Electric Water:
Lucid Energy/Portland Water Bureau
Conduit 3 Hydroelectric Project

Presented by: Matt Hickey, PE
May 3, 2017

murraysmith

Presentation Outline

Introduction

About Lucid

Project Background

How Murraysmith became Involved

Design & Permitting

Project Challenges

Construction

Conclusion/Summary

Project Team

- **Lucid Energy** – (Mechanical/Electrical/Turbine Design) Susan Priddy
- **Portland Water Bureau** – (Water Facilities Owner) Mike Saling, PE & Stan VandeBergh, PE
- **Murraysmith** — Civil Consultant
- **R&W, Inc.** — Electrical & Mechanical Engineers
- **Ground Water Solutions, Inc.** — Hydrogeologist
- **SSC** — Primary Contractor
- **Emery & Sons** — Large Waterline Contractor
- **Team Electric** — Electrician
- **Westerberg** — Well Drillers
- Mechanical Contactor
- Many Others

About Lucid

Problem - The price of water is rising

Energy and water are linked:

- 6% of energy in the US and 20% in California is used to move water
- Energy is most water utilities'single largest expense, often 40%-50%
- The EPA estimates over $650BN needed in new investment for water infrastructure over the next 20 years

Business proposition:

Reduce costs required to deliver safe, clean drinking water

Business ppportunity:

>100 yrs old (US) and failing infrastructure = many repairs allowing Lucid Energy's turbines to be inserted

Opportunities for Technology

U.S. Markets:

- Total U.S. market opportunity: $5.2B to $5.9B range = power sales in the $700M/yr to $800M/yr range
  - Public and domestic supply (municipal water transmission and distribution) - $1.2B to $1.4B
  - Thermoelectric power plants - $2.5B to $2.9B
  - Irrigation - $1.1B to $1.3B
  - Industrial water and wastewater/effluent - $230 to $270M

Global Markets:

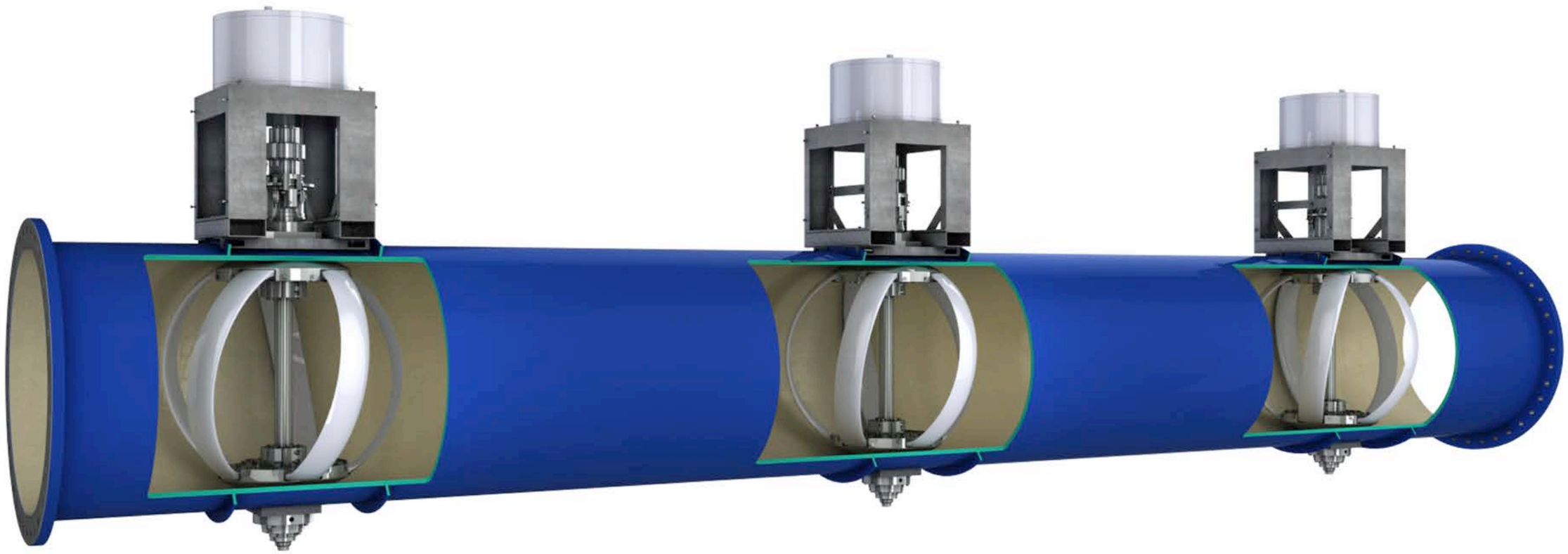
- Global market opportunity: $15B to $20B range.
  - Unit sales potential for the LPS - 150,000 to 200,000 units worldwide

Estimate $20 billion potential global market for in-pipe hydropower

Competitive Analysis

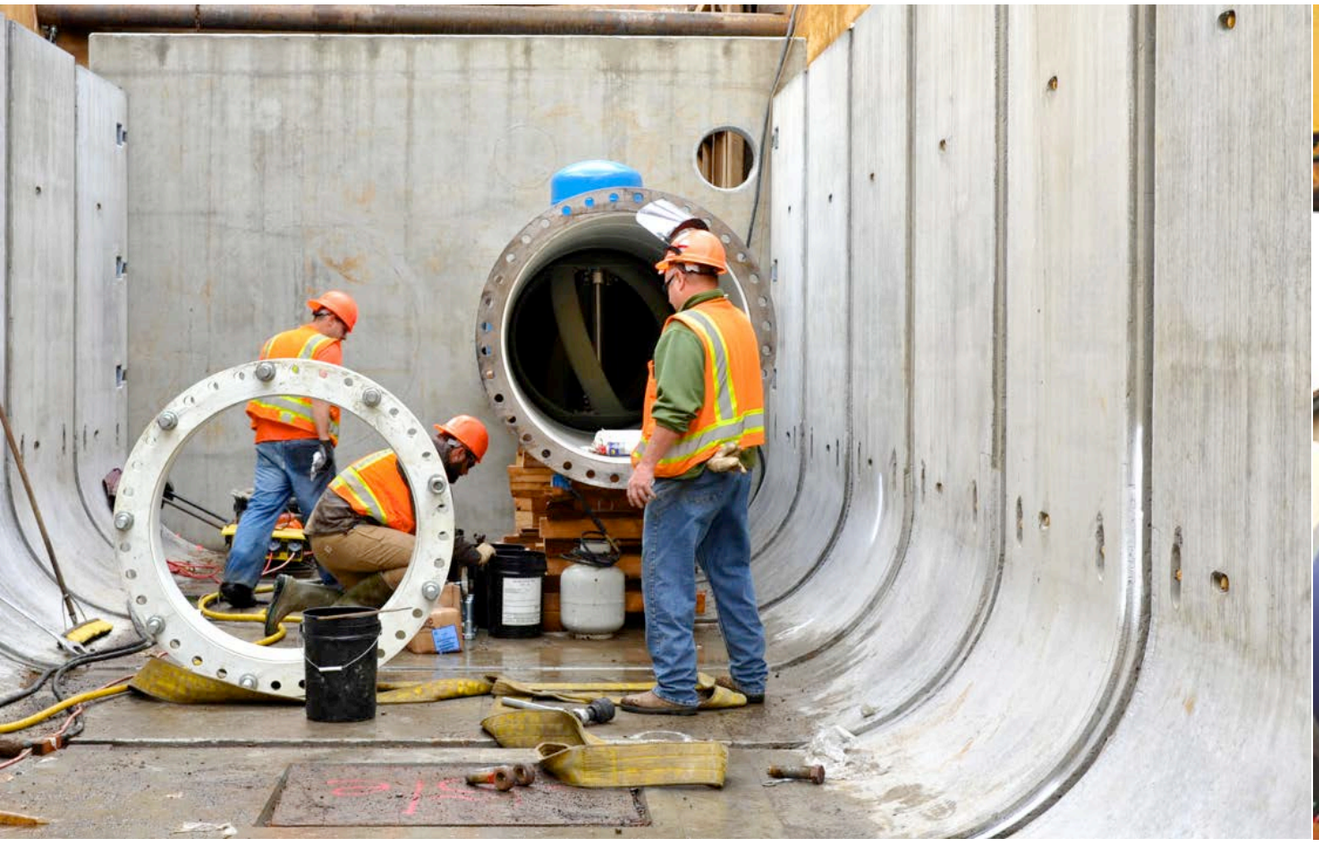
	LucidPipe	Small Wind	Small Solar	Hydro	Hydro-kinetics
Efficiency/Capacity Factor	High	Low	Low	High	Unpredictable
Electricity Price	Low	High	High	Low	Low
Quality	High	Low	Low	High	Medium
Major Environmental Issues	None	Yes	Yes	Yes	Yes

The LucidPipe™ Power System



- Hydropower that doesn’t harm ecosystems
- Generates consistent, predictable energy 24/7
- Turns waste-stream (excess pressure) into revenue stream
- Reduces operating costs
- Pays for infrastructure upgrades
- Provides off-grid power for energy & water security

