AMIGOS BRAVOS

Because Water Matters

THE WATER-ENERGY NEXUS IN NEW MEXICO

Cover photographs are courtesy of Jim O'Donnell

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THE WATER-ENERGY NEXUS IN NEW MEXICO
AN AMIGOS BRAVOS REPORT

Authored by Megan O'Reilly, 2016

AMIGOS BRAVOS is a statewide river conservation organization guided by social justice principles. Amigos Bravos' mission is to protect and restore the waters of New Mexico. Amigos Bravos works locally, statewide, and nationally to ensure that the waters of New Mexico are protected by the best policy and regulation possible.

In May 2013, Amigos Bravos hosted a strategic planning session where staff, board members, representatives of community groups, and legal and technical experts identified priorities for Amigos Bravos' work from 2014-2018. A key outcome from this process was the recommendation that Amigos Bravos investigate the interplay between water and energy — the water-energy nexus — in New Mexico. As part of that research, participants recommended that Amigos Bravos develop a set of water-energy nexus recommendations to guide sound policy making decisions, and to create increased awareness about the relationship between energy development and its impacts on water resources in New Mexico as well as the energy-intensive ways we treat and transport water across the state.

This Report is the first piece of Amigos Bravos' investigation into the water-energy nexus. Specifically, this report outlines how production of electricity, including the development of fossil fuels for that production, impacts water resources in New Mexico. In addition, this report makes recommendations for incorporating the results of this study into ongoing and future work on the relationship between water and energy production, and suggests additional studies to address other facets of the water-energy nexus in New Mexico.

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GLOSSARY

Casing:
Pipe that is lowered into a well and cemented into place.[1]

Capacity Factor:
Capacity factor refers to a power plant's actual operation compared to its maximum potential generation.[2] For example, a plant that runs 24 hours a day, 365 days a year would have a capacity factor of 100 percent.

Conventional Oil or Natural Gas Deposit:
Reservoirs of natural gas or oil where the fluids/gases are pooled and sealed in place and readily available to flow into wellbores.[3]

Evaporation Pond:
Artificial ponds created and used to evaporate water from contaminated waters; solid contaminants are left over and must be disposed of in another manner.

Flaring:
A means of disposing of unwanted gas by burning the gas through a pipe at the well site.[4]

Flowback:
Water that returns to the surface directly after hydraulic fracturing; flowback can include water from geological formation as well as the chemicals injected in the hydraulic fracturing fluids.[5]

Hydraulic Fracturing (also known as "fracking"):
A method used to access unconventional oil or natural gas deposits by which a mixture of chemicals, sand, and water under pressure high enough to crack impermeable rock formations (10,000-20,000 psi) is injected into the well.[6]

Interburden:
Material in between coal seams.

Overburden:
Material overlying a coal seam (often referred to as "spoil").

Play:
An area of prospective oil and gas accumulations that share similar geologic and geographic properties.[7] "Often 'play' refers to regions that are commercially viable, whereas basins refer more closely to geologic characteristics."[8]

Produced Water:
Water produced from a well that does not consist of the treatment fluids injected into the well.

Shale Gas or Oil Deposits:
"Locations where natural gas or oil is attracted to and trapped onto the surfaces of rock particles. More technically challenging procedures, with higher volumes of fluids are required to start the oil or gas flow to the wellbore than production for tight deposits. Some view shale deposits as a subset of tight oil deposits."[9]

Thermoelectric power:
Electricity generated at a power plant that uses a fuel to convert water to steam to turn a turbine, which is then used to rotate the shaft of an electric generator.[10] Most fossil fuel-fired and nuclear power plants are thermoelectric power plants.

Topdressing:
Topsoil.

Unconventional Oil or Natural Gas Deposit:
"Natural gas or oil which is still associated with the "parent-rock" from which it was formed, often of low permeability and unable to flow to the wellbore on its own. Tight and shale deposits are examples of unconventional oil or gas deposits. Coalbed methane production, also known as coal seam gas, can also be included as an unconventional energy resource."[11]

Venting:
A means of disposing of unwanted pressure or gas by letting gas vent into the atmosphere.

Water Consumption:
Water taken from a watershed and used, and therefore not returned to the watershed.

Water Withdrawals or Diversions:
Water taken from a watershed for transfer or use.

Wellbore:
Also known as the borehole. The hole drilled to access underground resources, such as oil and natural gas. Includes the uncased portion of the well.[12]

ACRONYMS AND ABBREVIATIONS

AF: acre-feet

APS: Arizona Public Service

BGD: billion gallons per day

BLM: Bureau of Land Management

BTU: British Thermal Unit

CCW: Coal Combustion Waste (sometimes also referred to as coal combustion residuals (CCR) or coal combustion byproducts (CCB))

CFS: cubic foot per second

CSP: Concentrated Solar Power (Also called Concentrated or Concentrating Solar Thermal-Electric Power)

CWA: Clean Water Act; the formal name is the Federal Water Pollution Control Act, 33 U.S.C. §§ 1251-1376

DOE: Department of Energy

EMNRD: Energy Minerals Natural Resource Department (New Mexico)

EPA: Environmental Protection Agency

EPE: El Paso Electric Company

ESA: Endangered Species Act

FCPP: Four Corners Power Plant

GPM: gallons per minute

IRP: Integrated Resource Plan

ISL: In-Situ Leaching

kW: kilowatt = 1,000 watts

kWh: kilowatt hour

MGD: million gallons per day

MMD: Mining and Minerals Division (division of EMNRD)

MBTU: million British Thermal Units (also noted as MMBTU)

MW: megawatt = 1,000,000 watts or 1,000 kilowatts

MWh: megawatt hour = 1,000 kilowatt hours

NEPA: National Environmental Policy Act

NMED: New Mexico Environment Department

NPDES: National Pollutant Discharge Elimination System

OCD: Oil Conservation Division (division of EMNRD)

PNM: Public Resource Company of New Mexico

PV: Photovoltaic solar

PVNGS: Palo Verde Nuclear Generating Station

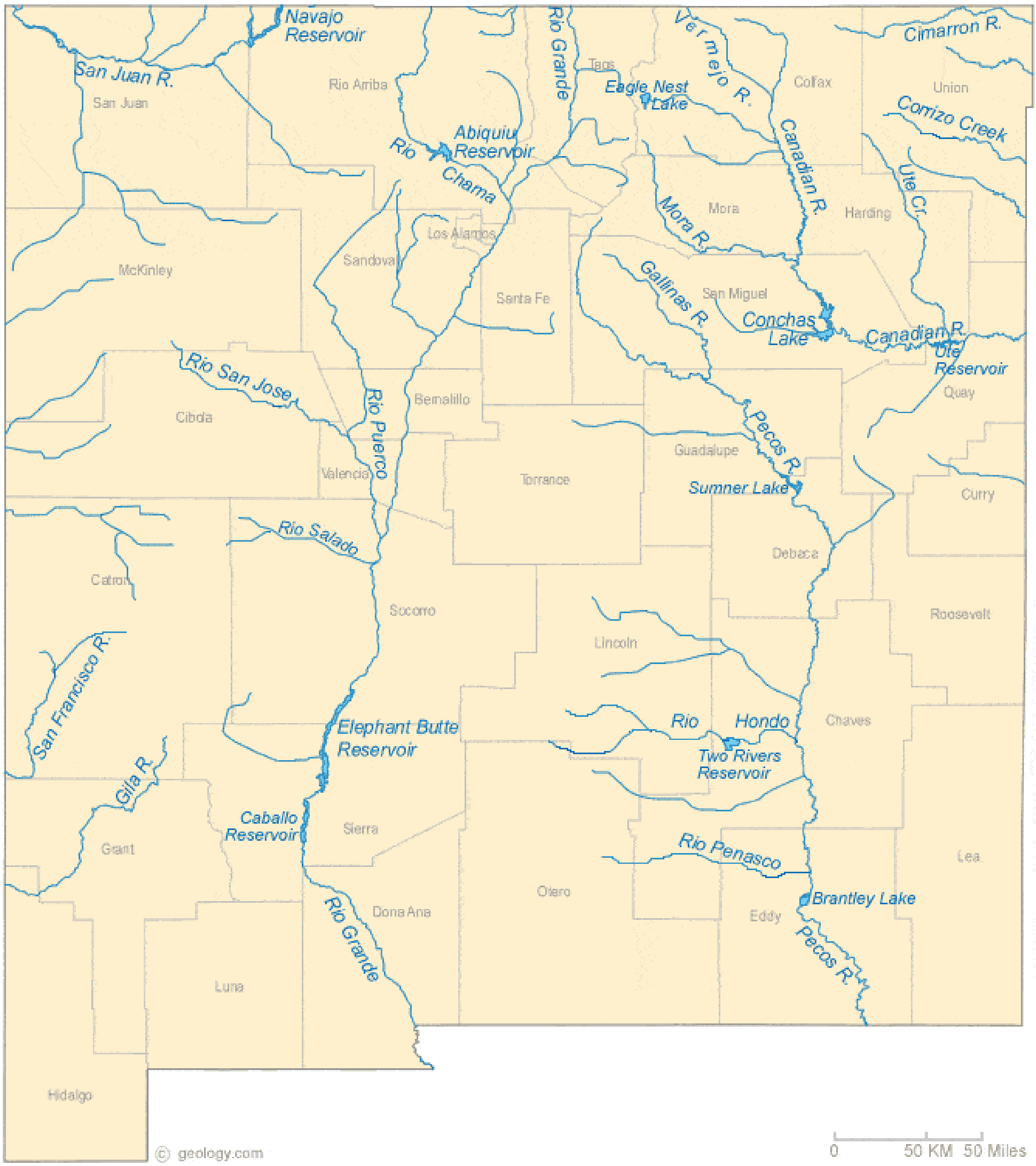
SDWA: Safe Drinking Water Act, 42 U.S.C. §§ 300f-300j.

SJGS: San Juan Generating Station

SMCRA: Surface Mining Control and Reclamation Act

SPS: Southwestern Public Service Company, a subsidiary of Xcel Energy

USFWS: United States Fish and Wildlife Service



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I. INTRODUCTION

Water and energy are intertwined; we use water to produce energy and we use energy to pump, transport, and deliver water. This relationship is known as the water-energy nexus.

Currently, it takes enormous amounts of water to produce energy in New Mexico because of our reliance on water-intensive options, including coal, natural gas, and nuclear energy. Vast amounts of water are needed to extract coal, oil, natural gas, and uranium; even more water is needed for cooling at power plants using those fuels; pollution from all of these processes further impacts watersheds. Exacerbating this dynamic, we then use this water-intensive energy to transport water for municipal, commercial, industrial, and agriculture uses.

Even more troublesome is the impact that these using these fuels to produce electricity has on our climate; fossil-fuel based electricity generation is an enormous contributor to climate change. Thus, as our changing climate undermines this already precarious dependency on water for energy, continued reliance on coal and natural gas intensifies the problem by contributing to climate change, which causes precipitation and temperature pattern changes that threaten the Southwest's water supplies. The supply of already scarce water resources is becoming less and less reliable at the same time that we are subjecting it to increasingly competing demands. In sum, continued reliance on water-intensive energy options is no longer a wise choice.

This report focuses on the first component of the water-energy nexus in New Mexico: the impacts of energy production on New Mexico water quantity and quality. Primarily this report focuses on water used to produce electricity, although we also address water for oil and gas production, which is used for electricity, heating, and other services. This report examines how different sources of energy in New Mexico impact water, specifically coal mines and coal-fired power plants; oil and natural gas production and combustion; uranium mines and nuclear plants; and finally renewable sources of energy, including wind and solar resources. The final section of the Report makes recommendations for increased awareness and efficient use of water and energy in New Mexico. This report does not address the second component of the water energy nexus — how much energy we use to pump and transport water throughout New Mexico — that piece warrants a report of its own.

II. EXECUTIVE SUMMARY

Discussed in more detail below, this report arrives at several key conclusions about the impacts of energy development in New Mexico:

- Fossil fuel development and combustion contribute to climate change, and at the same time compound the impacts caused by climate change. For example, fossil fuel production and combustion take significant amounts of waters out of streams at the same time that climate change is causing decreased precipitation in the Southwest, and thus decreased flows in those same streams. Similarly, fossil fuel production and combustion is adding pollution to waterways, while decreased flows decrease the ability of these streams to assimilate that pollution.

- The only way to truly address this situation is to move as rapidly as possible to clean, renewable sources of energy; in so doing we can both decrease contributions to climate change and almost eliminate our need to use large amounts of water for energy.

- Fossil fuel production and combustion contribute to water pollution at every step of those processes, with cumulative impacts that are greater than the sum of their parts. First, fossil fuel production and combustion takes large amounts of water from our streams and aquifers, much of which is not returned to the watershed. Second, fossil fuel production contributes pollution to streams and aquifers both during active mining and drilling and for years following as a result of legacy pollution. Third, pollutants are often introduced to streams and aquifers when fossil fuels are stored and/or transported. Fourth, combustion of fossil fuels causes water pollution when pollutants are discharged or improperly contained at the plant, and through air pollution, which ends up in streams and aquifers through deposition. Fifth, disposal and storage of combustion byproducts cause additional water pollution. Finally, reclamation uses additional water, thus taking water away from watersheds even when energy is not being produced. These impacts pancake on top of one another, affecting human health, watershed health, and the people and wildlife that depend on these systems; these impacts are particularly troublesome because they decrease the resiliency of people, wildlife, and ecosystems to withstand other impacts of climate change.

- The heavy concentration of fossil fuel development and combustion in the Northwest part of the State, areas where water resources are already constrained and stressed. Considering these local and regional impacts is critical, as that is where the impacts are felt most. Averaging out the impacts across the state as a whole may make the situation appear less dire, but is an inaccurate presentation of the effects.

- Although existing regulatory mechanisms are insufficient to address larger questions about resource choices, they can and should be used to address some of the impacts on water resources from energy development. For example, ensuring that National Environmental Policy Act (NEPA) processes are truly comprehensive in their analysis of cumulative impacts of proposed energy development is a powerful tool for educating both the public and decision-makers. Although these analyses provide a strong foundation for good decisions about how we use our scarce water resources, unfortunately they do not mandate decisions that protect water resources.

- Given the limitations of engagement in regulatory processes, interested stakeholders must also weigh in about choices regarding our energy resources. We must ensure that our electric utilities are considering impacts to water quantity and quality of their resource choices, and ultimately that they are transitioning to renewable energy resources.

III. OVERVIEW: CLIMATE CHANGE IMPACTS TO NEW MEXICO'S WATERS

The water-energy nexus has become an important point of discussion because the relationship between how we produce electricity is critical to efforts to stem the effects of climate change. Fossil-fuel based electricity generation contributes to large scale climate change, and efforts are being made throughout the world to transition to renewable energy. In the West, this transition is of particular importance as water supplies are reduced and become less reliable due to climate change, it is necessary to more carefully scrutinize priorities for water usage.

> Water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013).[13]

The Environmental Protection Agency has concluded that the Southwest's "water supplies are already constrained under current climate conditions."[14] Climate change only exacerbates these constraints:

- "Increasing temperatures are projected to further reduce snowpack, which will lead to reduced streamflows;"

- "springtime precipitation is likely to decrease significantly, making it more difficult to meet water demands during the summer when conditions are typically the driest;"

- "climate change will likely result in more frequent and more severe droughts associated with increases in wildfires;"

- "while severe droughts are already part of the Southwest climate, human-induced climate change will likely result in more frequent and more severe droughts with associated increases in wildfires."[15]

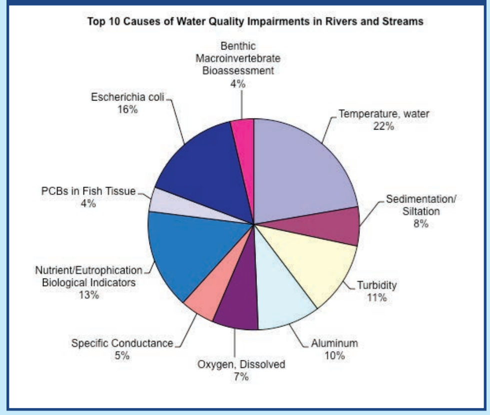
These impacts will be compounded as they both contribute to, and are aggravated by, declining water quality. As a National Climate Assessment report notes, “surface water quality will be affected by scarcity of water, higher rates of evaporation, higher runoff due to increased precipitation intensity, flooding, and wildfire.”[16]

Already, according to NMED’s 2014 Impaired Waters Report, of the 7,710 categorized stream miles in New Mexico, nearly 4,170 assessed miles, or 54 percent, are not meeting water quality standards.[17] Moreover, this number is most likely artificially low as only 83 percent of the 7,710 stream miles have been analyzed. [18] Lakes, reservoirs and playa lakes are not faring better; 66,143 out of 94,415 acres (70 percent) of categorized, publicly-owned lakes, reservoirs, and playas do not meet water quality standards.[19] Even more troubling is the fact that water quality continues to decline. In 2012, the number of waters not meeting water quality standards was much lower; 32 percent, or 2,500 miles, of New Mexico’s categorized streams were not meeting standards at that time.[20] In the two years between assessments, water quality in an additional 1,670 miles, or 22 percent of New Mexico’s waters, declined below water quality standards. Declining water quality has impacts to our use of our waters and to the aquatic life that inhabit them. “The State has issued fish consumption advisories for a variety of fish species in 26 lakes and reservoirs and three rivers due to elevated concentrations of various contaminants, including mercury, dichlorodiphenyltrichloroethane (DDT), and polychlorinated biphenyls (PCBs).”[21] [Rachel to add more here re. 2016 report]

At the same time that our water supplies are in such dire condition, we rely almost entirely on energy sources that require tremendous amounts of water. Furthermore, these sources contribute to climate change, thus doubly impacting our waters. The production of electricity is one of the largest uses of water in the United States and worldwide.[22] In 2010, withdrawals in the United States for thermoelectric power exceeded every use, accounting for 45 percent of total fresh surface water withdrawals.[23] The power sector withdrew 161 billion gallons of water per day just for thermoelectric generation; that number grows substantially when water used to produce the coal, oil, natural gas, and uranium fueling that generation is included.[24] In New Mexico, electricity generation requires at least 44 billion gallons per year—a number that also does not account for the water lost due to pollution directly tied fuel extraction and electricity generation.[25]

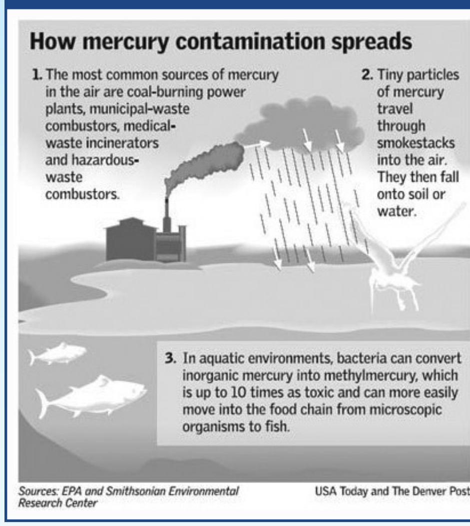
Impacts from pollution result in much larger amounts of water being affected by electricity generation, including the impacts from withdrawals from river systems, pollution from fuel production and combustion, and pollution from waste products such as coal combustion waste and produced water from oil and natural gas wells. The impacts are also more sharply felt in arid regions, and yet 25 percent of electric generation nationwide is located in counties projected to be at high or moderate water sustainability risk in 2030.[26]

TEMPERATURE



Temperature is one of the most common pollution problems in New Mexico’s rivers and streams resulting in the impairment of close to 1,800 miles of streams.

MERCURY



Mercury is another one of the most common pollution problems in New Mexico’s lakes and reservoirs resulting in the impairment of 60,000 acres of lakes and reservoirs in the states. This is more than double the amount of impaired acres caused by any other pollution source.

Many forms of electricity generation thus have a triple impact on water quality. First, fossil-fuel electricity generation contributes to climate change; climate change increases the temperature of our waters, a major cause of New Mexico water quality impairments, and decreases flow, which concentrates existing pollution in waterways. Second, fossil-fuel electricity generation facilities in New Mexico directly discharge pollutants into our ground and surface waters. Third, fossil-fuel electricity generation facilities in New Mexico divert large amounts of water from our rivers and streams which result in lower flows and thus higher temperatures (smaller streams heat up faster), and less dilution for other pollutants such as heavy metals and nutrients (E.coli is another major source of contamination in New Mexico's surface water).

In order to maintain reliable power supply as our climate changes and water supplies are diminished, we must switch to electricity generation that does not use scarce water resources. A Morgan Stanley study on utilities and water risk, noted: "'Business as usual' is no longer appropriate given the scale, magnitude and variety of water-related risks facing the [utility] sector," and indeed 86 percent of global utility sector respondents identified water risks to direct operations.[27] The Department of Energy has similarly stated: "Thermoelectric power generation facilities are at risk from decreasing water availability and increasing ambient air and water temperatures, which reduce the efficiency of cooling, increase the likelihood of exceeding water thermal intake or effluent limits that protect local ecology, and increase the risk of partial or full shutdowns of generation facilities."[28]

In sharp contrast, most sources of renewable energy use little to no water.[29] As a result, the attendant water pollution that is so problematic for conventional energy sources is virtually nonexistent with renewable sources. The National Renewable Energy Laboratory (NREL) found that if the U.S. were to transition to an energy mix that includes 80 percent renewable energy sources — using currently available technology — water withdrawals would decrease by 51 to 60 percent and water consumption by 47 to 57 percent just for operational uses at power plants.[30] In the Southwest, NREL found that water consumption would decrease even as this area increases electricity exports.[31]

As we transition to renewable sources, we can dramatically cut the amount of water we use to generate electricity, and, as we increase the efficiency of our water usage, we can decrease the amount of energy needed to transport water—further decreasing our water footprint. We can accomplish this transition while becoming an energy exporter, thus boosting our state's economy.[32] We must decide whether we want to continue to expend limited water resources to generate electricity when cleaner, more durable options are available that use or impact little to no water.

While multiple regulatory mechanisms set requirements aimed at protecting the environment from impacts due to energy production activities in New Mexico, these mechanisms are fragmented. In addition, these mechanisms fail to raise the bigger questions at play, such as: should we, as an arid state, pursue water-intensive electricity sources or should we rapidly transition to electricity generation that safeguard water quality and quantity? The failure of current regulation to arrive at such broader questions underscores the need for systemic change both to the regulatory framework and to how we generate electricity. Thus, even as we leverage existing regulatory mechanism to protect the quality and quantity of our state's waters in the near-term, we must also work toward a different approach to electricity generation.

Each section of this report includes a table that outlines the current regulatory mechanisms in place for the energy source addressed in that section. This information provides a guide to identify current regulatory processes and decision-making avenues through which to apply the water-energy nexus recommendations identified below.

IV. WATER FOR ENERGY

Water is used in almost every phase of electricity generation in New Mexico. First, water is used to mine coal, uranium, and to produce oil and natural gas resources. Second, water is needed for cooling in coal, natural gas, and nuclear plants. Finally, water is required for reclamation at these sites. All of these processes impact even greater amounts of water as a result of pollution at and around the extraction and generation sites, and from deposition of pollutants from fossil fuel combustion that end up in rivers, streams, and other waters. On a statewide basis, the amount of water used and affected to generate electricity is significant relative to other uses. At the local level, the impacts are even greater, as areas in the Northwest and Southeast part of the state are disproportionately affected.

This report outlines how fossil fuel production and combustion use and impact water resources. Where possible, this report quantifies the amount of water used for these processes. Although harder to quantify, these sections also discuss the ways in which water resources are further impacted as a result of pollution from these processes. The final section includes recommendations for additional study, ways in which Amigos Bravos can incorporate the results of this work into its current and future work, and questions to consider about our energy choices more broadly.

TABLE 1: WATER USAGE FOR ENERGY IN NEW MEXICO

Can we qualify this first column? Industries?	AMOUNT DIVERTED OR PUMPED (acre-feet/year)	AMOUNT CONSUMED (acre-feet/year) *does not include water impacted by pollution*	AMOUNT CONSUMED AS PERCENTAGE OF NM PUBLIC WATER SUPPLY (317,410 acre-feet/year)[34]	AMOUNT CONSUMED AS PERCENTAGE OF TOTAL NM WATER DEMAND FOR ENERGY[35]
COAL MINING	2,847[36]	2,847[37]	0.9%	3.9%
COAL-FIRED POWER PLANTS	53,625[38]	42,259[39]	13.3%	58%
OIL AND NATURAL GAS PRODUCTION	12,255[40]	12,255[41]	3.9%	16.8%
OIL AND NATURAL GAS POWER PLANTS	6,405[42]	6,405[43]	2%	8.8%
URANIUM MINING	726[44]	726[45]	0.2%	1%
NUCLEAR POWER (PALO VERDE- AZ)	8,532[46]	8,532[47]	2.7%[48]	11.7%
SOLAR PHOTOVOLTAIC	Close to 0	Close to 0	0%	0%
WIND	0	0	0%	0%
TOTALS	84,390	73,024	23%	~100%

The San Juan Basin in Northwest New Mexico illustrates how the impacts of our energy development, and usage of water, are not felt proportionately. The San Juan Basin is home to:

- All three of New Mexico's three coal-fired power plants, two of which are located across the San Juan River from one another;
- All four of its active coal mines, two of these also within close proximity to the San Juan River;

- A large percentage of the oil and natural gas production in the state, including over 40,000 oil and natural gas wells, along with associated pipelines, compressors, separators, dehydrators, and processing facilities;[49]

- A majority of the legacy uranium mines in the State;[50]

- Impaired waterways, and is listed as a Watershed Restoration Priority Area.[51]

This high concentration of energy development in the region compounds the impacts from each source, and in particular, the impacts to water quality in the San Juan River.

The impacts discussed below are all felt in the San Juan Basin. For example, water diverted for coal mining, coal-fired power, and oil and gas operations can deplete flows in the San Juan River, thus rendering it more susceptible to pollution and higher temperatures. Pollution from coal-fired power plants, in the water as a result of ongoing discharges or disposal of coal combustion waste, and from airborne deposition of pollutants, including mercury, can further threaten water quality. Oil and gas operations divert or pump more water from the Basin still, and threaten water quality through drilling itself, or as a result of spills or leaks from wastewater or produced water storage. Legacy pollution from uranium mines contaminates even more water supplies.

The San Juan Basin illustrates how our choices about energy development have long-lasting impacts, which are not felt in isolation. The San Juan Basin is also home to world-class renewable resources, and thus holds opportunity for New Mexico's future. Thus, while the San Juan Basin demonstrates the impacts of our previous choices, it could also provide an example of how we generate electricity and reclaim our rivers.

A. COAL: MINING AND COMBUSTION

This section discusses the impacts of coal-fired generation on water supplies from coal mining in New Mexico, coal combustion in New Mexico and adjacent states that deliver power to New Mexico, and finally the impacts of coal-related pollution to watersheds.

1. COAL MINING

At its core, coal mining rips apart landscapes to extract coal that has been buried underneath the ground for hundreds of millions of years. Included within the layers that are exploded and shaved away are aquifers and streambeds. Left in the rubble are mine spoils that contain heavy metals and other contaminants. Even after reclamation, buried mine spoils or coal combustion waste may continue to impact water quality.

There have been several coal mines of various sizes in New Mexico's history.[54] This report considers the five largest ones: Navajo Mine, located adjacent to and around the Four Corners Power Plant; San Juan Mine, located next to San Juan Generating Station, about 8 miles north of Navajo Mine; Lee Ranch Mine, located about 30 miles northeast of Grants; El Segundo Mine, located about 35 miles north of Grants;[55] and McKinley Mine, located northwest of Gallup. Four of the five — Navajo, San Juan, Lee Ranch, and El Segundo — remain active; the fifth, McKinley Mine, was shut down in 2009.[56] Of these mines, four are strip or surface mines, and one, San Juan Mine, began as a strip mine, and then transitioned to underground operations.

