Nu‘uanu Hydro-Managed Aquifer Recovery, a Stormwater Capture, Treatment, Energy Recovery and Aquifer Recharge Solution for a Climate Change Future

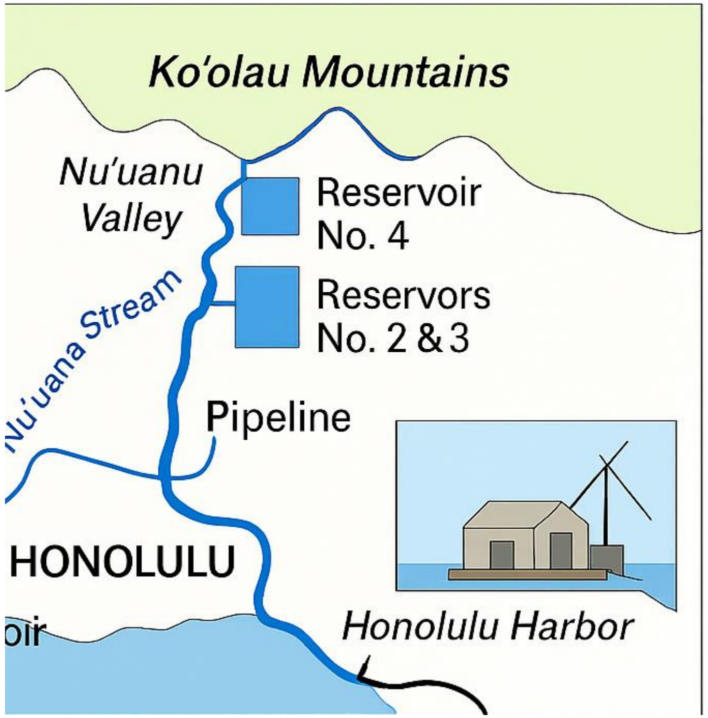
2025 Hawai’i Water Works Conference

Judy Nishimoto

October 16, 2025

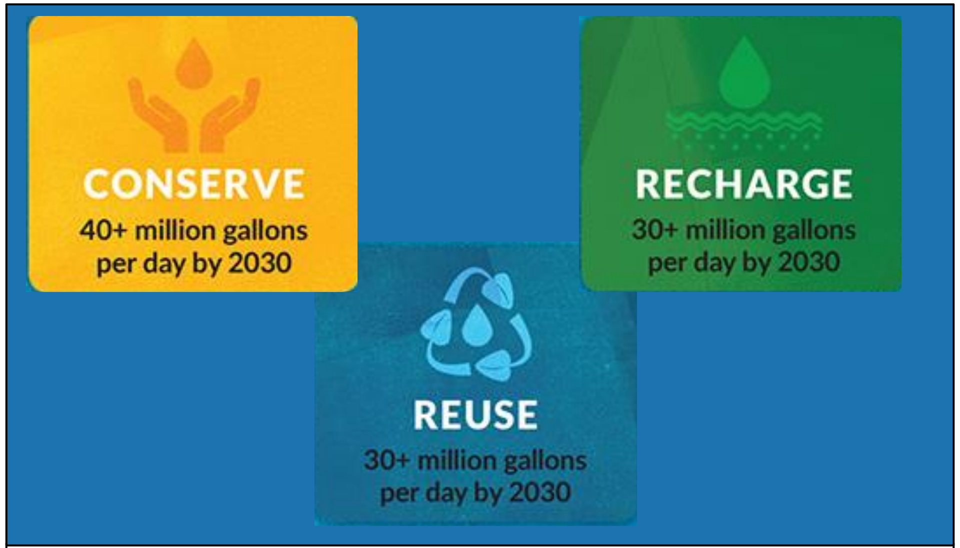
Honolulu’s Early Water Supply (source: ASCE Hawaii)

