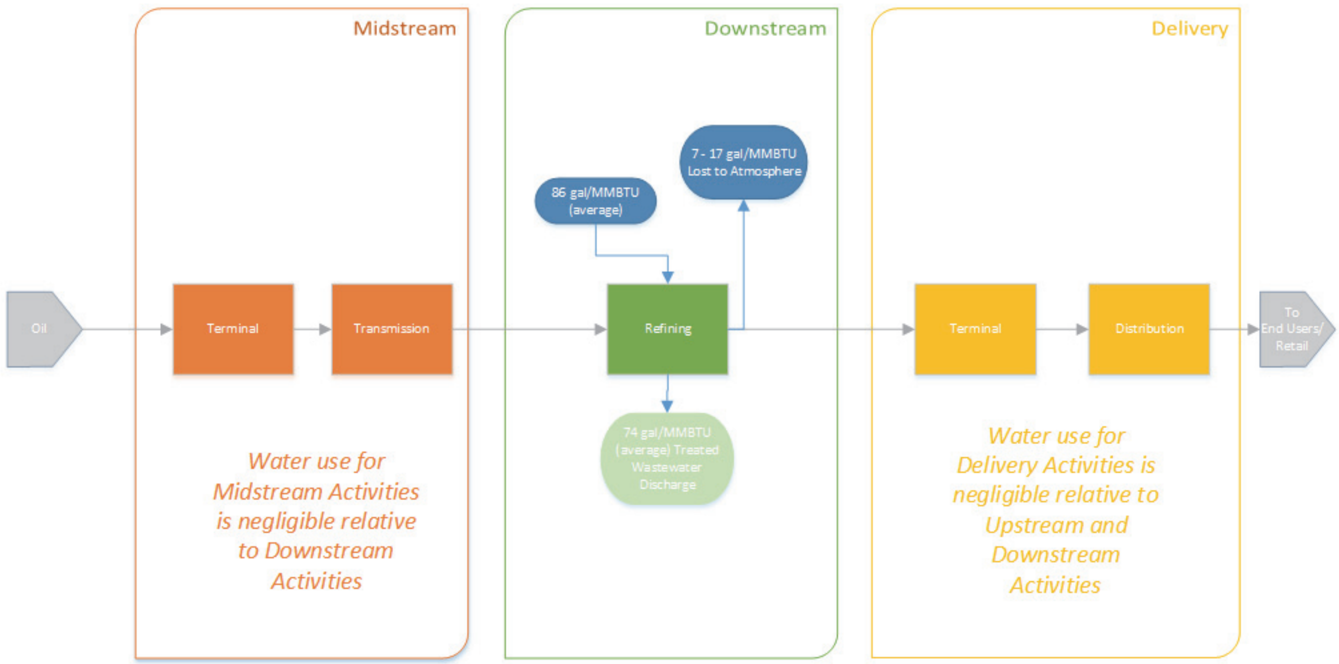


Figure 11—Water Footprint of Midstream, Downstream, and Delivery Phases of the Oil Life Cycle

In midstream oil terminals, there is typically a net positive generation of water, meaning more water is generated as part of the process than is required as input to the process. In the case of oil terminals, water that is contained within the oil separates out during storage and is removed via tank draws. Transmission of oil does require some water input for construction and maintenance of pipelines and pump stations; however, these requirements are relatively low.

Downstream oil activities are focused on oil refining. Average water withdrawals for a traditional refinery are approximately 86 gal/MMBtu (Gleick 1994). Of this water, input to the refinery (between 7 and 17 gal/MMBtu, or, on average, 14 %) is evaporated to atmosphere and considered "consumed" (Gleick 1994). The remaining water in the refinery system is generally treated and either reused within the refinery or discharged to a surface water body. Downstream of the refinery, relatively little water is used for delivery and distribution systems.

An important aspect of evaluating water use and water footprint is the determination of how much water is ultimately returned to the hydrologic cycle and how much is removed from the hydrologic cycle. For many water uses in the midstream, downstream, and delivery phases of the oil life cycle, the water that is used is ultimately returned to the hydrologic cycle, either as treated wastewater or evaporated process water. This is illustrated in the water footprint provided in Figure 11.

6.3 Water Use in Midstream, Downstream, and Delivery Phases of the Gas Life Cycle

The overall water intensity of natural gas transmission, gas processing, and distribution is generally less than that for the oil life cycle. An overview of water use in the natural gas life cycle is provided in Figure 12.