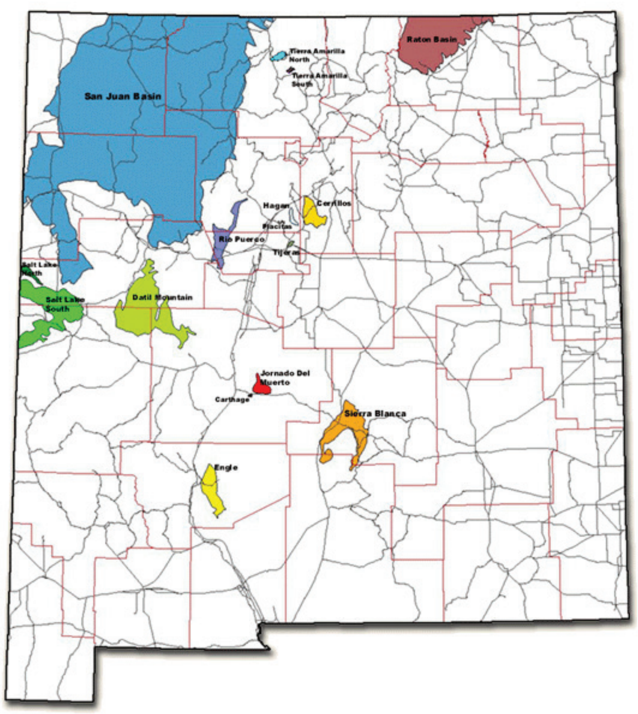
a. PROCESS

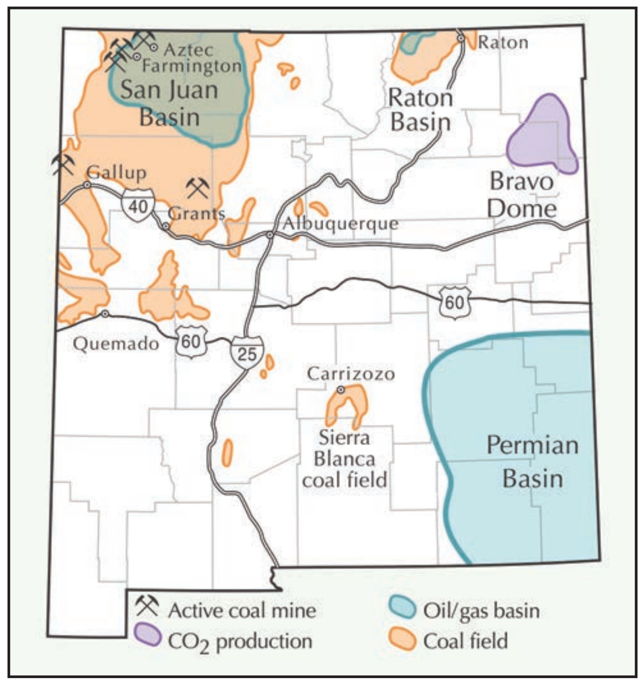
To understand how coal mining affects water resources, it is helpful to understand the coal mining process.

Navajo Mine[52]

Navajo Mine[53]

MAP 1: COAL MINES IN NEW MEXICO[57]





Map of coal mines and oil and natural gas basins in New Mexico.[58]

Strip mining, also referred to as "dragline stripping," is the primary method used to mine coal in New Mexico.[59] Strip mining involves several steps to reach and extract the coal seam. First, vegetation and topdressing,[60] or topsoil, is removed from the area.[61] Topdressing is removed ahead of mining activities so that it can be salvaged for later use in reclamation, although that is not always possible.[62] Once the topdressing has been removed, rotary drills are used to drill overburden blast holes, which range in diameter from 5 to about 11 inches and are typically drilled to the top of the coal seam.[63] Once these holes have been drilled, they are filled with explosives, and the overburden, or the material overlying the coal seam (often referred to as "spoil"), is then blasted.[64] The overburden is then removed in parallel cuts or "strips" using electric-powered walking draglines.[65] Contiguous sequences of strips comprise a "pit."[66] Pits range in depth from 5 to 240 feet, are at least 100 feet wide, and range in length from 1,000 to 15,000 feet.[67] Bulldozers, front-end loaders, and haul trucks are also used to remove overburden as needed.[68] After the coal seam is exposed, the top layer of coal is removed by small front-end loaders. The remainder of the coal seam is then drilled for blasting, and then blasted in a manner similar to that used for the overburden. [69] The coal is then extracted using large front-end loaders that load large-capacity haul trucks.[70] Successive layers between coal seams, or "interburden" are then removed in by further blasting and excavation, and the steps are repeated.[71]

Underground mining is limited in New Mexico to the San Juan Mine. The San Juan Mine is an underground longwall mine.[72] The San Juan underground mine is accessed through portals in the former surface mine pit.[73] Currently, coal is mined at San Juan from a single longwall face.[74] Longwall operations at San Juan are automated with articulated components.[75] Supports, or roof shields, hold the roof up, while a coal shear cuts the coal from the face. The coal is then pushed onto a conveyor belt and transported out of the underground mine to a surface stacker tube.[76] Once on the surface, coal is transported by truck 1.55 miles (2.5 km) to San Juan Generating Station, or to stockpiles close to the power plant.[77]

b. WATER USAGE

New Mexico coal mines do not use a significant amount of water themselves. However, coal mining degrades the quality of water resources both as a result of pollution created at the mine site and exacerbated by the placement of coal combustion waste in mined out areas. As Stanford's Water in the West Water-Energy Nexus Literature Review concluded: "The major water-related concern of coal mining is not the quantity of the water that is used, but the discharge of pollutants affecting local water quality."[78] This pollution similarly decreases the amount of water available for other uses. Having water that is too polluted to be used for other uses such as public drinking water supplies or aquatic life is akin to having no water at all.

Water use for the mines in New Mexico is as follows, in Table 2:

c. IMPACTS

From the very beginning of a mine until often well after the coal has been mined out, coal mining negatively impacts water resources.

First, the creation of these large pits fundamentally alters the landscape. Strip mining can completely eliminate streams, ponds, arroyos, and other water features, altering the natural drainage patterns of the area.[103] At Navajo Mine, for example, 13,353 acres have been disturbed.[104] Included in that acreage are drainages and arroyos that previously brought water from storm events and other sources to larger drainages.[105] At San Juan Mine, 5,388 acres have been disturbed on the surface and underground mining causes additional impacts above and below ground.[106] Stream channels of Stevens Arroyo and Hutch Canyon, for example, may be impacted by mine subsidence.[107] Other channels have been relocated completely.[108] Lee Ranch has disturbed 7,132 acres,[109] and El Segundo Mine has impacted another 3,054 acres.[110] Continued mining will remove additional ephemeral channels and swales at the mine site, with those flows contained within the mine in retention ponds, or diverted around the site.[111] As a result, flows downstream of the mine will be decreased.[112] McKinley Mine impacted another 5,581 acres, bringing the total for just the five largest mines to 34,508 acres or about 54 square miles, an area more than one and a half times the size of City of Santa Fe, New Mexico.[113]

Second, although many of the streams around these mines are ephemeral, they can carry large quantities of water in response to summer precipitation events.[114] During periods of active mining, and before disturbed areas are reclaimed, ground disturbance from construction and mining may intensify sediment loading in stormwater runoff, degrading downstream water quality.[115]

Third, groundwater is also impacted. The overburden or interburden layers may be saturated with groundwater, and indeed, coal layers often function as aquifers themselves. When areas are mined through, these aquifers may be eliminated

TABLE 2: WATER FOR COAL MINES IN NEW MEXICO

Mine	Water Used (acre-feet per year)	Source	Discharges	Acres disturbed (to 2010)	Years mined	Power plant(s) supplied
El Segundo Mine	650[79]	Groundwater-private wells[80]	Kim-me-ni-oli Valley Tributary (tributary to Chaco River), Inditos Draw (tributary to Rio Puerco)	3,054[81]	2008-present[82]	Cholla Power Plant, Springerville G.S., Apache G.S., Escalante G.S., Coronado G.S.[83]
Lee Ranch Mine	224[84]	Groundwater (private wells)[85]	Mulatto Canyon Arroyo (Rio Grande Basin)[86]	7,132[87]	1984-present[88]	Escalante Generating Station[89]
McKinley Mine	n/a		Coal Mine Wash, Defiance Draw, Bonita Wash (tributaries to the Rio Puerco)[90]	5,581[91]	1959-2010[92]	Cholla Power Plant, Coronado G.S., Irvington Station, Apache G.S.[93]
Navajo Mine	1000[94]	San Juan River	Morgan Lake, Chaco River, San Juan River[95]	13,353[96]	1957-present	Four Corners Power Plant; Navajo residents[98]
San Juan Mine	973	San Juan River	Shumway Arroyo, Westwater Arroyo, San Juan River[99]	5,388[100]	1973-present	San Juan Generating Station[102]
TOTALS	2,847			34,508		

completely or disturbed.[116] Well levels may decline due to surface mining drawdown influences.[117] In addition, springs or seeps may be exposed, or groundwater otherwise released, wasting, groundwater to the mining pits.

Water in aquifers may also be impacted where groundwater is used for mining operations. At El Segundo Mine, for example, all of the mine's water comes from groundwater wells, and studies of this pumping have shown that over the life of the mine, the quantity of water in the aquifer, as well as the pressure of the aquifer, will be decreased for other users.[118] Recovery of groundwater resources at El Segundo will take 50 years or more.[119]

Second, when coal is extracted, other heavy metals and contaminants are disturbed as well. Left undisturbed, those materials may not present any issues, but when even naturally occurring toxics are unearthed and concentrated, those materials can cause extensive pollution. However, mining through aquifers and other pockets of groundwater releases water that can become contaminated. Stormwater going into or over the site adds to the problem.

This wastewater is often stored in holding or evaporation ponds. The Clean Water Act regulates discharges from mines into surface water through the National Pollutant Discharge Elimination System (NPDES) permit program.[120] Common pollutants of concern in Western mines include: pH, alkalinity, dissolved iron, total suspended solids (TSS) and sediment.[121] Other contaminants are also of concern. By way of example, the San Juan Mine NPDES permit includes the list of pollutants, in the table on the following page, that must be monitored and reported.[122]

Considering just a few of the chemicals reveals the potential for impacts to human health and the environment if releases occur. Arsenic is a known carcinogen and at high levels can cause death; lower levels can increase the risk of cancer of the skin, liver, bladder, and lungs, and can cause intestinal issues, serious skin issues, decreased production of red and white blood cells, which may cause fatigue, abnormal heart rhythm, blood-vessel damage resulting in bruising, and impaired nerve function causing a "pins and needles" sensation in your hands and feet.[123] Benzene is also a known carcinogen, and long-term exposure can cause leukemia; as a result, EPA has set a set a goal of waters free of benzene.[124] Carbon Tetrachloride is a probable carcinogen and causes liver and kidney damage.[125] Vinyl chloride is a known carcinogen; brain, lung, and some cancers of the blood are associated with moderate exposure."[126] The numerous other pollutants on the list are also associated with serious impacts to human health, and degradation of the environment.[127] Even more troublesome are the combined impacts from such a slew of contaminants.

Although discharges from San Juan Mine are supposed to be infrequent, EPA confirmed that sampling would provide a means of assessing the effectiveness of Best Management Practices at the mine.[128] Another mine owned and operated by San Juan Coal Company, La Plata Mine, continues to discharge water with levels of selenium and mercury that are above water quality standards, even after reclamation has been completed.[129]

Tailings piles are a third cause of contamination created by coal mining.[130] Tailings, or overburden and interburden, the material excavated to reach the coal seams, are placed in large piles while mining is underway.[131] These piles are exposed to wind and rain, and thus present a direct threat to air quality through wind erosion and to water quality through leaching until they are put back in the mining pits when reclamation occurs.[132] The extent of this source of pollution has not been adequately addressed.[133]

Coal Ash:

Placement of coal combustion waste (CCW) in mined out areas of coal mines is a significant and lasting source of pollution at coal mines. Both San Juan Mine and Navajo Mine have serious issues of contamination as a result of CCW disposal in the mine pits that are discussed in more detail in section IV(A)(2)(c).

Antimony (dissolved (D))	Arsenic (D)	Nickel (D)
Selenium (D)	Cyanide, weak acid	Carbon Tetrachloride
Benzene	Bromoform	1, 1,2,2-Tetrachloroethane
Thallium (D)	Zinc (D)	2,3,7,8-TCDD (Dioxin)
Acrolein	Acrylonitrile	Chlorobenzene
Clorodibromomethane	Chloroform	Dichlorobromomethane
1,2-Dichloroethane	1,1-Dichloroethylene	1,2-Dichloropropane
1,3-Dichloropropene	Ethylbenzene	Methyl Bromide
Methylene Chloride	Tetrachloroethylene	Toluene
1,2-trans Dichloroethylene	1,1,2-Trichloroethane	Trichloroethylene
Anthracene	Benzidine	Vinyl Chloride
Benzo(a)pyrene	2,3,7,8-TCDD dioxin	Hexachlorobenzene
PCBs	2-Chlorophenol	2,4-Dichlorophenol
2,4-Dimethylphenol	2-Methyl-4-6-Dinitrophenol	2,4-Dinitrophenol
Pentachlorophenol	Phenol	2,4,6-Trichlorophenol
Acenaphthene	Benzo(a)anthracene	Benzo(a)pyrene
Benzo(b)fluoranthene	Benzo(k)fluoranthene	Phthalate
Bis (2-chloroethyl)	Bis (2-chloroisopropyl)	Bis (2-ethylhexyl)
Butyl	Benzyl	2-Chloronapthalene
Chrysene	Dibenzo(a,h)anthracene	1,2-Dichlorobenzene
1,3-Dichlorobenzene	1,4-Dichlorobenzene	3,3-Dichlorobenzidine
Diethyl Phthalate	Dimethyl Phthalate	Dibutyl Phthalate
2,4-Dinitrotoluene	1,2-Diphenylhydrazine	Fluoranthene
Nitrobenzene	Gamma-BBC	Fluorene
Hexachlorobenzene	Hexachlorobutadiene	Hexachlorocyclopentadien
Hexachloroethane	Indeno (1,2,3-cd)	Pyrene
Isophorone	n-Nitrodimethylamine	n-Nitrosodi-n-Propylamine
n-Nitrosodiphenylamine	Pyrene	1,2,4-Trichlorobenzene
Aldrin	Ether Alpha-BHC	Beta-BHC
Phthalate	Chlordane	4, 4’-DDT and derivatives
Dieldrin	Alpha-Endosulfan	Beta-Endosulfan
Endosulfan sulfate	Endrin	Heptachlor
Heptachlor Epoxide	Endrin Aldehyde	Toxaphene

d. RECLAMATION

Although post-mining reclamation may address some of the impacts of coal mining, it is, at best, an approximation of the pre-mining environment. At worst, coal mining can permanently alter the fundamental structure, function, and composition of the pre-mining environment. Extraction of a layer of the earth, and disturbance of all that surrounded that layer has lasting, even irreparable, impacts.

As an initial matter, a significant interval exists between the commencement of mining and final reclamation. During that time, mining impacts accumulate. At Lee Ranch Mine, for example, mining began in 1984, and over 7000 acres have been disturbed. [136] None of that land has been reclaimed.[137] Similarly, at El Segundo Mine, over 3000 acres have been disturbed, but final reclamation has not occurred anywhere at the mine.[138] At San Juan Mine, mining began around 1973,[139] and over 5000 acres have been disturbed; only around 600 acres have been reclaimed.[140] Since 1957, over 13,255 acres have been disturbed at Navajo Mine, and only about 8000 acres have been reclaimed; furthermore, the application for expanded mining operations at Navajo Mine requests that contemporaneous reclamation requirements be relaxed, further slowing the rate of reclamation.[141] McKinley Mine was in operation from 1962-2009 with reclamation complete in 2012; impacts were thus occurring for 50 years, and other impacts to groundwater systems may continue to occur.[142] As noted above, even where reclamation has been completed, as at La Plata Mine, impacts may continue.

Furthermore, reclamation does not result in the same topography or geology as the pre-mining site, and thus water resources are changed from their pre-mining state. Arroyos may be impacted by mine subsidence.[143] Downstream flow may be altered by the use of sandier soils for reclamation, which are more permeable, and thus release less water downstream.[144] Reclamation also results in a more isotropic soil profile, thus changing groundwater flow. Moreover, as detailed below, where coal ash has been placed in mine pits, contamination may continue for decades after mining operations have ceased.

Active Mining and tailings piles at Navajo Mine[134]

Mine pit and spoils piles at Navajo Mine[135]

With the collapse of the coal industry in 2016, and the dubious self bonding practices applicable to many coal mines, it is doubtful that coal companies will have the financial fortitude to complete required reclamation.[145]

In sum, although regulation addresses some of the impacts of coal mining, altering the landscape and its watersheds in such a fundamental way necessarily results in pernicious effects to human health and the environment.

TABLE 3: REGULATION OF COAL MINING IN NEW MEXICO

Agency	Activity Regulated	Governing Statute	Permits Required
Environmental Protection Agency	Discharges to surface water, but there is an exemption from the NPDES program for discharges from conveyances at mining operations that carry storm water that has not been exposed to materials associated with development.[146]	Clean Water Act (CWA), section 402, 33 U.S.C. § 1342; exemption at § 1342(l)(2); 40 C.F.R. § 122.26(a)(2).	National Pollutant Discharge Elimination System (NPDES) permit[147]
United States Army Corps of Engineers	Discharge of dredged or fill materials into waters of the U.S., including wetlands.	Clean Water Act section 404, 33 U.S.C. § 1344.	Section 404 permit[148]
Navajo Nation or New Mexico Environment Department (depending on location of regulated activity)	Discharges to surface water and discharges of dredged or fill materials into waters of the U.S.	Clean Water Act, section 401, 33 U.S.C. § 1341.	CWA Section 401 certification (allows State or Tribe the opportunity to add conditions onto a 402 or 404 permit, or prevent issuance of the permit if certification is denied).
Office of Surface Mining Reclamation and Enforcement	Mine application renewals and expansions; must prevent damage to the hydrologic balance. Oversees state programs, issues permits on Tribal lands.	Surface Mining Control and Reclamation Act (SMCRA), 30 U.S.C. §§ 1201-1328.	Surface Mining Control and Reclamation Act permits
New Mexico Energy, Minerals and Natural Resources Department, Mining and Minerals Division	Mine application renewals and expansions to protect the hydrologic balance; does not regulate on Tribal lands in the state.	SMCRA; New Mexico Surface Mining Act, NMSA §§ 69-25A-1 – 69-25A-36	Mining permit
United States Bureau of Land Management	Coal leasing of federal mineral estate.	Mineral Leasing Act, 30 U.S.C. §§ 181 – 287.	Lease
United States Fish and Wildlife Service	Impacts to endangered and threatened species and their critical habitat	Endangered Species Act, 16 U.S.C. §§ 1531 – 1544.	Biological Opinion
Agency undertaking major federal action	Major federal actions, includes approvals for action	National Environmental Policy Act (NEPA), 42 U.S.C. §§ 4321-4370h; 40 C.F.R. §§ 1500.0-1518.4.	Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), or Environmental Impact Statement (EIS) and Record of Decision (ROD)
Environmental Protection Agency, Office of Resource Conservation and Recovery	Past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste which may present an imminent and substantial endangerment to health or the environment. Primarily an issue for CCW.[149]	Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901-6992k.	n/a
New Mexico State Engineer			Water permits

e. TRANSPORT TO COAL-FIRED POWER PLANTS/COAL DUST

Once coal is mined, it is delivered to field stockpiles, and then is typically loaded with large front-end loaders into railcars or trucks to be delivered to purchasers.[150] Along these routes, coal dust can impact water resources in the area.

Coal from Navajo Mine is delivered to stockpiles by truck, and then to Four Corners Power Plant via a 15-mile railway.[151] Each train has 20 railcars, each with 100- to 125- ton capacity, and is powered by an electric locomotive.[152] Historically, the trains have averaged 12 trips a day.[153]

Coal from San Juan Mine is delivered to San Juan Generating Station first by truck, and then by a conveyer to point of delivery at the power plant.[154]

Coal from Lee Ranch Mine is sent by rail to Escalante Generating Station (Tri-State) in Prewitt, New Mexico.[155] Lee Ranch previously supplied other plants in New Mexico, but those deliveries have been replaced by deliveries from El Segundo. [156]

Coal from El Segundo is sent by rail (in descending order of amount) to Cholla Power Plant (APS), near Joseph City, Arizona; Springerville Generating Station (SRP), near Springerville, Arizona; Apache Generating Station (AZ Electric Co-op) in Cochise, Arizona; Escalante Generating Station (Tri-State) in Prewitt, New Mexico, and Coronado Generating Station (SRP) near St. John's Arizona.[157]

Coal from McKinley Mine was delivered by rail to Cholla Power Plant (APS), near Joseph City, Arizona; Apache Generating Station (AZ Electric Co-op) in Cochise, Arizona; Coronado Generating Station (SRP) near St. John's, Arizona, and Irvington Station, near Tucson, Arizona, and Stone Container near Snowflake, Arizona.[158]

The transport of coal impacts water resources along the routes of the coal trains. As coal trains travel from mine to power plant, coal dust escapes from the cars, ending up in the air, soil, and water. According to BNSF Railway, when addressing the issue in the Powder River Basin:

> BNSF has done studies indicating that from 500 lbs to a ton of coal can escape from a single loaded coal car. Other reports have indicated that as much as 3% of the coal loaded into a coal car can be lost in transit. In many areas, a thick layer of black coal dust can be observed along the railroad right of way and in between the tracks.[159]

When it rains or snow melts this dust is then transported to local waterways.

The USGS is conducting studies to determine the extent of this pollution, specifically looking at the mercury and other coal-related chemical levels in air, water, sediment, and biota at sites near rail lines.[160] Already, the U.S. Surface Transportation Board has concluded that "coal dust is a significant problem" and that "coal dust poses a risk of harm to the environment."[161]

In New Mexico, coal from Navajo Mine is taken by rail to FCPP, and coal from Lee Ranch and El Segundo Mines is transported by rail to destinations in New Mexico and Arizona. Coal dust impacts have not been studied in New Mexico, but given the impacts in the Eastern United States, and in the Powder River Basin in Wyoming and Montana, it is fair to assume that there are potentially serious impacts here as well.[162] The impact of coal dust in New Mexico should therefore be studied to ensure that harm is not being done to scarce water resources, as well as more generally.

Navajo and San Juan mines are in close proximity to the power plants they supply. This proximity, however, does not mean that there are not impacts from coal transport and storage. Notably both of these plants are in close proximity to the

San Juan River, one of the larger river systems in the state. Coal piles at Four Corners Power Plant are directly adjacent to Morgan Lake, a lake used for fishing, wind surfing, and other recreation, and from which outflows return to the San Juan River.[163]

Coal preparation facility at FCPP, adjacent to Morgan Lake[164]

In addition to the direct impacts caused by coal mines, coal mines also supply the fuel that allows for, and encourages, the continuation of coal-fired electricity generation. Without "cheap" coal, coal-fired power plants are most certainly an inefficient choice (see San Juan/Navajo Mine issues). And coal-fired power plants themselves cause and exacerbate impacts to water, as discussed in the following section.

2. COAL COMBUSTION: COAL-FIRED POWER PLANTS

> "Severe drought in the Four Corners region, similar to the 2002 drought, could affect the availability of the SJGS and Four Corners plants because they use surface water for cooling." Public Service Company of New Mexico.[165]

San Juan Generating Station[166]

Four Corners Power Plant[167]

Escalante Generating Station[168]

San Juan Generating Station with Four Corners Power Plant in the background[169]

Coal-fired power plants, especially those located adjacent to the mines that supply them, add impacts to the very same water resources already impacted by coal mining. Coal-fired power plants use a significant amount of water, and as with coal mines, impact water resources even more broadly as a result of pollution both at the plants and through climate and air pollution that ends up in rivers and other water bodies hundreds of miles from the plants. These plants are also a significant contributor of greenhouse gases; according to the Energy Information Administration, coal-fired power emitted 71 percent of carbon dioxide emissions from the United States power sector.[170] Once the coal is burned, the disposal of coal combustion waste inside the mines compounds the impacts of coal-fired power to water resources.

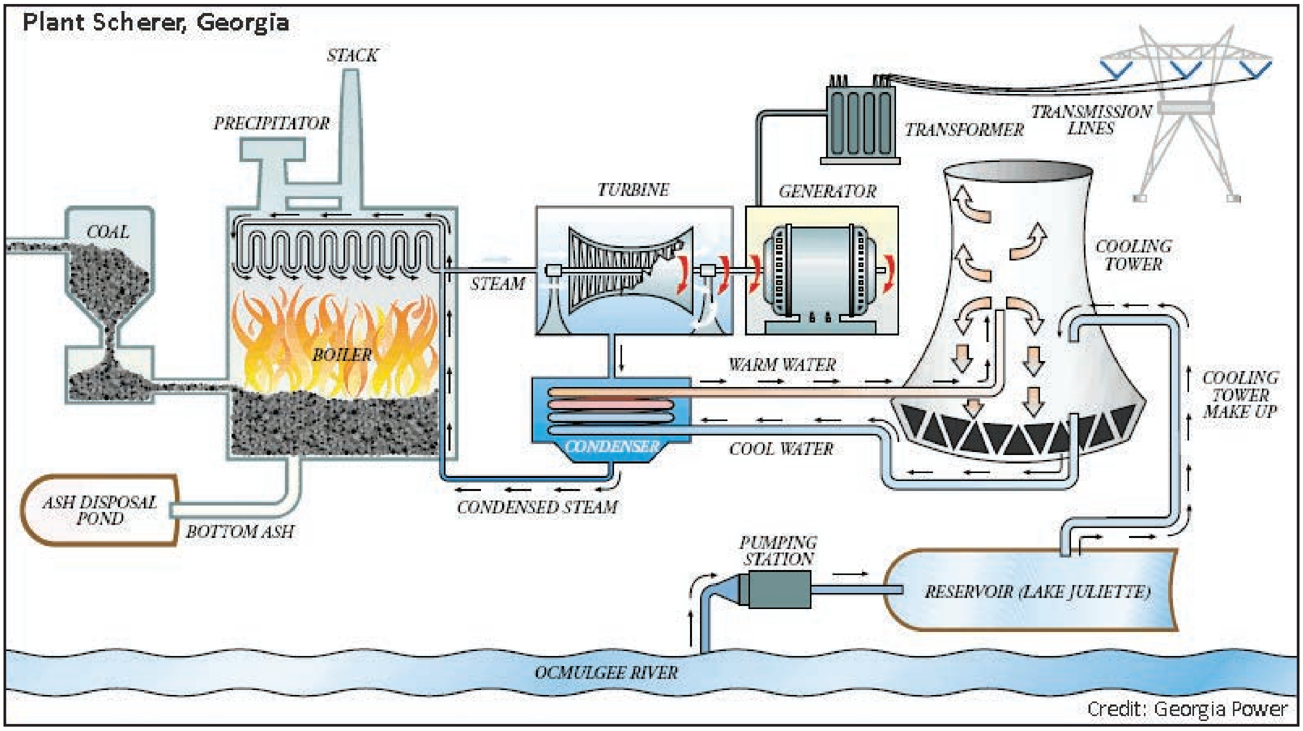
As with coal mines, this section will first outline how water is used in coal-fired power plants. Next, the amounts of water diverted from waterways, and the amounts of water consumed in the process are discussed. The impacts to this water during the coal combustion process are then detailed. Finally, the impacts to water from disposal and/or storage of coal combustion waste are addressed.

There are three coal-fired plants in New Mexico. Two are close to Farmington, New Mexico, and across the San Juan River from one another, just 8 miles apart. San Juan Generating Station is north of the river, and adjacent to San Juan Mine; Four Corners Power Plant is south of the river, and adjacent to Navajo Mine. The third plant is Escalante Generating Station, located near Prewitt, New Mexico.