Where is Lucid Now



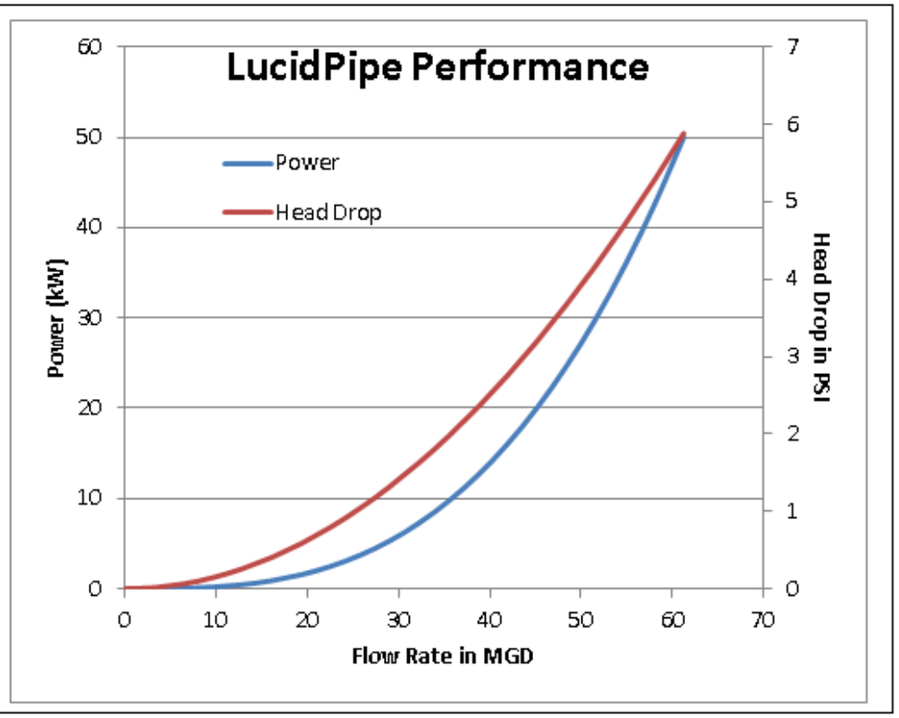
- Two patents on turbines, additional IP from Gen2 product
- Pilot and single-turbine installation in Riverside, California (2011)
- Four-turbine commercial installation at Portland Water Bureau (2015)
- 258 media articles in 2015 with up to 70 million viewers (Meltwater)
- Gen2 testing: complete Nov, 2016, proves 50% reduction in capital costs
- $41 million in potential pipeline projects in negotiation
- City of Johannesburg South Africa ($5.5 million bid)
- Most viable private/public partnership

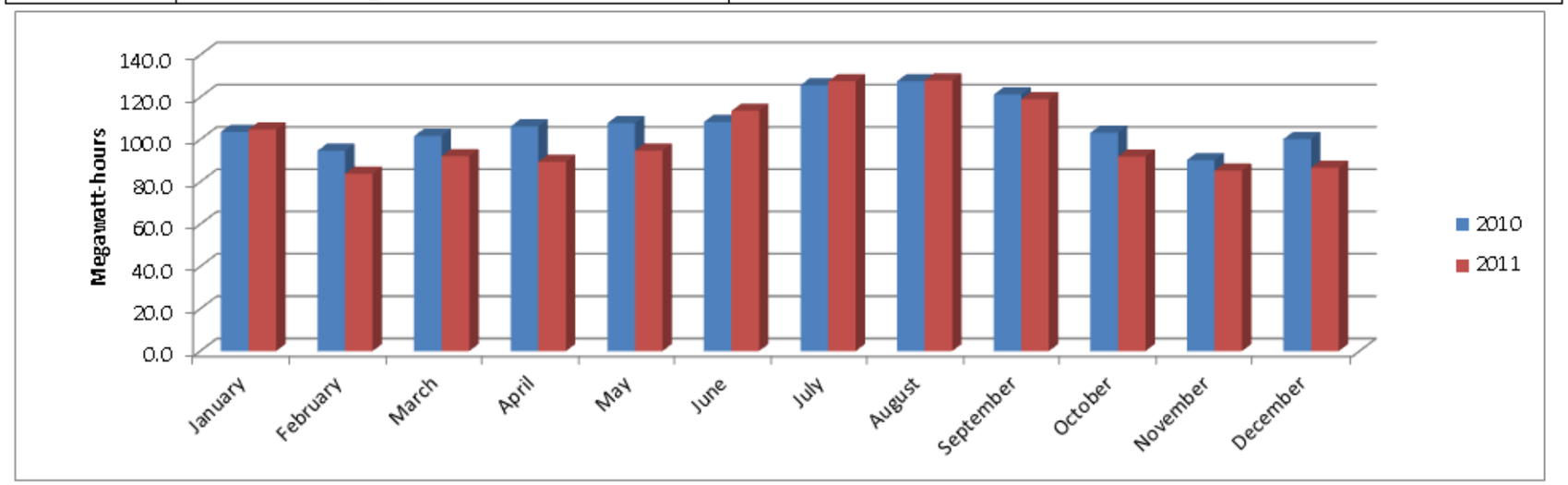
Project Background

- Lucid contacted PDC & PWB regarding potential sites
- PWB had project involving Conduit 3
- Two other sites investigated
- Preliminary concepts developed

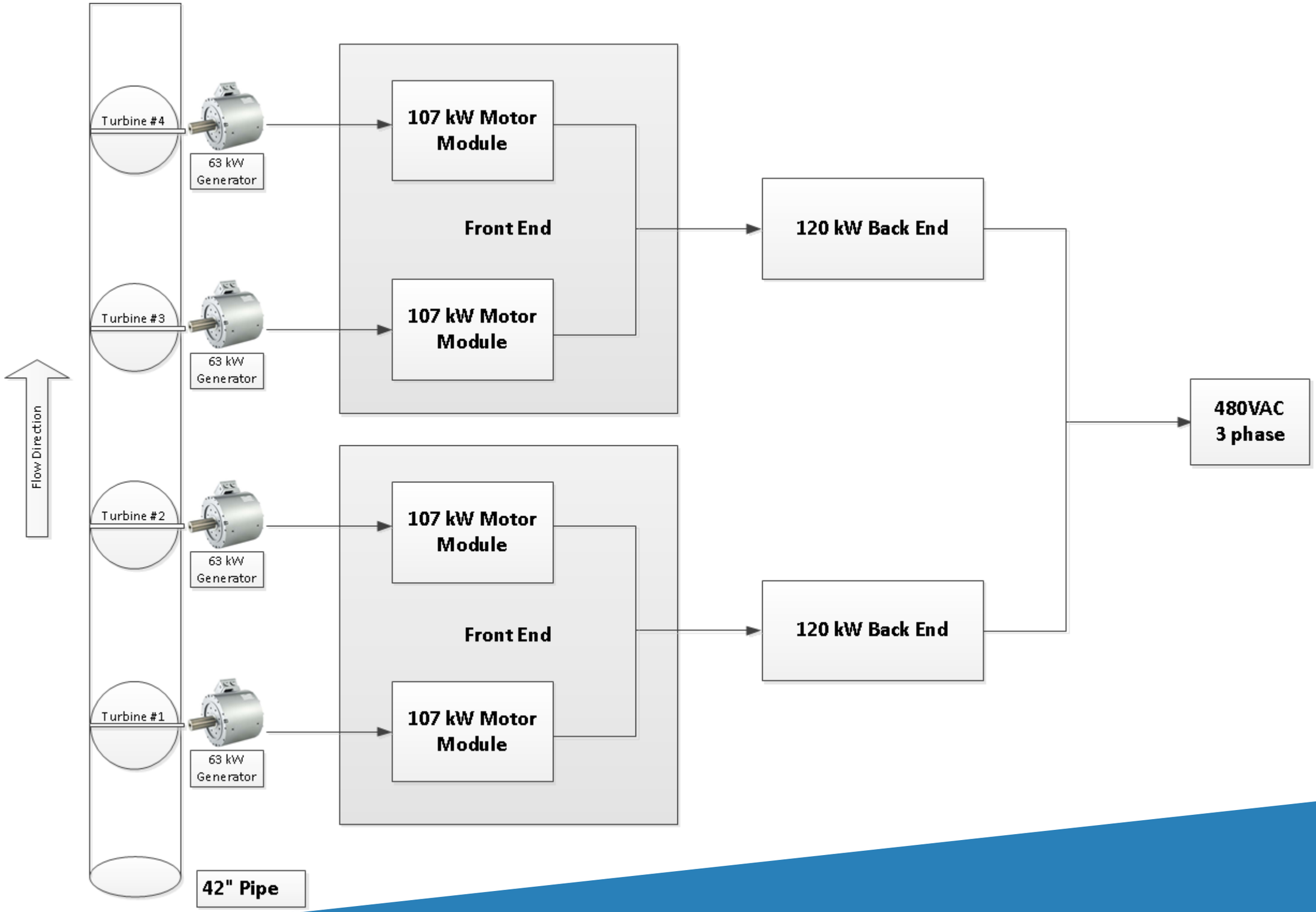
Estimated Nominal Energy Production

	Pipeline Name	Conduit 3	
System Performance Projections	**Total Turbines in System**	**4**	
	Nameplate Capacity (kW)	172	kW
	Avg Capacity	143.12	kW
	Avg Head Drop	20.62	PSI
	Annual Output	1253.6	MWh
LucidPipe Specifications	**Nominal Diameter**	**42**	Inches
	Actual Inner Diameter	43 1/8	Inches
	Rated Pressure Extraction	5.88	PSI
	Rated Power	50	kW
	Rated Gauge Pressure	70	PSI
Site Data Details	**Historical Flow Period**	2.0	Years
	Pipeline Diameter	50	Inches
	Avg Flow	57	MGD
	Head Available @ Avg Flow	22	PSI
	Peak Flow	61	MGD
	Head Available @ Max Flow	20	PSI