- **Pre-1848**: Drinking water is from springs, streams, and shallow wells.
- **1848:** First government water system installed; pipeline from Nuʻuanu Valley reservoir to Harbor Master’s tank for ships.
- **1850–1860s:** Expansion with masonry reservoirs near Nuʻuanu Avenue and Bates Street; water drawn from King’s Spring.
- **Late 1800s**: King Kalākaua initiated water works and hydroelectric projects, powering ʻIolani Palace lighting.
- **1880:** First drinking water well is drilled
- **1882:** a growing city struggles with water shortages, usage restrictions
- **1888-1889:** severe drought
- **1888:** water wheel is installed turning on electric street lights
- **1889**: Construction of Reservoir 1 (23MG) at the Electric Light Works, Reservoir 2 (8MG), Reservoir 3 (12MG) to increase hydroelectric power and water supply
- **1900:** Kalihi wells are built
- **1910:** Reservoir 4 (700MG) built in Nuʻuanu Valley after droughts; increase supply for growth, support domestic supply, fire protection.
- **1929:** Electric Light Works production halts, switches to electric power from HECO
- **1934:** concerns over water quality, BWS proposes a filtration plant near Reservoir 1 or removal of the dams.
- **1940:** water distribution system is mapped
- **1969**: reservoirs are used solely for flood control, opened to recreational fishing



Fast Forward to 2025: Water Resource Challenges

Finite Groundwater Sources



State Goals to Address Reliability

Climate Change Pressures

Supporting Statewide Goal for Groundwater Recharge

CWRM Water Resources Protection Policy:
"Demands for fresh water are outpacing conventional source development…State and county governments must actively pursue alternative water supplies to sustain Hawai'i's growing population, meet the needs of industry, and help ensure the long-term viability of our ground water aquifers and watershed areas."

Table 2-11 of the 2019 Water Resource Protection Plan

Alternative Water Supply	Potential Uses/Benefits
Stormwater Reclamation (i.e., Rainwater Harvesting) Definition: Runoff water from the impervious surfaces in cities and developed areas, such as streets, sidewalks, roofs, parking lots, and other areas where water cannot percolate into the subsoil.	• Domestic uses (washing bathing, drinking, toilet and urinal flushing, etc) • Ground water recharge • Irrigation • Construction-related uses • Industrial uses • Aesthetic uses (ponds and water features) • Freshwater conservation • Ground water recharge • Landscape enhancement • Pollution reduction and prevention • Erosion reduction • Flood control and containment • Clean Water Act compliance

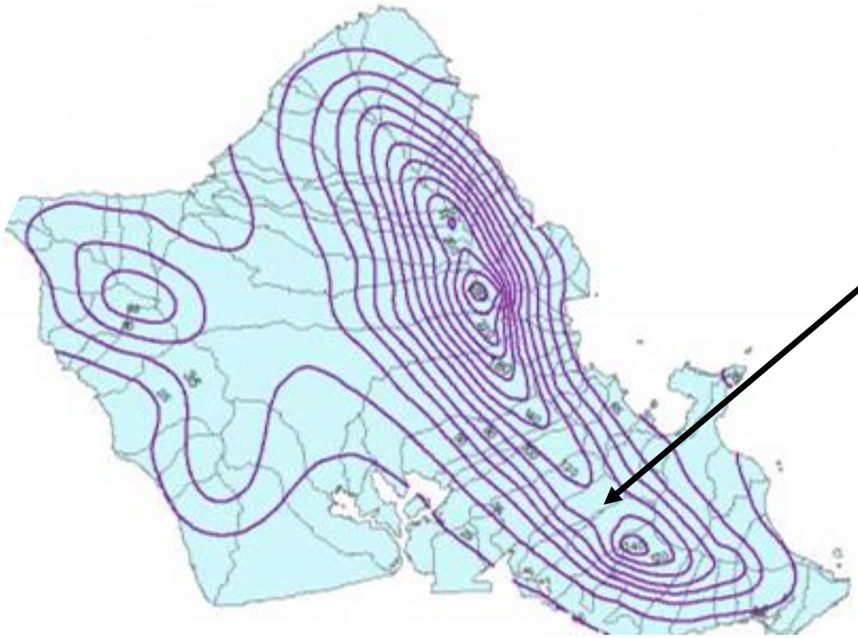
CWRM Strategy:
"promote water delivery and use efficiency, alternative water supplies where appropriate…reduce barriers to alternative water supplies