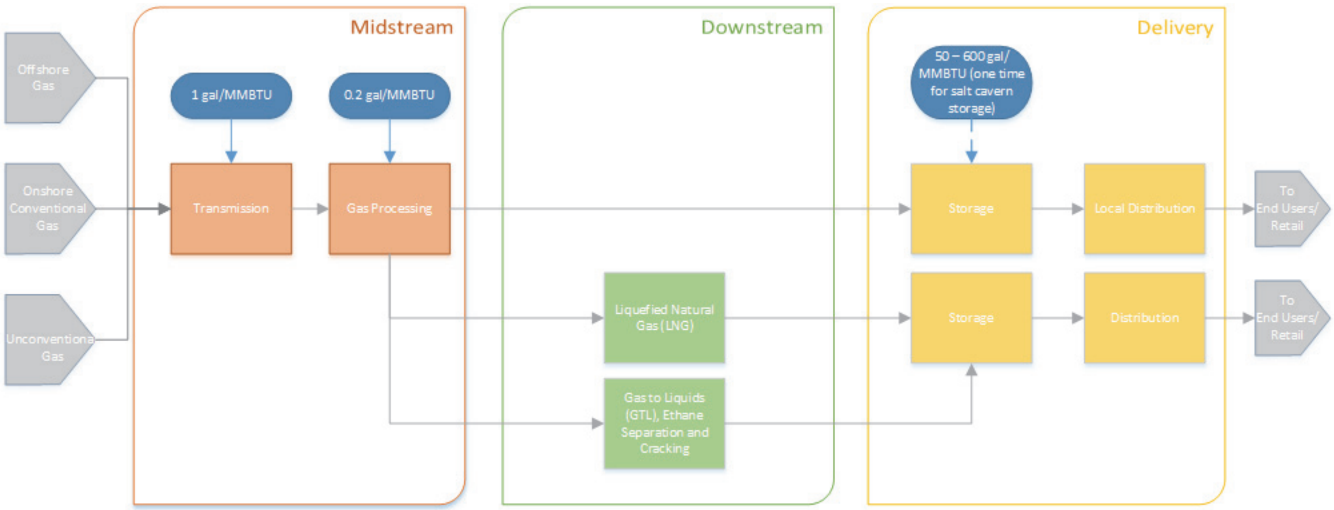


Figure 12—Gas Life Cycle Water Footprint

Gas processing can occur near the well field, at a midstream location, or some combination of the two. The combined water intensity of gas processing activities is relatively low at 0.2 gal/MMBtu (BP International, Ltd 2013). Transmission of gas though pipelines also requires some water input for periodic compression stations. The water intensity of transmission activities is estimated to be 1 gal/MMBtu (Gleick 1994).

Downstream gas activities in the U.S. can include LNG facilities, ethane separation, and ethane cracking (ethylene production). The first GTL plant in the U.S. is in the planning stages and is projected to begin operation in 2019. However, the vast majority of the natural gas extracted in the U.S. is ultimately distributed to end users as natural gas. LNG, ethane crackers, and GTL facilities do require some water, although much of it is recycled within the facility and the overall water intensity is very low.

Delivery of natural gas to end users involves storage to provide equalization of produced gas and consumer demand. Some of this storage occurs in salt caverns, which are "mined" using water to create storage capacity (see Section 3 for description of this process). When salt caverns are mined for natural gas storage, the water intensity varies based on the storage pressure of the reservoir, which depends upon the depth below ground surface. This salt mining can require a one-time water input of between 50 and 600 gpm per MMBtu of storage (DOE 2006). The distribution of natural gas from storage facilities to consumers requires relatively little water input aside from that for hydrostatic testing of new pipelines.

Water losses from the hydrologic cycle for gas production, processing, and delivery are similar to those discussed in the preceding section for oil. Most of the water that is used within the gas life cycle is ultimately returned to the hydrologic cycle as either treated wastewater or evaporated process water.

7 Comparison of Oil and Gas Industry Water Use

7.1 The Water–Energy Nexus

Water and energy are critical resources that are mutually linked. Over the past decade, there have been many references to the energy–water nexus. A significant multi-year effort was made by a consortium of the USDOE's national laboratories and the Electric Power Research Institute to study the implications of this nexus on national energy and environmental policy. Sandia National Laboratory led the consortium and published various documents, including a 2006 report to Congress (USDOE 2006).

Water demand for energy and power production is not limited to the oil and gas industry. It is also associated with coal, hydropower, nuclear power, and even solar power. Several key references show comparative estimates of water usage per-unit-energy produced during combustion, including water use for producing transportation fuels (USDOE 2006; King and Webber 2008; Mantell 2009; Carter 2010).

Much of the energy-water nexus work has focused on water intensity (the amount of water required to generate a unit of energy). To permit a relative comparison of the water needed to develop and utilize a broad range of energy resources, the information is presented as the volume of water used per-unit-energy produced (gallons of water per MMBtu) (USDOE 2006). Some fuels (e.g. coal) are used primarily or exclusively for electric power generation. For these fuels, the water use per unit of thermal energy (expressed as gallons of water per MMBtu) is shown.

Mantell (2009) compiled data showing the volume of water used to produce a MMBtu of energy by various type of raw fuel source (Table 6).

Table 6—Water Use Efficiency by Raw Fuel Source
Range of Gallons of Water Used per MMBtu of Energy Produced
(Mantell 2009)

Energy Resource	Range of Gallons of Water Used per MMBtu of Energy Produced	Data Source
CHK Deep Shale Natural Gas*	0.60–1.80	Includes: Drilling, Hydraulic Fracturing; Source: Chesapeake Energy 2009b
Natural Gas	1–3	Includes: Drilling, Processing; Source: USDOE 2006, p 59
Coal (no slurry transport) (with slurry transport)	2–8 13–32	Includes: Mining, Washing, and Slurry Transport as indicated; Source: USDOE 2006, p 53-55
Nuclear (processed Uranium ready to use in plant)	8–14	Includes: Uranium Mining and Processing; Source: USDOE 2006, p 56
Conventional Oil	8–20	Includes: Extraction, Production, and Refining; Source: USDOE 2006, p 57-59
Synfuel–Coal Gasification	11–26	Includes: Coal Mining, Washing, and Processing to Synthetic Gas; Source: USDOE 2006, p 60
Oil Shale Petroleum	22–56	Includes: Extraction/Production, and Refining; Source: USDOE 2006, p 57-59
Tar Sands (Oil Sands) Petroleum	27–68	Includes: Extraction/Production, and Refining; Source: USDOE 2006, p 57-59
Synfuel–Fisher Tropsch (Coal)	41–60	Includes: Coal Mining, Washing, Coal to Gas to Liquid Conversion Processing; Source: USDOE 2006, p 60
Enhanced Oil Recovery (EOR)	21–2,500	Includes: EOR Extraction/Production, and Refining; Source: USDOE 2006, p 57-59
Fuel Ethanol (from irrigated corn)	2,510–29,100	Includes Feedstock Growth and Processing; Source: USDOE 2006, p 61
Biodiesel (from irrigated soy)	14,000–75,000	Includes Feedstock Growth and Processing; Source: USDOE 2006, p 62

*Does not include processing, which can add from 0–2 gal per MMBtu

Source: Mantell (2009).

Water consumption by the energy sector has also been estimated in absolute terms (that is, gallons per day). Elcock (2008) summarized the estimated water consumption by energy sector other than biofuels from 2005 to 2030 (see Figure 13). For the oil industry, water consumption for oil refining in 2030 is expected to increase to 1.5 billon gallons per day (bgd) from 1.3 bgd in 2005. Changes in fuel formulation and improved techniques for restructuring organic molecules have increased water consumption requirements (Elcock 2008; Elcock 2010). This is because the process used to upgrade the quality of the product (hydrogenation) uses hydrogen, which is obtained by dissociating water (Gleick 1994).