System Overview



Agreement

How Murraysmith Became Involved

- Lucid needed civil engineer to assist
- Site and piping designs
- Coordination with agencies
- PWB suggested consultants
- Teamed with R&W - Electrical/Mechanical
- Fast track schedule

ENGINEERING FACT

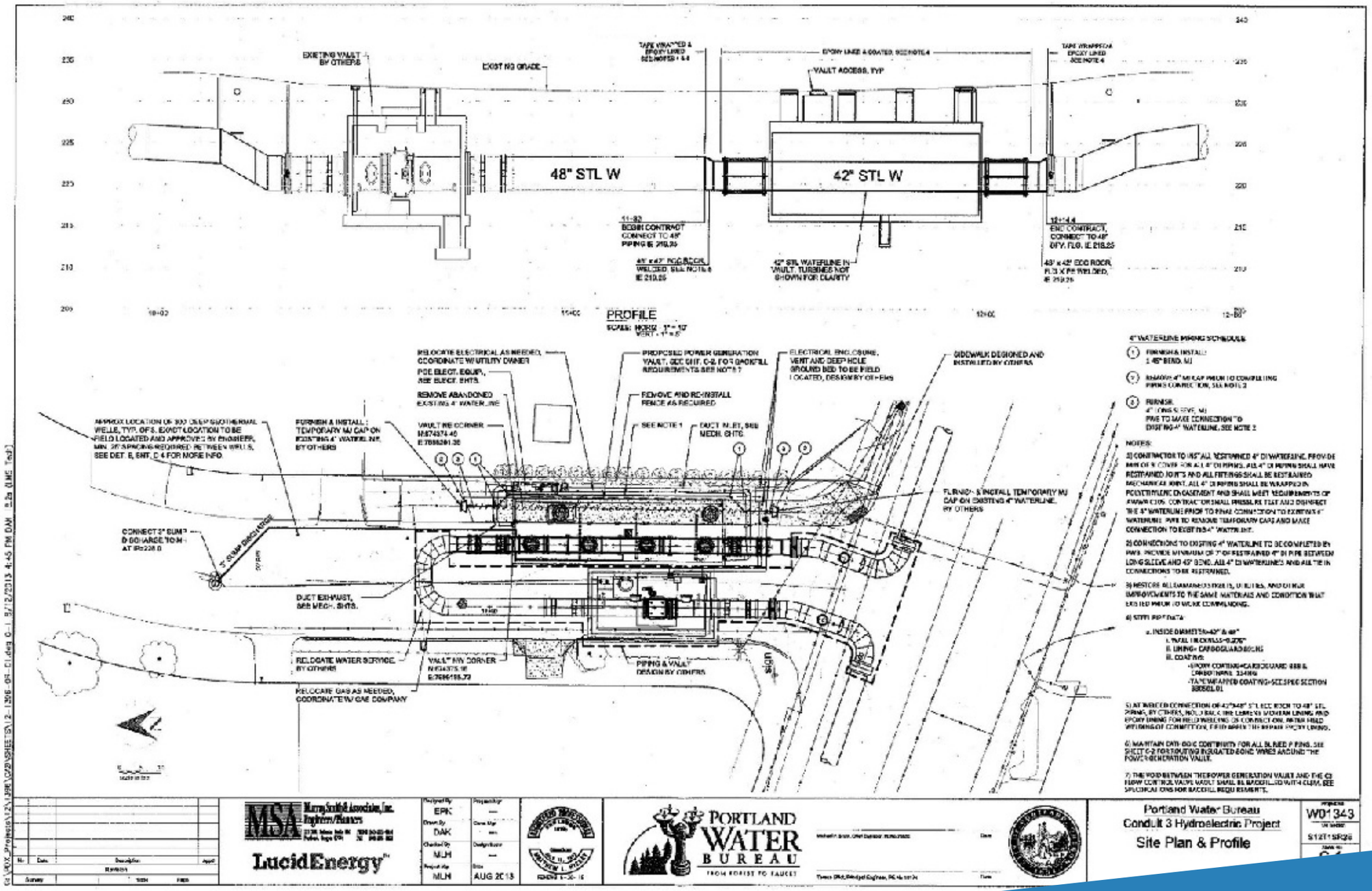
Nothing makes an engineer more productive, than the "last minute"

Murraysmith's Role

- Design/configure precast vault
- Design relocation of utilities and utility coordination

Key Design Elements

- Design 42” waterline connections
- Design sanitary sewers and drains
- Design geothermal cooling wells
- Siting for equipment

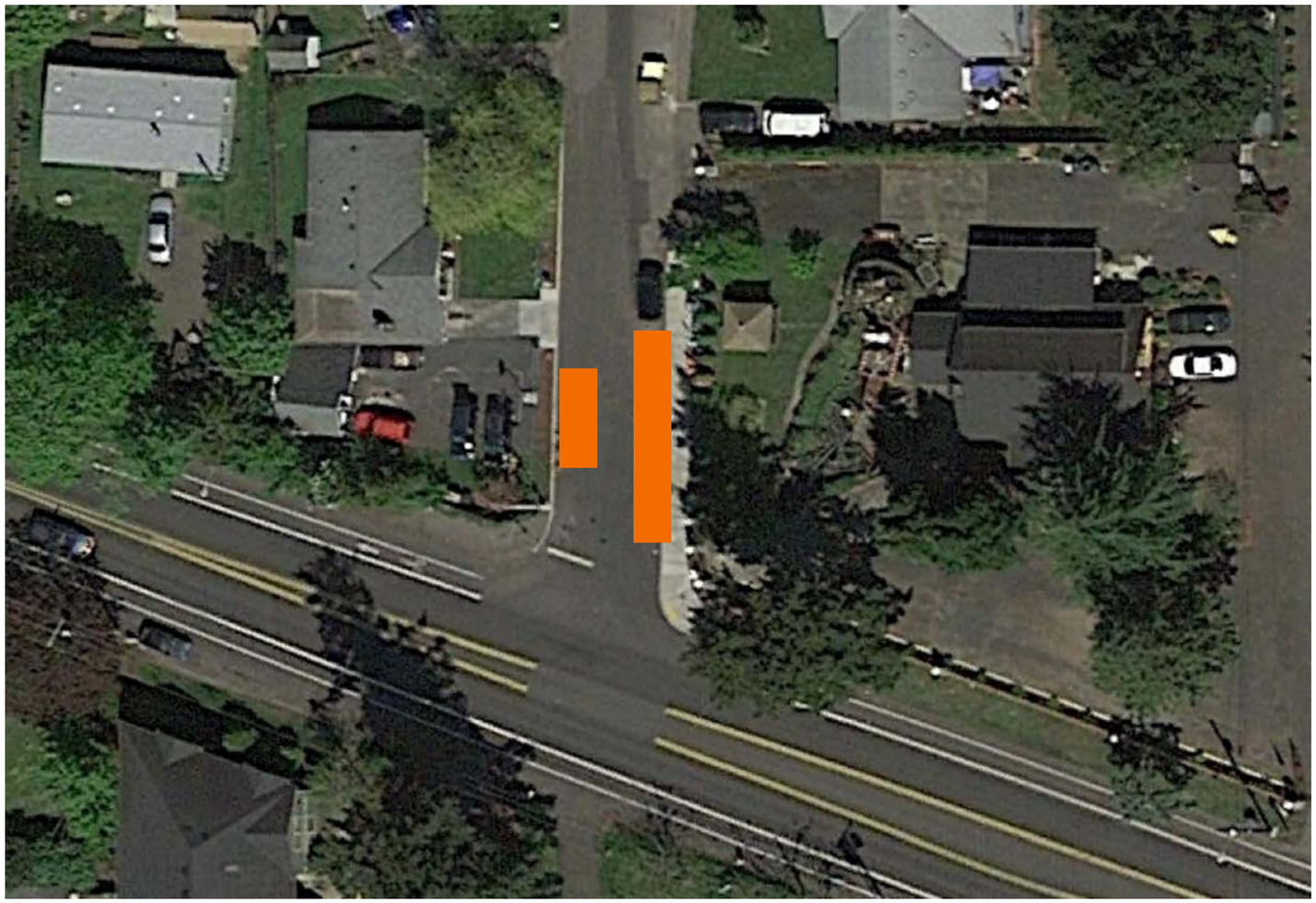


Permit Challenges

- Obtain permits and approvals
  - PBOT
  - BDS
  - BES
  - PWB
  - ODOT coordination
  - PGE
  - OWRD
- Assist with FERC permit
- Assisted with coordination of other disciplines and contractors