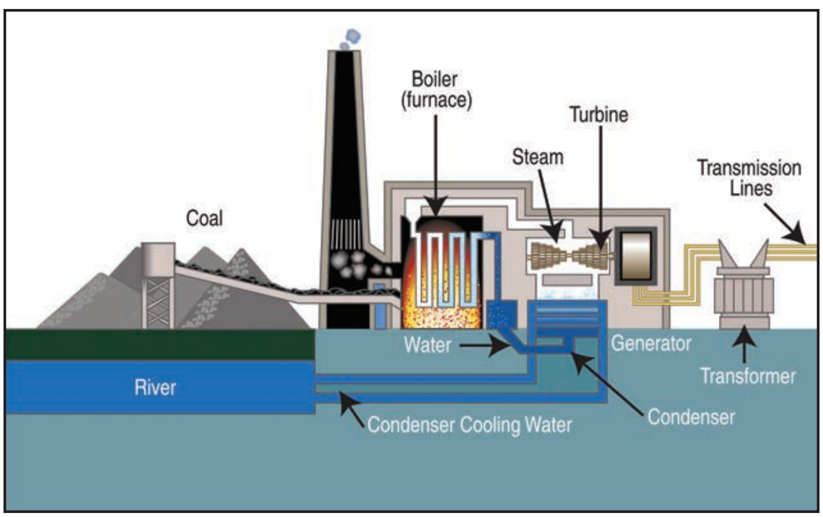
Perhaps this is one of the numbered maps, or does it simply need a caption?

a. PROCESS

Diagrams of coal-fired power plant with water usage:



Plant Scherer, Georgia. Credit: Georgia Power: *http://water.usgs.gov/edu/wupt-coalplant-diagram.html*



Credit: Tennessee Valley Authority, tva.com

Coal-fired power plants like the ones in New Mexico are thermoelectric plants, which use fuel to heat water to create high-pressure steam to drive a turbine; the turbine then rotates a generator, which converts the mechanical energy of the turbine into electricity.[171] As relevant for this section, coal is used to heat the water, but other fuels can be used, including uranium, oil, natural gas, biomass, geothermal energy, or concentrated solar energy.[172]

As noted above, coal is delivered to power plants by truck, train, and/or conveyor belt to storage silos.[173] The coal is then pulverized, and transferred to boilers where it is ignited.[174] Units 4 and 5 at FCPP, for example, burn approximately 19,000 tons of coal per day.[175] The heat energy given off during combustion is transferred through the furnace walls to convert water to steam.[176] The steam is then passed through super heaters, and heated to a temperature of 1000 degrees Fahrenheit.[177] This steam is used to turn a turbine, and the turbine's energy is used to rotate the shaft of an electric generator.[178] The electrical output is then transformed to a higher voltage, delivered to the adjacent switchyard, and ultimately delivered to transmission lines.[179]

Hot flue gases resulting from the combustion process pass through different types of filters. At FCPP units 4 and 5, flue gases pass through baghouses, which are fabric filters, and a desulfurization system before the gases are released out of the plant smokestacks.[180] The baghouses remove entrained fly ash, and the desulfurization system removes sulfur dioxide.[181] The ash is transported for disposal, as discussed in more detail below. The resulting sulfur dioxide is combined with a lime slurry, creating calcium sulfite and calcium sulfate solids, which precipitate and create FGD slurry.[182] That slurry is then transported to impoundment ponds or back to the scrubbers.[183]

b. WATER USAGE

Water has always been a constraint for thermal electricity generation, given the large volumes of water required for steam generation and cooling.[184] Tens of thousands of acre-feet of water are used for thermoelectric generation. The water rights for operations at San Juan Generating Station, FCPP, and Navajo Mine — rights totaling 51,600 acre-feet per year — are held by BHP Billiton New Mexico Coal, Inc.[185] FCPP also has an agreement with the Jicarilla Apache tribe for additional water if necessary.[186] Escalante Generating Station pumps groundwater for its operations, and holds rights to 6,440 acre-feet per year.[187] In total, coal-fired power plants in New Mexico divert and pump 53,622 acre-feet annually, and presently consume 42,256 acre-feet per year. For comparison, public water supply in all of New Mexico is 317,410 acre-feet/year.[188] The three coal-fired power plants in New Mexico use as much water as about 13% of the entire state population, the equivalent of about 271,000 people, or almost four times the population of Santa Fe.[189]

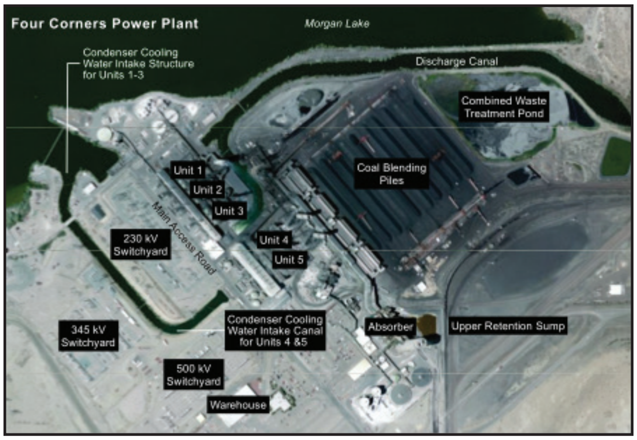
By way of example, at FCPP, operators pump water from the San Juan River to Morgan Lake for both water supply and cooling purposes.[216] Morgan Lake is directly adjacent to FCPP. Arizona Public Service Company constructed the man-made lake in 1961 for power plant needs.[217] On average, 27,682 acre-feet is diverted from San Juan River to FCPP each year.[218] At a constant rate of diversion, this amounts to the equivalent of a continuous diversion of 38 cfs for FCPP alone. FCPP historically has consumed 22,856 acre-feet per year of this water, so 83 percent of the water diverted has not been returned to the river.[219] Water is used at FCPP primarily for steam condenser cooling water; units 4 and 5, the two units that remain in service at FCPP, evaporate 13,000 acre-feet per year of cooling water alone.[220] Sulfur dioxide scrubbing requires a significant amount as well, with 5,000 acre-feet per year for units 4 and 5.[221] FCPP also uses water for air compressor and other equipment cooling water, dust control, washwater for vehicles and facilities, and domestic purposes.[222] In addition, Morgan Lake, with a capacity of 39,000 acre-feet, loses 7,432 acre-feet per year to evaporation; it gains about 472 acre-feet from precipitation, resulting in a net loss of 6,960 acre-feet per year, or about 18 percent of Morgan Lake's total capacity.[223]

The physical diversion from the San Juan River consists of two 10-foot by 10-foot intake bays. The intake bays are located just upstream of an Arizona Public Service weir, which has a control gate so that the water depth can be controlled at the intake location.[224] The intake pumps run approximately 80 percent of the time, and are operated in two modes, pumping either 37 cfs (17,000 gallons per minute (gpm)), generally from October to May, or 71 cfs (32,000 gpm), generally from May to October.[225] The different rates are driven primarily by the evaporation rate of Morgan Lake.[226] Diversions from the San Juan River for both FCPP and San Juan Generating Station can take up to 200 cubic feet per second (cfs) from all diversion points at any one time.[227] From 2000-2014, the San Juan River's flows at Farmington have been as low as 510 cfs, and winter flows average around 800 cfs.[228] Thus, at lower flows, power plant diversions can take over one third of the river's flow, and for nine months out of the year (excluding spring run-off), FCPP and San Juan Generating Station can divert from one third to one sixth of the river's flow.

TABLE 4: WATER FOR COAL-FIRED POWER PLANTS IN NEW MEXICO

Power Plant	Water Diverted (acre-feet per year)	Water Consumed (acre-feet per year)	Water Used (gal per MWh)	Water Source	Water Discharges	Type of Cooling Technology	Coal Source	Plant Capacity (MW)/ Capacity Factor
Escalante Generating Station	6,440[190]	3,646[191]	667[192]	Underground wells[193]	Evaporation Ponds[194]	Recirculating[195]	El Segundo Mine; Lee Ranch Mine[196]	245[197] 77%[198]
Four Corners Power Plant	27,682[199]	19,110[200]	577[201]	San Juan River (via Morgan Lake)[202]	Morgan Lake to No Name Wash to Chaco River to San Juan River	Cooling pond/wet recirculating[203]	Navajo Mine[204]	1,540[205] 80%[206]
San Juan Generating Station	19,503[207]	19,503[208]	593[209]	San Juan River[210]	PNM asserts that SJGS is a no discharge facility[211]	Recirculating[212]	San Juan Mine[213]	1,683[214] 85%[215]
TOTAL AVERAGE	53,625	42,259	612					3468

Morgan Lake is also used to recirculate and cool down condenser cooling water from FCPP.[229] Cooling water from the main condensers and other equipment condensers is discharged to the condenser cooling water discharge canal, which then flows into Morgan Lake. [230] APS circulates from 1 to 1.7 billion gallons of cooling water per day through Morgan Lake.[231] Water is also periodically discharged, at a daily maximum flow rate of 14.7 million gallons per day (23 cfs), from Morgan Lake to No Name Wash which flows to Chaco Wash, which in turn flows back to the San Juan River, about 5 miles northwest of the plant. [232] Water discharged to Morgan Lake is approximately 105 °F.[233] Morgan Lake's water temperature ranges from 65°F to 90°F.[234] Discharges from Morgan Lake to No Name Wash are to remain under a daily maximum of 95°F.[235] By contrast, water temperature in the San Juan River upstream near Farmington generally ranges from 35°F to 75°F.[236]



Four Corners Power Plant[237]


Four Corners Power Plant[238]

c. IMPACTS

• Amount Diverted

As noted above, the amount of water diverted at Four Corners Power Plant and San Juan Generating Station can be a significant percentage of the San Juan River's flow. Furthermore, given that the majority of that diversion is consumed at the plants, largely through evaporation, a significant amount of water is taken from the watershed permanently. As the USFWS explained:

> [N]atural flow regimes are essential to the ecological integrity of large western rivers (USFWS 1998) and for the maintenance or restoration of native aquatic communities (Lytle and Poff 2004, Propst and Gido 2004, Propst et al. 2008). The flow regime works in concert with the geomorphology of the basin to establish and maintain the physical, chemical, and biological components of a stream ecosystem.
>
> To the extent that water is exported out of the basin (San Juan-Chama Project) or consumptively used (e.g., evaporation from fields, irrigation canals, reservoir surface) it is not available to maintain flows within the river.[241]

Climate change exacerbates water scarcity issues; it is anticipated that climate change will create additional depletions of 8 to 45 percent to the San Juan River.[242] The San Juan River is already a heavily impacted watershed; such large withdrawals in such close proximity tax the river further.

TABLE 5: REGULATION OF COAL-FIRED POWER IN NEW MEXICO

Agency	Activity Regulated	Governing Statute	Permits Required
U.S. Environmental Protection Agency	Discharges to surface water	Clean Water Act (CWA), section 402, 33 U.S.C. § 1342.	National Pollutant Discharge Elimination System (NPDES)
U.S. Environmental Protection Agency	Air emissions	Clean Air Act, 42 U.S.C. §§ 7651 – 7651o; 7661 – 7661f.	Title V permit; Title IV Acid Rain Permits[239]
Tribal authorities or New Mexico Environment Department (depending on location of regulated activity)	Discharges to surface water and discharges of dredged or fill materials into waters of the U.S.	Clean Water Act, section 401, 33 U.S.C. § 1341.	CWA Section 401 certification (allows State or Tribe the opportunity to add conditions onto a 402 or 404 permit, or prevent issuance of the permit if certification is denied).
United States Fish and Wildlife Service and Navajo Nation	Impacts to endangered and threatened species and their critical habitat	Endangered Species Act, 16 U.S.C. §§ 1531 – 1544.	Biological Opinion
Tribal authorities (where power plant is located on tribal land)	Impacts to cultural resources	National Historic Preservation Act, 16 U.S.C. §§ 470 – 470x-6.	
Agency undertaking major federal action	Major federal actions, includes approvals for action	National Environmental Policy Act (NEPA), 42 U.S.C. § 4321 *et seq.*	Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), or Environmental Impact Statement (EIS) and Record of Decision (ROD)
Public Regulation Commission	Public Utilities- rates and changes to facilities	New Mexico Public Utility Act, NMSA §§ 62-3-1 *et seq.*	Certificate of Public Convenience and Necessity (CCN)
Environmental Protection Agency, Office of Resource Conservation and Recovery	Past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste which may present an imminent and substantial endangerment to health or the environment. Primarily an issue for CCW.[240]	Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901-6992k.	n/a
New Mexico State Engineer	Water rights; dam safety.	NM Stat. § 72-1-1 *et seq.*; NM Stat. § 72-5-32 *et seq.*	Water right permit; Dam permit.

• Water Intake

Operations related to FCPP and SJGS affect the endangered fish and other species in the San Juan River. The San Juan River is home to endangered species of fish including the Colorado pikeminnow, and the razorback sucker. The United States Fish and Wildlife Service has determined that the long-term viability of these species remains uncertain because of relatively limited or degraded habitat between the Navajo Dam and Lake Powell.[243] Without help, the species will be extirpated from the San Juan River in 20 to 30 years.[244] Threats to the fish include water diversions, depletion of water, non-native species, limited habitat and diminished water quality.[245]

FCPP and SJGS contribute to these impacts in numerous ways. As noted above, diversions from the river are significant, depleting water supply for endangered species. Water quality is also degraded, as discussed below. In addition, weirs used to hold water at adequate levels for diversion impede fish passage.[246] The SJGS weir, at River Mile 166, prevented fish passage until 2003 when a selective fish ladder was completed.[247] However, not far downstream, the FCPP weir, at River Mile 163.3, continues to inhibit fish passage.[248] The FCPP weir is a concrete structure that crosses the entire river; this weir prevents fish passage to habitat upstream from the weir whenever the control gate for the structure is closed.[249] In its most recent Biological Opinion, the USFWS required that APS modify the weir, which will "allow endangered fish increased access of up to 18 miles of fish habitat, including new portions of Colorado pikeminnow critical habitat."[250] Although changes to the weirs are a positive step, decreased habitat has been a factor in the species' decline.[251]

The fish are also impacted by the intake itself. Aquatic organism impingement and entrapment at the intakes is a serious issue, and the subject of new regulation. As the EPA has explained:

> The withdrawal of cooling water by existing facilities removes and kills hundreds of billions of aquatic organisms from waters of the United States each year, including plankton (small aquatic animals, including fish eggs and larvae), fish, crustaceans, shellfish, sea turtles, marine mammals, and many other forms of aquatic life. Most impacts are to early life stages of fish and shellfish. Aquatic organisms drawn into [cooling water intake structures] are either impinged (I) on components of the intake structure or entrained (E) in the cooling water system itself.
>
> The beneficiaries of fish protection at cooling water intakes include fisherman, both recreational and commercial, and people interested in well-functioning and healthy aquatic ecosystems. [252]

The FCPP intakes have screens that have openings of about 1 inch by 3 inches, and the velocity toward the screen is 0.38 cfs.[253] There are not any fish collection or return facilitates at the intake, and fish, larvae and eggs can become entrained in the screen.[254]

The USFWS required that APS modify the intake to "optimize avoidance of entrainment of larvae and impingement of larger fishes." [255] Unfortunately, the USFWS's mandate is weakened in that it only required APS to modify the intake to the extent it can "without altering the current operating configuration" of pumping to serve FCPP. [256] According to the EPA, the intake screens meet requirements for interim best technology available, but they may have to be upgraded to meet more stringent requirements in the next permit cycle.[257] Thus, current compliance is satisfactory only from a regulatory standpoint; impacts continue to occur at levels that reveal the need for more stringent technology.

• Water Pollution

Thermoelectric facilities like those in New Mexico also cause pollution to water around plants, and have the potential to cause even greater pollution if something goes awry. Pollution is generated in coal preparation water, cooling water, boiler blowdown, bottom ash, and fly ash, all of which contain heavy metals, toxics, chemicals like chlorine used for water treatment at the plant, as well as thermal pollution.[258]

At FCPP, for example, one outfall discharges from a combined waste treatment pond that treats 8 to 13 million gallons per day of various waste streams, including stormwater runoff from the plant.[259] These discharges are blended with cooling water, but then discharged to Morgan Lake.[260] Selenium warnings have been issued for Morgan Lake,[261] and the BLM has warned of mercury in bottom sediments.[262] Morgan Lake is nevertheless open to recreation, including fishing, and it is touted as a recreation destination and asset.[263]

At Escalante Generating Station, 1,440,000 gallons of wastewater per day are discharged to evaporation lagoons; three of the lagoons are clay-lined, two of them have synthetic liners.[270] Discharges contain contaminants or toxic pollutants which may be elevated above water quality standards. [271]

- Coal Combustion Waste

Coal Combustion Waste ("CCW") consists of the bottom ash, scrubber sludge and fly ash left over from the combustion of coal.[272] Bottom ash accumulates along the inside walls and floors of the boiler units.[273] By way of example, Units 4 and 5 produce approximately 40 tons of bottom ash per hour during full load conditions.[274] This ash is removed by a hydraulic-vacuum system and is then transported via sluice water pipelines to dewatering bins, where the water is decanted.[275] Fly ash consists of the small particles that are driven out of the boiler with the flue gas, and then are captured by filtration equipment.[276] At FCPP, fly ash constitutes approximately 80 percent of the total ash output; units 4 and 5 produce about 150 tons per hour during full load conditions.[277] A fly ash handling system removes the fly ash from filtration system, or baghouses, and conveys the ash to silos for storage.[278] The ash is then mixed with scrubber process water for dust control and compaction purposes.[279]

At least seventeen potentially toxic elements are commonly present in CCW: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, hexavalent chromium, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, zinc and radionuclides.[280] When CCW becomes exposed to water, leaching of these toxic elements can occur.[281] The U.S. Environmental Protection Agency recently determined that coal ash, due to the potential presence of numerous toxics, can pose a "substantial present or potential hazard to human health and the environment when improperly treated, stored, transported, disposed of."[282] Additionally, "the cancer risk associated with arsenic ingestion via [the groundwater ingestion and fish ingestion pathway] emerged as a principal factor in the [EPA's CCW human health risk assessment] report's conclusion that there are 'potentially significant risks to human health from CCW disposal in landfills and surface impoundments.'"[283] Even more troubling is the fact that CCW wastes often generate a complex mixture of com-

Despite the fact wastewater is discharged into a lake that is simultaneously touted as a recreational area, Morgan Lake lies in a regulatory dead zone. Morgan Lake and FCPP are located on land owned by the Navajo Nation and leased to APS.[264] Thus, ordinarily, Navajo Nation water quality standards would apply to the lake.[265] The Navajo Nation EPA ("NNEPA") has determined that water quality at Morgan Lake should support primary human contact, secondary human contact, fish consumption, aquatic life and habitat, and livestock watering.[266] However, a provision in the lease agreement between APS and the Navajo Nation exempts FCPP from tribal regulation.[267] As such, it is unclear how EPA arrived at effluent limitations for FCPP's discharges into Morgan Lake. However, what is apparent from the current and draft NPDES permits is that effluent limitations for the outfalls from FCPP to Morgan Lake are limited. The current and new draft permit include only standards for pH, chlorine, oil and grease, iron, copper, and total suspended solids, and do not include consideration of the numeric standards NNEPA has adopted as necessary to support the designated uses.[268] Notably, the permits do not include consideration of mercury or selenium, both of which have been identified as water quality concerns at Morgan Lake.[269]

pounds that can have adverse synergistic effects on those exposed to the mixed wastestream.[284] As a result, risk assessments often underestimate the risk to human health from exposure to CCW waste because the entire effect of exposure to each compound is not accounted for.[285]

According to the EPA, "coal fly ash is one of the largest waste streams generated in the United States."[286] New Mexico's plants demonstrate that fact: FCPP units 4 and 5 alone produce 190 tons of CCW per hour at full load. [287] This ash must be disposed of, and unfortunately, disposal presents a serious risk to water resources.

FCPP disposed of CCW in unlined mine pits at Navajo Mine from 1962 until 2008.[288] This practice was discontinued in 2008, resulting in the disposal of the majority of CCW in Ash Disposal Areas at the FCPP site beginning in 2008, and continuing to the present.[289] Disposal is expected to remain at FCPP throughout the remaining life of FCPP. [290] From 1962 to the present, approximately 33.5 million tons, or 20,800 acre-feet, of fly ash, bottom ash, and Flue Gas Desulfurization (FGD) solids have been placed into the FCPP ash disposal areas.[291] To visualize that weight, consider that it is the equivalent to more than 82 Empire State Buildings, or 240,000 blue whales.[292] OSM has calculated the "Navajo Mine On-site Land Disposal Release of Toxic Release Inventory Chemicals," to include between 1.5 million and 2.2 million pounds of toxic chemicals in CCW in each year between 2002 and 2007, including arsenic, barium, lead, mercury, selenium, and thallium.[293]

Operators of the San Juan Generating Station also disposed of CCW, including precipitator ash, bottom ash, waste water sludge, flue gas desulfurization sludge, and other power plant wastes, into unlined surface pits at the San Juan Mine.[294] From 1973 to 2010, operators of SJGS disposed of at least 40 million tons of CCW in unlined pits that range from 50 to 200 feet deep, one hundred to several hundreds of feet wide, and several hundreds to several thousands of feet long.[295]

Escalante Generating Station also disposes of coal ash on-site. A dry-ash handling system is used to process the coal combustions wastes, which include "fly ash, bottom ash, flue gas emission control residuals (i.e., scrubber sludge/flue gas desulfurization (FGD) solids) and wastewater solids."[296] Over 35 percent of the CCW from the plant is sold for reuse in concrete and cement. [297] The remainder of the CCW materials are dewatered, some in evaporation ponds, and then placed in an on-site landfill.[298]

Recent studies show that groundwater contaminated by CCW can migrate quickly and extensively — during the lifetime of operations at a coal plant rather than on the order of hundreds to thousands of years.[299] The impacts at FCPP, Navajo Mine, and San Juan Mine are illustrative.

> At the Four Corners Power Plant, boron and selenium downstream from the plant's coal ash ponds are much higher than upstream levels and approximately twice the levels established to protect aquatic life.[300]

CCW constituents, including selenium, are migrating into the San Juan River ecosystem.[301] More specifically: "[t]he Chaco Basin surface water quality data collected and analyzed in this study are strongly indicative that CCW disposal practices at the mine and power plant have adversely impacted the water quality of the Chaco River, a tributary to the San Juan River."[302]

Although the exact placement of all CCW at Navajo Mine is "unknown," at least two of the pits where CCW is present are now saturated with groundwater.[303] This groundwater may be affecting the Chaco River alluvium, and the San Juan River, which the Chaco River feeds; mercury, cadmium, and lead have been detected above standards for designated uses.[304] Other downstream samples showed concentrations of TDS, selenium, and sulfate were more than three times higher than upstream concentrations; boron was almost 12 times greater than upstream concentrations.[305] Another study showed significant increases in downsteam samples of boron, copper, lead, zinc, and mercury. [306]

San Juan Mine exhibits similar issues, with concentrations of arsenic, barium, boron, cadmium, chromium, flouride, lead, nitrate, selenium, uranium, and sulfates in wells down gradient of CCW disposal areas.[307] Surface water samples downstream of disposal areas also showed selenium, sodium, chloride, sulfate, and total dissolved solids above standards.[308] Concerns about contamination at San Juan Mine led to a lawsuit and a ten million dollar settlement, with provisions to contain waters polluted by CCW.[309]

Additional contamination is likely; although those impacts may not occur for decades after mine closure, once "groundwater within the mine spoil has rebounded," those impacts will become more evident.[310]

• Air Pollution to Water

In addition to direct discharges, or seepage from coal ash disposal, water quality is affected in and around (sometimes significant distances away as well) as a result of air pollution from coal-fired power plants.[311] Numerous sources, including FCPP and SJGS, have deposited mercury in and around the San Juan Basin.[312] At Mesa Verde National Park in the San Juan River Basin, only 35 miles north of FCPP and SJGS, total mercury concentrations in dry deposition and/or precipitation are among the highest measured in the United States, and trajectories tracing back to the FCPP/SJGS area support the theory that those plants are contributing to mercury deposition in the San Juan River Basin.[313]

The majority of mercury deposition is on land rather than in rivers or lakes themselves.[314] Over time, however, some of these deposits are carried over land in storm water or snow melt to New Mexico waterbodies.[315] Once atmospheric mercury is deposited, it can be converted to a biologically available form.[316] The USFWS model predicts that mercury concentrations in the San Juan River and fish tissue will increase over time because the watershed has not yet equilibrated with the rate of atmospheric deposition in the San Juan River basin.[317]

Statewide, mercury contamination is the single largest cause of impairment of water quality standards in New Mexico's lakes and reservoirs.[318] Fish tissue mercury contamination occurs in 60,000 acres, or 63.5 percent, of New Mexico's 94,415 assessed lake and reservoir acres.[319]

Selenium is another contaminant of concern as it is toxic in higher concentrations.[320] Selenium is a natural component of coal, and can be released when coal is burned, and deposited to land and water through coal plant emissions and/or coal ash.[321] Selenium can also be released from oil refineries, compounding the problem in an area, like the San Juan Basin, where both coal and oil and natural gas development occur.[322] "Water depletions, by reducing dilution effects, can increase the concentrations of selenium and other contaminants in water, sediments, and biota (Osmundson et al. 2000)."[323]

The additive and synergistic cumulative impacts of coal mines, coal plant emissions, emissions from oil and natural gas development, oil and natural gas plants, and the interaction of the various contaminants[324] all serve to degrade water quantity and quality, further undermining the resiliency of this important ecological system in the face of climate change—an event caused, in the first place, by anthropogenic climate pollution, in particular carbon dioxide from coal-fired power plants.

B. OIL AND NATURAL GAS: PRODUCTION AND COMBUSTION

Oil and gas production, including unconventional oil and gas production (which constitutes an expanding share of the nation's energy supply) is vulnerable to decreasing water availability given the volumes of water required for enhanced oil recovery, hydraulic fracturing, and refining.[325]

Like coal, both the production and combustion of oil and natural gas impact water resources in significant ways. The increased production of oil and natural gas through hydraulic fracturing threatens water supplies in new and frightening ways. Combustion of natural gas, though often touted as a "cleaner" alternative to coal-fired plants, uses large amounts of water and the lifecycle impacts of natural gas production call into question any claim that it is a "clean" alternative.

This section will first consider the process by which oil and natural gas are produced. Next, the impacts of production on water resources are outlined.

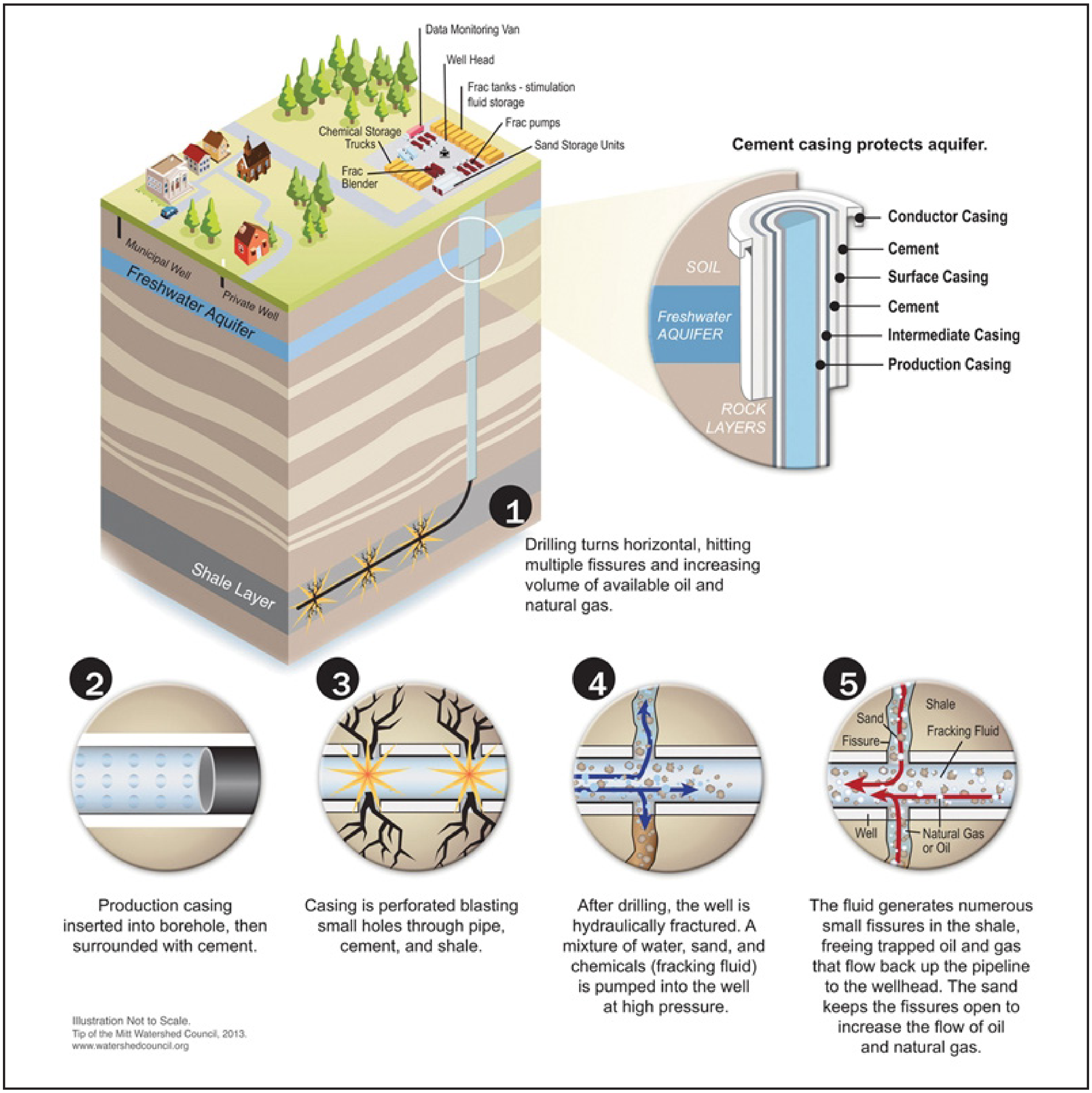
1. OIL AND NATURAL GAS PRODUCTION

Roads and well pads from oil and natural gas development around Farmington.[326]

a. PROCESS

Oil and natural gas production has undergone a boom due to the access that horizontal drilling and hydraulic fracturing — often used in tandem — provide to previously inaccessible oil and natural gas deposits.[327] "Excluding federal offshore areas, New Mexico ranked sixth in crude oil production in the nation in 2013."[328] "New Mexico's marketed production of natural gas accounted for 4.8% of U.S. marketed natural gas production in 2012, despite a decline in statewide production of 20% between 2007 and 2012."[329] Water plays a role in every step of oil and natural gas production.[330]

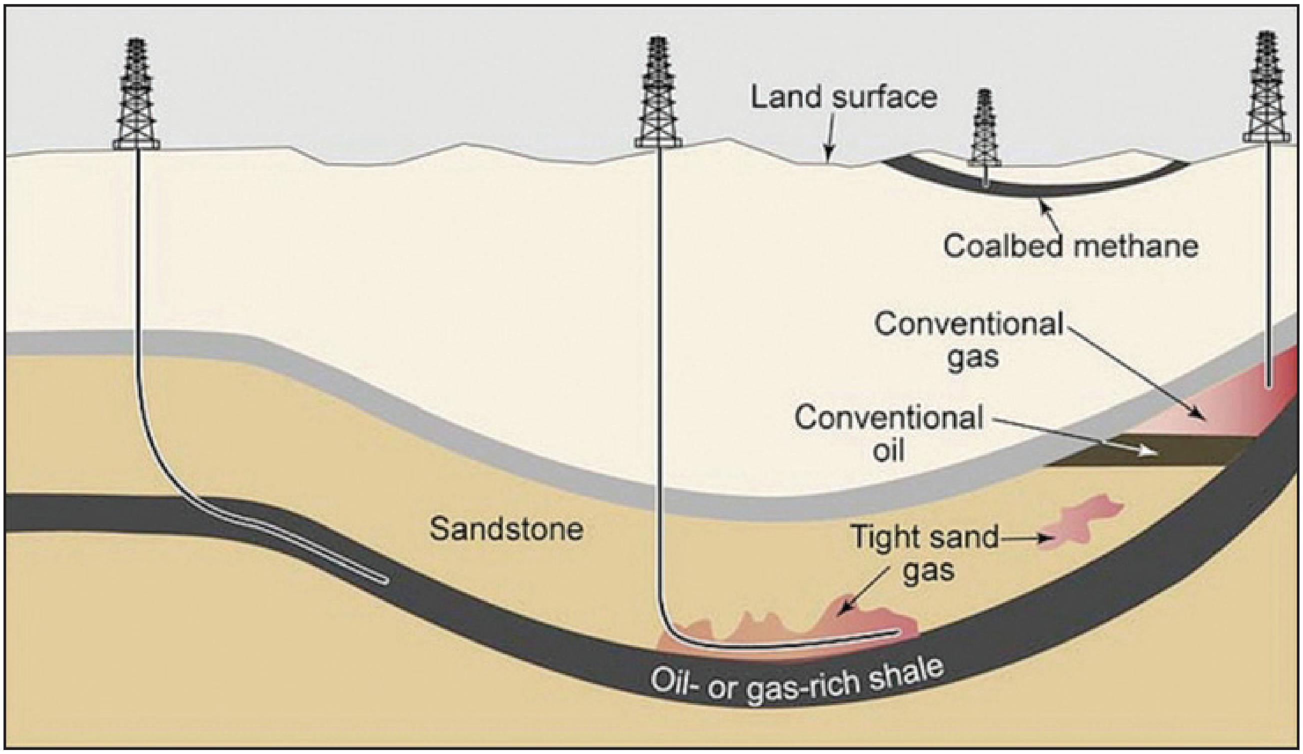
To understand the issues and water impacts associated with oil and natural gas production, it is very helpful to have some understanding of the process by which these fuels are extracted.[332]



Tip of the Mitt Watershed Council diagram[331]

Oil and natural gas deposits exist in geologic formations at various depths below the surface; conventional resources are found at fairly shallow depths while unconventional, or low permeability, natural gas resources are found in geologic formations ranging from 1,500 to 15,000 feet (1/4 to almost 3 miles) below the surface.[333] Although formations that are tapped for oil and natural gas development are generally below aquifers, in some cases the target formation can be above the aquifer, presenting different issues.