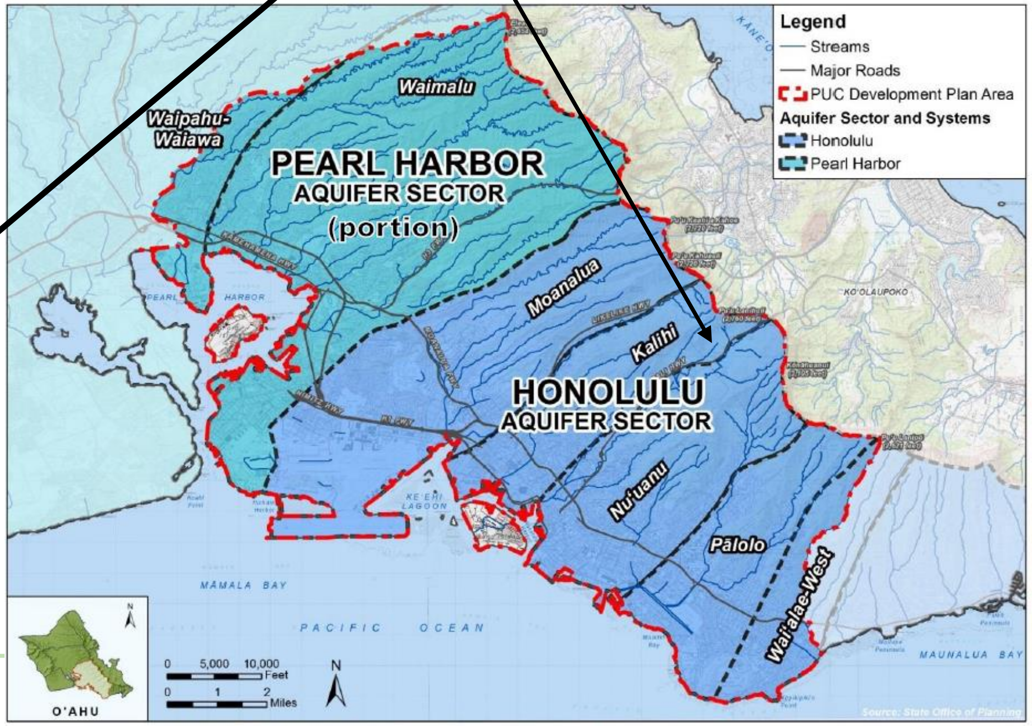
BWS Project Purpose: Enhance sustainability of the ground water aquifer through groundwater recharge (underground injection) of captured stormwater that would otherwise flow out to sea, while creating renewable energy

Recharge

- Water supply is groundwater
- Climate change may reduce rainfall & groundwater recharge
- ~130 inches rainfall in the Nu’uana watershed
- Current groundwater yield Kalihi ~ 9 MGD (20% of Honolulu Sector)