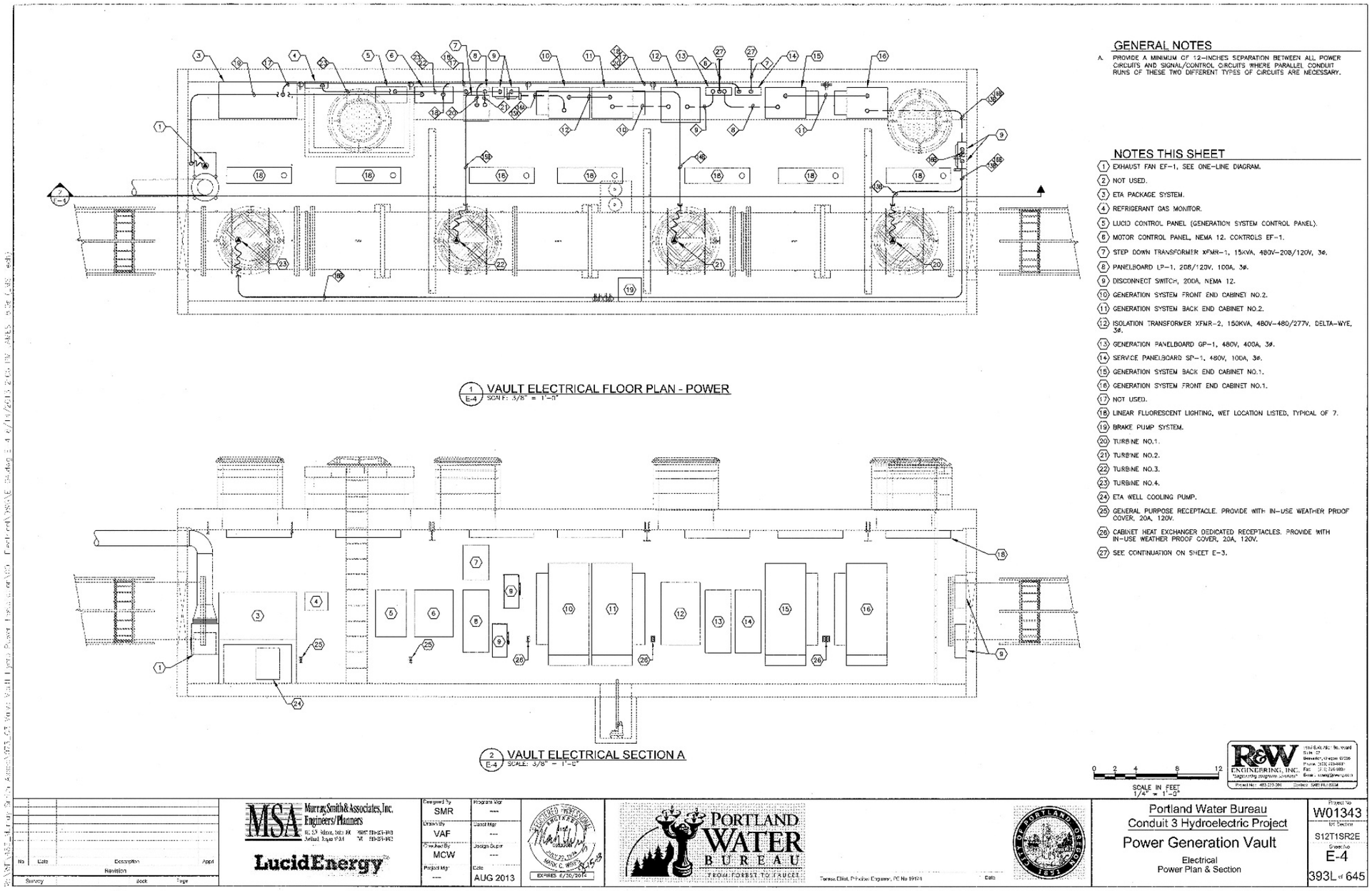
Project Challenges

Siting equipment



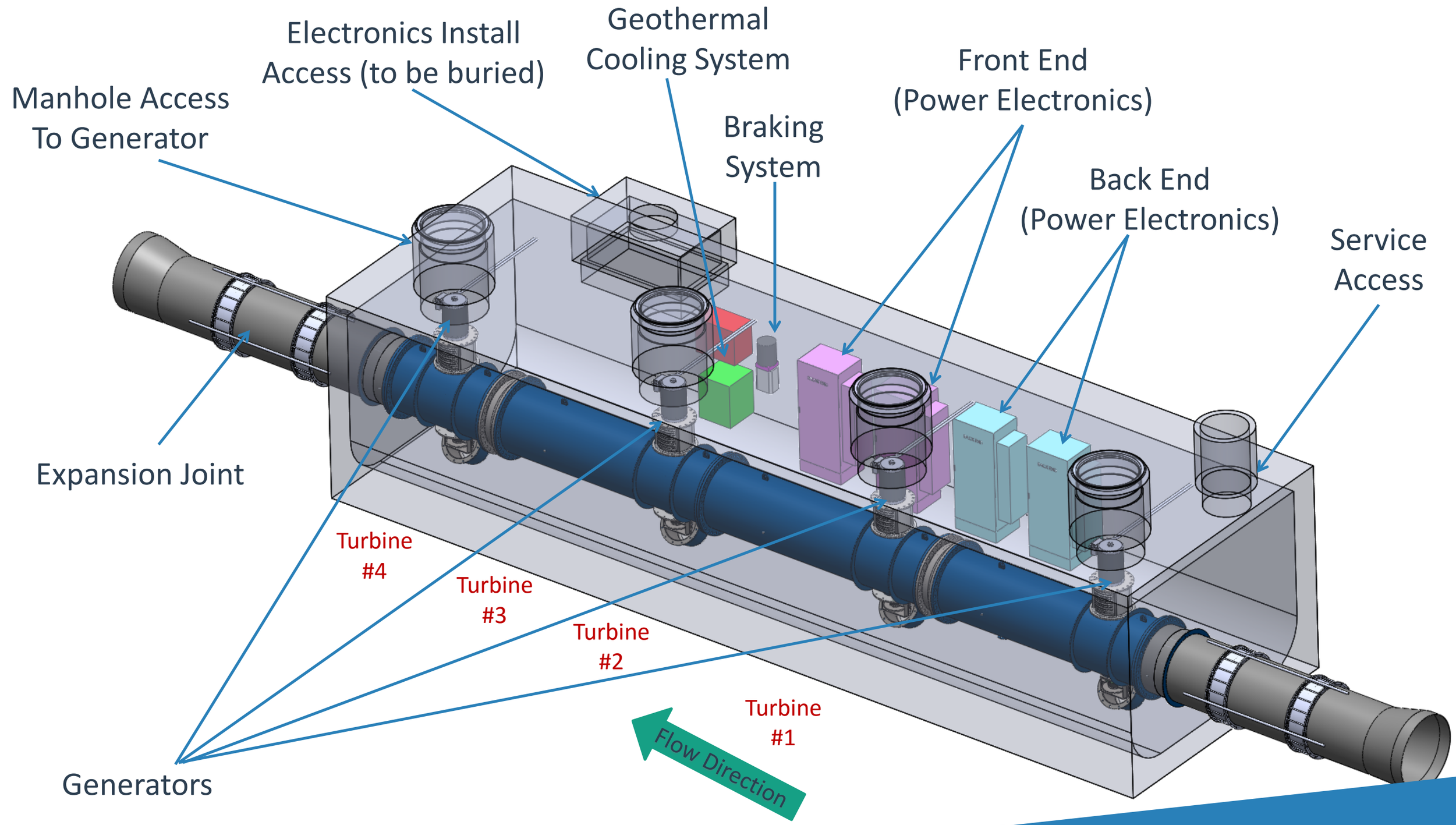
Constrained Site In Neighborhood

Housing Electrical Equipment



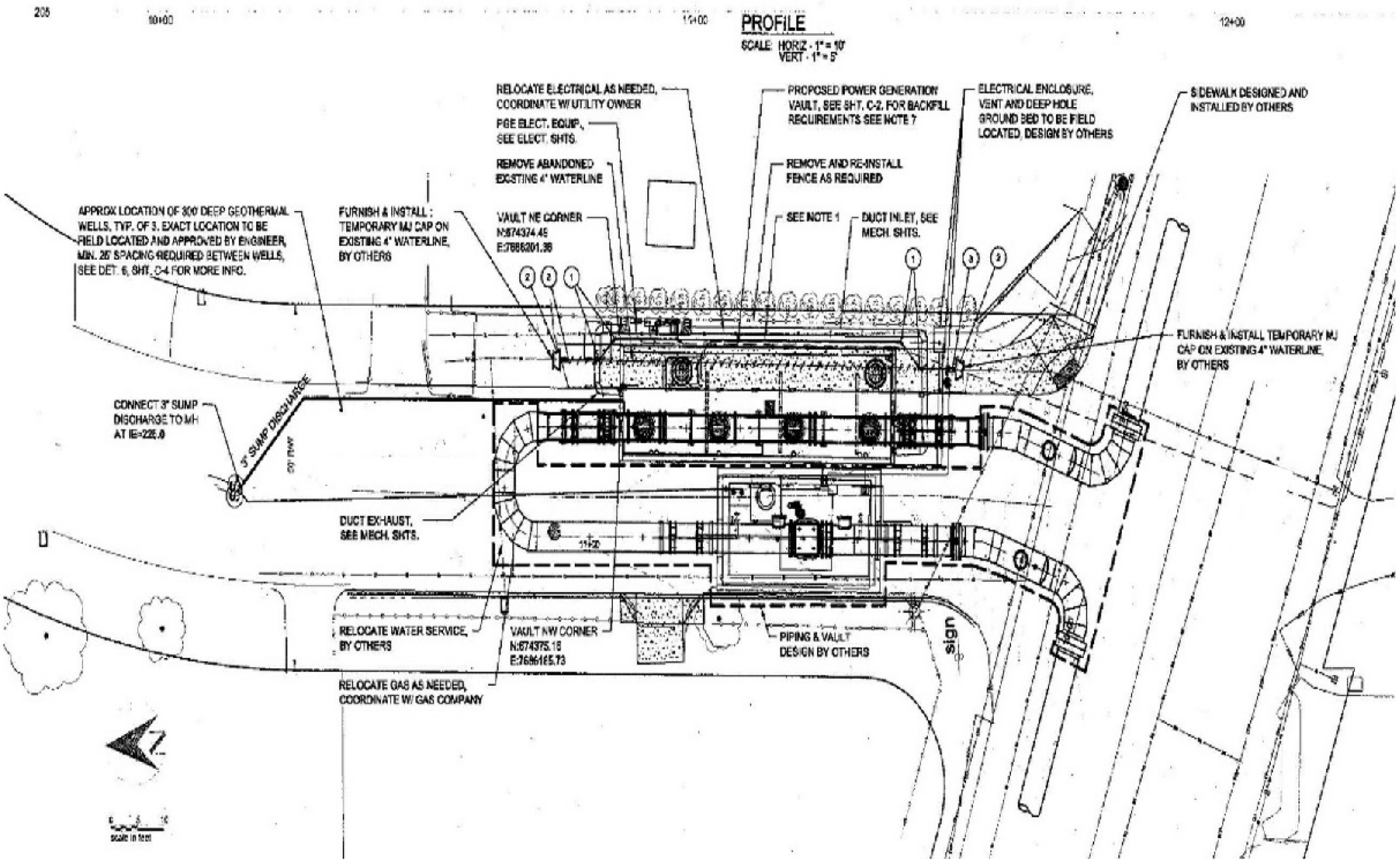
Below ground is selected option

Vault Equipment Overview