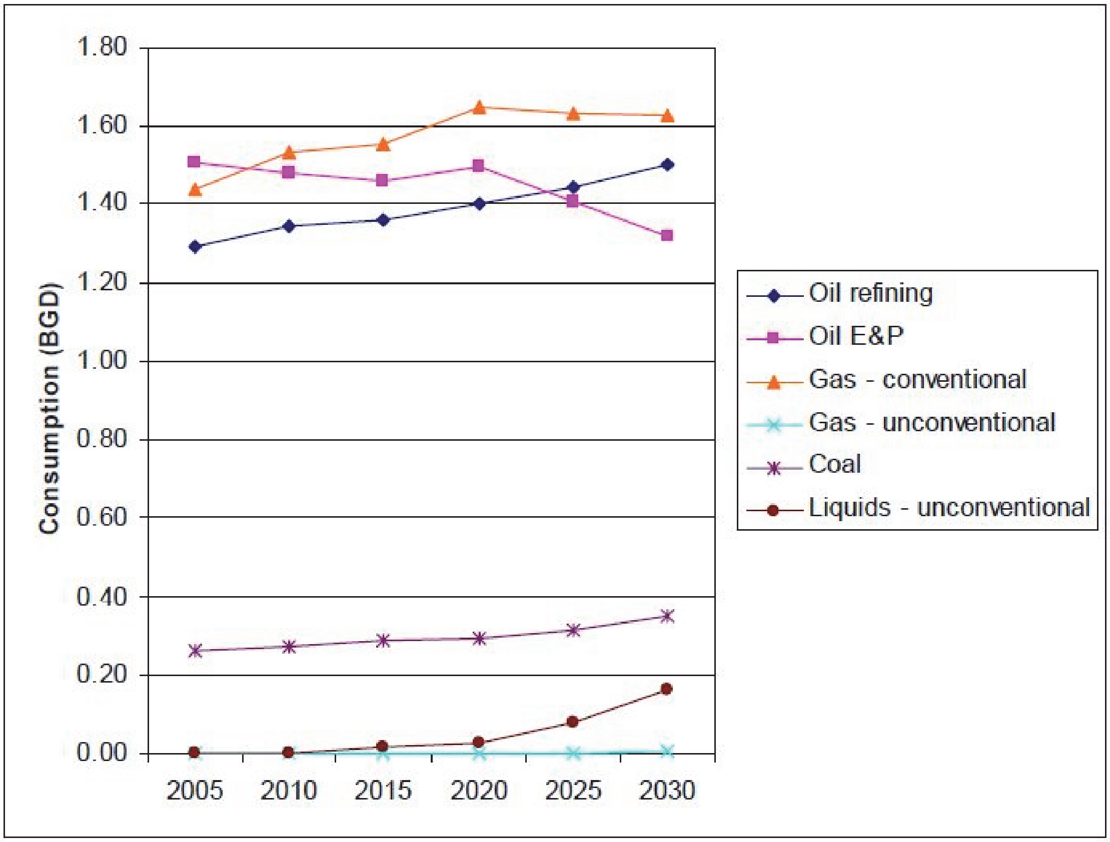


Figure 13—Water Consumption in Billions of Gallons per Day by Energy Sector Other than Biofuels (Elcock 2008)

For the natural gas industry, estimated water consumption for conventional gas production (processing, transportation, and other gas plant operations) is projected to increase to about 1.6 bgd from 1.4 bgd in 2005. Water consumption for unconventional gas sources is low relative to that for conventional gas sources. U.S. unconventional oil and gas production has expanded quickly since 2008, and U.S. natural gas and coal exports may rise (Carter 2013). Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water.

Water consumption by transportation fuels is anticipated to increase between 2005 and 2030. An increase in miles driven and the increasing water-intensity of fuels, as a result of irrigated biofuels (i.e. biofuels derived from irrigated feedstock like corn), overwhelms the water gains from improving vehicle fuel efficiency (Carter 2010). This projection has spurred studies on water use efficiency and water intensity of transportation fuels (King and Webber 2008, 2008a; Mantell 2009).

In the United States, 97 % of all transportation was fueled by conventional petroleum based gasoline and diesel in 2005, with some fuels containing up to a 10 % ethanol mixture to reduce air emissions (King and Webber 2008a).

More recently, there has been a significant push towards the use of non-conventional fossil fuels (liquid fuels derived from coal, oil shale, oil sands), biofuels (ethanol, biodiesel), compressed natural gas, hydrogen, and electricity for powering vehicles.

Relative to the overall water resources of the United States, conventional petroleum-based fuels have historically had a relatively low impact. According to King and Webber (2008), conventional petroleum gasoline consumes between 7 and 14 gallons of water per 100 miles driven and conventional petroleum diesel consumes between 5 and 11 gallons of water per 100 miles. King and Webber (2008a) stated "In general, fuels more directly derived from fossil fuels are less water-intensive than those derived either indirectly from fossil fuels or directly from biomass."