130” Rainfall

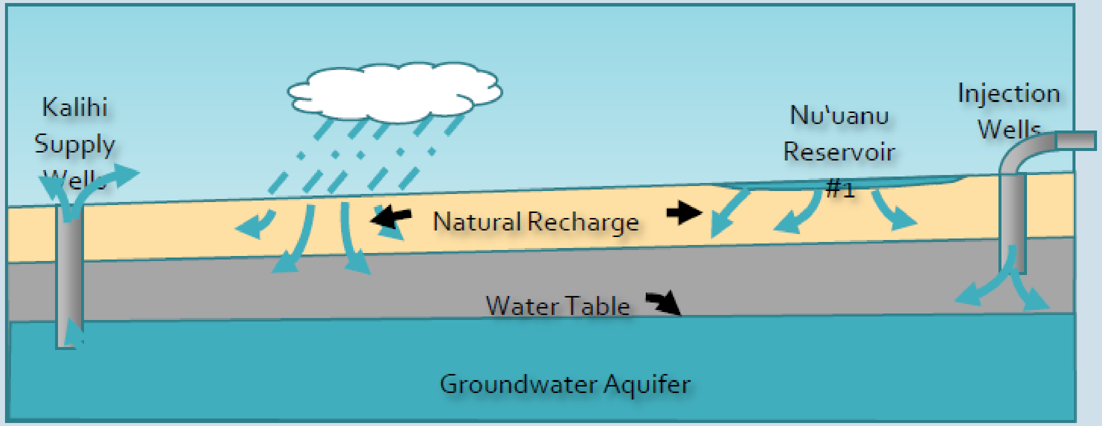




AQUIFER SUSTAINABLE YIELD	
PEARL HARBOR SECTOR AREA	
Waipahu-Waiawa (only partially in PUC)	104
Waimalu	45
HONOLULU SECTOR AREA	
Moanalua	16
Kalihi	9
Nu‘uanu	14
Pālolo	5
Wai‘alae-West (only partially in PUC)	4
TOTAL	197

Nu’uanu Reservoir Hydroelectric and Managed Aquifer Recharge Project

- Capture stormwater at BWS Reservoir
- Generate hydroelectricity
- Filter and inject stormwater into Kalihi aquifer
- Enhance ground water aquifer recharge
- Allows Kalihi Pump Station to sustain or increase pumping levels
  - Increase water supply by 1 to 2 million gallons per day (mgd)



Year 2100, depending on water conservation and climate change impacts, worst case could see a 26% reduction in yield.

Project purpose is to mitigate risk to the groundwater drinking water source.

Sustainable Water Management Strategies of Yesterday Continued Today

Alternative Drinking Water Supply

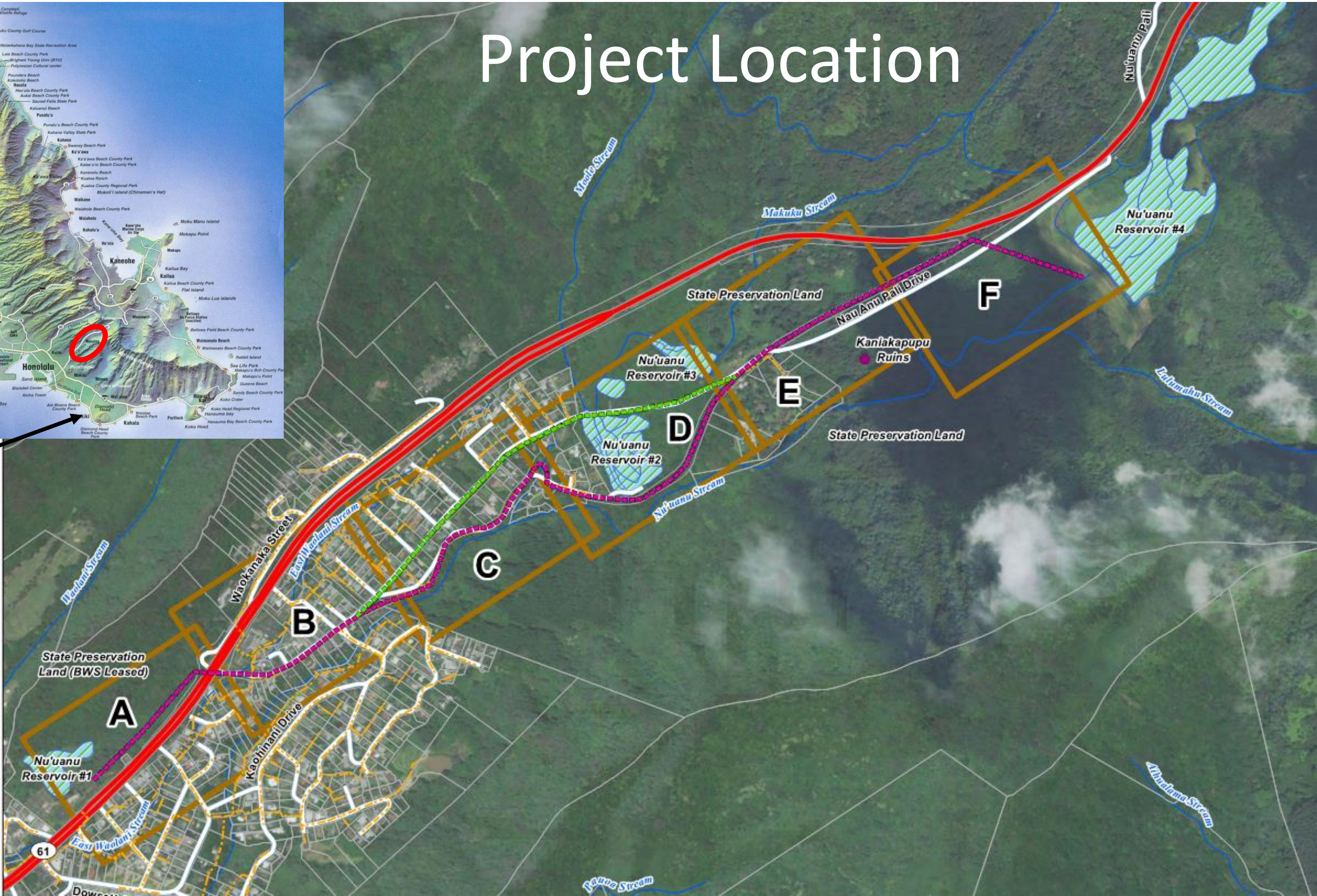
- 1 to 2 MGD injected daily
- Use of stormwater for groundwater recharge from Reservoir #4