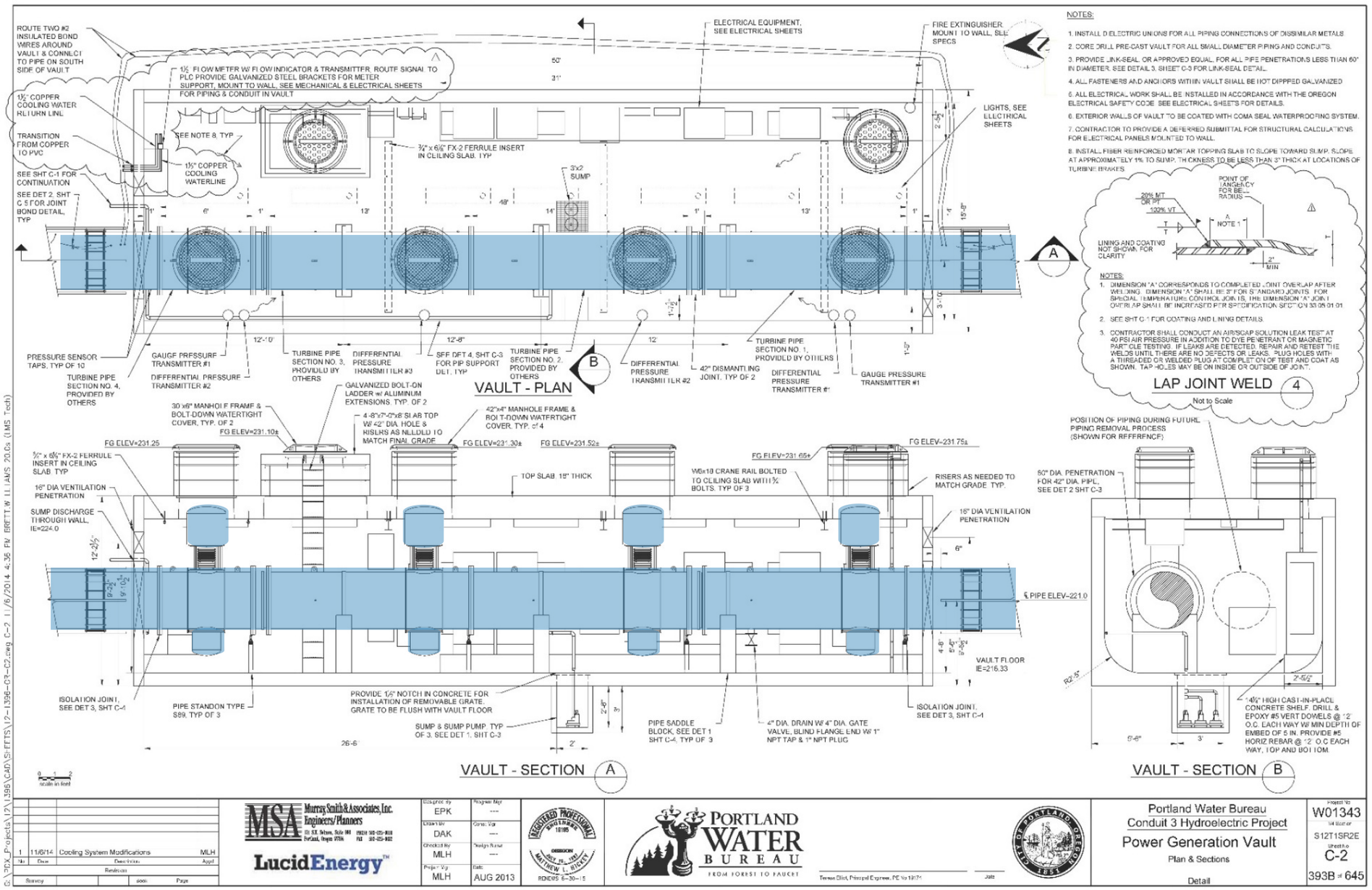


Congested Underground Utilities

Congested Right of Way



Precast Vault

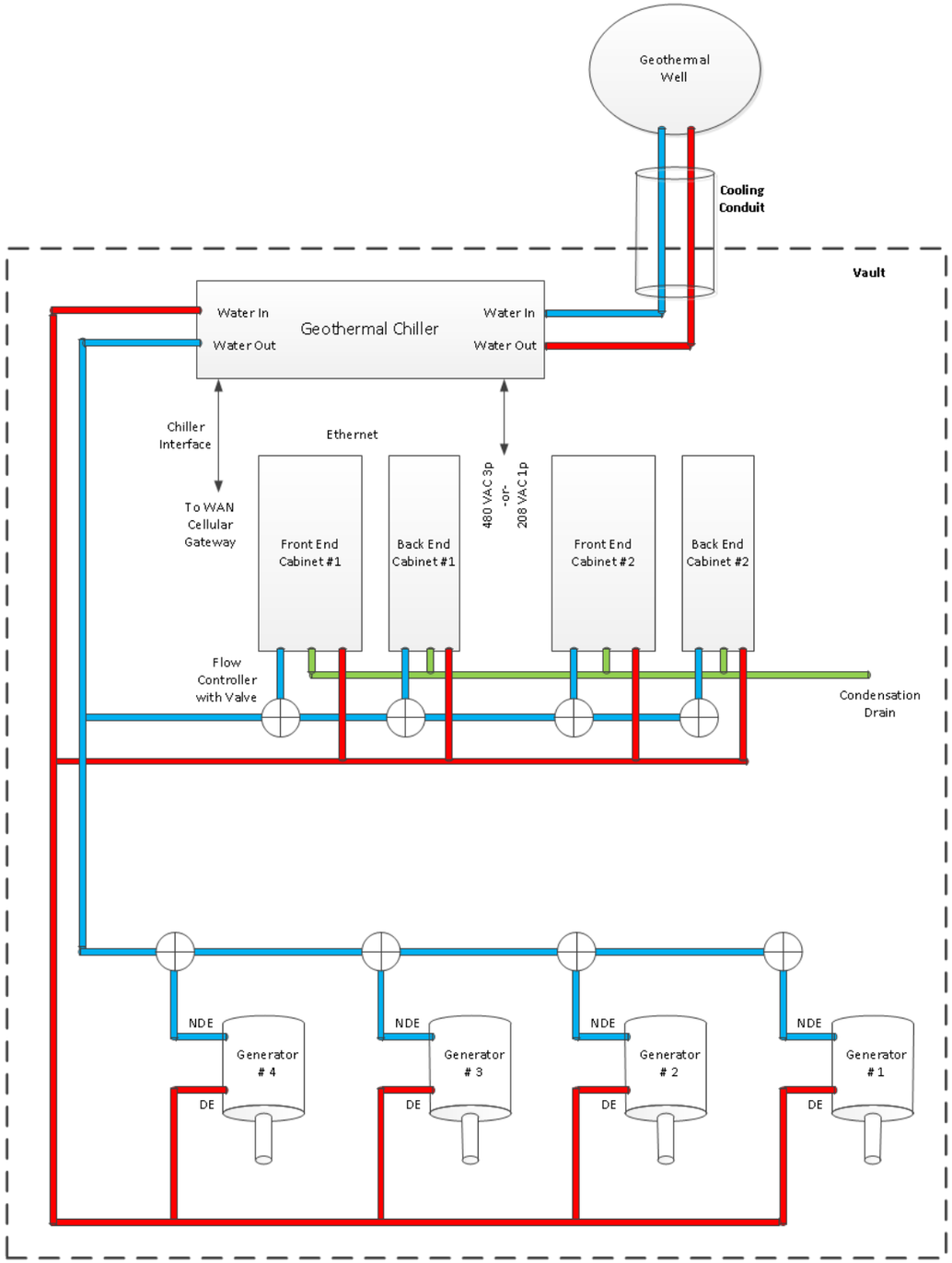


- Coordinate with Lucid Equipment
- H-2O rated
- Maintain dry environment ventilation system

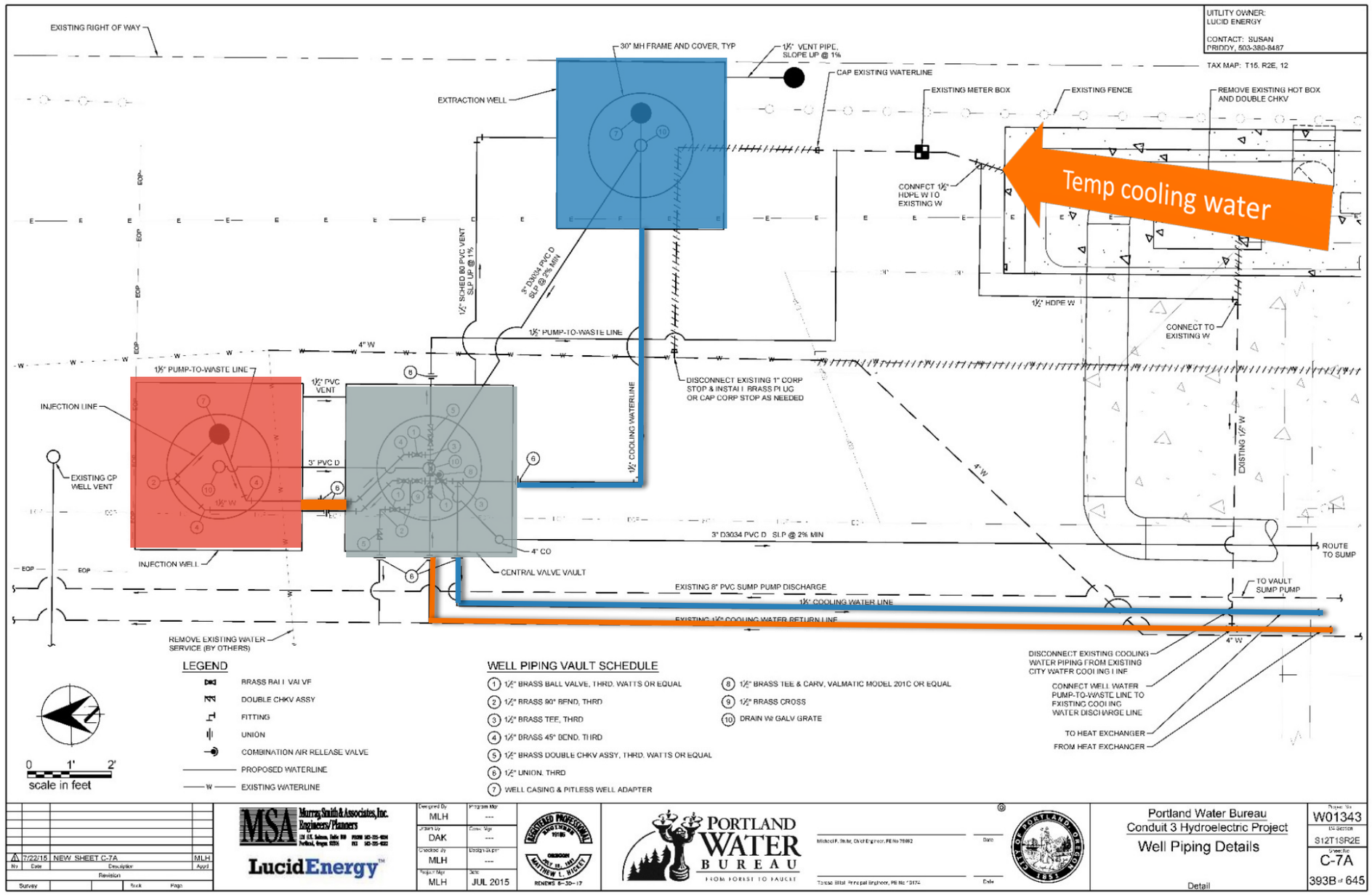
Ventilation System

Geothermal Cooling

- The cooling system will be geothermal for improved efficiency and minimal impact
- Utilizes Direct Exchange technology
- A closed system will recirculate cooling water to all the generators and electronic cabinets
- A second closed loop circulates water to geothermal wells for heat rejection