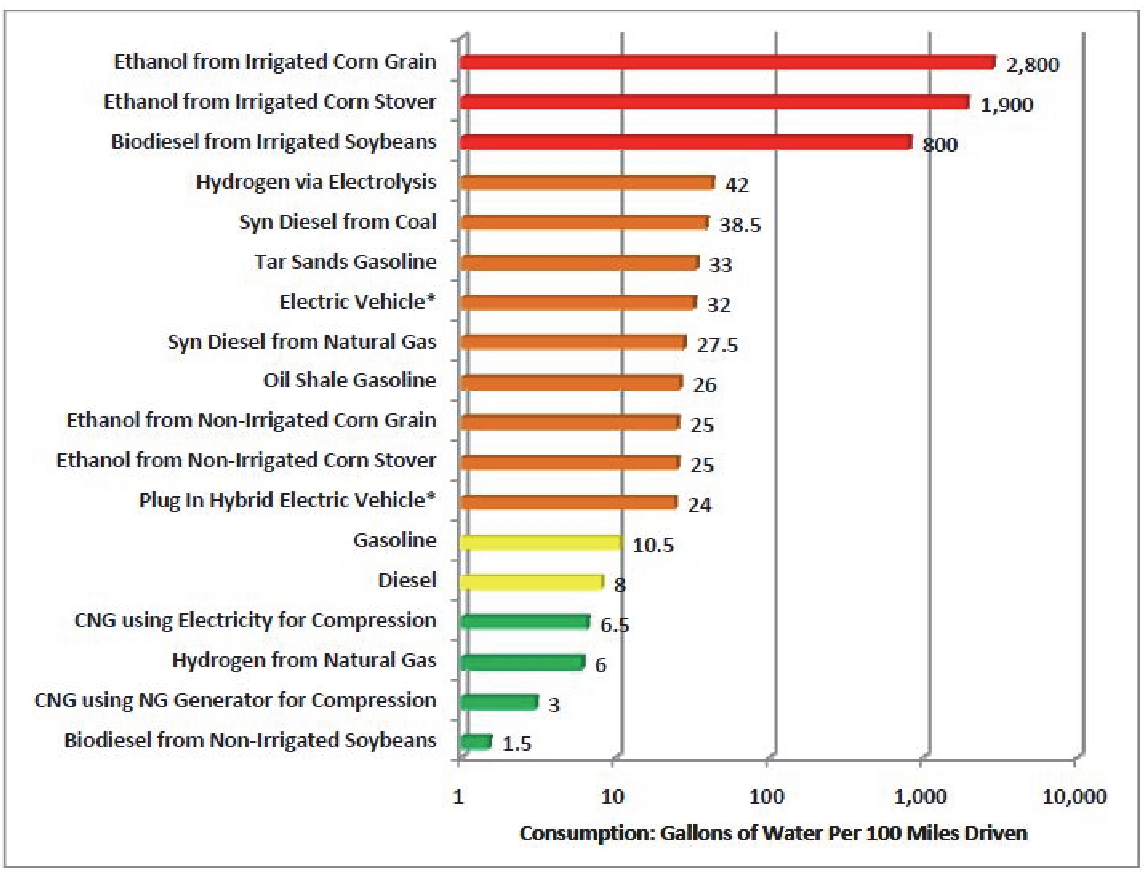
Figure 14 is a logarithmic plot that shows 18 different transportation fuels and their respective water consumption rates reported in gallons of water per 100 miles driven (Mantell 2009). The different colors of the plots show:

— Green: fuels that consume less water per mile than the traditional fuels,

— Yellow: traditional fuels,

— Orange: higher water consumption than traditional fuels,

— Red: significantly higher water consumption than traditional fuels. .



*Source: Adapted from King and Webber 2008a; *Adapted from King and Webber 2008b*

Figure 14—Water Intensity of Transportation Fuels (King and Webber 2008a and 2008b)

The energy's sector's water consumption is projected to increase significantly from 2005 to 2030 to meet increasing energy demands. Figure 15 shows the projected water consumption for various energy production sectors from 2005 to 2030 (Elcock 2010). It combines projections of energy production, developed by the USDOE, with estimates of water consumption on a per-unit basis (water-consumption coefficients) for coal, oil, gas, and biofuels production to estimate and compare the domestic freshwater consumed in absolute terms. Although total domestic freshwater consumption is expected to increase by nearly 7 % between 2005 and 2030, water consumed for energy production is expected to increase by nearly 70 % and water consumed for biofuels (biodiesel and ethanol) production is expected to increase by almost 250 %. By 2030, water consumed in the production of biofuels is projected to account for nearly half of the total amount of water consumed in the production of all energy fuels. It can be clearly seen from Figure 15 that water consumption from biofuels is significantly larger than that from the oil and gas industry.

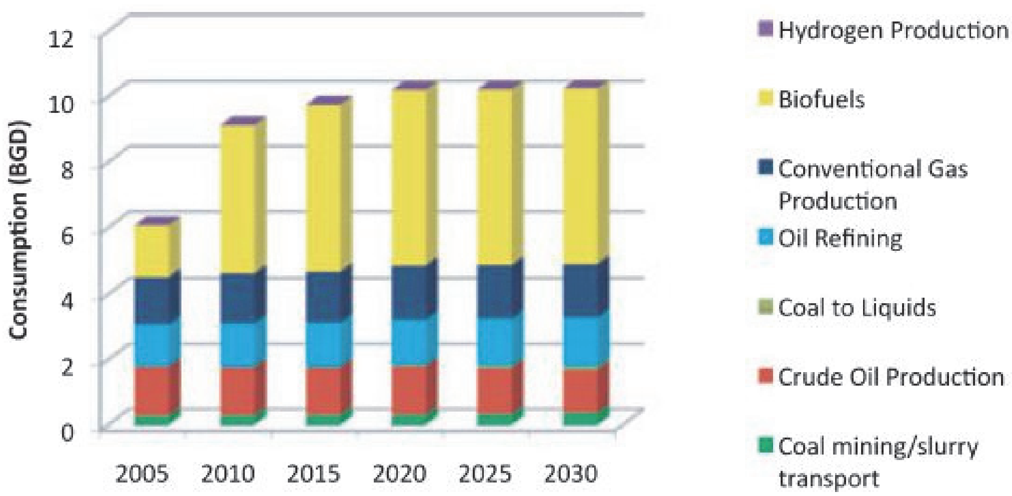


Figure 15—Projected Water Consumption for Energy Production Sectors, 2005–2030 (Elcock 2010)

In some older references, the actual water demand by the oil and gas industry is so relatively small so that it is included with demand from other industries, such as mining (TWDB 2011). In more recent studies, demands specific to oil and gas are broken out separately for some states such as Texas, Oklahoma, and Colorado (TWDB 2012; Nicot and Scanlon, 2012; Murray 2012; COGCC 2012).

7.2 Comparison with other Industries

The latest nationwide water use estimation (freshwater and seawater) by the USGS (Maupin 2014) estimated water withdrawals in the United States for 2010 for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together were 10 % of total water withdrawals. Notable statistics from this USGS report included the following.