Once an oil and/or natural gas deposit has been identified, extensive infrastructure is put into place to allow for access to a well site. This infrastructure includes roads built to sustain heavy loads, well pads, water reserve pits and tanks, disposal



U.S. Energy Information Administration and U.S. Geological Survey diagram.[334]

wells, pipelines, and compressor stations.[335] The well is then drilled to tap the deposit. Wells may be drilled vertically (as is the case with most conventional deposits), or vertically and then horizontally into a deposit (unconventional wells).[336]

The natural pressure of the earth may allow some of the oil and/or gas to come to the surface, but in most current wells, to increase the flow, a mixture of chemicals, sand, and often large volumes of water under pressure high enough to crack impermeable rock formations (10,000-20,000 psi) is injected into the well.[337] New Mexico and other large oil and natural gas producing states estimated that in 2012 78-99 percent of new oil and natural gas wells in those states were hydraulically fractured.[338] Wells might be drilled 1-3 kilometers (0.6 - 1.8 miles) horizontally, and divided into twenty 100-meter long stages.[339] Sand or another proppant is used in the mixture to prop open fractures to allow trapped oil and natural gas to flow to the surface.[340] Hydraulic fracturing is now being used in both conventional and unconventional deposits.[341]

Numerous chemicals and compounds are often added to the water used to fracture oil and natural gas wells. The Endocrine Disruption Exchange ("TEDX") has documented nearly 1,000 products energy companies inject into the ground in the process of extracting natural gas. Many of these products contain chemicals that are harmful to human health. According to TEDX:

> In the 980 products identified…[for use during natural gas operations], there were a total of 649 chemicals. Specific chemical names and CAS numbers could not be determined for 286 (44%) of the chemicals, therefore, the health effects summary is based on the remaining 362 chemicals with CAS numbers…Over 78% of the chemicals are associated with skin, eye or sensory organ effects, respiratory effects, and gastrointestinal or liver effects. The brain and nervous system can be harmed by 55% of the chemicals. These four health effect categories…are likely to appear immediately or soon after exposure. They include symptoms such as burning eyes, rashes, coughs, sore throats, asthma-like effects, nausea, vomiting, headaches, dizziness, tremors, and convulsions. Other effects, including cancer, organ damage, and harm to the endocrine system, may not appear for months or years later. Between 22% and 47%

> of the chemicals were associated with these possibly longer-term health effects. Forty-eight percent of the chemicals have health effects in the category labeled 'Other.' The 'Other' category includes such effects as changes in weight, or effects on teeth or bones, for example, but the most often cited effect in this category is the ability of the chemical to cause death.[342]

Large amounts of water are contaminated by the fracturing process. [343] Flowback water" returns to the surface directly after hydraulic fracturing and can include water from geological formation as well as the chemicals injected in the hydraulic fracturing fluids.[344] A percentage of the hydraulic fracturing fluids remain in the geologic formation and do not "flowback." Water also returns to the surface with the oil and natural gas being pumped and is known as "produced water."[345]

b. WATER USAGE

Water requirements for oil and natural gas development vary dramatically depending on the region, the specific deposit being accessed, and the method of production. Accordingly, and because the impacts are often felt most starkly on the local level, the amount of water used for oil and natural gas drilling is best understood in a local context.[346] Understanding these impacts can, however, be difficult because there is inconsistent or no data on where water is sourced, when it is sourced, how much is used and consumed, and how it is disposed of.[347] To properly understand these impacts, better local data is therefore essential.

Drilling for conventional natural gas or oil resources uses a relatively modest amount of water, primarily "for preparing drilling fluid (cleaning and cooling of the drill bit, evacuation of drilled rocks and sediments, providing pressure to avoid collapse of the well).[348] Drilling for conventional oil resources uses more than conventional natural gas, but still uses much less water than unconventional deposits.[349]

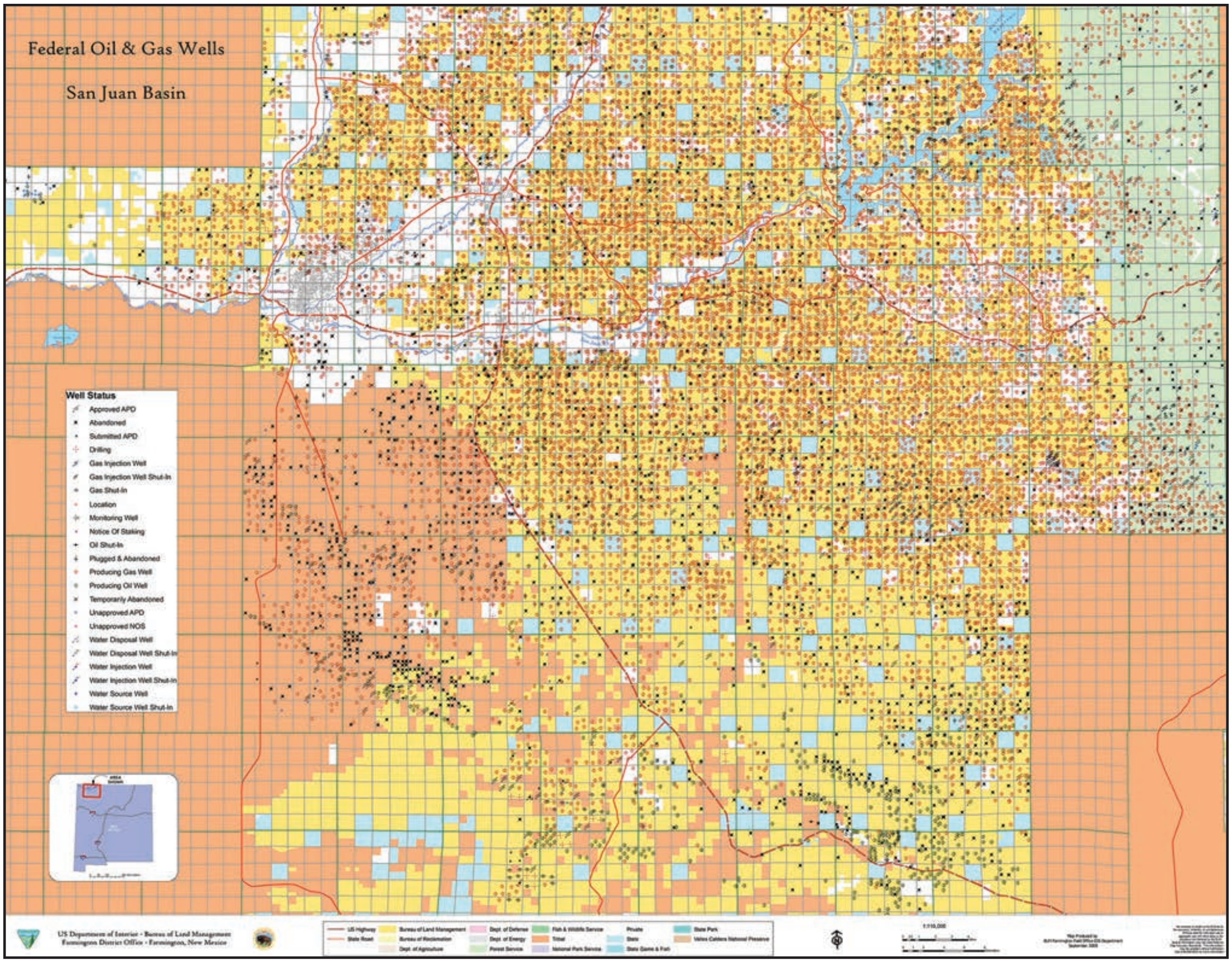
Extracting natural gas and/or oil from unconventional deposits, such as tight oil and natural gas or shale formations, on the other hand, requires large amounts of water for each well.[350] Although the amount per well varies significantly, the typical range cited is from 1 million to 6 million gallons per well, with the upper end seeming more common for unconventional deposits. [351] Extracting natural gas versus oil deposits can impact how much water is used as well.[352] In New Mexico, development has traditionally been for natural gas, but with the ability to access shale oil, oil is increasingly becoming a target in current development.[353]

The majority (90 percent) of this water is for hydraulic fracturing, not for the drilling itself.[354] Water for hydraulic fracturing can come from surface water supplies, groundwater, municipal sources, transfers from agricultural transfers, or reused water from oil and natural gas operations or other sources.[355]

Nationally, the EPA estimates that 11,000 wells are fractured each year.[356] At the low range of 4 million gallons per well, and 11,000 wells per year, 44 billion gallons of water is required each year for oil and natural gas drilling operations. That is the equivalent of a continuous flow of 186 cfs or 135,000 acre-feet per year, enough water for 1.2 million people for one year.[357] As those wells rapidly become unproductive, new wells must be drilled and hydraulically fractured to maintain production.[358] Some wells are hydraulically fractured multiple times; while this practice may decrease the number of wells that need to be drilled, and thus may decrease total land disturbance, refracturing can take twice as much water as the original hydraulic fracturing step.[359]

In New Mexico, historical numbers do not tell the whole story as unconventional drilling has increased dramatically in recent years. In 2010, the State Engineer reported that 2,244 acre-feet were used for oil and natural gas development.[360] However, with increased development the amounts of water needed for hydraulic fracturing and horizontal drilling for shale gas and oil have increased.[361] Looking at current and forecasted development in the San Juan and Permian Basins reveals that water usage is now around 12,500 acre-feet per year.[362] As the BLM noted in its Reasonable Foreseeable Development Scenario for the Permian Basin: "The need for fresh water for stimulation (hydraulic fracturing) in horizontal wells will be a serious problem for the dry southwest."[363]

In Northwest New Mexico, in particular, boom and bust cycles have been endemic since oil and natural gas drilling and development started in the 1920s.[364] Estimates are that the San Juan Basin has 40,000 existing oil and natural gas wells with many plugged and abandoned wells that may or may not be properly cased/cemented.[365]



Data from the Energy Information Association illustrates the number of oil and gas wells in the San Juan Basin. The blue dots represent gas wells (natural gas and coalbed methane) and the pink dots represent oil wells. You can explore this EIA data here.[366]

New technologies may decrease the amount of estimated water per well. Strategies such as using recycled water, produced water, or nitrogen foam are implemented at some wells. However, these methods come with their own set of issues. Nitrogen foam, for example, can reduce the water usage of a well by 70 percent,[367] but a 70 percent reduction in a hydraulically-fractured horizontal well still requires around 1 million gallons to produce.[368] Furthermore, the initial oil or gas produced by nitrogen foam-fractured wells usually consists of about 60-70 percent nitrogen. Oil or gas cannot be put in a pipeline until it has only 6 percent nitrogen content, and thus this initial oil or gas must be flared off usually for 60 to 90 days.[369] Aside from the air quality issues that flaring causes, flaring the oil or gas decreases the production of the well, thus leading to drilling more wells, which require more water and/or nitrogen foam.[370]

TABLE 6: REGULATION OF OIL AND NATURAL GAS DEVELOPMENT IN NEW MEXICO

Agency	Activity Regulated	Governing Statute	Permits Required
Environmental Protection Agency	Discharges to surface water. However, National Pollutant Discharge Elimination System ("NPDES") permits are not required for "exploration, production, processing, or treatment operations or transmission facilities" where storm water discharges do not come into contact with or are not contaminated by "any overburden, raw material, intermediate products, finished product, byproduct, or waste products located on the site of such operations."[371] Discharges of produced water are covered.[372]	CWA section 402, 33 U.S.C. § 1342; exemption at § 1342(l)(2), 40 C.F.R. § 122.26(a)(2); *see also* § 1362(24) (definition of "oil and gas exploration and production."	NPDES permit.
Environmental Protection Agency	Regulates and protects drinking water supplies, and sources of drinking water. Also regulates injection wells to protect underground drinking water resources from via the Underground Injection Control Program, but another exemption excludes from regulation "the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities."[373] Where diesel fuel is used in the hydraulic fracturing fluids and is injected in an underground injection well, EPA can regulate.[374]	Safe Drinking Water Act, 42 U.S.C. §§ 300f *et seq.*; exemption at § 300(h)(d)(1)(B)(ii)	
United States Army Corps of Engineers	Discharge of dredged or fill materials into waters of the U.S., including wetlands	CWA section 404, 33 U.S.C. § 1344.	CWA section 404 permit[375]
Navajo Nation or New Mexico Environment Department (depending on location of regulated activity)	Discharges to surface water and discharges of dredged or fill materials into waters of the U.S. (where not exempted)	CWA, section 401, 33 U.S.C. § 1341.	CWA section 401 certification (allows State or Tribe the opportunity to add conditions onto a 402 or 404 permit, or prevent issuance of the permit if certification is denied).
United States BLM	Resource Management Plans (RMP), Leasing of lands for oil and natural gas development, Application for Permit to Drill (APD)	Mineral Leasing Act, 30 U.S.C. §§ 181 – 287.	RMP allowance, Lease, APD
United States Fish and Wildlife Service	Impacts to endangered and threatened species and their critical habitat	ESA, 16 U.S.C. §§ 1531 – 1544.	Biological Opinion
Agency undertaking major federal action	Major federal actions, includes approvals for action. Oil and gas industry enjoys more lenient analysis under National Environmental Policy Act (NEPA) for many activities pursuant to the Energy Policy Act of 2005 allowance for analysis under a categorical exclusion, effectively shifting the burden of proof to the public to argue for more stringent analysis.[376]	NEPA, 42 U.S.C. § 4321 *et seq.*	Environmental Assessment ("EA") and Finding of No Significant Impact ("FONSI"), or Environmental Impact Statement ("EIS") and Record of Decision ("ROD")
New Mexico Oil Conservation Division (OCD), Energy, Minerals and Natural Resources Department	Oil and natural gas development.	New Mexico Oil and Gas Act, NMSA §§ 70-2-1 – 38, NMAC §§ 19.15.1 –19.15.112.	
New Mexico State Engineer	Water rights; dam safety.	NM Stat. § 72-1-1 *et seq.*; NM Stat. § 72-5-32 *et seq.*	Water right permit; Dam permit.

b. IMPACTS

As with coal mining and combustion, the amount of water taken from a watershed is only one aspect of the overall impact that oil and natural gas development has on water resources. Numerous other issues impact water resources: first, wastewater, including flowback and produced water, at each well contain numerous contaminants, and thus present issues of storage, disposal, and spills. Second, well integrity is an issue throughout the life of a well to ensure that aquifers are not contaminated. Finally, unintended impacts like increased seismic activity may lead to the contamination of water supplies.

• Large-scale Impacts to Land and Water

Specific impacts from oil and natural gas development are discussed below, but the overriding impact of such pervasive oil and natural gas development in our state should not be overlooked. As the picture above illustrates, although each well pad may be relatively small in size, the cumulative impact of thousands of sites can be devastating. BLM estimates that surface disturbance for each well is 2.5 acres, with an additional 0.5 acres of access road disturbance.[377] Such extensive development can fragment the landscape, degrading the integrity of ecological systems critical to clean water. Exemptions in the very laws that are supposed to protect water quality from development instead allow for unfettered development and attendant impacts.[378] In the San Juan River, for example, anglers have seen a dramatic decline in the quality of fishing due to increased sediment that has coincided with a significant increase in oil and natural gas development near the river.[379] The New Mexico Environment Department, when discussing stream impairments, has noted that "[s]ediment impairments are of special note, as excessive deposition of fine sediment on the bottom substrate of streams and rivers can negatively impact aquatic life."[380]

• Wastewater

Oil and natural gas operations in the United States generate more than 2 billion gallons of wastewater per day, the equivalent of a continuous flow of 3,094 cfs or 2,242,000 acre-feet/year (for comparison, the Rio Grande at Albuquerque flows at an annual average of between about 450 cfs to 2,500 cfs[381], and water withdrawals (surface and groundwater) in New Mexico for all purposes totaled 3,815,945 acre-feet[382]).[383] Were it clean, the amount of wastewater from oil and natural gas operations nationally would be enough water for 20 million people's daily usage.[384]

Although wastewater can be highly contaminated with hydraulic fracturing chemicals, heavy metals, and drill cuttings, it is classified as "special waste" and thus it is not regulated under the Resource Conservation and Recovery Act.[385] Likewise, there is an exemption under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) for oil and natural gas production even though there is potential, or actual, release of hazardous substances that would otherwise make CERCLA applicable.[386] As a result of lack of federal regulation or even guidance, regulation of oil and natural gas production wastewater takes many different forms, and different methods of storage and disposal are allowed in different states.[387]

Wastewater is generally classified as flowback or produced water. Flowback water returns to the surface after a well is hydraulically fractured, but before oil and natural gas production begins, during the days to weeks of well completion.[388] Flowback water consists of 10-40 percent of the injected fracturing fluids and chemicals pumped underground (on average 1 of the 4 million gallons of fluids used to hydraulically fracture the well) mixed with natural brines that come from the shale formation; the proportion of natural brines to hydraulic fracturing fluids increases over time. [389] "In addition to the proprietary hydraulic fracturing chemicals, flowback water may also contain high concentrations of sodium, chloride, bromide, arsenic, barium and other heavy metals leached from the subsurface, as well as radionuclides that significantly exceed drinking-water standards . . . ."[390] Exposure to these contaminants at high levels may pose risks to human health; for example, barium can cause high blood pressure; benzene may cause anemia and increase cancer risks.[391]

Produced water flows to the surface during extended oil and natural gas production.[392] "It primarily reflects the chemistry and composition of deep formation waters and capillary-bound fluids. These naturally occurring brines are often saline to hypersaline (35,000 to 200,000 mg/L TDS) and contain potentially toxic levels of elements such as barium, arsenic, and radioactive radium."[393] The U.S. Bureau of Reclamation has reported impacts from produced water since the mid-1800s when the first oil and natural gas wells were drilled and operated, including degradation of soils, groundwater, surface water and the ecosystems they support.[394]

Coal bed methane deposits present a slightly different situation as the methane is extracted from coal formations, which often act as aquifers themselves. As a result, there is generally a great deal of produced water.[395] Depending on the situation, produced water may need little to no treatment, or it may need extensive treatment. [396]

Flowback and produced water are generally stored at the well site in holding ponds until they can be disposed of, are trucked off-site, or are reinjected at the site.[397] Disposal of oil and natural gas wastewater is accomplished in several different ways.

The vast majority of oil and natural gas wastewater in the United States, from 90-98 percent, is re-injected underground; approximately 59 percent is injected into producing formations to enhance production, and approximately 40 percent is injected into non-producing formations.[398] In 2010, there were 150,855 injection wells in the United States authorized for injection of oil and natural gas wastewater; 4,585 of those are located in New Mexico.[399] Wastewater is generally not treated prior to injection, unless the injection well has minimum requirements to control excessive solids, dissolved oil, corrosion, chemical reactions, or the growth of bacteria and other microbes.[400]

Despite the widespread use of reinjection, reinjection of fracturing fluids is exempt from regulation under the Safe Drinking Water Act ("SDWA").[401] Underground injection can only be regulated if the hydraulic fracturing fluids to be injected include diesel fuel.[402] When diesel fuel is part of the hydraulic fracturing fluids, either EPA or authorized states, including New Mexico, require producers to obtain permits for injection wells to ensure that underground sources of water are protected.[403] However, because of the SDWA's exemption, the vast majority of fracturing fluids are not regulated. The practice of underground injection as a means of disposal of fracturing fluids is illegal in Europe due to concern about increased risk of seismic activity, which can, in turn, threaten well integrity.[404]

Wastewater is also sometimes disposed of in municipal or commercial treatment facilities, despite the inability of those facilities to handle the volume of water, and their inability to handle or even identify, much less address, the chemicals in the wastewater.[405]

Other states still allow wastewater to be sprayed for dust control or directly onto lands; an experimental application of flowback water on a section of forest in West Virginia killed more than half the trees in 2 years.[406] Wastewater is also sometimes managed in surface impoundments — lined or unlined ponds — where it is allowed to evaporate.[407] Remaining solids must then be disposed of.[408] Management of produced water that is discharged to surface waters is regulated by the NPDES program. [409]

• Reducing Surface Spills

Surface spills and leaks at well pads and wastewater holding ponds, or "pits," are a significant threat to water contamination.[410] Contamination of this kind unfortunately has been common and is well documented.

In Weld County, Colorado, where there is a high density of hydraulically fractured wells, 77 surface spills affecting groundwater were documented in only one year. BTEX — benzene, toluene ethylbenzene, and xylene — levels exceeded the EPA's National Primary Drinking Water standards in 90 percent, 30 percent, 12 percent, and 8 percent of the cases, respectively. [411] Nearly 7,000 cases of pits causing soil and water contamination were recorded by the Oil Conservation

Divisions's Environment Bureau between the mid-1980s and 2003.[412] OCD released data showing that pits had contaminated groundwater in almost 400 incidents; sampling showed carcinogens in all samples taken from the pits and heavy metals in 2/3 of the samples.[413]

These figures likely do not capture the whole problem; in New Mexico in 2010, 53,000 wells were drilled but there were only 12 OCD inspectors to oversee the wells.[414] That amounts to more than 4,000 wells per inspector, leaving some inspectors able to visit well sites only once every five years.[415]

The New Mexico Pit Rule was passed in 2008 in response to the extensive contamination from oil and natural gas wastewater storage.[416] The pit rule made progress towards addressing surface spills and pit leakage: recognizing that all pits, even lined ones, can leak, the rule required that waste meet health-based groundwater standards; it prohibited permanent burial of waste in pits if the waste did not meet these standards; it established setbacks from homes, schools, springs, lakes, and perennial waterways; it required site-specific data groundwater quality data to be collected prior to the construction of a waste pit system, and it did not allow for multi-well pits.[417] Unfortunately, however, the rule was weakened in 2013 in response to industry protest: it now allows increased concentrations of toxins to be buried in pits, including hydrocarbons, toxic heavy metals, and volatile organic compounds; it relaxes setbacks; it allows industry to make educated guesses about groundwater quality instead of requiring site-specific data; and it allows for multi-well pits that can be of unlimited size.[418] On March 24, 2016, environmental organizations filed a petition for writ of certiorari to the New Mexico Supreme Court, asking for review of the rule and the Court of Appeals ruling upholding it.[419]

• Well Integrity

> Any well drilled into the Earth creates a potential pathway for liquids and gases trapped underground to reach the surface. The same technologies that power the unconventional energy boom—horizontal drilling and hydraulic fracturing—create challenges for maintaining well integrity. Today's unconventional wells are typically longer, must curve to travel laterally, often access substantially overpressured reservoirs, and must withstand more intense hydraulic fracturing pressures and larger water volumes pumped underground than do traditional conventional oil and gas wells.[420]

Well integrity is an issue of great concern to ensure that the environment and human health are protected, and in particular, that oil and natural gas drilling does not impact much greater amounts of water through aquifer contamination. Oil and natural gas development can threaten groundwater contamination at all phases of production, including during drilling and operations, and can continue to cause problems if the well is not properly plugged at the end of operations. [421]

There are several pathways for contamination, including blowouts at the wellhead, deep fractures providing a pathway to aquifers or fractures connecting with natural faults or fractures such as abandoned wells or other existing fractures that provide a pathway to aquifers, or through holes or defects in the steel casing, joints or mechanical seals inside or outside the well that allow liquids or gases to escape into surrounding aquifers inside or outside of the well.[422] One metric of well performance is the occurrence of sustained casing pressure, which occurs when pressure builds up inside the well annulus as a result of a failure of one or more barriers in a well.[423] Sustained casing pressure is three to four times more likely to occur in wells that are slanted or deviated from vertical, an important figure given the prevalence of horizontal drilling.[424] Unfortunately, there are few studies on the frequency, consequences, or severity of failures of well integrity. [425] However, the possibilities and potential consequences of failure are discussed below.

The first means by which a well may fail is as a result of a blowout. [426] Blowouts can occur during drilling when pressure is not balanced between the high fluid pressure of the reservoir with the hydrostatic pressure of drilling mud, steel, and cement. [427] Gas in pore spaces and pockets within intermediate layers must also be prevented from entering the well during drilling. [428] Although rare, when blowouts occur they can have severe consequences both to the environment and to the safety of workers at the site. [429] Of particular concern are blowouts that occur as a result of one well affecting a neighboring well, as occurred in one incident in New Mexico. In that case, over 8,400 gallons of fracturing fluid, oil, and water spilled from a traditional well when a well about a half mile away was being fractured, and the hydraulic fracturing fluids intersected the well. [430] The fracture was too much for the older well to withstand and the well experienced a blowout.[431] Aging concrete and other degradation at older wells, blowouts of this kind remain a concern.[432]

As the blowout discussed above demonstrates, another means by which groundwater contamination can occur is when hydraulic fractures could connect to incipient fractures providing a pathway between the fractured deposit and a drinking water aquifer.[433] Oil and gas deposits are typically (although not always) thousands of feet below drinking water aquifers, thus reducing the concern for direct contamination to aquifers.[434] Furthermore, studies have shown that man-made fractures rarely propagate. [435] However, of greater concern is the potential for groundwater contamination from blowouts, fractures that propagate themselves, or fractures that connect to a natural fault or fracture, an abandoned well or some other pathway. [436]

Well integrity is also threatened as wells degrade over time. Wells are designed for fluids to be kept inside the well and within the target formation using steel casing, cement, and mechanical components that are designed to isolate the fluids from the outside casing and surrounding rock. [437] Nevertheless, "casing leaks can occur through faulty pipe joints, corrosion, or mechanical failure due to thermal stresses or overpressuring."[438]

Steel corrosion is the most common chemical attack on wells; in wells with carbon dioxide- and hydrogen sulfide-bearing brines, corrosion can occur quickly as reactions form corrosive acids in water. [439] Means to reduce steel corrosion, including chemical inhibitors, cathodic protection, and corrosion-resistant alloys are all used to reduce steel corrosion but these measures only reduce the rate of corrosion, they do not eliminate it altogether.[440]

Defects in the cement surrounding the well casings can also allow for leaks. Issues can occur "by the development of fluid channels, casings that are not centered in the well, poor bonding and shrinkage, and losses of cement into the surrounding rock." [441] Operations at the well can also damage cement as a result of temperature and pressure changes occurring during pressure testing, hydraulic fracturing, the production and injection of fluids of contrasting temperatures, as well as damage occurring when equipment is inserted and removed in the well. [442] "Perforations, hydraulic fracturing, and pressure-integrity testing can cause thermal and pressure changes that damage the bond between cement and the adjacent steel casing or rock or that fracture the cement or surrounding caprock."[443]

The increasing use of nitrogen foam as a replacement for water in hydraulic fracturing fluids may actually exacerbate issues of well integrity. New Mexico BLM officials have noted that nitrogen gas has a greater permeability, thus increasing the likelihood of contamination.[444]

Increasingly, incidents of water contamination as a result of oil and natural gas development are being discovered and reported.