Power Generation

- Large static head difference between Reservoir #4 and recharge locations
- Maximize the amount of hydropower and feed directly into HECO’s power grid system

✓ First alternative water supply by groundwater injection in the state of Hawaii
✓ Contributes to the state’s renewable energy goals
✓ Increases dam safety and flood control of Reservoir No. 4

Project Location

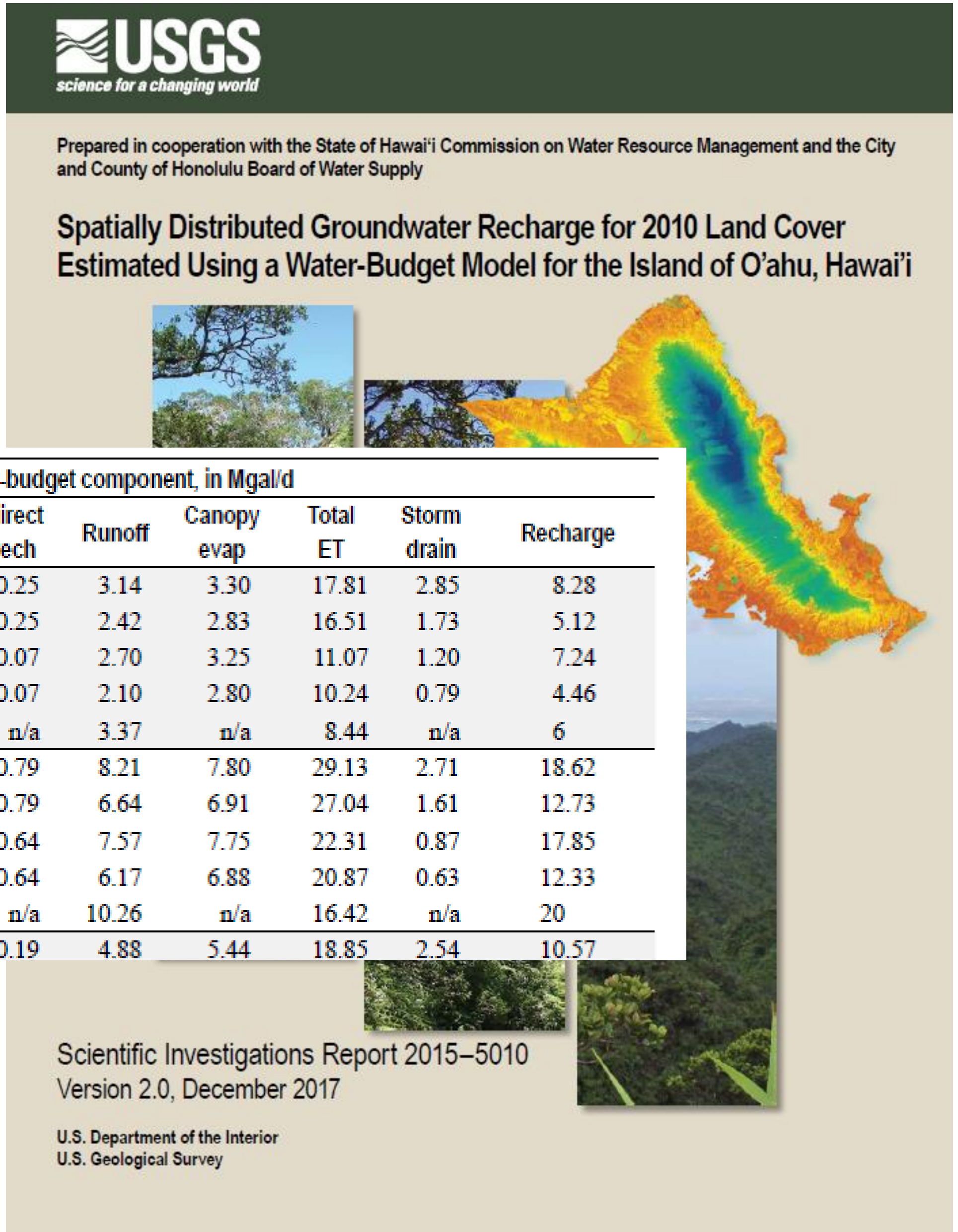


Waikiki

Groundwater modeling shows the valley flows to the Kalihi wells

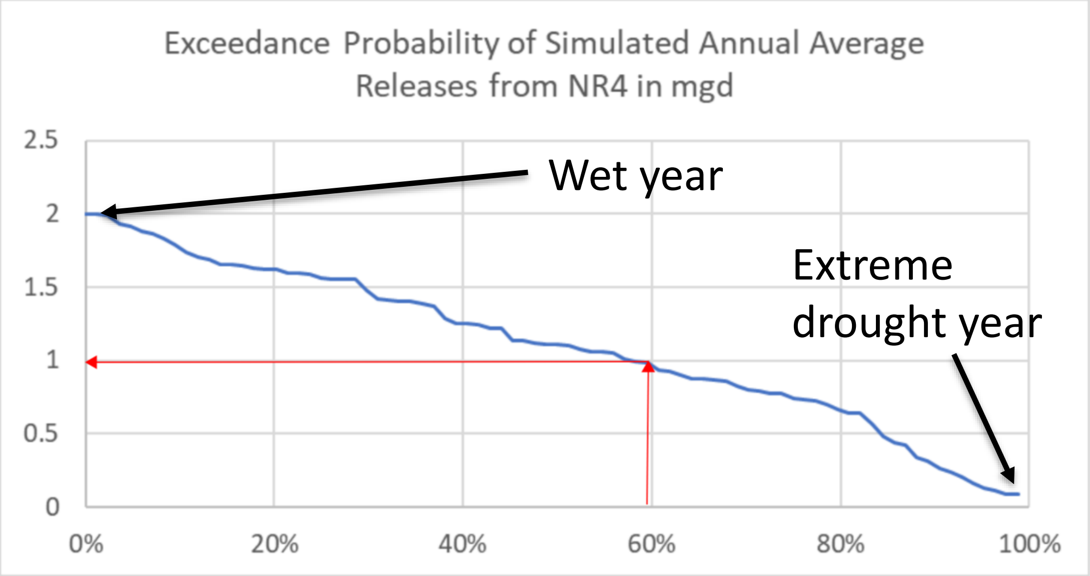
USGS Water Balance for Nuuanu Aquifer

Aquifer sector	Aquifer system	Source of estimate	Water-budget-area description	Area, in square miles	Condition/ Scenario	Water-budget component, in Mgal/d									