— Thermoelectric power withdrawals account for 45 % of total water withdrawals.

— Irrigation withdrawals represent 33 % of total water withdrawals.

— Public supply represented about 12 % of total water withdrawals.

Industrial withdrawals represented about 4 % of total withdrawals. Petroleum refining was included under the industrial category.

Mining withdrawals, which included crude petroleum and natural gas, represented about 1 % of total withdrawals.

Compared to other water use sectors, the oil and gas industry uses significantly less water than the thermoelectric power industry, agricultural irrigation, biofuels for energy production, and public water supplies.

Figure 16 shows the trends of estimated water use in the United States from 1950 to 2010. The water use by oil and gas industry was included under the "Other" category, which represents self-supplied industrial, mining, commercial, and aquaculture water uses.

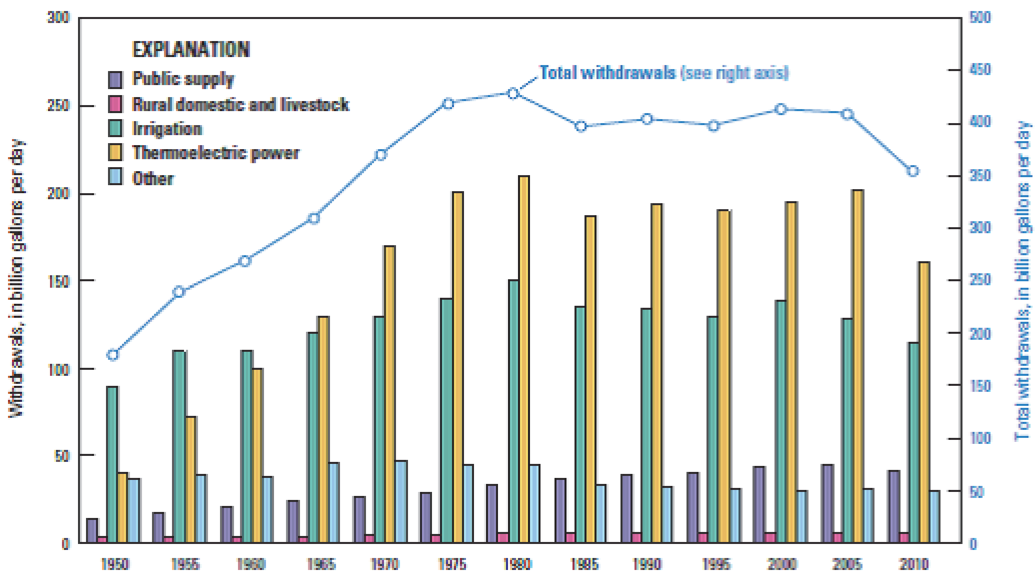


Figure 16—Trends in Estimated Water Use in the United States, 1950–2010 (Maupin 2014)

7.2.1 Social Benefits of Oil and Gas Industry

Economic impacts of the oil and gas industry result:

— directly from the employment and production within the oil and gas industry ("direct impacts");

— indirectly through the industry's purchases of intermediate and capital goods from a variety of other U.S. industries ("indirect impacts"); and

— induced impacts through the personal purchases of employees and business owners both within the oil and gas industry and the broader oil and gas industry supply chain and from dividends received from oil and natural gas companies.

In describing these economic impacts, it is important to consider these three separate channels (the direct impact, the indirect impact, and the induced impact) to provide a measure of the total economic impact of the U.S. oil and natural gas industry. The U.S. oil and gas industry's total employment impact to the national economy in 2011, combining the operational and capital investment impacts, amounted to 9.8 million full-time and part-time jobs and accounted for 5.6 % of total U.S. employment (Table 7).

At the national level, each direct job in the oil and natural gas industry supported approximately 2.8 jobs elsewhere in the U.S. economy in 2011. Counting direct, indirect, and induced impacts, the industry's total impact on labor income was $598 billion, or 6.3 % of national labor income in 2011. The industry's total impact on the U.S. Gross Domestic

Product (GDP) was $1.2 trillion, accounting for 8.0 % of the national total in 2011 (PricewaterhouseCoopers 2013).

Value added refers to the additional value created at a particular stage of production. The sum of value added across all industries in a country or region is, by definition, equivalent to its GDP. Value added consists of employee compensation, proprietors' income, income to capital owners from property, and indirect business taxes (e.g. those borne by consumers rather than producers). Based on the data provided in Table 7 for 2011, the value added of the U.S. oil and gas industry was 8 % of the U.S. GDP.

Table 7—Total Operational and Capital Investment Impacts of the Oil and Natural Gas Industry on the U.S. Economy, 2011 (PricewaterhouseCoopers 2013)

	Direct Impacts	Indirect and Induced Impacts		Total Impacts	Percent of U.S. Total
		Operational Impacts	Capital Investment Impacts		
Employment[a]	2,590,700	5,854,500	1,388,100	9,833,200	5.6 %
Labor Income ($ billions)[b]	$203.6	$311.8	$82.2	$597.6	6.3 %
Value Added ($ billions)	$551.0	$522.5	$135.8	$1,209.4	8.0 %

Source: PwC calculations using the IMPLAN modeling system (2011 database).

NOTE Details may not add to totals due to rounding.

[a] Employment is defined as the number of payroll and self-employed jobs, including part- time jobs.

b) Labor income is defined as wages and salaries and benefits as well as proprietors' income.

The economic impact of the oil and natural gas industry reaches all 50 states and the District of Columbia. Across the U.S., the total number of jobs directly or indirectly attributable to the oil and natural gas industry's operations ranged from a low of 13,700 (in District of Columbia) to 1.9 million (in Texas) in 2011.

There are five states that had greater than 12 % jobs directly or indirectly attributable to the oil and natural gas industry's operations as of 2011:

— Wyoming,

— Oklahoma,

— Louisiana,

— Texas, and

— North Dakota.

Including these 5 states, the top 15 states that have a significant percentage of jobs relating to oil and gas industry, and the percentage of jobs attributable to the oil and gas industry, are presented in Figure 17 below.