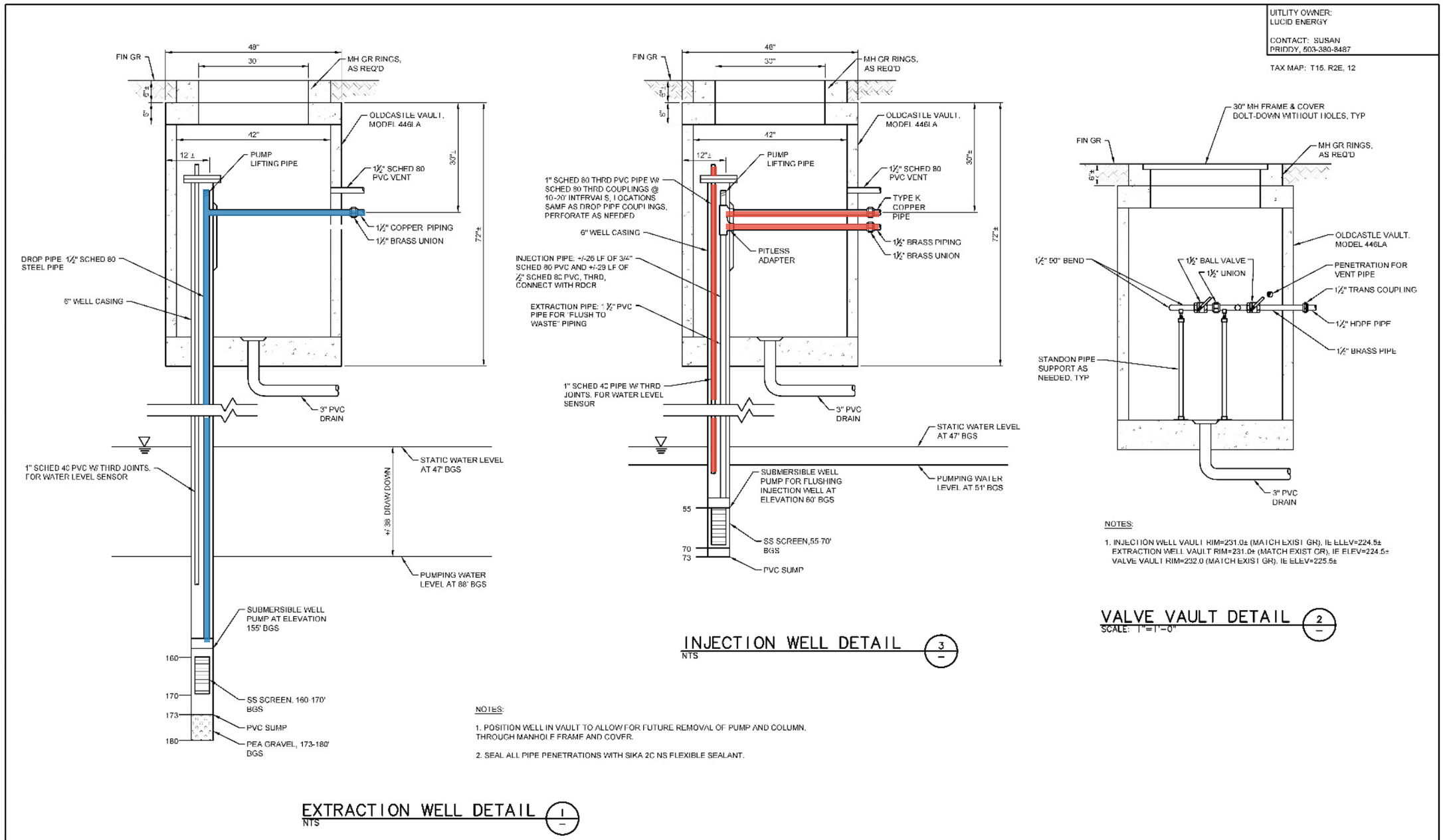


Cooling Water Wells - Plan

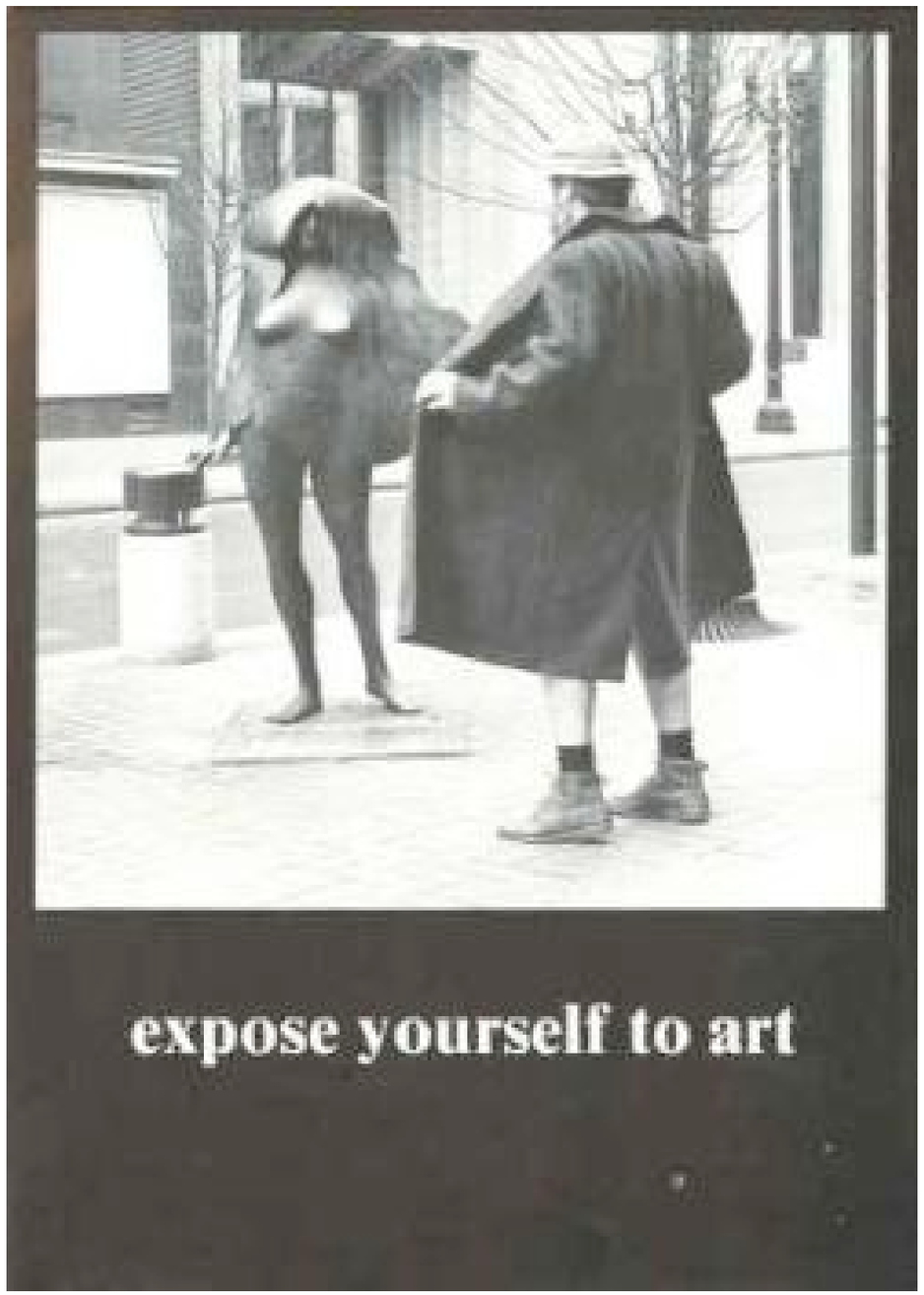


- Initial cooling system for start-up – City water
- Aquifer characteristics

Cooling Water Wells



Art For Site



Screening Above Ground Electrical Equipment

Screened with art wrap

Screening Above Ground Electrical Equipment

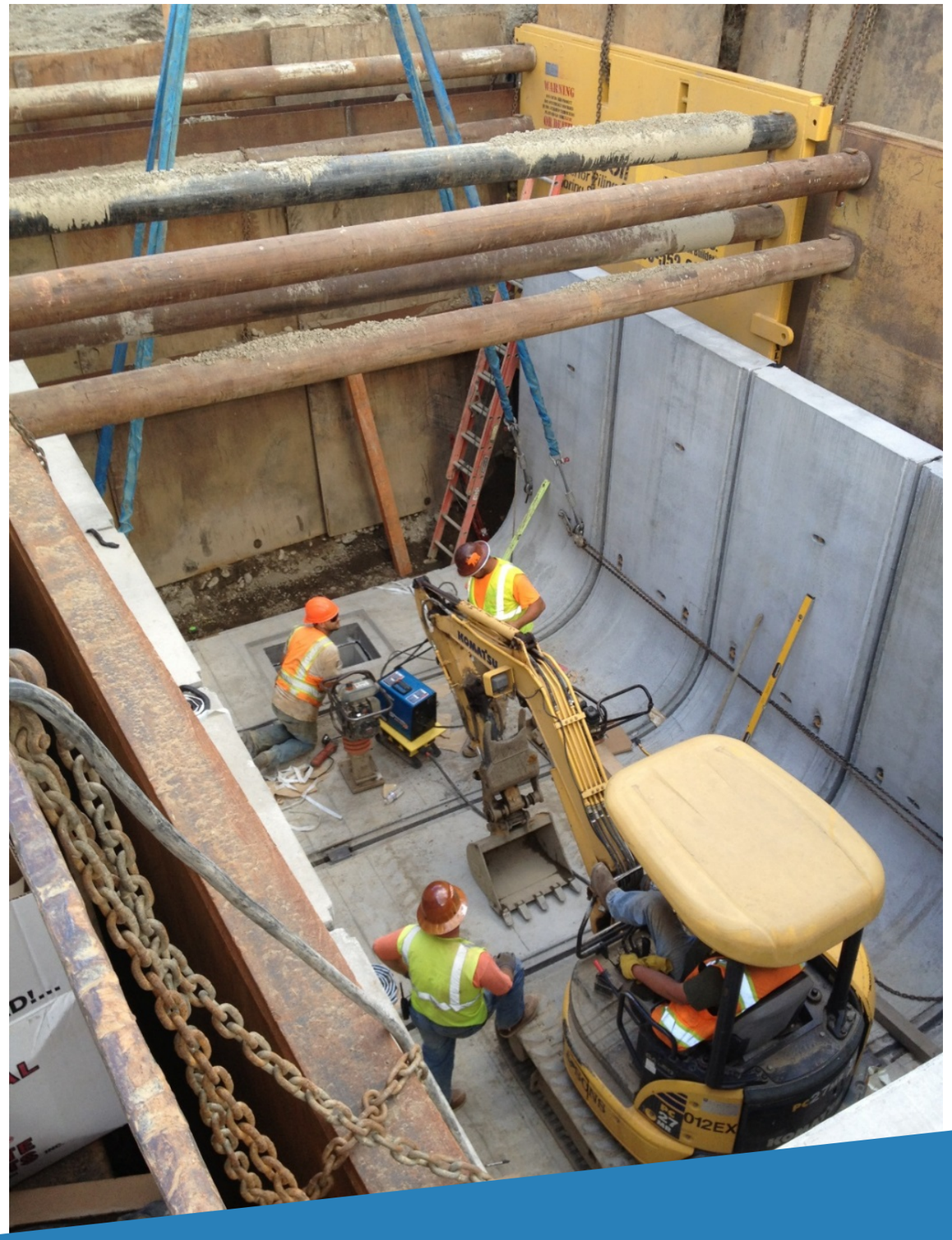
Teamwork

Together, we can accomplish anything!

Construction

- Multiple contributors/contractors
- Schedule: Fall 2013 – Fall 2014

Vault Installation



Vault Installation Cont.

Prepping for Pipe Installation

Pipe & Turbine Installation

Pipe & Turbine Installation (Cont.)