In Garfield County, Colorado, gas was discovered bubbling up in West Divide Creek and nearby ponds. The Colorado Oil and Gas Conservation Commission (COGCC) took samples of the water and discovered that the water contained benzene, toluene, and m- & p-xylenes at concentrations of 99, 100, and 17 micrograms per liter (mg/l), respectively. These contaminants indicated that the gas seeping into West Divide Creek was not likely biogenic methane gas (gas made by the decomposition of organic matter by methanotrophic bacteria), but rather thermogenic gas, and further testing revealed that the gas seeping into the creek was from the Williams Fork Formation where EnCana had been drilling for natural gas.[445] EnCana was subsequently fined 371,000 dollars as a result of contaminating West Divide Creek.

In 2007, EPA hydrologists sampled a drinking water aquifer under the Jonah Well Field near Pinedale, Wyoming. They found high levels of benzene, a known carcinogen, in 3 wells and low levels of hydrocarbons in an additional 82 wells (out of the 163 wells sampled).[446] These contaminated wells are located in an area stretching across 28 miles in an undisturbed landscape in which the only industry that exists is natural gas extraction.

In Pennsylvania, state regulators have uncovered more than 50 cases where methane and other contaminants have exploded out of wells or leaked underground into drinking water supplies.[447]

A house in Bainbridge, Ohio, exploded on November 15, 2007. The Ohio Department of Natural Resources attributed the explosion to a methane leak from a nearby hydraulic fractured well. The faulty cement casing of the well developed a crack allowing methane to seep underground and fill the basement.[448]

Abrahm Lustgarten, an investigative reporter with ProPublica, who has won the George Polk Award for Environmental Reporting for his work on the dangers of natural gas drilling, writes:

> Dennis Coleman, a leading international geologist and expert on tracking underground migration, says more data must be collected before anyone can say for sure that drilling contaminants have made their way to water or that fracturing is to blame. But Coleman also says there's no reason to think it can't happen. Coleman's Illinois-based company, Isotech Laboratories, has both the government and the oil and gas industry as clients. He says he has seen methane gas seep underground for more than seven miles from its source. If the methane can seep, the theory goes, so can the fluids.[449]

However, perhaps the most thorough evidence of groundwater contamination from hydraulic fracturing is found in a newly released EPA draft report investigating ground water contamination near Pavillion, Wyoming ("Pavillion Report").[450] Among its findings, the Pavillion Report states:

> Elevated levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells.[451]
>
> Detection of high concentrations of benzene, xylenes, gasoline range organics, diesel range organics, and total purgeable hydrocarbons in ground water samples from shallow monitoring wells near pits indicates that pits are a source of shallow ground water contamination in the area of investigation. Pits were used for disposal of drilling cuttings, flowback, and produced water. There are at least 33 pits in the area of investigation. When considered separately, *pits represent potential source terms for localized ground water plumes* of unknown extent. When considered as whole they represent potential broader contamination of shallow ground water.[452]
>
> The explanation best fitting the data for the deep monitoring wells is that *constituents associated with hydraulic fracturing have been released into the Wind River drinking water aquifer at depths above the current production zone*. [453]
>
> Although some natural migration of gas would be expected above a gas field such as Pavillion, data suggest that *enhanced migration of gas has occurred to ground water at depths used for domestic water supply and to domestic wells*. [454]
>
> A lines of reasoning approach utilized at this site best supports an explanation that *inorganic and organic constituents associated with hydraulic fracturing have contaminated ground water at and below the depth used for domestic water supply*. . . . A lines of evidence approach also indicates that *gas production activities have likely enhanced gas migration* at and below depths used for domestic water supply and to domestic wells in the area of investigation. [455]

EPA did not finalize its Pavillion Report, but a recent study by Standford researchers confirms that oil and gas operations have impacted drinking water in the area.[456]

These incidents illustrate the existing impacts and additional threats that oil and natural gas development poses to water quality.

Well integrity also must be considered in long-term as wells age, and potentially degrade further. [457] Proper care must be taken when wells are plugged and abandoned. Such barriers include the use of mechanical or cement barriers to prevent fluids from migrating up or down a well once a well is no longer commercially viable.[458] "Improperly abandoned wells provide a short circuit that connects the deeper layers to the surface." [459] Unplugged wells, improperly abandoned orphan wells, and wells that are sitting idle can all cause additional issues that are not adequately addressed given the extensive amount of new oil and natural gas development.[460] Due to the history of oil and natural gas production in Northwest New Mexico, there is uncertainty over locations of legacy wells that may or may not have been cemented/cased.

In the San Juan and Permian Basins in New Mexico, there are numerous public water system sources located within one mile of at least one, but often many more, hydraulically fractured wells. [461] Also in New Mexico, the EPA found that there is a high population of people served by private water wells in counties where there are more than 400 hydraulically fractured wells.[462]

d. PROCESSING AND STORAGE

Williams Field Services Processing Facility, Bloomfield, NM. Photo courtesy of Ecoflight, and ecoflight.org.[463]

Oil and natural gas are generally brought to processing facilities via pipeline.[464] Natural gas is very close to its final product and requires little refining.[465] "Natural gas processing plants remove water, hydrocarbon liquids (which can have substantial market value), helium (the totality of global helium production comes from natural gas processing), carbon dioxide, hydrogen sulfide and other contaminants."[466] Water is used in these processes for scrubbing and cooling; one estimate is that 2 gallons of water per MBTU are used in natural gas processing, but further study is warranted. [467]

Oil, on the other hand, requires significant processing.[468] Estimates as to how much water is used in these processes from 7.2 gallons per MBTU to 32 gallons per MBTU. [469] Newer, more efficient facilities are usually at the lower end of this range. [470] Additional concerns regarding water contamination arise, however, from the disposal of process and cooling water, which contains organic compounds, sulfur, ammonia, and heavy metals.[471]

Water is also required to create storage for oil and natural gas.[472] Demand for natural gas fluctuates primarily due to seasonal variations as well as the influence of the economy on demand.[473] Supply, on the other hand, remains relatively constant, and as a result, excess natural gas must be stored for future use.[474] Natural gas is stored in underground areas including depleted oil and natural gas fields, aquifers, and salt caverns. [475] Oil reserves are stored in the salt caverns of the Strategic Petroleum Reserve.[476] Salt caverns are created through slurry mining, and require 7 gallons of water to create 1 gallon of storage capacity. [477] The mining slurry created by this process is highly saline and presents additional disposal issues. [478]

Leaks from underground storage tanks also present threats to water quality, contaminating groundwater resources with compounds such as benzene and toluene. [479] "In the U.S., the EPA has recorded more than 490,000 confirmed leaks from underground storage tanks (USTs), mainly storing petroleum products," although there is no information about the volumes of leaked fuel.[480]

2. OIL AND NATURAL GAS COMBUSTION

There are numerous gas-fired power plants in New Mexico. Like the coal-fired power plants discussed above, natural gas plants are also thermal plants and use large amounts of water to create steam, which drives a steam turbine, which in turn drives an electrical generator. Natural gas plants are generally more water-efficient than coal-fired or nuclear plants, but nevertheless use large amounts of water to produce power.[481]

a. PROCESS

The relative efficiency of natural gas plants is greatly dependent on the type of natural gas plant being used; single cycle plants withdraw, on average, 14,844 gal/MWh, and consume 244 gal/MWh whereas combined cycle plants, on average, withdraw 1,170 gal/MWh and consume 95 gallons/MWh.[535] There are numerous types of natural gas plants, including simple cycle, combined cycle, and aeroderivative turbines.

Natural gas simple cycle plants produce electricity through use of a simple cycle turbine that turns a generator directly by burning fuel in the turbine, similar to jet engines in aircraft.[536] These plants do not use any water for cooling.[537] Combined cycle plants use two processes to produce electricity: first, electricity is generated by a simple cycle turbine; the heat produced by the simple cycle turbine — heat that would otherwise by lost to the atmosphere — is then used to produce steam that turns a steam turbine.[538] Because the simple cycle turbine generates some of the electricity produced at combined cycle plants, these plants use less water than similar-sized thermoelectric plants. [539] Combined cycle plants use varying amount of water depending on the cooling technology used to cool the steam produced in the thermoelectric process at the plant.[540]

b. IMPACTS

Although natural gas plants may burn cleaner than coal-fired facilities, they nevertheless have significant impacts to the environment and in particular, water resources. As noted above, they divert and consume considerable amounts of water. Moreover, despite burning cleaner, they still contribute significant amounts of greenhouse gases to the atmosphere, in particular when taking into consideration the production, transportation, and storage of oil and natural gas.[541] Substantial amounts of methane leaks to the atmosphere as a result of venting, flaring, poor seals in pipelines, holes in pipelines or collection tanks, and emissions from underground storage areas.[542] As noted above, climate change is both causing and exacerbating current water shortages, as well as intensifying the stress on our waters.

TABLE 7: WATER FOR NATURAL GAS PLANTS IN NEW MEXICO

Power Plant	Water Consumed (acre-feet per year)[483]	Water Consumed (gal per MWh)	Water Source	Type	Plant Capacity (MW)/net generation (MWh)[484]
Afton (PNM)	223.3	104[485]	groundwater[486]	Combustion turbine (simple cycle) or combined cycle[487]	230; 699,762[488]
Carlsbad 1 (SPS)	n/a	n/a[489]	n/a	Combustion turbine (simple-cycle)[490]	11; 6,745[491]
Cunningham 1&2 (SPS)	2,047	670[492]		Steam production[493]	255; 955,312[494]
Cunningham 3&4 (SPS)	0.3	670[495]		Combustion turbine (simple-cycle)[496]	216; 88,625[497]
Delta-Person (PNM)	2.5	37[498]	groundwater[499]	Combustion turbine-natural gas or oil[500]	5; 22,413[501]
La Luz (PNM)	n/a	Not yet in service[502]	groundwater[503]		
Lordsburg (PNM)	6.3	461[504]	groundwater[505]	Aero-derivative[506]	80; 4,460[507]
Luna Energy Facility (PNM)	260[508]	209/260[509]	Groundwater and reclaimed city wastewater[510]	Combined cycle[511]	558; 376,304[512]
Maddox 1 (SPS)	1,385	1,180[513]		Steam production[514]	118; 382,462[515]
Maddox 2 (SPS)	141.7	1,180[516]		Combustion turbine (simple-cycle)[517]	61; 42,749[518]
Moore 3 (SPS)	n/a	n/a[519]		Steam production[520]	32; 28,032[521]
Pyramid 1, 2, 3, & 4 (Tri-State)	126.9	295[522]		Simple-cycle combustion turbine523	160; 140,160[524]
Reeves (PNM)	274.2	957[525]	groundwater[526]	Steam turbine generator[527]	154; 93,360[528]
Rio Grande 7, 8, & 9 (EPE)	1,892[529]				276[530]
Valencia (PNM)	5.5	22[531]	groundwater[532]	Gas turbine[533]	145; 81,732[534]
TOTAL	6,364.7				

TABLE 8: REGULATION OF NATURAL GAS PLANTS IN NEW MEXICO

Agency	Activity Regulated	Governing Statute	Permits Required
Environmental Protection Agency	Discharges to surface water	Clean Water Act (CWA), section 402, 33 U.S.C. § 1342.	National Pollutant Discharge Elimination System (NPDES)
United States Army Corps of Engineers	Discharge of dredged or fill materials into waters of the U.S., including wetlands	Clean Water Act section 404, 33 U.S.C. § 1344.	Section 404 permit
Navajo Nation or New Mexico Environment Department (depending on location of r egulated activity)	Discharges to surface water and discharges of dredged or fill materials into waters of the U.S.	Clean Water Act, section 401, 33 U.S.C. § 1341.	CWA Section 401 certification (allows State or Tribe the opportunity to add conditions onto a 402 or 404 permit, or prevent issuance of the permit if certification is denied).
United States Fish and Wildlife Service	Impacts to endangered and threatened species and their critical habitat	Endangered Species Act, 16 U.S.C. §§ 1531 – 1544.	Biological Opinion
Agency undertaking major federal action	Major federal actions, includes approvals for action	National Environmental Policy Act (NEPA), 42 U.S.C. § 4321 *et seq.*	Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), or Environmental Impact Statement (EIS) and Record of Decision (ROD)
New Mexico State Engineer	Water rights		Water permits

C. NUCLEAR ENERGY

New Mexico has a long and troublesome history of that reveals the devastation that uranium mining can cause. Massive legacy pollution exists within the state and in particular on the Navajo Nation, and the impacts to health of the workers at those mines are egregious.[543]

Although there are not any nuclear plants in New Mexico itself, New Mexico utilities own shares of Palo Verde Nuclear Generating Station in Arizona. El Paso Electric owns 16 percent of Palo Verde. [544] Public Service Company of New Mexico owns 10 percent, and is seeking to increase its use of Palo Verde.[545]

1. URANIUM MINING

Abandoned uranium mine on the Navajo Nation[546]

Uranium is a naturally occurring element in the Earth's crust, and together New Mexico and Wyoming have 80 percent of the U.S. proven reserves.[547] Uranium prices have declined in recent years, uranium prices have recently started leveling off, although there is still interest in reopening mines in New Mexico.[548] At the time of this report, there are no uranium mines currently operating in New Mexico. However, two facilities are partially permitted and licensed.[549] Recommencing uranium mining in the state could lead to 3 to 5 million gallons of produced water per day, and a commensurate increase in water demands.[550]

Uranium has been mined in the United States for over 100 years, but methods have changed dramatically in that time.[551] Historically, uranium was mined in open or underground mines, but 90 percent of production now comes from In-Situ Leaching.[552]

In-situ leaching allows for the mining of uranium while minimizing surface disturbance by extracting uranium from porous sandstone deposits with acidic or basic aqueous solutions (depending on the underlying geology) through a number of injection wells.[553] In-situ leaching works when the deposit is in a permeable sandstone aquifer; often this aquifer must be hydraulically fractured to release the uranium.[554] As a result, groundwater quality is a serious concern.[555] Moreover, although in-situ leaching does not produce the significant tailings of a traditional mine, it uses much more water.[556] Surface uranium mines use approximately 0.1 to 1.5 gallons per MBTU of ore; underground mines 0.5 to 1.0 gallons per MBTU of ore; in-situ leaching uses approximately 14.6 gallons per MBTU of ore — about 10 to 146 times more water than traditional mines.[557] As noted, if projects to reopen uranium mines in New Mexico and Utah go forward, millions of gallons of wastewater water per day would be produced, and would need to be handled and disposed of.[558]

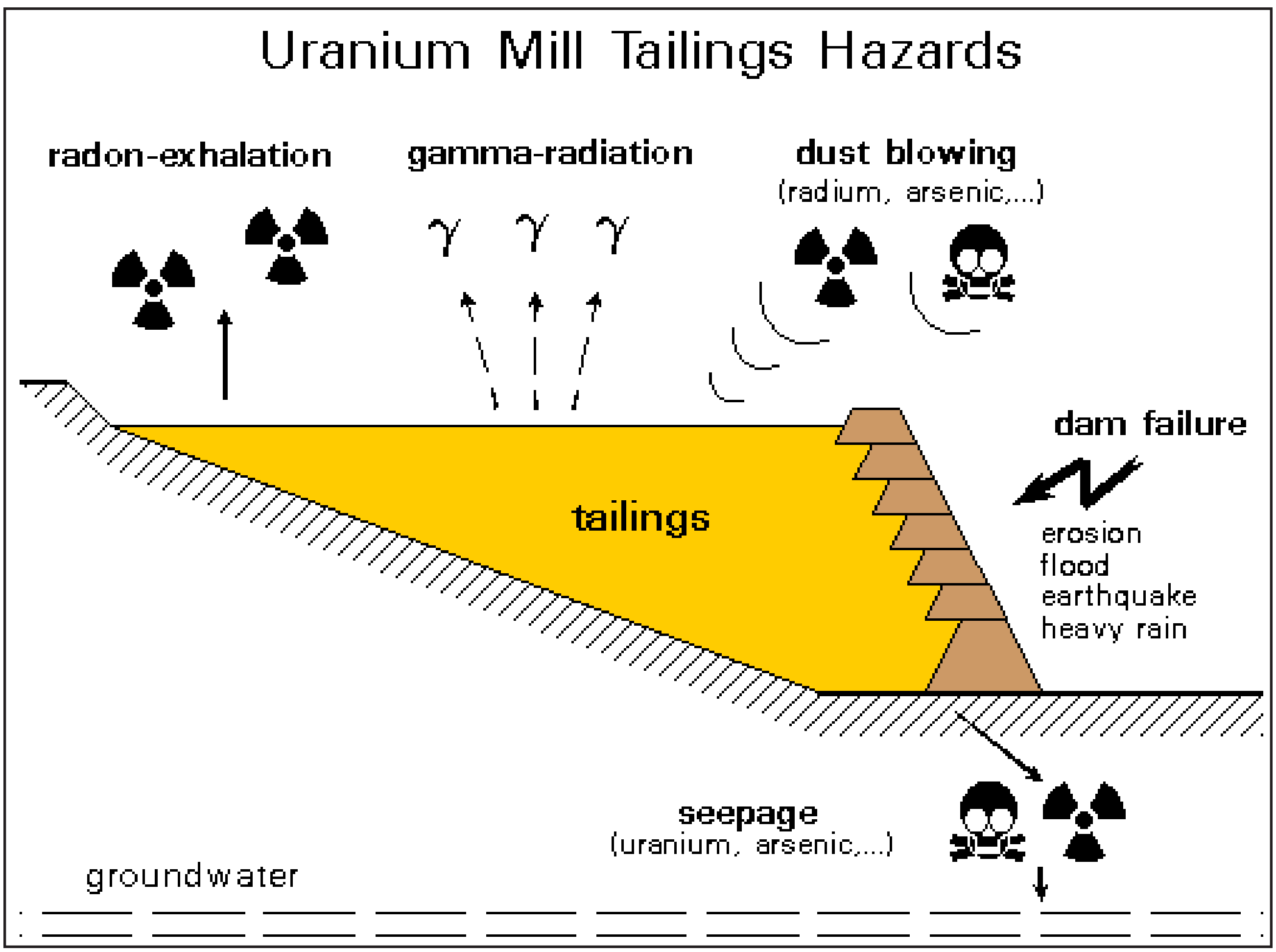
Legacy pollution from tailings at old mines is an issue that continues to plague New Mexico.[559] Not only have old uranium mines in New Mexico polluted water throughout their lives and continuing into the present, they are now contaminating additional fresh water as part of remediation efforts.

Uranium wastes include both metals and radionuclides, including, among others, arsenic, selenium, uranium-238, thorium-230, radium-226+228, radon-222, and lead-210.[560] The San Mateo Creek watershed contains most of the inactive and abandoned uranium mines and mills in New Mexico and continues to be affected decades after the facilities have closed.[561]

The 20,000,000-ton uranium tailings pile at the Homestake Mine, for example, has been a Superfund site for more than 30 years.[562] The Homestake site is located on alluvium of the San Mateo Creek floodplain and thus presents a perpetual flood risk.[563] Already it contaminated four local aquifers.[564] The mining waste sites' proximity to communities in New Mexico exacerbates the problem of polluted waters as the potential for exposure and attendant health risks is heightened.[565]

Reclamation at the Homestake site contaminates even more water. Although typically the goal in remediation efforts is to dry out tailings piles so that there is not water seepage into the ground, at the Homestake site, uranium was found in the tailings.[566] To extract this uranium, freshwater is being used to flush the uranium out of the tailings, with the goal of then intercepting that water before it enters the ground. Homestake's discharge permit allows it to discharge up 450 gpm of freshwater to treat contamination at the site.[567] In total, it is allowed to discharge 5,500 gpm of freshwater and treated groundwater.[568]

Processing the uranium ore opens the door to significant additional pollution. Mined ore contains only 0.06 percent to 2.71 percent uranium concentrations, and thus requires significant processing.[569] The processing has several effects on water sources. First, it requires significant amounts of water and sulfuric acid to leach out the uranium.[570] Next, it leaves behind massive stockpiles of radioactive and toxic waste rock and sand-like tailings that can leach radioactive (radon, uranium), toxic (selenium, arsenic, uranium and thorium) and conventional pollutants to surface water and groundwater.[571] Evaporation from tailings ponds can account for additional consumption of 3 gallons per MBTU of product.[572]



Uranium Tailings Issues[573]

After processing, uranium must be enriched before it is ready to be sent to a plant. [574] Two methods are primarily used: diffusion or centrifugation. [575] Diffusion can use an additional 7 to 8 gallons per MBTU and centrifugation can use 4 to 5 gallons per MBTU. [576] Enrichment creates large amounts of depleted uranium; storage and/or disposal of this depleted uranium, often in uranium mill tailings, continues "to pose serious water, environmental and human threats, and long-term solutions have yet to be found."[577] After enrichment, the uranium is converted into fuel rods, which then must travel back to nuclear-powered plants.[578] Transport for uranium can thus be significant; one analysis showed that Canadian uranium travels an average of 4,000 miles during its life cycle, thus adding to the water intensity of uranium.[579] In total, the water intensity of uranium mining and enrichment is about 5 to 14 gallons per MBTU, for an average usage of around 9.5 gallons per MBTU. [580]

Despite the impacts to New Mexico's waters, the New Mexico Legislature has not funded an active and abandoned uranium mine program.[581]

2. NUCLEAR POWER PLANTS

Palo Verde Nuclear Generating Station[582]

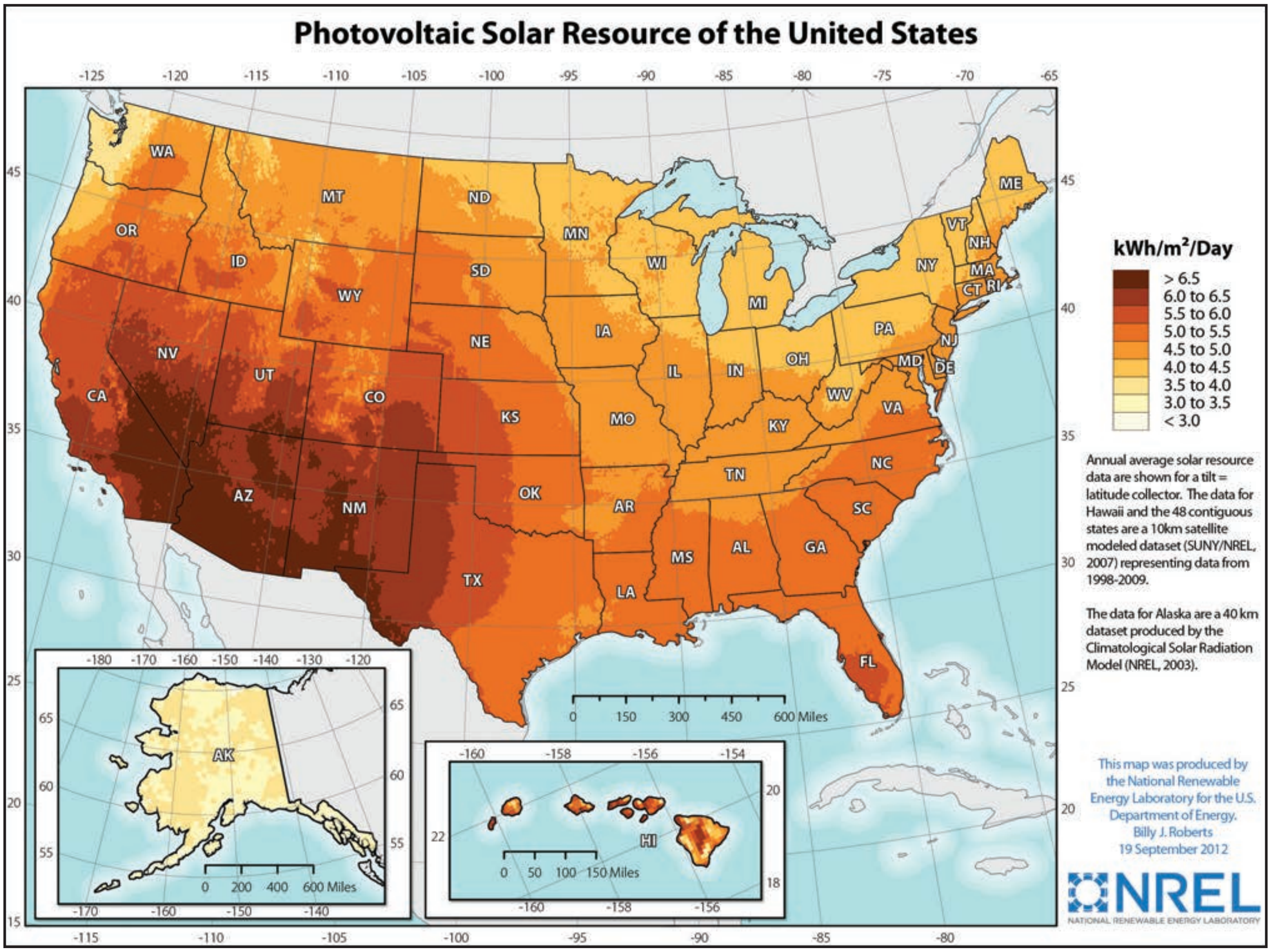
New Mexico draws power from Palo Verde Nuclear Generating Station, the largest nuclear power plant in the nation, rated at 3,937 net megawatts.[583] Palo Verde NGS is located on a 4,050-acre site near Wintersburg, Arizona about 52 miles West of downtown Phoenix.[584] Like the coal-fired plants discussed above, Palo Verde is a thermoelectric plant, but Palo Verde uses uranium rather than coal to heat water to produce steam, that, in turn, turns a steam turbine, which then drives an electrical generator.[585] As with coal-fired power plants, significant amounts of water are both used and consumed in the process. Nuclear thermoelectric plants usually withdraw and consume even more water than coal-fired power plants, due to technological characteristics and restrictions.[586]

Nuclear-powered generating stations withdraw 9,000 to 24,000 gallons per MWh and consume 400 to 650 gallons per MWh;[587] on average, 14,732 gallons per MWh are withdrawn and 532 gallons per MWh are consumed.[588] Palo Verde uses 20 billion gallons of water, or about 61,000 acre-feet, annually,[589] and consumes 3,714,037,325 gallons of water per year, or 11,400 acre-feet per year.[590] Palo Verde uses 768 gallons per MWh; 745 gallons of that total are reclaimed wastewater from Phoenix and other nearby cities, and the remaining 23 gallons are freshwater.[591] Although the use of treated wastewater is preferable to freshwater use, it is not without impacts to local ecosystems. The wastewater used at Palo Verde is diverted from the Phoenix watershed and does not return to that system; indeed, 20 billion gallons, or 60,000 acre-feet used at Palo Verde evaporates each year.[592]

Despite their huge water use, the U.S. Energy Information Administration ("EIA") stopped requiring nuclear plants to report their water use from 2002 to 2008.[593] That exemption "left 6.3 trillion to 16.7 trillion gallons (19 million to 51 million acre-feet) of freshwater withdrawals and 280 billion to 460 billion gallons (870,000 to 1.4 million acre-feet) of freshwater consumption unaccounted for, representing 27 percent of all freshwater withdrawals, and 24 percent of all freshwater consumption."[594] The EIA has again started to require nuclear plants to report their water usage.[595]

D. RENEWABLE ENERGY

Solar Photovoltaic ("PV") Array at Wastewater Treatment Plant in Northern New Mexico[596]