In addition to the economic benefits of the industry described above, many companies within the industry also promote the social well-being of the communities in which they operate through a variety of programs to provide economic development, promote public health, and improve educational opportunities.

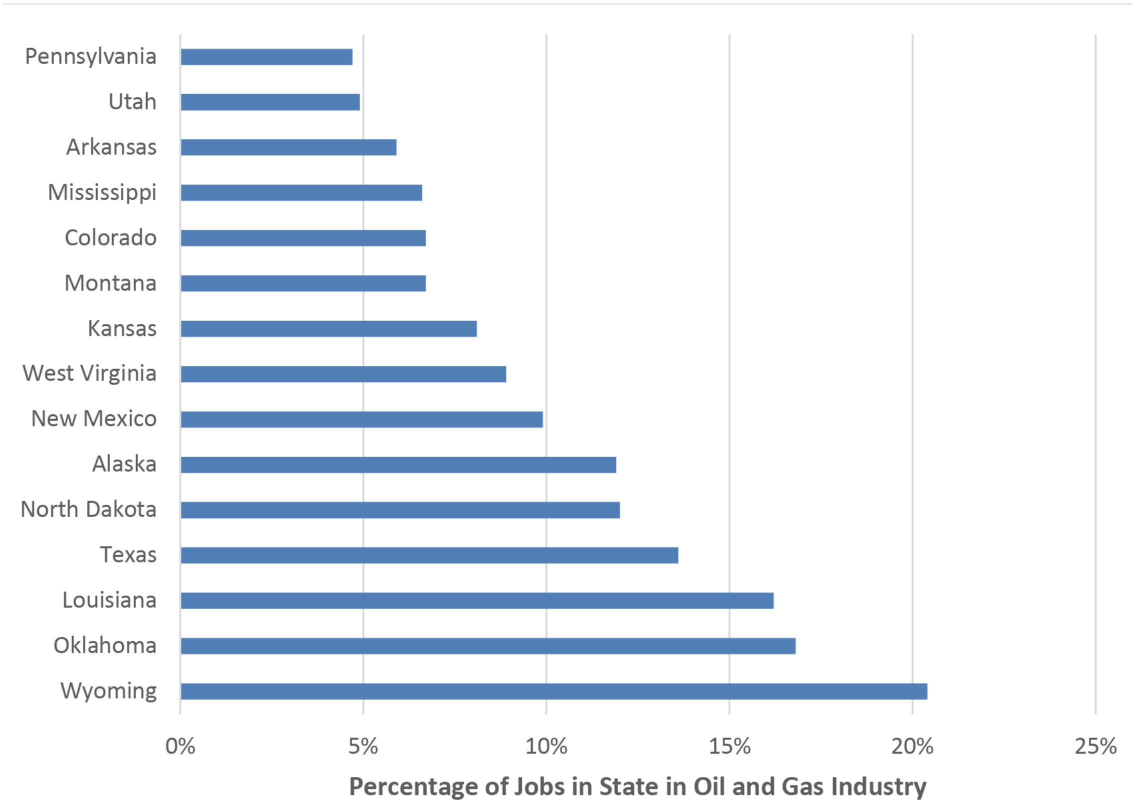


Figure 17—Top 15 States With Significant Percentage of Jobs in Oil and Gas Industry

8 Conclusions

Water is used throughout the midstream, downstream, and delivery phases of the oil and gas life cycle. The most significant of these uses, however, is for oil refining. Water use in gas processing, oil and gas transmission (midstream), and oil and gas delivery phases is negligible compared to the amount of water used for oil refining. Therefore, these conclusions focus on water management and stewardship in oil refining operations.

— **Water Use.** Water is used in oil refining primarily as cooling water, process water, and process steam. Most of the water used returns to the hydrologic cycle either as treated discharges back to the environment or through evaporation to the atmosphere. Typical practices to reduce freshwater use in oil refining include use of alternative, lower-quality water sources (reclaimed/recycled water, brackish water, saline water) and reuse of process water within refineries. Use of seawater cooling systems can greatly reduce freshwater demands for oil refineries.

— **Regulation of Oil and Gas Industry Water Management.** Many different federal, state, and local regulations pertain to water used in oil refining, although the regulations with the most direct and significant impact on water management include the CWA, including the CWA's NPDES program. In many states, the USEPA has delegated authority for implementation of the NPDES program. In addition, the USEPA has established specific ELGs for the petroleum refining industry.

— **Industry-led Stewardship Activities.** Through industry-leading organizations and stakeholder partnerships, the oil and gas industry has been taking action to improve water stewardship and sustainability practices, including in the area of oil refining which is of most relevance to this report. Key organizations leading these efforts include API, IPIECA), and PERF. Examples of activities conducted through these organizations include development of guidance on sustainability reporting and water management for oil and gas activities and documentation of best practices and strategies for water usage minimization in refineries.