						Rain	Fog	Irr	Septic	Direct rech	Runoff	Canopy evap	Total ET	Storm drain	Recharge
Honolulu	Pālolo	This study	A	10.10	Average climate	28.27	0.09	3.05	0.01	0.25	3.14	3.30	17.81	2.85	8.28
		This study	A	10.10	Drought	21.66	0.06	3.35	0.01	0.25	2.42	2.83	16.51	1.73	5.12
		This study	B	5.36	Average climate	21.31	0.09	0.75	0.01	0.07	2.70	3.25	11.07	1.20	7.24
		This study	B	5.36	Drought	16.62	0.06	0.84	0.01	0.07	2.10	2.80	10.24	0.79	4.46
		WRPP	D	4.43	Natural	17.29	n/a	n/a	n/a	n/a	3.37	n/a	8.44	n/a	6
	Nu'uanu	This study	A	14.79	Average climate	55.82	0.24	1.86	0.02	0.79	8.21	7.80	29.13	2.71	18.62
		This study	A	14.79	Drought	44.94	0.18	2.05	0.02	0.79	6.64	6.91	27.04	1.61	12.73
		This study	B	9.72	Average climate	47.53	0.24	0.41	0.02	0.64	7.57	7.75	22.31	0.87	17.85
		This study	B	9.72	Drought	38.88	0.18	0.48	0.02	0.64	6.17	6.88	20.87	0.63	12.33
		WRPP	D	8.62	Natural	41.45	n/a	n/a	n/a	n/a	10.26	n/a	16.42	n/a	20
	Kalihi	This study	A	9.83	Average climate	34.94	0.07	1.57	0.00	0.19	4.88	5.44	18.85	2.54	10.57

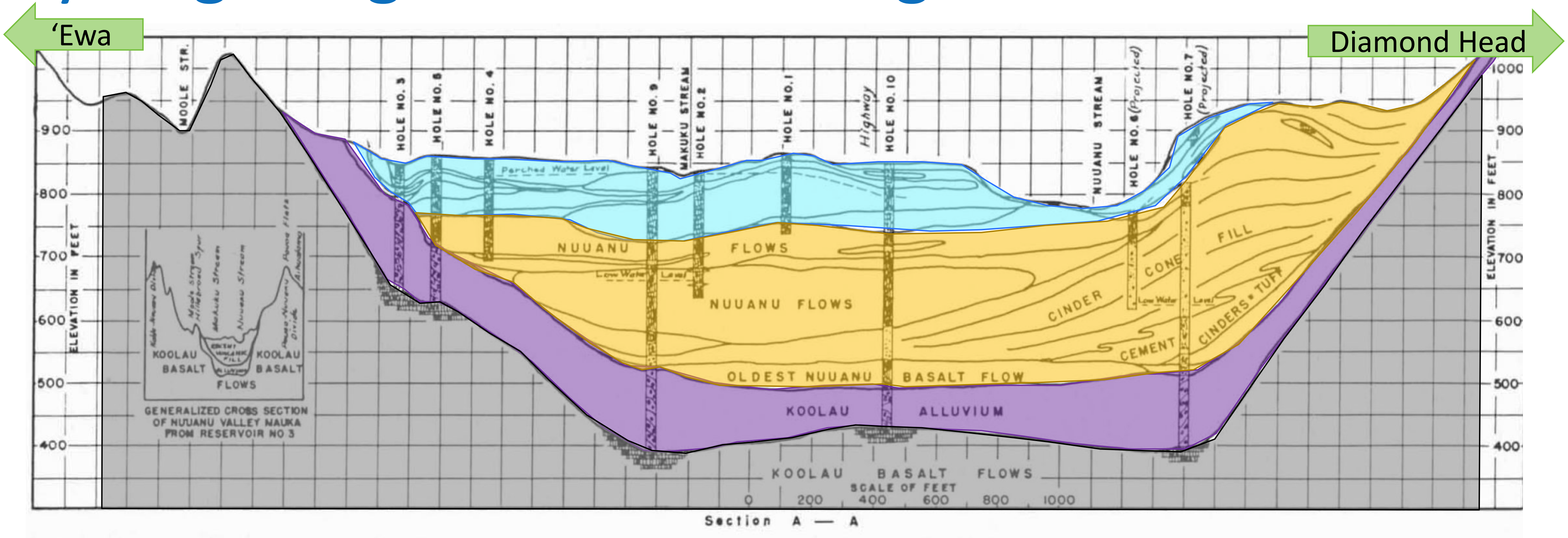


Reservoir 4 Flow Available

- Reviewed
  - Historical water balance (USGS report)
  - Rainfall data
  - Data measured in Nu'uanu Stream
- Continue flow to Nu'uanu Stream, maintain a minimum flow depth (Q70) of 0.57 mgd will continue from watershed area contributing, and dam outflows
- Average annual release = 1.1 mgd