Vault Cover Installation

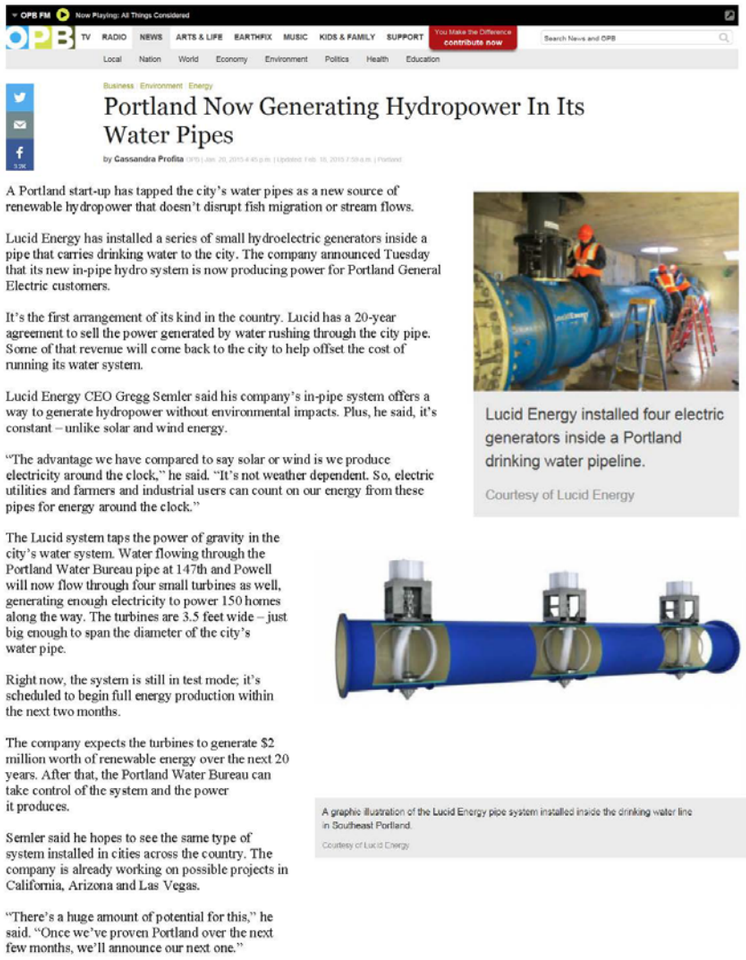
Installed Turbines & Pipe

Cooling Water Wells

Heat Exchange

Completed Site

Summary/Conclusion



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Portland Now Generating Hydropower In Its Water Pipes

by Cassandra Profita

A Portland start-up has tapped the city's water pipes as a new source of renewable hydropower that doesn't disrupt fish migration or stream flows.

Lucid Energy has installed a series of small hydroelectric generators inside a pipe that carries drinking water to the city. The company announced Tuesday that its new in-pipe hydro system is now producing power for Portland General Electric customers.

It's the first arrangement of its kind in the country. Lucid has a 20-year agreement to sell the power generated by water rushing through the city pipe. Some of that revenue will come back to the city to help offset the cost of running its water system.

Lucid Energy CEO Gregg Semler said his company's in-pipe system offers a way to generate hydropower without environmental impacts. Plus, he said, it's constant – unlike solar and wind energy.

"The advantage we have compared to say solar or wind is we produce electricity around the clock," he said. "It's not weather dependent. So, electric utilities and farmers and industrial users can count on our energy from these pipes for energy around the clock."

The Lucid system taps the power of gravity in the city's water system. Water flowing through the Portland Water Bureau pipe at 147th and Powell will now flow through four small turbines as well, generating enough electricity to power 150 homes along the way. The turbines are 3.5 feet wide – just big enough to span the diameter of the city's water pipe.

Right now, the system is still in test mode; it's scheduled to begin full energy production within the next two months.

The company expects the turbines to generate $2 million worth of renewable energy over the next 20 years. After that, the Portland Water Bureau can take control of the system and the power it produces.

Semler said he hopes to see the same type of system installed in cities across the country. The company is already working on possible projects in California, Arizona and Las Vegas.

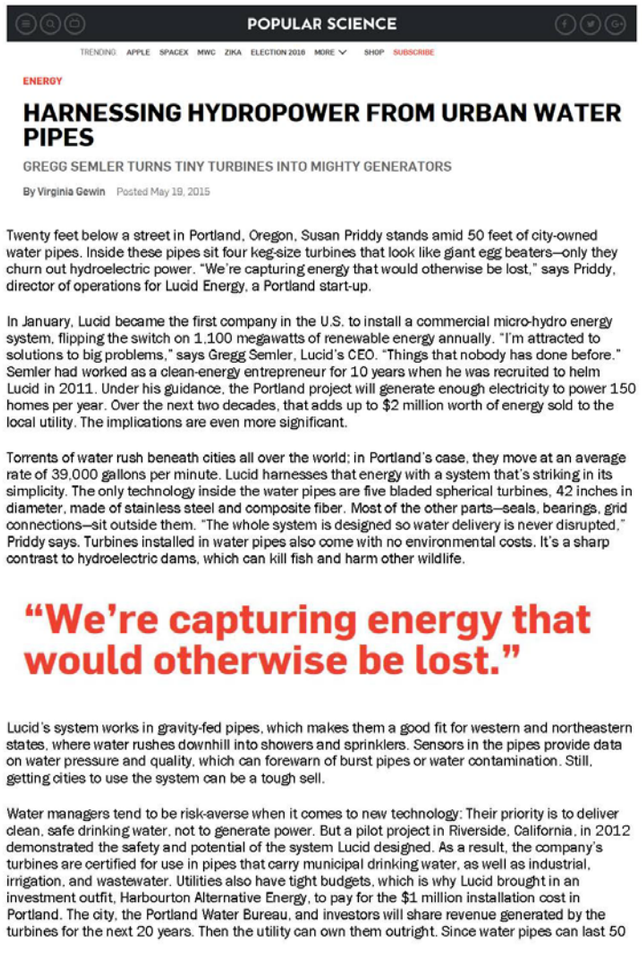
"There's a huge amount of potential for this," he said. "Once we've proven Portland over the next few months, we'll announce our next one."

Lucid Energy installed four electric generators inside a Portland drinking water pipeline.

Courtesy of Lucid Energy

A graphic illustration of the Lucid Energy pipe system installed inside the drinking water line in Southeast Portland.

Courtesy of Lucid Energy



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ENERGY

HARNESSING HYDROPOWER FROM URBAN WATER PIPES

GREGG SEMLER TURNS TINY TURBINES INTO MIGHTY GENERATORS

By Virginia Gewin Posted May 19, 2015

Twenty feet below a street in Portland, Oregon, Susan Priddy stands amid 50 feet of city-owned water pipes. Inside these pipes sit four keg-size turbines that look like giant egg beaters—only they churn out hydroelectric power. "We're capturing energy that would otherwise be lost," says Priddy, director of operations for Lucid Energy, a Portland start-up.

In January, Lucid became the first company in the U.S. to install a commercial micro-hydro energy system, flipping the switch on 1,100 megawatts of renewable energy annually. "I'm attracted to solutions to big problems," says Gregg Semler, Lucid's CEO. "Things that nobody has done before." Semler had worked as a clean-energy entrepreneur for 10 years when he was recruited to helm Lucid in 2011. Under his guidance, the Portland project will generate enough electricity to power 150 homes per year. Over the next two decades, that adds up to $2 million worth of energy sold to the local utility. The implications are even more significant.

Torrents of water rush beneath cities all over the world; in Portland's case, they move at an average rate of 39,000 gallons per minute. Lucid harnesses that energy with a system that's striking in its simplicity. The only technology inside the water pipes are five bladed spherical turbines, 42 inches in diameter, made of stainless steel and composite fiber. Most of the other parts—seals, bearings, grid connections—sit outside them. "The whole system is designed so water delivery is never disrupted," Priddy says. Turbines installed in water pipes also come with no environmental costs. It's a sharp contrast to hydroelectric dams, which can kill fish and harm other wildlife.

"We're capturing energy that would otherwise be lost."

Lucid's system works in gravity-fed pipes, which makes them a good fit for western and northeastern states, where water rushes downhill into showers and sprinklers. Sensors in the pipes provide data on water pressure and quality, which can forewarn of burst pipes or water contamination. Still, getting cities to use the system can be a tough sell.

Water managers tend to be risk-averse when it comes to new technology: Their priority is to deliver clean, safe drinking water, not to generate power. But a pilot project in Riverside, California, in 2012 demonstrated the safety and potential of the system Lucid designed. As a result, the company's turbines are certified for use in pipes that carry municipal drinking water, as well as industrial, irrigation, and wastewater. Utilities also have tight budgets, which is why Lucid brought in an investment outfit, Harbourton Alternative Energy, to pay for the $1 million installation cost in Portland. The city, the Portland Water Bureau, and investors will share revenue generated by the turbines for the next 20 years. Then the utility can own them outright. Since water pipes can last 50

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COMMUNITIES

Portland Now Generates Electricity From Turbines Installed In City Water Pipes

by Rafi Schwartz

Share February 24, 2015

image via lucidenergy.com

You'd be forgiven if the phrase "Portland goes green with innovative water pipes" doesn't immediately call to mind thoughts of civil engineering and hydro-electric power. And yet, that's exactly what Oregon's largest city has done by partnering with a company called Lucid Energy to generate clean electricity from the water already flowing under its streets and through its pipes.

Portland has replaced a section of its existing water supply network with Lucid Energy pipes containing four forty-two inch turbines. As water flows through the pipes, the turbines spin and power attached

LucidEnergy Contact: Dr. Nina Bergan French, PE; Nina.French@lucidenergy.com, 707.732.7049

Questions?

Matt Hickey, PE
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