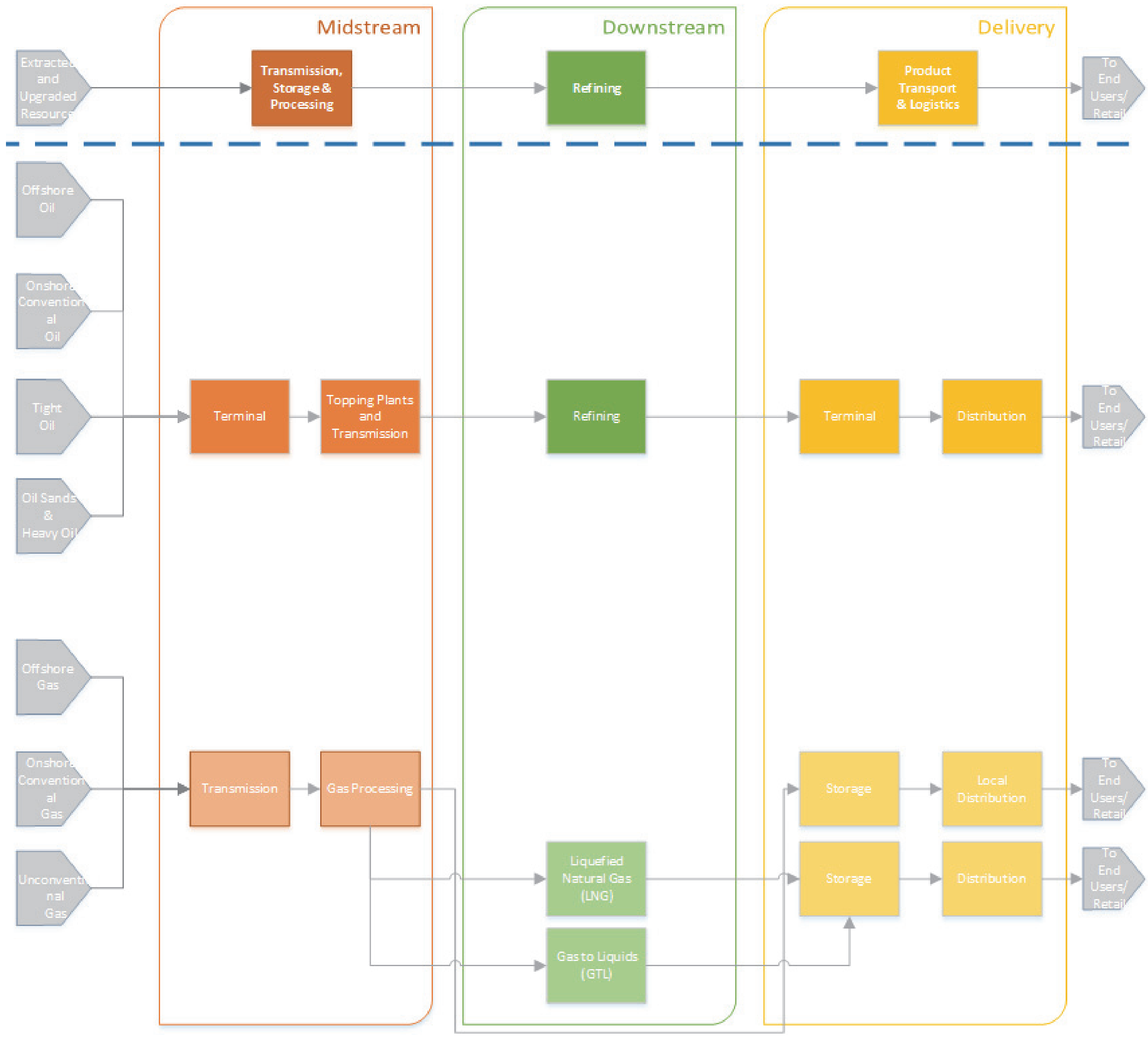
— **Water Footprint.** The water footprint for oil refining dominates all other water uses for oil and gas within the midstream, downstream (such as gas processing), and delivery phases of the life cycle. Water consumed in the refining process is defined as the water lost to atmosphere through evaporation. This water is returned to the hydrologic cycle but is not immediately available for reuse. The remainder of the water used is treated, reused, and ultimately discharged back to the hydrologic cycle. The estimated consumptive water use for oil refining is between 5 and 9 gal/MMBtus. Consumption water use for all other activities in midstream, downstream, and delivery phases of the oil and gas life cycle is 1 gal/MMBtu or less. For context, 1 MMBtu is enough energy to provide heating for the average U.S. household for approximately 10 days. The consumptive water use for oil refining is significantly less than that for production of fuel ethanol (from corn) or biodiesel (from soy), which require between 2,510–29,100 and 14,000–75,000 gal/MMBtu, respectively.

— **Comparison of Oil and Gas Industry Water Use.** The latest nationwide water use estimation by the USGS (Maupin 2014) estimated water withdrawals in the United States for 2010 for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together accounted for less than 10 % of total water withdrawals. Industrial withdrawals represented about 4 % of total withdrawals. Petroleum refining was included in the industrial category. Compared to other water use sectors, the oil and gas industry uses less water than the thermoelectric power industry, agricultural irrigation, biofuels for energy production, and public water supply.

With further sharing and implementation of best practices and increased use of alternative water sources for refinery water demands (such as seawater for cooling), the industry trend of declining water requirements for refining is expected to continue.