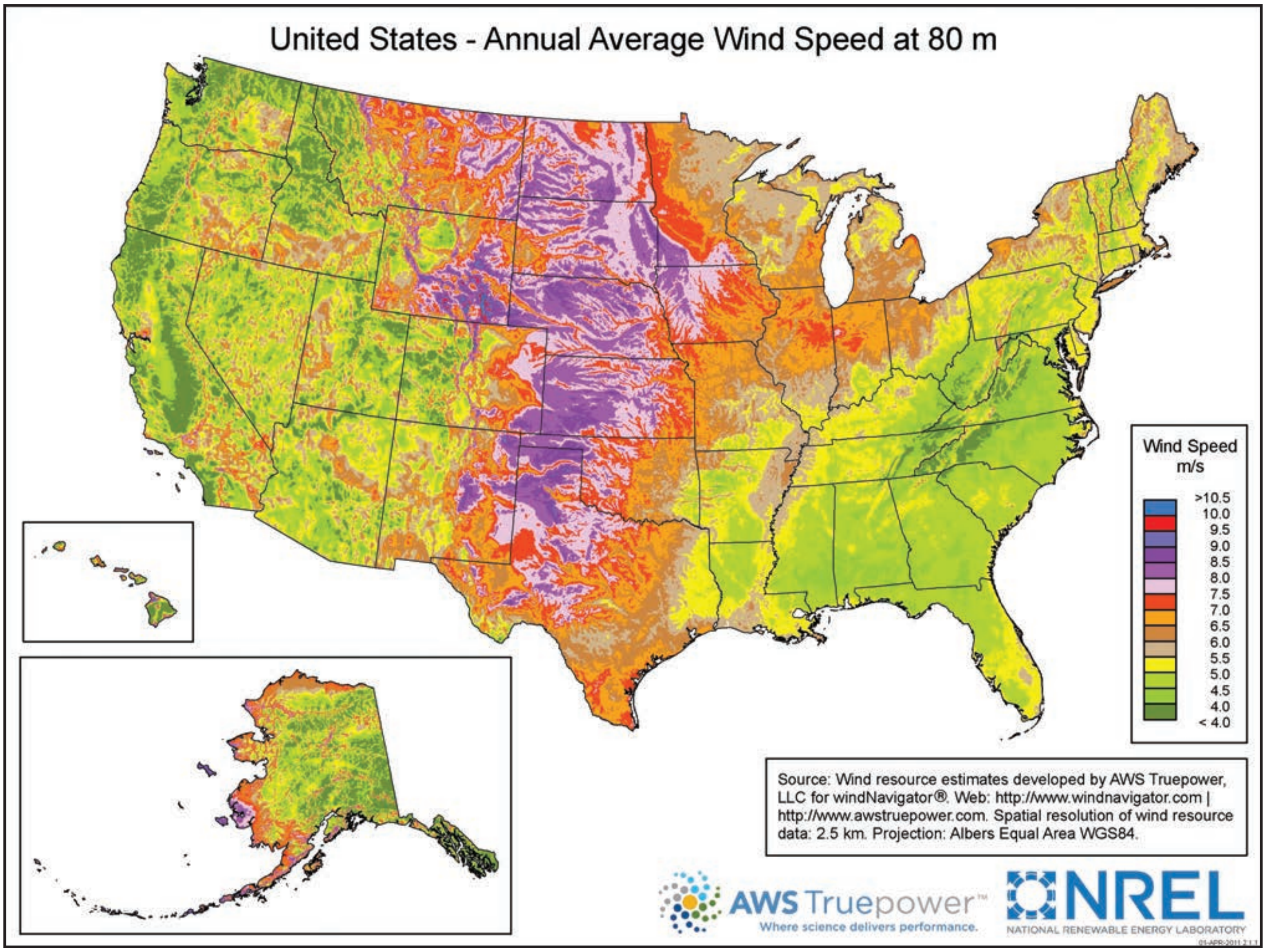
Solar Potential[599]

In stark contrast to the fossil-fuel and nuclear resources discussed above, which use tens of thousands of acre-feet of water each year to produce electricity, solar PV and wind turbines use very minimal amounts of water, and no water for daily operations.[597] New Mexico possesses some of the best sites in the nation for solar PV and wind resources.[598]

Recognizing that the "connection between energy and water is significant," PNM touts the ability of renewables to decrease water usage. [601] Unfortunately, PNM fails to capitalize on the ability of renewables to serve our needs, and instead continues to rely — and indeed double down on — mainly coal and nuclear sources, with natural gas plants close behind.[602]

V. INTRODUCTION TO WATER FOR ENERGY

The choices that we make regarding our energy sources, and in particular their use and impact on water, are especially important when considered in light of the fact that we use this same energy to transport, deliver, and use water every day. With population increases in the Southwest, energy needs for water transport will also increase. How we use water affects how much energy we need to produce; decreasing our water demands decreases the amount of energy we need to transport and deliver that water. Moreover, if we are also efficient in our energy use, we also reduce the amount of energy that utilities must supply, and consequently decrease the amount of water used to produce that energy. Although outside the scope of this report, this issue warrants further study and consideration as to how Amigos Bravos and other stakeholders can address these issues.



Wind Potential[600]

VI. RECOMMENDATIONS AND DECISION MAKING CRITERIA

1. As an arid state still feeling the effects of prolonged drought, New Mexico needs to address fundamental questions about the relationship between our water and our energy sources:

    - Does it make sense for New Mexico to continue to use the equivalent of 25% of our state's public water supply for energy production given we have less water intensive options available (wind, solar) and we are facing potential water shortages for domestic and municipal uses?
    - How much water should be allocated for energy in an arid state like New Mexico?
    - What are the long-term water impacts of our current energy sources (coal, nuclear, and oil and natural gas) that we have yet to discover?

2. The issue of the water-energy nexus needs to be amplified.

    - Legislation to bring the issue to the attention of decision makers would be helpful to highlight the issue and provide opportunities for education of decision makers and the public.
    - Resolutions could also be introduced in water planning forums, and at the town and county levels.

3. Current energy and water regulatory mechanisms should be maximized to reduce water quality and water quantity impacts of energy production and development. More specifically, the following areas allow for participation and input and environmental groups and other stakeholders should endeavor to participate:

   - National Environmental Policy Act (NEPA) analyses need to comprehensively address the water quality and quantity impacts of new energy development;
   - Increased participation and oversight of water conservationists in SMCRA processes may aid in ensuring that those processes live up to their potential;
   - CWA permitting processes for energy development and combustion provide an opportunity to address water quality requirements for current facilities and to ensure that these facilities are not able to pass the costs of pollution onto the public;
   - Resource planning decisions by utilities throughout the state, such as Integrated Resource Planning processes, and cases addressing the useful lives of current facilities, decisions about new facilities, and rate structure, are key places to engage to advocate for less water-intensive options.
   - Advocacy is needed to eliminate exemptions for oil and natural gas development from environmental and consumer protection laws. Including under the CWA, SDWA, RCRA, CERCLA.

4. The impact to water resources needs to be included in public discourse about energy:

   - When discussing how much energy we are using, we need to also include information about the attendant water usage, and the opportunity cost of using that water for energy production;
   - When discussing impacts to land, and landscapes, we need to include discussion about impacts to rivers (for example, debate about wind and solar tends to address landscape values, but discussion of other sources does not include the consequent impacts to our rivers);
   - Discussion of energy production impacts to water should note that even lower-quality water may be needed as water supplies diminish; thus degradation of even low-quality water is problematic;[603] [604]
   - Greater water efficiency and reuse during energy production is beneficial, but it is not a long-term solution.[605] The long-term goal of moving towards cleaner and less water intensive energy sources should not be forgotten while advocating for more efficiency in current traditional water intensive energy sources.

5. Advocacy for legislation and regulatory changes that require greater transparency regarding water impacts and energy development is needed; disclosure in oil and natural gas development is especially important given the significant increases in development.[606] Increased transparency measures could include:

   - reporting for oil and natural gas fracturing fluids- FRAC Act- tried and failed in 2009, 2011
   - reporting of total water used, ideally this would be expressed in a water used per kilowatt metric
   - identification of the source of water
   - information about the security of the water resource
   - percentage of freshwater
   - disposal of water used in energy development
   - requirements for robust stakeholder engagement

6. As we transition to less water-intensive energy sources, we need to address how the water being saved as a result of those transitions is being used:

   - For example, operators have touted the water "savings" as a result of the retirement of units at FCPP and SJGS, but what are the operators doing with that water? This question warrants further study.
   - Water "savings" are not savings if the water is transferred to oil and natural gas development, for example.

7. Additional study is needed:

    - Broadly, as noted above, the energy used for water delivery in New Mexico warrants a report of its own;
    - Study into the sources of water used for oil and natural gas production is needed;
    - Study to address water transfers:

        - Ag to hydraulic fracturing[607]
        - Muni to hydraulic fracturing[608]
        - Industrialization of rural areas;[609]

    - Study into the regulatory situation at FCPP, including the impaired water list (303(d)) on the Navajo Nation.

NOTES

- this report does not address energy involved in the transportation sector

- this report does not directly address energy used for heating

- this report does not address all electricity sources serving NM as the depth of that analysis is beyond the scope of this report; nevertheless, this report does discuss the fossil-fuel sources in NM, and as many of those export energy, there is some balance there.

1 Schlumberger, Oilfield Glossary, available at: *http://www.glossary.oilfield.slb.com* (last accessed March 25, 2016) [hereinafter "Oilfield Glossary"].

2 U.S. Energy Information Administration website, Today in Energy, Monthly generator capacity factor data now available by fuel and technology (Jan. 15, 2014): *http://www.eia.gov/todayinenergy/detail.cfm?id=14611* (last accessed April 16, 2016).

3 Monika Freyman, Ceres, Hydraulic Fracturing & Water Stress: Water Demand by the Numbers, 14 (Feb. 2014) [hereinafter "Ceres Hydraulic Fracturing Report"].

4 Oilfield Glossary.

5 Ceres Hydraulic Fracturing Report.

6 Id.; Water in the West, Stanford University, Water and Energy Nexus: A Literature Review (Aug. 2013) [hereinafter "Water and Energy Nexus Literature Review"].

7 Oilfield Glossary.

8 Ceres Hydraulic Fracturing Report at 14.

9 Id.

10 Water and Energy Nexus Literature Review at 88.

11 Ceres Hydraulic Fracturing Report at 14.

12 Oilfield Glossary.

13 UN-Water, The United Nations Inter-Agency Mechanism on All Freshwater Related Issues, Including Sanitation, Water Security (2013), available at: *http://www.unwater.org/topics/water-security/en/* (last accessed January 3, 2016); cited in: Jessica Alsford et al., Power Generation Utilities Navigating Global Water Risk, Morgan Stanley Research (December 9, 2014) [hereinafter "Morgan Stanley Research"].

14 U.S. Environmental Protection Agency; Climate Impacts in the Southwest, *http://www3.epa.gov/climatechange/impacts-adaptation-renamed/southwest.html* (last accessed January 3, 2016).

15 Id.

16 Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy, eds., Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment. A report by the Southwest Climate Alliance, at 14, 201, 286. Washington, DC: Island Press (2013).

17 New Mexico Environment Department Surface Water Quality Bureau, 2014-2016 State of New Mexico Clean Water Act Section 303(d)/Section 305(b) Integrated Report, ix, (November 8, 2014), available at: *https://www.env.nm.gov/swqb/303d-305b/2014-2016/2014-2016NMReport.pdf* (last accessed January 3, 2016) [hereinafter "2014 303(d) Report"].

18 Id.

19 Id.

20 New Mexico Environment Department Surface Water Quality Bureau, 2012-2014 State of New Mexico CWA §303(d)/§305(b) Integrated Report, viii, (US EPA-approved May 8, 2012) [hereinafter "2012 303(d) Report"].

21 2014 303(d) Report at ix.

22 United States Geological Survey, Thermoelectric Power Water Use, *http://water.usgs.gov/edu/wupt.html* (last accessed January 3, 2016).

23 United States Geological Survey, Total Water Use in the United States, 2010, *http://water.usgs.gov/edu/wateruse-total.html* (last accessed January 3, 2016).

24 Id.

25 See Table 1.

26 U.S. Department of Energy, U.S. Energy Sector Vulnerabilities To Climate Change And Extreme Weather, 23 (July 2013) [hereinafter "DOE Energy Sector Vulnerabilities"].

27 Morgan Stanley Research at 21.

28 DOE Energy Sector Vulnerabilities at i.

29 See, e.g., Kristen Averyt et al., Freshwater Use by U.S. Power Plants Electricity's Thirst for a Precious Resource, A Report of the Energy and Water in a Warming World Initiative, 7 (November 2011) [hereinafter "EW3 Freshwater Use"]; Public Service Co. of New Mexico, PNM Integrated Resource Plan 2014-2033, 22 (July 2014) ["PNM 2014 IRP"].

30 National Renewable Energy Laboratory, Renewable Electricity Futures Study, A-63, Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. eds. 4 vols. NREL/TP-6A20-52409 (2012) [hereinafter "NREL Renewable Electricity Futures"]; available at: *http://www.nrel.gov/analysis/re_futures/* (last accessed January 3, 2016); see also DOE Energy Sector Vulnerabilities at 25.

31 NREL Renewable Electricity Futures at A-64 - A-65.

32 Id.

33 With the exception of Palo Verde, this table — and this report as a whole — show the water used for energy within New Mexico. In reality, the situation is not this simple; coal, uranium, and oil and gas are exported from New Mexico to other states; and electricity is both exported and imported. Nevertheless, New Mexicans feel the impacts of the energy development in the state.

34 John W. Longworth et al., N*ew Mexico Water Use By Categories 2010, New Mexico Office of the State Engineer Technical Report 54, i (October 2013) (hereinafter "State Engineer Report"); available at: http://www.ose.state.nm.us/Pub/TechnicalReports/TechReport%2054NM%20Water%20Use%20by%20Categories%20.pdf* (last accessed January 3, 2016).

35 *Id.*

36 see Table 2.

37 see Table 2.

38 see Table 4.

39 see Table 4.

40 The amount of water used for oil and gas production depends on the amount of development occurring at any one time, and the amount of water used for each well depends on the formation. These figures are therefore estimates based on a review of numerous development projections and forecasts. For example, in the Permian Basin in Southeast New Mexico, a typical horizontal well stimulation uses "in excess of 4 million gallons of water per well." Engler, T. Balch, R., Cather, M., Reasonable Foreseea*ble Development (RFD) Scenario for the B.L.M. New Mexico Pecos District, 33 [her*einafter "Pecos RFD"]. In the San Juan Basin in the Northwest part of the State, BLM estimates 1.02 millions per well, although higher amounts, in excess of 4 million gallons per well, are noted for oil plays. Engler, T. Balch, R., Cather, M., Reasonable Foreseeable *Development (RFD) Scenario for Northern New Mexico,* 5, 22-23 (Oct. 2014) [hereinafter *"N*orthern NM RFD"]; Susan Harvey*, Declaration, Diné Citizens Against* Ruining Our Environ-

ment, et al. v. Sally Jewell, et al. (Dist. N.M.), 20-25 (May 8, 2015). The Pecos RFD estimates that there will be 800 new well completions per year and about 1200 total well completions. Pecos RFD at 21-22, 39. In the San Juan Basin, the RFD estimated fewer completions per year, around 40, although given increased development in the area, these estimates are likely on the low side. Northern NM RFD at 9. Thus, for the Permian, taking an average of 1000 completions at 4 million gallons per well, for a total of 4 billion gallons per year or 12,280 acre-feet per year, plus predicted water use of 275 acre-feet per year in the Mancos, results in a total of 12,555 acre-feet per year using conservative and likely incomplete estimates. Pecos RFD at *21-22, 39;* Northern *NM RFD* at 23.

41 *Id.*

42 See Table 8.

43 See Table 8.

44 The water used for uranium mines currently is for reclamation purposes. See Section IV(C). This number is based on Homestake's discharge permit, which allows for 450 gpm, or 726 acre-feet per year, of freshwater to be used in the reclamation processes. At the time of this report, there are not any uranium mines currently operating in New Mexico. However, two facilities are partially permitted and licensed; if those projects move forward, water usage for uranium mining would be much greater as discussed in Section IV(C). U.S. Energy Information Administrati*on, Domestic Uranium Production Report 4th Quarter 2015, 5 (Feb. 2016), available at: http://www.eia.gov/uranium/production/quarterly/pdf/qupd.pdf* (last accessed March 27, 2016).

45 Id.

46 Overall, Palo Verse uses 61,378 acre-feet of water per year. See U.S. Governmental Accountability Offic*e, Energy-Water Nexus, Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use (GAO-10-23), 21 (Oct. 2009) [hereinafter "GAO Improvements to Federal Water Use Data"]; EW3 Freshwater Use at 18; see also El Paso Electric Company, Integrated Resource Plan of El Paso Electric Company for the Period 2015-2034, Table A-03 (July 16, 2015) [hereinafter "EPE 2015 IRP"]; PNM 2014 IRP at 22-23. The numbers here were calculated by taking the percentage of Palo Verde likely used for New Mexico electricity demands: PNM owns 10.2 percent of Palo Verde; EPE owns 15.8 percent. PNM 2014 IRP at 11. However, New Mexico operations make up only 24 percent of EPE's total retail customers, and we have therefore taken only 24 percent of EPE's share or 3.7 percent of Palo Verde. EPE 2015 IRP at 7. Thus in total, New Mexico utilities use about 13.9 percent of Palo Verde, or about 8,532 acre-feet of the 61,378 acre-feet water used at Palo Verde.*

47 *Id.*

48 This percentage shows a comparison of the amount of water used for New Mexico demands at Palo Verde to New Mexico's public water supply, but as Palo Verde is located in Arizona, it does not use water within New Mexico.

49 San Juan Citizens Alliance website, Oil & Gas: *http://www.sanjuancitizens.org/oil-gas/* (last accessed April 16, 2016).

50 See Geoffrey H. Fettus, Matthew G. McKinzie, Natural Resources Defense Council, Nuclear Fuel's Dirty Beginnings, Environmental Damage and Public Health Risks From Uranium Mining in the American West, 6 (March 2012), available at: *https://www.nrdc.org/sites/default/files/uranium-mining-report.pdf* (last accessed April 16, 2016).

51 2014 303(d) Report at 13.

52 Jordyn Dahl, A Path Paved In Coal Navajo Nation Looks to Old Energy to Break From Past, The Durango Herald, January 27, 2013, available at: *http://www.durangoherald.com/article/20130127/NEWS01/130129627/A-path-paved-in-coal#/storyimage/DU/20130127/NEWS01/130129627/EP/1/4/EP-130129627.jpg&maxw=620&maxh=400* (last accessed March 21, 2016).

53 Peter Marcus, N.M. power plant extension called 'devastating' Federal officials approve operations at area coal facilities, The Durango Herald, July 21, 2015, available at: *http://www.durangoherald.com/article/20150721/NEWS01/150729958* (last accessed March 21, 2016).

54 See New Mexico Energy, Minerals and Natural Resources Department (EMNRD) NM Coal Mines Query, available at: *http://wwwapps.emnrd.state.nm.us/MMD/CoalMinesQuery/default.aspx?Mode=MineInformation* (last accessed March 21, 2016) [hereinafter "EMNRD Online Database"].

55 Peabody Energy, NMER Mines Located in McKinely (sic) County New Mexico, available at: *http://www.bmi.state.nm.us/images/maps/Lee%20Ranch%20El%20Segundo.pdf* (last accessed March 21, 2016).

56 Market Watch, Chevron leaving U.S. Coal Industry, January 29, 2011, available at: *http://www.marketwatch.com/story/chevron-leaving-us-coal-industry-2011-01-29* (last accessed March 21, 2016).

57 New Mexico Bureau Of Geology & Mineral Resources A Division Of New Mexico Tech, New Mexico's Coal and Electricity Industries, Lite Geology, 2 (Fall 2014). ***This footnote MAY need to change! emnrd.state.nm.us***

58 New Mexico Bureau of Geology and Mineral Resources, Oil and Gas Program, Producing Basins Research website, *http://geoinfo.nmt.edu/resources/petroleum/* (last accessed March 25, 2016).

59 See U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement (OSMRE), Four Corners Power Plant and Navajo Mine Energy Project Final Environmental Impact Statement, 2-5 (May 2015) [hereinafter "FCPP FEIS"].

60 Id. at 2-8.

61 Id. at 2-5.

62 Id. at 2-9.

63 Id. at 2-9.

64 Id. at 2-9.

65 Id. at 2-9.

66 Id. at 2-10.

67 Id. at 2-10.

68 Id. at 2-10.

69 Id. at 2-10.

70 Id. at 2-10.

71 Id. at 2-10.

72 For an informative, albeit promotional, video about longwall mining, see Cat Mining, Principles of Longwall Mining (Sept. 10, 2012), *https://www.youtube.com/watch?v=bXORrVmxwbM* (last accessed March 28, 2016).

73 John M. Mercier, Coal Mining in the Western San Juan Basin, San Juan County, New Mexico, 177-78, Fassett, James E.; Zeigler, Kate E.; Lueth, Virgil W., [eds.], New Mexico Geological Society 61st Annual Fall Field Conference Guidebook (2010) [hereinafter "Coal Mining in the Western San Juan Basin"]; see also United States Department Of Labor Mine Safety And Health Administration Coal Mine Safety And Health, Report of Investigation Underground Coal Mine Fatal Machinery Accident San Juan Mine 1 (November 12, 2007).

74 Coal Mining in the Western San Juan Basin at 178.

75 Id. at 177.

76 Id. at 177-78.

77 Id. at 177.

78 Water and Energy Nexus Literature Review at 63.

79 U.S. Bureau of Land Management Farmington Field Office, Environmental Assessment El Segun*do Mine Lease By Application, Section 34, Township 17 N, Range 9 W, 3-10 (Jan. 2014) [hereinafter "El Segundo EA"]. The mine has not used the full right in any given year, but it retains the right to the full amount. Id.*

80 Id.

81 EM*NRD Online Database*.

82 *Id.*

83 U.S. Energy Information Administration, Coal Data Browser, *available at: http://www.eia.gov/beta/coal/data/browser/* (last accessed March 21, 2016) [hereinafter "EIA *Coal Database"].*

84 New Mexico Environment Department, L*ee Ranch Mine, Minor Individual Permit; SIC 1221; NPDES Compliance Evaluation Inspection; NPDES NM0029581, (Sept. 10, 2014).*

85 *Id.*

86 U.S. Environmental Protection Agency, Region 6, NPDES permit NM0029581, Lee Ranch Coal Company*, (issued September 8, 2010), available at: https://www.env.nm.gov/swqb/documents/swqbdocs/NPDES/Permits/NM0029581-LeeRanch.pdf* (last accessed March 23, 2016).

87 EM*NRD Online Database*.

88 Id.; Peabody Energy, Lee Ranch Mine Summary, available *at: http://www.peabodyenergy.com/content/278/publications/fact-sheets/lee-ranch-mine* (last accessed March 23, 2016).

89 EIA *Coal Database*.

[90] U.S. Environmental Protection Agency, Region 9, N*PDES Permit No. NN0029386, McKinley Mine, (issued October 26, 2009), available at: https://www3.epa.gov/region9/water/npdes/pdf/navajo/McKinleyMineFinalPermit2009.pdf* (last accessed March 31, 2016) [hereinafter "Mc*Kinley Mine NPDES Permit"].*

[91] EM*NRD Online Database*.

[92] Id.; John C. Wilso*n, The McKinley Mine, New Mexico Geol. Soc. Guidebook, 28th Field Conf., San Juan Basin III, 253 (1977), available at: https://nmgs.nmt.edu/publications/guidebooks/downloads/28/28_p0253_p0255.pdf* (last accessed March 23, 2016).

[93] EM*NRD Online Database*.

[94] FCPP FEIS at *4.12-7*

[95] U.S. Environmental Protection Agency, Region 9, NPDES Permit No. NN0028193, Navajo Mine, *(issued March 5, 2008), available at: https://www3.epa.gov/region9/water/npdes/pdf/navajo/bhp-navajo-final-permit-02-13-08.pdf* (last accessed March 31, 2016) [hereinafter "Na*vajo Mine NPDES Permit"].*

[96] Id. at 2-2 (this figure includes disturbance to May 2015*).*

[97] Id. at 2*-1.*

[98] Id. at 2-1*1.*

[99] U.S. Environmental Protection Agency, Region 6, NPDES Permit No. NM0028746, San Juan Mine, *(issued August 29, 2013), available at: https://www.env.nm.gov/swqb/NPDES/Permits/NM0028746-SanJuanCoalCo.pdf* (last accessed March 23, 2016) [hereinafter "Sa*n Juan Mine NPDES Permit"].*

[100] EM*NRD Online Database*.

[101] FCPP FEIS at *4.18-17*.

[102] EM*NRD Online Database*.

[103] *FCPP FEIS at 4.5 (passim).*

[104] *Id. at 2-2 (this figure includes disturbance to May 2015).*

[105] *BHP Billiton, Approved Navajo Mine Permit Application, Permit No. NM-0003F, 41-7 (Jan. 2013), available at: http://www.wrcc.osmre.gov/initiatives/navajoMine/permitApplication.shtm (last accessed March 28, 2016); Id. at Figure 4.5-1; Waters of the United States, or "WOUS" are waters that are classified as "jurisdictional," or subject to the jurisdiction and protections of the CWA. The EPA is in the process of drafting a rule that would define WOUS more definitively (see http://www2.epa.gov/cleanwaterrule), but for purposes of this report, it is necessary only to know that classification as a WOUS means that the water is protected by the CWA.*

[106] *EMNRD Online Database.*

[107] *San Juan Mine Permit, Permit No. 04-01, 802-2 (March 2006).*

[108] *Id.*

[109] *EMNRD Online Database.*

[110] *Id.*

[111] *El Segundo EA at 4-6.*

[112] *Id.*

[113] *EMNRD Online Database.*

[114] *San Juan Mine Permit, Permit No. 04-01 at 802-2; El Segundo EA at 4-6.*

[115] *El Segundo EA at 4-6.*

[116] *FCPP FEIS at 4.12-7.*

[117] *San Juan Mine Permit 04-01 at 804-11.*

[118] *El Segundo EA at 4-6.*

[119] *Id.*

[120] *33 U.S.C. § 1342; 40 C.F.R. part 434.*

[121] *40 C.F.R. §§ 434.81; 434.82; see e.g., U.S. Environmental Protection Agency, Region 6, NPDES Permit No. NM0030996, Lee Ranch Coal Company - El Segundo Mine, (issued Sept. 20, 2014), available at: https://www3.epa.gov/region6/water/npdes/finalpermit/nm0030996fp.pdf (last accessed March 30, 2016); Water and Energy Nexus Literature Review at 64.*

[122] *San Juan Mine NPDES Permit at 5-6.*

123 *Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, Public Health Statement Arsenic (August 2007), available at: http://www.atsdr.cdc.gov/ToxProfiles/tp2-c1-b.pdf (last accessed March 30, 2016).*

124 *Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, Public Health Statement Benzene (August 2007), available at: http://www.atsdr.cdc.gov/ToxProfiles/tp3-c1-b.pdf (last accessed March 30, 2016).*

125 *Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, Public Health Statement Carbon Tetrachloride (August 2005), available at: http://www.atsdr.cdc.gov/phs/phs.asp?id=194&tid=35 (last accessed March 30, 2016); U.S. Environmental Protection Agency, Air Toxics website, Carbon Tetrachloride: http://www3.epa.gov/airtoxics/hlthef/carbonte.html (last accessed March 30, 2016).*

126 *Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, Public Health Statement Vinyl Chloride (July 2006), available at: http://www.atsdr.cdc.gov/ToxProfiles/tp20-c1-b.pdf (last accessed March 30, 2016).*

127 *Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, Toxic Substances Portal, http://www.atsdr.cdc.gov/substances/indexAZ.asp#V.*

128 *San Juan Mine NPDES Permit, Response to Comments at 6.*

129 *U.S. Environmental Protection Agency, Region 6, NPDES Permit No. NM0029505, San Juan Coal Company - La Plata Mine, Statement of Basis (June 2, 2014), available at: https://www3.epa.gov/region6/water/npdes/publicnotices/nm/nm0029505_statement_of_basis.pdf (last accessed March 30, 2016).*

130 *Water and Energy Nexus Literature Review at 64.*

131 *Id.*

132 *Id.*

133 *Id.*

134 *photo- EcoFlight*

135 *photo- EcoFlight*

136 *EMNRD Online Database; Peabody Energy, Lee Ranch Mine Summary, available at: http://www.peabodyenergy.com/content/278/publications/fact-sheets/lee-ranch-mine (last accessed March 23, 2016).*

137 *EMNRD Online Database. The EMNRD database does not list any land as fully reclaimed at the Lee Ranch Mine as of 2010, however, a 2014 EMNRD report does state that Peabody has applied for partial bond release for a small portion of the mine. See New Mexico Energy, Minerals & Natural Resources Department, 2014 Annual Report, available at: http://www.emnrd.state.nm.us/ADMIN/documents/2014_EMNRD_Annual_Report.pdf (last accessed March 31, 2016).*

138 *Id.*

139 *See Rebecca Fairfax Clay, Tribe at a Crossroads: The Navajo Nation Purchases a Coal Mine, Environmental Health Perspectives, Volume 122, Issue 4 (April 2014), available at: http://ehp.niehs.nih.gov/122-a104/ (last accessed March 31, 2016).*

140 *EMNRD Online Database (as of 2010).*

141 *FCPP FEIS at 2-1, 2-5.*

142 *McKinley Mine NPDES Permit; U.S. Environmental Protection Agency, Region 9, NPDES Permit No. NN0029386, McKinley Mine Fact Sheet, (2009), available at: https://www3.epa.gov/region9/water/npdes/pdf/navajo/McKinleyMine-FactSheetFinal.pdf (last accessed March 31, 2016); EMNRD Online Database.*

143 *See, e.g. San Juan Mine Permit, Permit No. 04-01 at 802-2.*

144 *El Segundo EA at 4-6.*

145 *See, e.g., National Public Radio, Bankruptcies Fuel Uncertainty In Coal Communities (Mar. 25, 2016).*

146 This exemption is problematic because by failing to regulate storm water, EPA is essentially saying that sediment is not an issue that needs to be addressed at these sites. However, given the nature of the development, storm water can pick up much more sediment than it would otherwise, causing issues for receiving waters. See Renee Lewis Kosnik, *Oil and Gas Accountability Project, A Project of Earthworks, The Oil and Gas Industry's Exclusions and Exemptions to Major Environmental Statutes, 10-11 (October 2007) (discussion of exemption, with a focus on oil and gas development, but helpful background).*

[147] Most states have "primacy" to issue NPDES themselves. Neither New Mexico nor the Navajo Nation have gained primacy, however, and thus EPA is responsible for issuing permits in New Mexico. On non-tribal lands in New Mexico, EPA Region 6 issues permits, and on the Navajo Nation, EPA Region 9 issues NPDES permits. Although the state and tribes in New Mexico have not gained primacy, NPDES permits are based on New Mexico and Tribal Water Quality Standards. See *generally: http://water.epa.gov/polwaste/npdes/basics/index.cfm*. Water quality standards available at: *https://www.env.nm.gov/swqb/Standards/#Current*; *http://water.epa.gov/scitech/swguidance/standards/wqslibrary/tribes.cfm#r6*.

[148] The Army Corps of Engineers has authority to issue 404 permits, but EPA is involved in section 404 enforcement as well. See generally: *http://water.epa.gov/lawsregs/guidance/cwa/dredgdis/*.

[149] After years of debate and controversy, EPA issued a final rule regarding the regulation of CCW under RCRA. The rule, Technical Amendments to the Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities, characterizes CCW as non-hazardous waste, similar to household garbage, under RCRA subtitle D, non-hazardous waste, instead of hazardous waste under subtitle C. 80 Fed. Reg. 21302 (April 17, 2015); see also *http://www.onearth.org/earthwire/epa-coal-ash-rules*.

[150] FCPP FEIS at 2-10.

[151] Id. at 2-11.

[152] Id.

[153] Id.

[154] EMNRD Online Database.

[155] EIA Coal Database.

[156] Id.

[157] Id.

[158] EMNRD Online Database.

[159] BNSF Railway, Coal Dust Frequently Asked Questions (BNSF has since changed their Coal Dust Frequently Asked Questions website (new website at: *http://www.bnsf.com/customers/what-can-i-ship/coal/coal-dust.html*), but the author has the cited version on file; Daniel Jaffe et al., Diesel particulate matter and coal dust from trains in the Columbia River Gorge, Washington State, USA, Atmospheric Pollution Research, 6, 946-952 (2015), available at *http://www.atmos.washington.edu/jaffegroup/modules/APOLLO/Jaffe_DPM_coal_dust_trains_ColumbiaRivGorge_2015.pdf* (last accessed April 1, 2016).

[160] United States Geological Survey, Coal Dust Transport, Project Summary, YA00FCG - USGS Pilot Study to Assess Ecosystem Effects of Increased Coal Transport Across the Northwest Region, available at: *http://wa.water.usgs.gov/projects/coaltransport/summary.htm* (last accessed March 31, 2016); Oregon Public Broadcasting, Earthfix, Scientists on a Quest for Knowledge About Coal Dust Risks (Sept. 17, 2014), available at: *http://kuow.org/post/scientists-quest-knowledge-about-coal-dust-risks* (last accessed March 31, 2016).

[161] Surface Transportation Board, Decision, Arkansas Electric Cooperative Corp.—Petition for Declaratory Order, Dkt. No. FD 35305 (Mar. 3, 2011).

[162] The author has not been able to find any studies regarding coal dust loss during transport in New Mexico. Should they exist, please contact Amigos Bravos with more information.

[163] New Mexico Energy Minerals and Natural Resources Dep't, New Mexico State Parks, Morgan Lake website: *http://www.emnrd.state.nm.us/SPD/BOATINGWeb/MorganLake.html* (last accessed April 5, 2016).

[164] FCPP FEIS at 2-12.

[165] PNM 2014 IRP at 24.

[166] photo Albuquerque Journal *http://www.abqjournal.com/500694/biz/turning-down-the-temperature.html*
(this may change to an EcoFlight photo credit)

[167] photo, Jared Blumenfeld, EPA — accessed at *http://www.wildearthguardians.org/site/MessageViewer?em_id=16481.0#.Vd4BEIsqdAI*
(possible replacement photo: *http://cronkitenewsonline.com/2014/03/four-corners-power-plant-looks-to-expand-nearby-coal-mining-operations/*)

[168] photo *http://www.abqjournal.com/622100/biz/nm-opts-to-comply-with-impending-carbon-rules.html*

[169] photo- Ecoflight

170 U.S. Energy Information Administration website, Frequently Asked Questions How much of U.S. carbon dioxide emissions are associated with electricity generation?: *http://www.eia.gov/tools/faqs/faq.cfm?id=77&t=11* (last accessed April 16, 2016).
171 Water and Energy Nexus Literature Review at 88.
172 Id.
173 FCPP FEIS at 2-21.
174 Id. at 2-21.
175 Id. at 2-21.
176 Id. at 2-21; Water and Energy Nexus Literature Review at 88.
177 FCPP FEIS at 2-21.
178 Id.
179 Id.
180 Id. at 2-22.
181 Id.
182 Id.
183 Id.
184 Erik Mielke, Laura Diaz Anadon, and Venkatesh Narayanamurti, Water Consumption of Energy Resource Extraction, Processing, and Conversion, 5, Discussion Paper #2010-15, Energy Technology Innovation Policy Discussion Paper Series, Belfer Center for Science and International Affairs, Harvard Kennedy School (Oct. 2010), available at: *http://belfercenter*.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf (last accessed March 31, 2016) [hereinafter "Water Consumption of Energy Resource Extraction, Processing, and Conversion"].
185 FCPP FEIS at 2-22, 2-34.
186 Id. at 2-22
187 State Engineer File No. 1605 supplemental.
188 John W. Longworth et al., New Mexico Office of the State Engineer, New Mexico Water Use by Categories 2010, i, New Mexico Office of the State Engineer Technical Report 54 (Oct. 2013) available at: *http://www.ose.state.nm.us/Pub/TechnicalReports/TechReport%2054NM%20Water%20Use%20by%20Categories%20.pdf* (last accessed March 31, 2016) [hereinafter "State Engineer 2010 Report"].
189 U.S. Census Bureau, Quick Facts, New Mexico, available at: *http://quickfacts.census.gov/qfd/states/35000.html* (last accessed March 31, 2016) (New Mexico population in 2014 was estimated at 2,085,572 people; 13 percent of that total is 271,124); U.S. Census Bureau, Quick Facts, New Mexico, Santa Fe city, available at: *http://quickfacts.census.gov/qfd/states/35/3570500.html* (last accessed March 31, 2016) (Santa Fe population is 70,297).
190 State Engineer File No. 1605 supplemental.
191 Tri-State Generation and Transmission Ass'n, Inc., Integrated Resource Plan/E*lectric Resource Plan (Nov. 2010) [hereinafter "Tri-State 2010 IRP"]. This figure is the result of a calculation using numbers given by Tri-State. Escalante Generating Station has a capacity of 245 MW; thus total possible capacity is 2,146,200 MWh/yr (245MW x 8760 hours/year) (Tri-State 2010 IRP at 37); Escalante operates at a capacity factor of 83% (Tri-State 2010 IRP at 37), and thus average capacity is 1,781,346 MWh/yr (2,146,200 MWh/yr x 0.83); water usage per MWh is 667 gal/MWh (Tri-State 2010 IRP at 37) and therefore total water usage per year is 1,188,157,782 gal/yr (1,781,346 MWh/yr x 667gal/yr) or 3,646 AF/yr.*
192 Id. at 37.
193 Tri-State Generation and Transmission Ass'n Inc. website: *http://www.tristategt.org/AboutUs/baseload-resources.cfm* (last accessed March 31, 2016) [hereinafter "Tri-*State website"].*
194 New Mexico Environment Department, Ground Water Discharge Permit Renewal and Modific*ation Escalante Generating Station, DP-206 (effective Feb. 10, 2015), available at: https://cloud.env.nm.gov/water/resources/_translator.php/jyeL9BeOHThsNWqntAii2xO8jIWWzZmRSFfuixCPtZ8AqoFq2N00jRfZRpK0uMPu/hfBGAH3eU/9Qe9uVGDh87L-z8YmRglAtLowvLybTdZ4=.pdf* (last accessed April 5, 2016) [hereinafter "Esc*alante Ground Water Discharge Permit"]*
195 Union of Concerned Scientists, UCS EW3 Energy-Water *Database V.1.3 (2012), available at: www.ucsusa.org/ew-3database (last accessed March 31, 2016) [hereinafter "UCS Database"].*
196 Tr*i-State website; EIA Coal Database.*

197 Tri-State *2010 IRP at 37.*

198 *Id.*

199 FCPP FEIS a*t 2-22.*

200 This figure is the result of a calculation using numbers given by PNM. FCPP units 4 and 5 have a capacity of 1540 MW (FCPP FEIS at 2-17); thus total possible capacity is 13,490,400 MWh/yr (1540 MW x 8760 hours/year); FCPP operates at a capacity factor *of 80% (FCPP FEIS at 2-21), and thus average capacity is 10,792,320 MWh/yr (13,490,400 MWh/yr x 0.8); water usage per MWh is 577 gal/MWh (PNM 2014 IRP at 22) and therefore total water usage per year is 6,227,168,640 gal/yr (10,792,320 MWh/yr x 577gal/yr) or 19,110 AF/yr. See also, FCPP FEIS at 2-22 (noting that units 4 and 5 use 5,000 acre-feet per year for operation of the SO2 scrubbers, and evaporate approximately 13,000 acre-feet per year of cooling water). Average consumption with all five units from 2000 to 2011 was 22,856 AF/yr. FCPP FEIS at 2-22.*

201 PNM 2014 *IRP at 22.*

202 FCPP FEIS *at 2-17.*

203 UCS *Database.*

204 FCPP FEIS *at 2-17.*

205 Id. at 2-17. The 1,540 MW figure represents units 4 and 5 only; before units 1-3 were retired, FCPP had a capacity of 2,100 MW. Units 1-3 had a capacity of 560 MW, thus their retirement caused of retirement of about 27% of plant capacity.

206 FCPP FEIS *at 2-21; see also RMT, Prepared for the California Public Utilities Commission, Four Corners Generating Station Project Navajo Nation Indian Reservation, San Juan County, New Mexico Final Initial Study/ Negative Declaration, Appendix B (Jan. 2012)*available at: *http://www.cpuc.ca.gov/Environment/info/mha/fourcorners/images/Four%20 Corners_Final%20ISND_website.pdf* (last accessed March 26, 2016).

207 In the Matter of the Application of Public Service Company of New Mexico for Approval to Abandon San Juan Generating Station Units 2 and 3, Issuance of Certificates of Public Convenience and Necessity for Replacement Power Resources, Issuance of Accounting Orders and Determination of Related Ratemaking, Case no. 13-00390-UT, Public Service Company of New Mexico's O*bjections And Responses to the Coalition for Clean Affordable Energy's Third Set of Interrogatories and Requests for Production of Documents, Table 3-2 (May 1, 2014) [hereinafter "CCAE Interrogatory"] (if units 2 and 3 are retired, PNM asserts that water usage will be reduced by 53%, but it is unclear what BHP (the water rights holder) will do with the excess water).*

208 *Id.*

209 Id.*; PNM 2014 IRP at 22 (IRP puts this number at 594 gallons/MWh).*

210 Ne*w Mexico Water Right Permit SP-2838, Event 1075493 2001-02-27 APP.*

211 CCAE In*terrogatory at 3.*

212 UCS *Database.*

213 *EMNRD Online Database.*

214 PNM 2014 I*RP at 193.*

215 Tri-Stat*e 2010 IRP at 37.*

216 Id. at 2-22

217 Id. at 2-22; USFWS, Joel D. Lusk, Eric Rich, R. Sky Bristol, Methylmercury And Other Environmental Contaminants In Water And Fish Collected From Four Recreational Fishing Lakes On The Navajo Nation 2004, 12 (July 2005).

218 FCPP FEIS at 2-22

219 Id.

220 Id.

221 Id.

222 Id.

223 Id.; State Engineer 2010 Report at ii (New Mexico's reservoirs lose an average of 7 percent of their volume to evaporation each year).

224 FCPP FEIS at 2-22

225 Id. at 2-23.

[226] Id.

[227] New Mexico Water Right Permit SP-2838, Event 1075493 2001-02-27 APP.

[228] USGS, National Water Information System: Web Interface, USGS Surface-Water Monthly Statistics for New Mexico, Site no. 09365000, San Juan River at Farmington, NM; available at: *http://nwis.waterdata.usgs.gov/nm/nwis/monthly/?search_site_no=09365000&agency_cd=USGS&referred_module=sw&format=sites_selection_links* [hereinafter "USGS Flow Data"].

[229] U.S. Environmental Protection Agency, Region 9, NPDES Permit No. NN0000019, Proposed NPDES Permit Fact Sheet, Four Corners Power Plant, 2 (2014), available at: *https://www3.epa.gov/region9/water/npdes/pdf/az/aps/nn0000019-aps-factsheet-2014.pdf* (last accessed April 5, 2016) [hereinafter "Proposed FCPP NPDES Permit Fact Sheet"].

[230] FCPP FEIS at 2-22.

[231] Proposed FCPP NPDES Permit Fact Sheet at 2.

[232] FCPP FEIS at 2-22; U.S. Environmental Protection Agency, Region 9, NPDES Permit No. NN0000019, NPDES Permit, Four Corners Power Plant, 2 (effective April 7, 2001), available at: *https://www3.epa.gov/region9/water/npdes/pdf/navajo/AZ-PublicServiceC0-permit.pdf* (last accessed April 5, 2016) [hereinafter FCPP NPDES Permit"]; U.S. Environmental Protection Agency, Region 9, NPDES Permit No. NN0000019, Proposed NPDES Permit, Four Corners Power Plant, 2 (2014), available at: *https://www3.epa.gov/region9/water/npdes/pdf/az/aps/nn0000019-aps-draft-permit-2014.pdf* (last accessed April 5, 2016) [hereinafter "Proposed FCPP NPDES Permit"].

[233] FCPP FEIS at 2-22.

[234] Id. at 2-22.

[235] FCPP NPDES Permit at 2; Proposed FCPP NPDES Permit at 2.

[236] USGS Flow Data; see: *http://nwis.waterdata.usgs.gov/nm/nwis/uv/?cb_00060=on&cb_00065=on&cb_00010=on&format=gif_default&site_no=09365000&period=365&begin_date=&end_date=*

[237] FCPP FEIS at Figure 2-3.

[238] photo- Ecoflight.

[239] FCPP FEIS *at 1-10*.

[240] After years of debate and controversy, EPA issued a final rule regarding the regulation of CCW under RCRA. The rule, Technical Amendments to the Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities, characterizes CCW as non-hazardous waste, similar to household garbage, under RCRA subtitle D, non-hazardous waste, instead of hazardous waste under subtitle C. 80 Fed. Reg. 21302 (April 17, 2015); see also *http://www.onearth.org/earthwire/epa-coal-ash-rules*.

[241] United States Dep't of the Interior, Fish and Wildlife Serv., Biological Opinion for Four Corners Power Plant and Navajo Mine Energy Project, 67 (April 8, 2015) available at: *http://www.wrcc.osmre.gov/initiatives/fourCorners/documents/FC_040915-FINALBiOpFCPP-NMEPARMS.pdf* (last accessed April 5, 2016) [hereinafter "FCPP BiOp"].

[242] Id. at 68.

[243] FCPP BiOp.

[244] Id.

[245] Id.

[246] Id. at 66.

[247] Id.

[248] Id. at 35 (map), 66.

[249] Id. at 66.

[250] Id. at 30.

[251] Id. at 44, 49.

[252] 79 Fed. Reg. 48299 (August 15, 2014).

[253] FCPP FEIS at 2-22

[254] Id.; FCPP BiOp at 109-10.

[255] FCPP BiOp.

[256] FCPP BiOp.

[257] Proposed FCPP NPDES Permit Fact Sheet at 7; 40 C.F.R. § 122.21(r).

258 Water and Energy Nexus Literature Review at 4, 102-03; FCPP FEIS at 2-23 — 2-25.

259 Proposed FCPP NPDES Permit Fact Sheet at 2-3.

260 Id.

261 Navajo Nation Environmental Protection Agency, Navajo Nation Fish Consumption Health Advisory, available at: *http://www.navajonationepa.org/Pdf%20files/unsavefish.pdf* (last accessed April 5, 2016) [hereinafter "Navajo Nation Fish Consumption Health Advisory"].

262 FCPP FEIS at Section 3.

263 FCPP FEIS at 2-17; Morgan Lake website.

264 Id.

265 Navajo Nation Environmental Protection Agency, Navajo Nation Surface Water Quality Standards (2007), available at *https://www.epa.gov/sites/production/files/2014-12/documents/navajo-tribe.pdf* (last accessed April 5, 2016) [hereinafter "Navajo National Water Quality Standards"]; FCPP FEIS at 4.5-5.

266 Navajo National Water Quality Standards.

267 FCPP FEIS at 4.8-2, 4.5-5.

268 FCPP NPDES Permit; Proposed FCPP NPDES Permit; Navajo National Water Quality Standards at Table 206.1.

269 Navajo Nation Fish Consumption Health Advisory; FCPP FEIS at Section 3.

270 Escalante Ground Water Discharge Permit.

271 Id.

272 FCPP FEIS at 2-24.

273 Id.

274 Id.

275 Id.

276 Id. at 2-22.

277 Id. at 2-24.

278 Id.

279 Id.

280 See Hazardous and Solid Waste Management: Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals from Electric Utilities, 63252 Fed. Reg. 17,197 (Oct. 12, 2011); Physicians for Social Responsibility and Earthjustice, Coal Ash The Toxic Threat to Our Health and Environment, vii (Sept. 2010); Earthjustice, EPA's Blind Spot: Hexavalent Chromium in Coal Ash (Feb. 1, 2011); Environmental Integrity Project, Toxic Waters Run Deep (June 23, 2011).

281 See 63252 Fed. Reg. 17,197.

282 U.S. Environmental Protection Agency, Hazardous and Solid Waste Management System; Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals From Electric Utilities, 75 Fed. Reg. 35128, 35168 (June 21, 2010).

283 Letter from Allan H. Smith, MD, PhD, Professor of Epidemiology, School of Public Health, Division of Environmental Health Sciences, University of California, and Marie Vahter, PhD, Professor of Environmental Toxicology, Institute of Environmental Medicine, Karolinska Institutet to Lisa Jackson, Administrator U.S. Environmental Protection Agency, re. Hazardous and Solid Waste Management System; Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals from Electric Utilities; Docket ID No. EPA–HQ–RCRA–2009–0640 (Nov. 14, 2010) (on file with the author).

284 Comments from Dr. Mary Fox, Assistant Professor in the Department of Health Policy and Management at the Johns Hopkins University Bloomberg School of Public Health to Lisa Jackson, Administrator U.S. Environmental Protection Agency, re. EPA-HQ-RCRA-2009-0640 (on file with the author).

285 Id.

286 Water and Energy Nexus Literature Review at 103.

287 FCPP FEIS at 2-24.

288 Id.

289 Id.

290 Id.

[291] Id.
[292] See: *http://www.esbnyc.com/sites/default/files/esb_fact_sheet_4_9_14_4.pdf; http://www.marinemammalcenter.org/education/marine-mammal-information/cetaceans/blue-whale.html.*
[293] FCPP FEIS at Table 4.15-1.
[294] SMCRA notice letter; 2009 SJCC Permit Renewal Application.
[295] Id.
[296] GEI Consultants, Coal Ash Impoundment - Specific Site Assessment FINAL Report — Tri-State Generation and Transmission Association: Escalante Generating Station, Appendix A (September 2009).
[297] Id.
[298] Id.
[299] Dr. Mary Fox Comments.
[300] Environmental Integrity Project and Earthjustice, Out of Control: Mounting Damages From Coal Ash Waste Sites. Thirty-one New Damage Cases of Contamination from Improperly Disposed Coal Combustion Waste (February 24, 2010), available at: *http://earthjustice.org/sites/default/files/library/reports/ej-eipreportout-of-control-final.pdf* (last accessed April 5, 2016) [hereinafter "Out of Control"].
[301] D.A. Zimmerman, A Preliminary Evaluation of the Potential for Surface water Quality Impacts from Fly Ash Disposal at the Navajo Mine, New Mexico, Zimmerman (May 25, 2005) [hereinafter "Zimmerman Study"]; Lauren Ross, Effects of Four Corners Power Plant Coal Combustion Waste Disposal on Surface and Groundwater Quality, (August 2007) [hereinafter "Ross Study"].
[302] Zimmerman Study at 35.
[303] FCPP FEIS at 4.5-19.
[304] Id. at 4.5-29.
[305] Zimmerman Study; Out of Control.
[306] Ross Study; Out of Control.
[307] SMCRA notice letter; RCRA notice letter; Complaint at ¶¶ 41-55.
[308] Id.
[309] Sierra Club v. San Juan Coal Company, Consent Decree, Case 10-cv-00332-MCA-LAM (D. N.M. March 28, 2012), available at: *http://www.westernlaw.org/sites/default/files/San%20Juan%20Mine%20Settlement%203.28.12.pdf* (last accessed April 5, 2016); Western Environmental Law Center, Conservation Group Seeks Clean Up of Open Pit Coal Combustion Waste Dump, (April 8, 2012), available at: *http://www.westernlaw.org/article/conservation-group-seeks-clean-open-pit-coal-combustion-waste-dump-press-release-4812* (last accessed April 5, 2016); see also, Sindhu Sundar, NM Cos. Pay $10M To End Sierra Club Coal Waste Suit, Law360 (March 28, 2012), available at: *http://www.law360.com/articles/324444/nm-cos-pay-10m-to-end-sierra-club-coal-waste-suit* (last accessed April 5, 2016).
[310] Letter from Geo-Hydro, Inc. to Mike Eisenfeld, San Juan Citizens Alliance, re. Geo-Hydro, Inc. Review of Draft Environmental Impact Statement Four Corners Power Plant and Navajo Mine Energy Project (June 27, 2014).
[311] FCPP BiOp; FCPP FEIS.
[312] FCPP BiOp at 73.
[313] Id.
[314] Id.
[315] Id.
[316] Id.
[317] Id.
[318] 2014 303(d) Report at 61.
[319] Id.
[320] FCPP BiOp at 96.
[321] Id. at 96-97.
[322] Id.
[323] Id.
[324] Id. at 103.
[325] DOE Energy Sector Vulnerabilities.

[326] photo- Ecoflight
[327] Ceres Hydraulic Fracturing Report.
[328] U.S. Energy Information Administration, New Mexico State Profile and Energy Estimates: *http://www.eia.gov/state/?sid=NM* (last accessed April 6, 2015).
[329] Id.
[330] See Water and Energy Nexus Literature Review at 68-79; Ceres Hydraulic Fracturing Report.
[331] Tip of the Mitt Watershed Council diagram: *http://www.watershedcouncil.org/hydraulic-fracturing.html*
[332] For a virtual (albeit rosy) tour of the oil and gas production process, see EFD Virtual Sites: *http://www.efdvirtualsite.org/?utm_source=October,+2014&utm_campaign=EFD+October+2014+Newsletter&utm_medium=email* (last accessed April 5, 2016); see also Michigan Oil & Gas Producers Education Foundation (MOGPEF): *http://www.mogpef.org/video_shale/index.html* (last accessed April 5, 2016).
[333] Water and Energy Nexus Literature Review at 72.
[334] U.S. Energy Information Administration and U.S. Geological Survey diagram: *http://www.watershedcouncil.org/hydraulic-fracturing.html* (citing EIA)
[335] Ceres Hydraulic Fracturing Report.
[336] See, e.g., Tip of the Mitt Watershed Council, Oil and Gas Development Using High Volume Hydraulic Fracturing webpage: *http://www.watershedcouncil.org/hydraulic-fracturing.html* (last accessed April 5, 2016) (provides a very good description of the process of hydraulic fracturing).
[337] Ceres Hydraulic Fracturing Report; Robert B. Jackson, Avner Vengosh, J. William Carey, Richard J. Davies, Thomas H. Darrah, Francis O'Sullivan, and Gabrielle Pétron, The Environmental Costs and Benefits of Fracking, Annual Review of Environment and Resources, Vol. 39: 327-362, 334 (Aug. 11, 2014), available at: *http://www.annualreviews.org/doi/abs/10.1146/annurev-environ-031113-144051* (last accessed April 5, 2016) [hereinafter "The Environmental Costs and Benefits of Fracking"].
[338] Interstate Oil and Gas Compact Commission, Groundwork, Hydraulic Fracturing State Progress: *http://groundwork.iogcc.ok.gov/topics-index/hydraulic-fracturing/state-progress* (last accessed April 5, 2016); see also U.S. Environmental Protection Agency, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft), EPA 600/R-15/047a, 2-27 (June 2015) available at: *https://www.epa.gov/hfstudy* (last accessed April 5, 2016) [hereinafter "EPA Assessment"]. But not supposed to cite…
[339] The Environmental Costs and Benefits of Fracking at 334.
[340] Ceres Hydraulic Fracturing Report.
[341] Id.
[342] The Endocrine Disruption Exchange (TEDX), Chemicals In Natural Gas Operations: *http://endocrinedisruption.org/chemicals-in-natural-gas-operations/introduction* (last accessed April 5, 2016).
[343] Ceres Hydraulic Fracturing Report.
[344] Id.
[345] Id.
[346] Ceres Hydraulic Fracturing Report at 20.
[347] Id. at 17, Figure 2.
[348] Water and Energy Nexus Literature Review at 71; Water Consumption of Energy Resource Extraction, Processing, and Conversion
[349] Water and Energy Nexus Literature Review at 71.
[350] Water and Energy Nexus Literature Review at 72; Ceres Hydraulic Fracturing Report; DOE Energy Sector Vulnerabilities.
[351] Id.
[352] GAO Water Produced during Oil and Gas Production at 11.
[353] See for example, increased development in the southern part of the San Juan Basin for shale oil.
[354] DOE Energy Sector Vulnerabilities.
[355] Ceres Hydraulic Fracturing Report; Climate Progress article; LA Times article; New Mexican; DOE report.
[356] Water and Energy Nexus Literature Review at 72.
[357] Using a per capita daily usage of 100 gallons per person per day, see *http://www.santafenm.gov/water_conservation#leave-site-alert*.