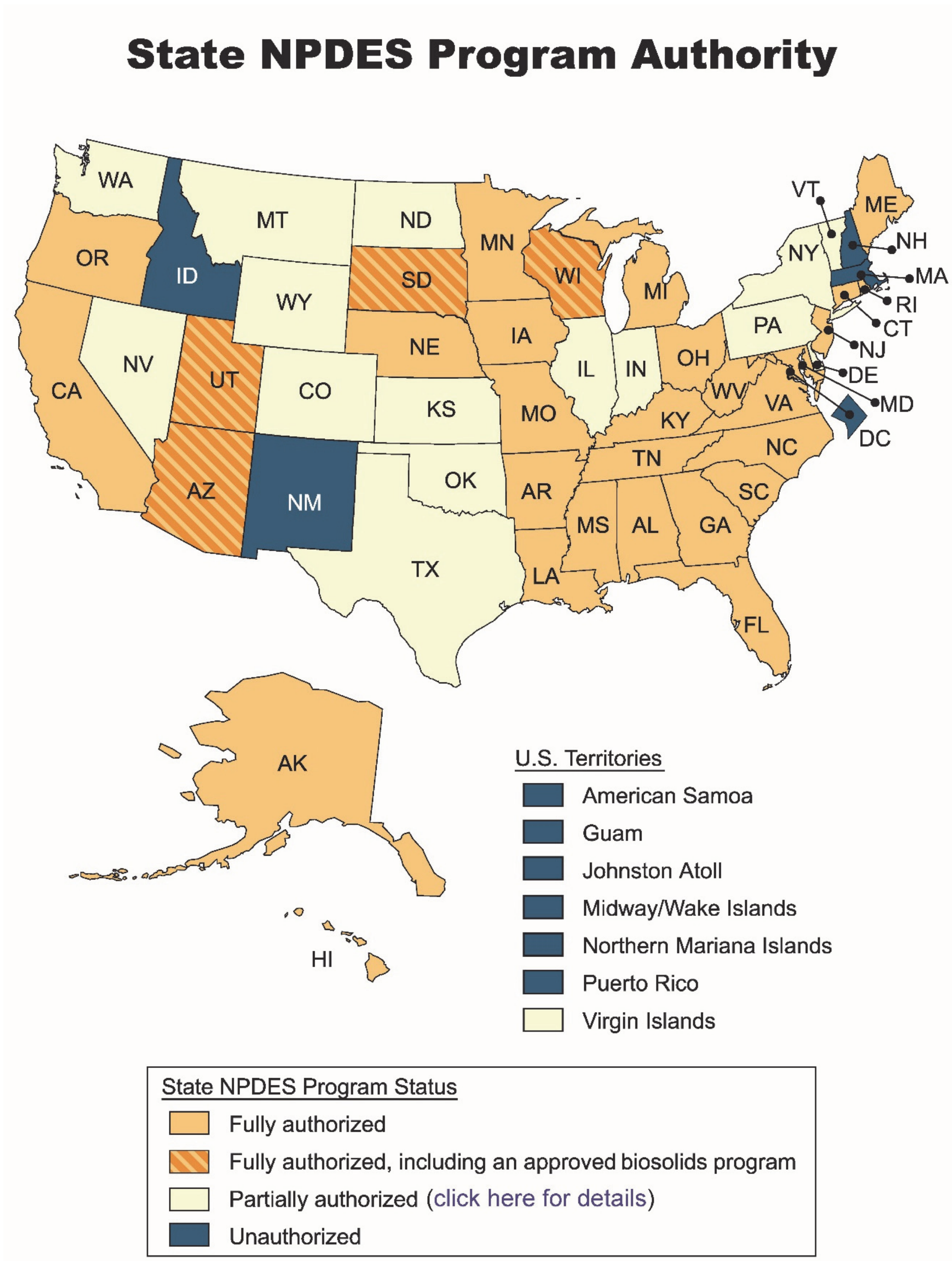
Annex A
(informative)

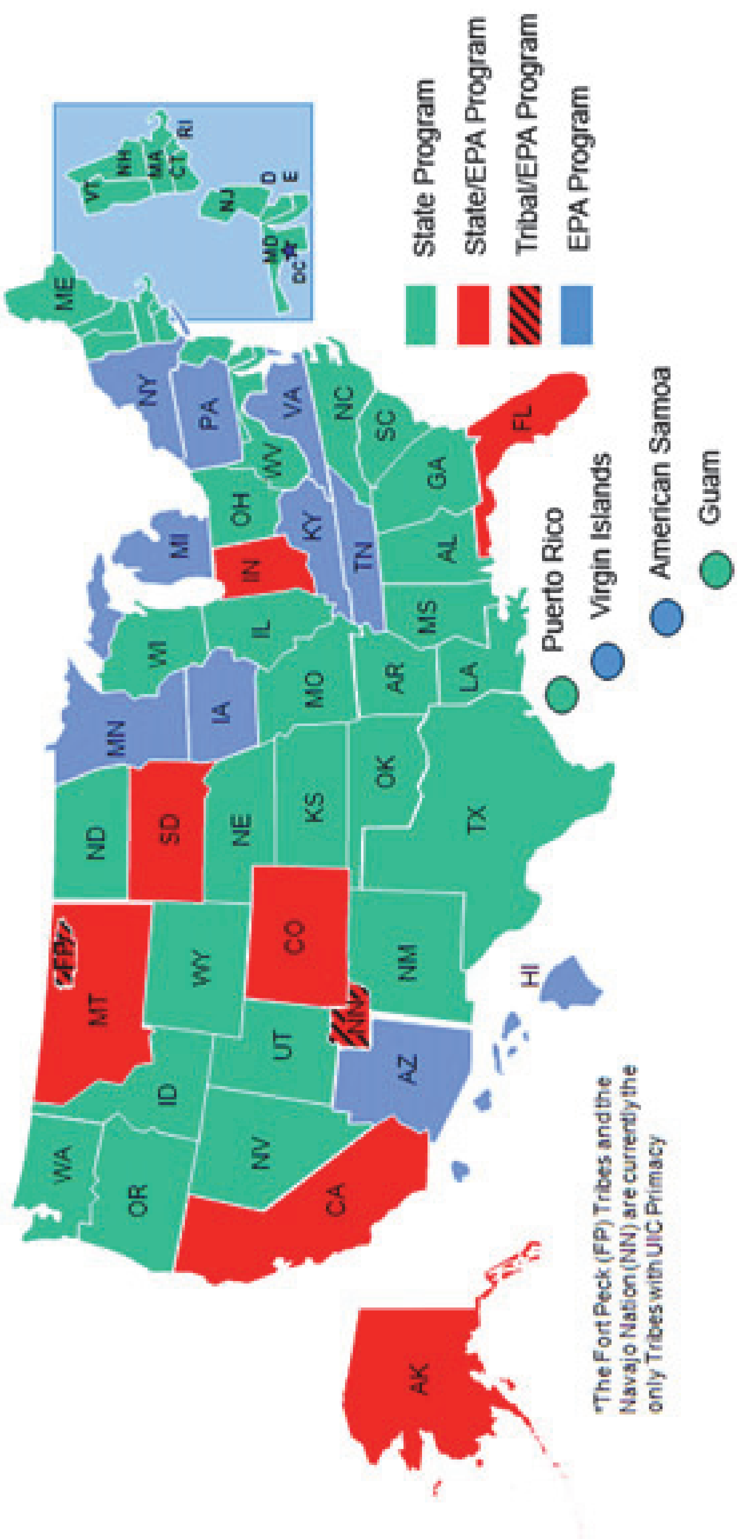
Diagram of the Midstream, Downstream, and Delivery Phases of the Oil and Gas Life Cycle



Annex B
(informative)

States with Delegated Authority by USEPA for State NPDES Program

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*The Fort Peck (FP) Tribes and the Navajo Nation (NN) are currently the only Tribes with UIC Primacy

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