[358] Water and Energy Nexus Literature Review at 72.
[359] The Environmental Costs and Benefits of Fracking at 7-11.
[360] State Engineer 2010 Report at 38-39 (oil and gas share is 5.4 percent of 41,559 acre-feet for entire mining category).
[361] See footnote 40.
[362] Id.
[363] Pecos RFD at 40.
[364] San Juan Citizens Alliance website, Oil & Gas in the San Juan Basin: *http://www.sanjuancitizens.org/oil-and-gas-in-the-san-juan-basin/* (last accessed April 5, 2016).
[365] Id.
[366] Id.
[367] Northern New Mexico RFD at 24.
[368] Based on Pecos RFD estimate of 4 million gallons/well.
[369] Conversations between Kyle Tisdel, Western Environmental Law Center and BLM Staff.
[370] Id.
[371] 42 U.S.C. § 1342(l)(2) (exemption for oil and gas activities); 42 U.S.C. § 1362(24) (definition of "oil and gas exploration and production); This exemption is problematic because by failing to regulate storm water, EPA is essentially saying that sediment is not an issue that needs to be addressed at these sites. However, given the nature of the development, storm water can pick up much more sediment than it would otherwise, causing issues for receiving waters. See Renee Lewis Kosnik, Oil and Gas Accountability Project, A *Project of Earthworks, The Oil and Gas Industry's Exclusions and Exemptions to Major Environmental Statutes, 10-11 (October 2007).*
[372] Red Lodge Clearinghouse, O*il and Gas Resource Development: http://rlch.org/content/oil-and-gas-resource-development#hydraulic* (last accessed April 5, 2016).
[373] 42 U.S.C. § 300(h)(d)(1)(B)(ii).
[374] Id.; U.S. Environmental Protection Agency*, Underground Injection Control, Class II Oil and Gas Related Injection Wells: http://www2.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells* (last accessed April 5, 2016).
[375] The Army Corps of Engineers has authority to issue 404 permits, but EPA is involved in section 404 enforcement as well. See generally: *http://water.epa.gov/lawsregs/guidance/cwa/dredgdis/.*
[376] Energy Policy Act of 2005, 42 U.S.C. 15942; see also U.S. Government Accountability *Office, Energy Policy Act of 2005, Greater Clarity Needed to Address Concerns with Categorical Exclusions for Oil and Gas Development under Section 390 of the Act (Sept. 2009), available at: http://www.gao.gov/assets/300/295281.pdf* (last accessed April 5, 2016).
[377] Bureau of Land Management, San Juan Public Lands Office, 2009 Addendum to the Oil and Gas Potential and Reasonable Foreseeable Development (RFD) Scenarios In The San Juan National Forest and BLM Public Lands, Colorado (July 2010), available at: *http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5433957.pdf* (last accessed March 26, 2016); see also Bureau of Land Management, Wildlife Management, Best Management Practices for Fluid Minerals (Jan. 2013), available at: *http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/bmps.Par.97783.File.dat/WO1_WildlifeMgmt_BMPs_Slideshow.pdf* (last accessed March 26, 2016).
[378] See Table X.
[379] See Environmental Working Group, Free Pass for Oil and Gas: Oil and Gas Industry Exemptions (March 26, 2009), available at: *http://www.ewg.org/research/free-pass-oil-and-gas/oil-and-gas-industry-exemptions* (last accessed April 5, 2016).
[380] 2012 303(d) Report at ix.
[381] USGS Flow Data: *http://waterdata.usgs.gov/nwis/annual?referred_module=sw&site_no=08330000&por_08330000_3=558903,00060,3,1942,2015&year_type=C&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list.*
[382] State Engineer 2010 Report at i.
[383] The Environmental Costs and Benefits of Fracking at 342; DOE Energy Sector Vulnerabilities at 18 (estimates 21 billion barrels or 2.4 billion gallons per day).

[384] Using a per capita daily usage of 100 gallons per person per day, see: City of Santa Fe, 2013 Annual Water Report, 15 (April 2015) (per capita water use in Santa Fe is 101.2 gallons per capita per day), available at: *http://www.santafenm.gov/media/files/Public_Utilities_WATER/2013_Annual_Water_Report-reduced.pdf* (last accessed April 5, 2016).
[385] The Environmental Costs and Benefits of Fracking at 342.
[386] See Renee Lewis Kosnik, Oil and Gas Accountability Project, A Project of Earthworks, The Oil and Gas Industry's Exclusions and Exemptions to Major Environmental Statutes, 4-5 (October 2007); 42 U.S.C. §§ 9601(9), (14), (22), 9607(a) – (c).
[387] The Environmental Costs and Benefits of Fracking at 342-43.
[388] Id. at 342.
[389] Id.
[390] Water and Energy Nexus Literature Review at 75.
[391] GAO Water Produced during Oil and Gas Production at 13.
[392] The Environmental Costs and Benefits of Fracking at 342.
[393] Id.
[394] U.S. Dep't of the Interior Bureau of Reclamation, Oil and Gas Produced Water Management and Beneficial Use in the Western United States,
[395] Science and Technology Program Report No. 157, 8 (Sept. 2011), available at: *https://www.usbr.gov/research/AWT/reportpdfs/report157.pdf* (last accessed April 6, 2016) [hereinafter "BOR Oil and Gas Produced Water"].
[396] Water and Energy Nexus Literature Review at 75-76.
[397] Id.
[398] Id. at 73-74; GAO Water Produced during Oil and Gas Production at 19 n. 24.
[399] DOE Energy Sector Vulnerabilities at 18; see also The Environmental Costs and Benefits of Fracking at 342-43 (95 percent); GAO Water Produced during Oil and Gas Production at 15 (90 percent) and at 17, n. 18 (also has 40 and 59 percent figures).
[400] GAO Water Produced during Oil and Gas Production at 17.
[401] Id. at 21.
[402] Safe Drinking Water Act, 42 U.S.C. §§ 300f et seq.; exemption at § 300(h)(d)(1)(B)(ii).
[403] GAO Water Produced during Oil and Gas Production at 7.
[404] Id. at 26; U.S. Environmental Protection Agency, Protecting Underground Sources of Drinking Water from Underground Injection (UIC) website: *https://www.epa.gov/uic* (last accessed April 6, 2016); New Mexico Energy, Minerals and Natural Resources Department, New Mexico Oil Conservation Division summary of Underground Injection Control Program: *http://www.emnrd.state.nm.us/OCD/tab1att1.html* (last accessed April 6, 2016).
[405] The Environmental Costs and Benefits of Fracking at 343; Anna Kuchment, Drilling for Earthquakes, Scientists are increasingly confident about the link between earthquakes and oil and gas production, yet regulators are slow to react (March 28, 2016) available at: *http://www.scientificamerican.com/article/drilling-for-earthquakes/* (last accessed April 6, 2016).
[406] The Environmental Costs and Benefits of Fracking at 343; DOE Energy Sector Vulnerabilities at 21; Water and Energy Nexus Literature Review at 73-74.
[407] GAO *Water Produced during Oil and Gas Production* at 19.
[408] *Water and Energy Nexus Literature Review*.
[409] GAO *Water Produced during Oil and Gas Production* at 27.
[410] *The Environmental Costs and Benefits of Fracking* at 343.
[411] *Id*.
[412] Earthworks, *New Mexico Pit Rule website*: *https://www.earthworksaction.org/issues/detail/new_mexico_pit_rule#.VeE75u-kqdAK* (last accessed April 6, 2016).
[413] *Id*.
[414] Earthworks, *New Mexico Oil and Gas Enforcement- Inspections website*: *https://www.earthworksaction.org/issues/detail/new_mexico_oil_gas_enforcement_inspections#.ViP868uSZAI* (last accessed April 6, 2016).
[415] *Id*.
[416] NMAC 19.15.2.

[417] New Mexico Environmental Law Center, *New Mexico Pit Rule Fact Sheet* (2016) available at: *http://nmenvirolaw.org/images/pdf/NM_Pit_Rule_Fact_Sheet_2016.pdf* (last accessed March 26, 2016).

[418] *Id.*; *see also* Phil Taylor and Mike Soraghan, *Public Lands: Interior unveils BLM frack rule -- FracFocus in, waste pits out*, E&E Publishing (March 20, 2015), available at: *http://www.eenews.net/stories/1060015477* (last accessed April 6, 2016); Mike Soraghan, *Oil and Gas Spills: Many mishaps among drillers, but few fines*, E&E Publishing (July 15, 2013), available at: *http://www.eenews.net/stories/1059984342* (last accessed April 6, 2016).

[419] *Pit Rule Fact Sheet*; Petition for Writ of Certiorari available at: *http://nmenvirolaw.org/images/pdf/160324_SC_Pit_Rule_Cert_Petition.pdf* (last accessed March 26, 2016).

[420] *The Environmental Costs and Benefits of Fracking* at 337.

[421] *Id.* at 338.

[422] *Id.* at 341.

[423] *Id.* at 338.

[424] *Id.* at 339.

[425] *Id.* at 338.

[426] *Id.*

[427] *Id.*

[428] *Id.*

[429] *Id.* at 338; *see e.g.* Gary Searles, *New Mexico Oil Well Blow-out Injures 4 Crewmen*, Oil Pro (*http://oilpro.com/post/3644/new-mexico-oil-well-blow-out-injures-4-crewmen*; KRQE, *New Mexico: "Fracking fluid blows out nearby well"* (Oct. 22, 2013) (report on hydraulic fracturing causing blowout at neighboring well), available at: *https://www.youtube.com/watch?v=DPdKZHfAwbg* (last accessed April 6, 2016); Briana Mordick, NRDC, *Blowout Exposes Gaps in Federal and State Oversight of Fracking* (Oct. 24, 2013), available at: *http://switchboard.nrdc.org/blogs/bmordick/blowout_exposes_gaps_in_blm_an.html* (last accessed April 6, 2016).

[430] *Id.*; Tina Jensen, KASA, *Fracking fluid blows out nearby well Cleanup costs, competing technologies at issue* (Oct. 19, 2013), available at: *https://www.earthworksaction.org/media/detail/fracking_fluid_blows_out_nearby_well* (last accessed April 6, 2016).

[431] *Id.*

[432] *Id.*; *The Environmental Costs and Benefits of Fracking* at 339-40 (concern about connection between wells as a result of new hydraulic fracturing).

[433] *The Environmental Costs and Benefits of Fracking* at 341.

[434] *Id.*

[435] *Id.*

[436] *Id.*

[437] *Id.* at 338.

[438] *Id.* at 339; In 2012, a former staffer responsible for managing and investigating groundwater contamination, warned of the impacts of hydraulic fracturing: "I'm familiar with the fate and transport of contaminants in fractured media, and let me be clear: hydraulic fracturing as it's practiced today will contaminate our aquifers. Not *might* contaminate our aquifers. Hydraulic fracturing *will* contaminate New York's aquifers. If you were looking for a way to poison the drinking water supply, here in the north-east you couldn't find a more chillingly effective and thorough method of doing so than with hydraulic fracturing." "No confining layer is completely competent; all geologic strata leak to some extent. The fact that a less-transmissive layer lies between the drill zone and a well does not protect the well from contamination. A drinking water well is never in 'solid' rock. If it were, it would be a dry hole in the ground. As water moves through joints, fissures and bedding planes into a well, so do contaminants. In fractured media such as shale, water follows preferential pathways, moving fast and far, miles per week in some cases." Paul Hetzler, *Letter to the Editor: Hydrofracking sure to contaminate* water, Watertown Daily Times (Dec. 13, 2011), available at: *http://www.watertowndailytimes.com/article/20111213/OPINION02/712139975* (last accessed April 6, 2016); *see also*, Karen McVeigh, *Fracking will poison New York's drinking water, critics warn*, The Guardian (Jan. 5, 2012), available at: *http://www.theguardian.com/environment/2012/jan/05/fracking-new-york-poison-claim* (last accessed April 6, 2016).

[439] *The Environmental Costs and Benefits of Fracking* at 338, 339.

[440] *Id.* at 339; Denis Brondel, Randy Edwards, Andrew Hayman, Donald Hill, Shreekant, Tony Semerad, *Corrosion in the Oil Industry* (April 1994), available at: *http://www.slb.com/~/media/Files/resources/oilfield_review/ors94/0494/composite.pdf* (last accessed April 6, 2016).

[441] *The Environmental Costs and Benefits of Fracking* at 339.

[442] *Id.*

[443] *Id.* at 337-38.

[444] Conversations between Kyle Tisdel, Western Environmental Law Center, and BLM Staff.

[445] Anthony W. Gorody, Results Of A Soil Gas Survey, West Divide Creek Area Near Silt, Colorado (Nov. 15, 2004), available at: *http://cogcc.state.co.us/documents/library/AreaReports/PiceanceBasin/WaterQuality/WestDivideSeep/FID_survey_results.pdf* (last accessed April 6, 2016).

[446] U.S. Dep't of Interior Bureau of Land Mgmt., *Wyoming News Release, BLM, Wyoming DEQ Require Test of Water Wells Within the Pinedale Anticline and Jonah Fields* (April 26, 2007), available at: *http://www.blm.gov/wy/st/en/info/news_room/2007/04/26pfo-DEQ-BLMwatertests.html* (last accessed April 6, 2016).

[447] See Robert B. Jackson, et al., *Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction*, PNAS, (Dec. 17, 2012) available at: *http://www.pnas.org/content/110/28/11250* (last accessed April 6, 2016).

[448] *See* Ohio Department of Natural Resources, Division of Mineral Resources Management, *Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio* (September 1, 2008) (attached as *see also* Joan Demirjian, *Insurance company [sues] driller over home explosion*, Chagrin Valley Times (Jan. 7, 2010), available at: *http://www.chagrinvalleytimes.com/NC/0/1571.html* (last accessed April 6, 2016).

[449] Abrahm Lustgarten, *Hydrofracked? One Man's Mystery Leads to a Backlash Against Natural Gas Drilling*, ProPublica (Feb. 25, 2011), available at: *http://www.propublica.org/article/hydrofracked-one-mans-mystery-leads-to-a-backlash-against-natural-gas-drill/single* (last accessed April 6, 2016).

[450] EPA Draft Report, *Investigation of Ground Water Contamination Near, Pavillion, Wyoming* (Dec. 2011), available at: *https://www.epa.gov/region8/pavillion* (last accessed April 6, 2016) [hereinafter "*EPA Pavillion Report*"]; *see also* John Noël, Attempts to Soften Scientists' Critiques of EPA's Fracking and Drinking Water Study Come Up Short, Clean Water Action Blog (Feb. 22, 2016), available at: *http://blog.cleanwateraction.org/2016/02/22/attempts-to-soften-scientists-critiques-of-epas-fracking-and-drinking-water-study-come-up-short/#sthash.jdOZbZgO.dpuf* (last accessed April 6, 2016);.

[451] *EPA Pavillion Report* at xiii.

[452] *Id.* at 33 (emphasis added).

[453] *Id.*

[454] *Id.* at 37 (emphasis added).

[455] *Id.* at 39 (emphasis added).

[456] Dominic C. DiGiulio and Robert B. Jackson, *Impact to Underground Sources of Drinking Water and Domestic Wells from Production Well Stimulation and Completion Practices in the Pavillion, Wyoming,*Field, American Chemical Society (March 29, 2016), available at: *http://pubs.acs.org/doi/abs/10.1021/acs.est.5b04970* (last accessed April 6, 2016); see *also* Natasha Geiling, *New Study Confirms Fracking Contamination That The EPA Walked Back On In 2011*, ClimateProgress (March 30, 2016), available at: *http://thinkprogress.org/climate/2016/03/30/3764784/fracking-drinking-water-contamination-wyoming/* (last accessed April 6, 2016).

[457] *The Environmental Costs and Benefits of Fracking* at 339.

[458] *Id.* at 338.

[459] *Id.* at 338.

[460] *Id.* at 340.

[461] *EPA Assessment* at 3-8.

[462] *Id.* at 3-7.

[463] Photo source: Ecoflight/ecoflight.org

[464] *Water and Energy Nexus Literature Review* at 77.

[465] *Id.*

[466] *Id.*

[467] *Id.*

[468] *Id.* at 112.
[469] *Id.*
[470] *Id.*
[471] *Id.*
[472] *Id.* at 78.
[473] *Id.*
[474] *Id.*
[475] *Id.*
[476] *Id.* at 113.
[477] *Id.* at 78.
[478] *Id.* at 113.
[479] *Id.*
[480] *Id.*
[481] *The Environmental Costs and Benefits of Fracking* at 336 (natural gas combined cycle plant uses one half to one third of the water that a nuclear or pulverized coal plant uses); *EW3 Freshwater Use* at 11; Wendy Wilson, Travis Leipzigm Bevan Griffiths-Sattenspiel, *Burning Our Rivers, The Water Footprint of Electricity*, River Network, 19 (April 2012), available at: *https://www.rivernetwork.org/resource/burning-our-rivers/* (last accessed April 6, 2016) [hereinafter "*Burning Our Rivers*"] (single cycle 14,844 gal/Mwh, combined cycle 1,170 gal/Mwh); *Water and Energy Nexus Literature Review* at 95.
[482] This table is limited to natural gas power plants in New Mexico although the utilities may have natural gas plants in other states, and/or have power purchase agreements for power from natural gas plants in other states.
[483] These numbers do not appear to be available in this form, and thus the figures in this column are calculated out using the net generation and water per MWh figures. See notes 157, 165 for examples of this calculation. Used the following conversion site to convert gallons per year to acre-feet per year: *http://www.convert-me.com/en/convert/flow_rate_volume/gallon_year.html*.
[484] Because natural gas plants often operate more intermittently than base-load resources like coal and nuclear plants, the net generation is also included, and used for calculations of water usage.
[485] PNM 2014 IRP.
[486] Id.
[487] Id. at 12.
[488] Id. at 5, 21.
[489] Southwestern Public Serv. Co., 2012 Integrated Resource Plan for New Mexico, 17 (July 16, 2012), available at: *https://www.xcelenergy.com/staticfiles/xe/Corporate/Corporate%20PDFs/2012_SPS_NM_IRP.pdf* (last accessed April 6, 2016) [hereinafter "SPS 2012 IRP"]. The SPS IRP does not give this figure. Given the size of the plant (11MW), and its capacity factor (7%), the exclusion of these numbers should not have a meaningful impact on the picture of water usage.
[490] Id. at v, 17, 63.
[491] Id. at 17.
[492] Id. at 39 (figure represents the plant average).
[493] Id. at 17.
[494] Id.
[495] Id. at 39 (figure represents the plant average).
[496] Id. at v, 17, 63.
[497] Id. at 17.
[498] PNM 2014 IRP.
[499] Id.
[500] Id. at 13.
[501] Id. at 5, 21.
[502] Id. at 14.
[503] Id. at 24.
[504] Id. at 22.

[505] Id. at 24.
[506] Id. at 12.
[507] Id. at 12, 21.
[508] Id. Luna uses 260 gallons per MWh total: 203 gallons is freshwater, and 57 gallons is wastewater. Because this table is calculating total water usage, and wastewater is nevertheless returned to the system rather than largely evaporated, the total gallons/MWh figure is used.
[509] Id. at 22, 23.
[510] Id.
[511] Id. at 12.
[512] Id. at 15, 21.
[513] SPS 2012 IRP at 39 (figure represents the plant average).
[514] Id. at 17.
[515] Id. at 17.
[516] Id. at 39 (figure represents the plant average).
[517] Id. at v, 17, 63.
[518] Id. at 17.
[519] Id. The SPS IRP does not give this figure. Given the size of the plant (30MW), and its capacity factor (10%), the exclusion of these numbers should not have a meaningful impact on the picture of water usage.
[520] Id.
[521] Id.
[522] Tri-State 2010 IRP at 38-39.
[523] Id. at 38.
[524] Id. at 38.
[525] PNM 2014 IRP.
[526] Id.
[527] Id. at 13.
[528] Id. at 15, 21.
[529] EPE 2015 IRP at Table A-03.
[530] Id. at 17.
[531] PNM 2014 IRP.
[532] Id.
[533] Id. at 13.
[534] Id. at 17, 21.
[535] *Burning Our Rivers* at 19.

[536] GAO *Improvements to Federal Water Use Data* at 1-2.
[537] *Id.* at 1-2; 20, Table 2, n. a.
[538] *Id.* at 2.
[539] *Id.* at 2.
[540] *Burning Our Rivers* at 50; *Water and Energy Nexus Literature Review* at 96.
[541] *See, e.g.*, Robert Howarth, Drew Shindell, Renee Santoro, Anthony Ingraffea, Nathan Phillips, and Amy Townsend-Small, *Methane Emissions from Natural Gas Systems Background Paper Prepared for the National Climate Assessment* (Feb. 25, 2012), available at: *http://www.eeb.cornell.edu/howarth/publications/Howarth_et_al_2012_National_Climate_Assessment.pdf* (last accessed April 6, 2016); Robert W. Howarth, *Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy*, Energy and Emission Control Technologies (Oct. 8, 2015), available at: *http://www.eeb.cornell.edu/howarth/publications/f_EECT-61539-perspectives-on-air-emissions-of-methane-and-climatic-warmin_100815_27470.pdf* (last accessed April 6, 2016).
[542] *Id.*
[543] See Consideration for Climate Change and Variability Adaptation on the Navajo Nation (March 2014) at 181; *see also*, Paul Robinson, Southwest Research and Information Center, *Uranium Issues in the Western US: Legacy, Current Production, Health Research and Resource Estimates Compiled for World Uranium Symposium April 14 – 16, 2015*

Quebec City, Canada, available at: *http://www.sric.org/uranium/docs/2015-04-12_Uranium_activities_Western_US_1a.pdf* (last accessed March 27, 2016) [hereinafter "*Uranium Issues in the Western US*"]; *see also*, Paul Robinson, Southwest Research and Information Center, *Uranium Legacy and Development Sites In New Mexico and the Navajo Nation* (Feb. 26, 2013), available at: *http://www.sric.org/uranium/docs/2013-02-26%20NM%20Uranium%20Activity%20List.pdf* (last accessed March 27, 2016).

544 *PNM 2014 IRP*.

545 *Id*.

546 Leslie Macmillan, *Uranium Mines Dot Navajo Land, Neglected and Still* Perilous, New York Times, (March 31, 2012), photo credit, Joshua Lott; available at: *http://www.nytimes.com/2012/04/01/us/uranium-mines-dot-navajo-land-neglected-and-still-perilous.html?_r=0*.

547 *Water and Energy Nexus Literature Review* at 81.

548 Conversation with Paul Robinson, Southwest Research Information Center (April 7, 2016); *Id*. at 83; *Uranium Issues in the Western US* ("Two uranium mines Roca Honda and La Jara Mesa are currently proposed in the Mt. Taylor [Traditional Cultural Property] and the exploration area for the Mt. Taylor mine is within the TCP.") General Atomics and Affiliated Companies, *Rio Grande Resources webpage*, *http://www.ga.com/rio-grande-resources* (last accessed March 27, 2016); Associated Press, *Company seeks to activate permit for New Mexico uranium mine*, Albuquerque Journal (Dec. 4, 2015), available at: *http://www.abqjournal.com/685914/news-around-the-region/company-seeks-to-activate-permit-for-new-mexico-uranium-mine.html* (last accessed March 27, 2016).

549 U.S. Energy Information Administration, *Domestic Uranium Production Report 4th Quarter 2015*, 5 (Feb. 2016), available at: *http://www.eia.gov/uranium/production/quarterly/pdf/qupd.pdf* (last accessed March 27, 2016).

550 *Water and Energy Nexus Literature Review* at 83.

551 *Id*. at 82.

552 *Id*.

553 *Id*.

554 *Id*.

555 *Id*.

556 *Id*. at 83.

557 *Id*. at 82.

558 *Id*.

559 Julie Nania, Karen Cozzetto, *Considerations for Climate Change and Variability Adaptation on the Navajo Nation*, 181 (March 2014), available at: *http://www.colorado.edu/law/content/considerations-climate-change-and-variability-adaptation-navajo-nation* (last accessed April 6, 2016).

560 Paul Robinson, Southwest Research and Information Center, *The Impact of Uranium Mining and Clean-up Activities in the the Grants Mineral Belt: Seven Key Points, A Presentation to the New Mexico Legislature Indian Affairs Committee Meeting Red Valley Chapter House, Navajo Nation* (October 1, 2015), available at: *http://www.sric.org/uranium/docs/10012015_IAC_Uranium_Impacts.pdf* (last accessed March 30, 2016) [hereinafter "*SRIC- The Impact of Uranium Mining*"].

561 *Id*.

562 *Id*.

563 *Id*.

564 *Id*.

565 *Id*.; Chris Shuey, Southwest Research and Information Center, *Health Concerns of Chronic Ingestion of Uranium in Drinking Water* (July 24, 2015), available at: *http://www.sric.org/uranium/docs/NewLands_presentation_072415_rev-1.pdf* (last accessed March 30, 2016).

566 New Mexico Environment Dep't, Ground Water Quality Bureau, *Homestake Mining Company of California Discharge Permit DP-200*, 8, (Sept. 18, 2014); Conversation with Paul Robinson, Southwest Research Information Center (April 7, 2016).

567 *Id*.; Homestake Mining Company of California, *Grants Reclamation Project 2015 Annual Monitoring Report/Performance Review For Homestake's Grants Project Pursuant to NRC License SUA-1471 And Discharge Plan DP-200*, 1.1-4 (March 2016).

[568] *Id.* This figure leads to the conclusion that 5,500 gpm, or 8,877 acre-feet per year, of water has been affected by the legacy contamination, but it was beyond the scope of this report to delve into the details of the reclamation processes at Homestake.
[569] *Water and Energy Nexus Literature Review* at 83-84.
[570] *Id.*
[571] *Id.* at 83.
[572] *Id.* at 84.
[573] *Id.* at 83.
[574] *Id.* at 84.
[575] *Id.*
[576] *Id.*
[577] *Id.* at 85.
[578] *Id.*
[579] *Id.*
[580] *Id.*
[581] *SRIC- The Impact of Uranium Mining.*
[582] photo- Ecoflight
[583] U.S. Energy Information Administration, *Arizona State Profile and Energy Estimates*: *http://www.eia.gov/state/?sid=AZ* (last accessed April 6, 2015).
[584] U.S. Energy Information Administration, *Arizona Nuclear Profile 2010*: *http://www.eia.gov/nuclear/state/arizona/* (last accessed April 6, 2015) [hereinafter "*EIA Arizona Nuclear Profile*"].
[585] *DOE Energy Sector Vulnerabilities* at 1.
[586] *Water and Energy Nexus Literature Review* at 95, 96.
[587] *EW3 Freshwater Use* at 17.
[588] *Burning Our Rivers* at 10.
[589] GAO *Improvements to Federal Water Use Data* at 21; *EW3 Freshwater Use* at 18.
[590] *EPE 2015 IRP* at Table A-03.
[591] *PNM 2014 IRP* at 23; *EIA Arizona Nuclear Profile*.
[592] *EW3 Freshwater Use* at 18.
[593] *Id.* at 21, 35; *Water and Energy Nexus Literature Review* at 99.
[594] *Id.* at 21; *Water and Energy Nexus Literature Review* at 99.
[595] *EW3 Freshwater Use* at 35.
[596] Photo credit, Andrew O'Reilly.
[597] *PNM 2014 IRP* at 22; *DOE Energy Sector Vulnerabilities* at 27. Concentrated solar plants can use large amounts of water as they are thermal plants; this report focuses on solar PV because with significant price decreases over the last several years, and given its simplicity, solar PV is increasingly favored.
[598] National Renewable Energy Laboratory, *Photovoltaic Solar Resource of the United States* (Sept. 19, 2012): *http://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg* (last accessed April 6, 2016); National Renewable Energy Laboratory, *United States — Annual Average Wind Speed at 80 m*: *http://www.nrel.gov/gis/images/80m_wind/USwind300dpe4-11.jpg* (last accessed April 6, 2016); *see also* U.S. Dep't of Energy, Solar Energy Potential: *http://energy.gov/maps/solar-energy-potential* (last accessed April 6, 2016).
[599] *Id.* at *http://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg*.
[600] *Id.* at *http://www.nrel.gov/gis/images/80m_wind/USwind300dpe4-11.jpg*.
[601] PNM, *Emissions & Water Usage*: *https://www.pnm.com/emissions-and-water* (last accessed April 6, 2016).
[602] *PNM 2014 IRP* at 5.
[603] Dismissing adding additional pollution to groundwater just because it is not being used now is irresponsible and illegal. "[I]f the existing concentration of any water contaminant in groundwater exceeds the [groundwater] standards . . . no degradation of the groundwater beyond the existing concentration will be allowed." NMAC 20.6.2.3101.A.2. As the New Mexico Court of Appeals found: "[c]ertainly, the legislature meant to capture the concept that clean water that is currently being withdrawn for use, or clean water that is likely to be used in the reasonably foreseeable future, must be protected." *Phelps Dodge Tyrone, Inc. v. New Mexico Water Quality Control Comm'n*, 143 P.3d 502,

509 (NM Ct. App. 2006). A Commissioner on the Water Quality Control Commission put it more simply: "we are darn sure obligated to make sure that the water that isn't contaminated outside of [the currently contaminated] area is protected." *Id.* The Commissioner's comment seems to state the obvious, and yet OSM has ignored this obvious obligation by failing to take a hard look at whether historic CCW disposal will cause further deterioration of groundwater, regardless of whether that groundwater is presently of the highest quality, or if it is presently used only for livestock watering.

604 El Segundo mine- wells in the area for cattle 2014 EA

605 e.g. LANL IX Power Organiclear for fracking water; reuse of produced water at power plants; using/treating brackish water…

606 *Ceres Hydraulic Fracturing Report*.

607 Jeff Spross, Charts: How Power Generation Threatens Water Supplies, And Climate Change Threatens Both (March 19, 2014), available at: *http://thinkprogress.org/climate/2014/03/19/3415761/iea-water-energy/* (last accessed April 6, 2016).

608 Jenny Deam, *In parched states, fracking's thirst grows Greeley, Colo., sells water to the oil and gas companies that have brought a drilling boom to town. Some residents wonder whether it will run out*, Los Angeles Times (Feb. 19. 2014), available at: *http://www.latimes.com/nation/la-na-colorado-fracking-20140220-story.html* (last accessed April 6, 2016).

609 *Ceres Hydraulic Fracturing Report*.

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