Hydrogeologic Understanding



Leverage long history of hydro-geologic studies completed in Nu'uanu Valley

- Shallow perched aquifers
- Mix of different aged basalts in first 300' of depth
- Thick alluvium layer separates shallow aquifers from production aquifer
- Production aquifer (Ko'olau Basalt) starts at 400' depth

Ko’olau Basalt Aquifer Recharge Potential

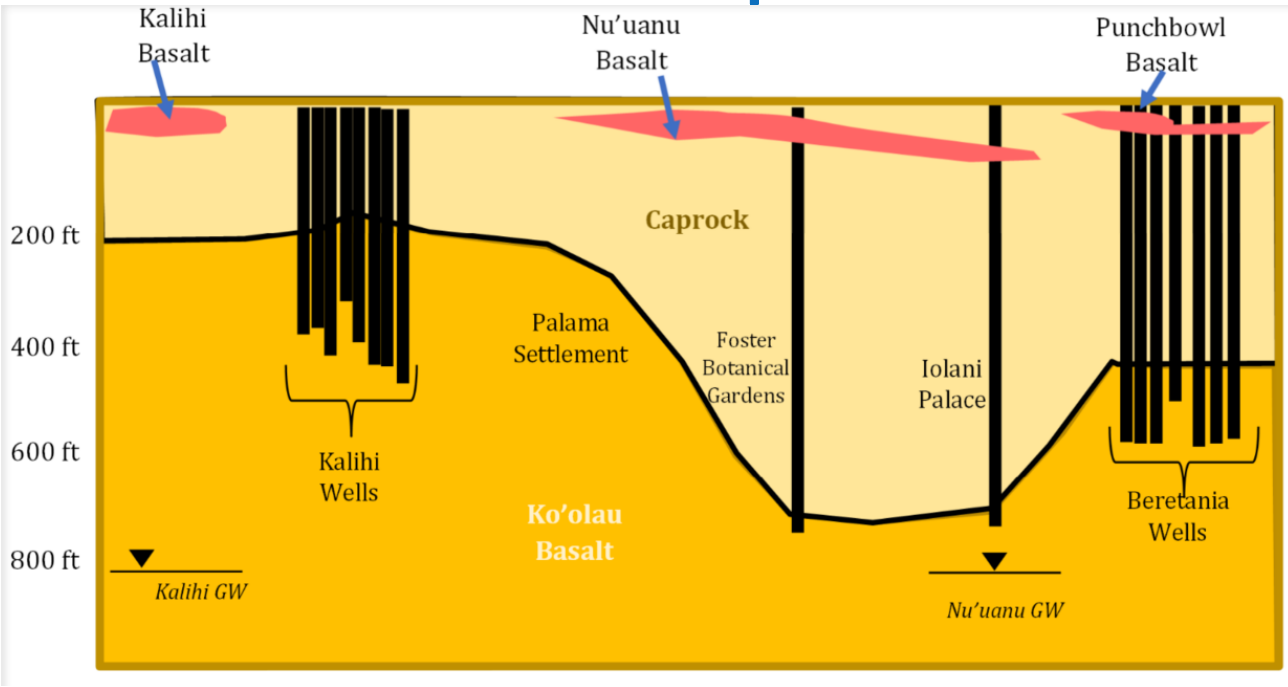


Table 1 Aquifer Parameter Values from Okuhata, 2017

Material	hydraulic conductivity (m/d)			conductance (1/d)	porosity & specific yield	
	horizontal (longitudinal)	horizontal (transverse)	vertical		scenario 1	scenario 2
Koolau basalt	600	150	0.75		0.08	0.3
Alluvium	0.05	0.05	0.05		0.3	0.5
Honolulu volc.	3	1	0.03		0.1	0.1
Caprock	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-8}	0.1	0.1
Upper limestone	100	100	0.5	1	0.2	0.2
Lagoonal deposit	1	1	0.5		0.1	0.1

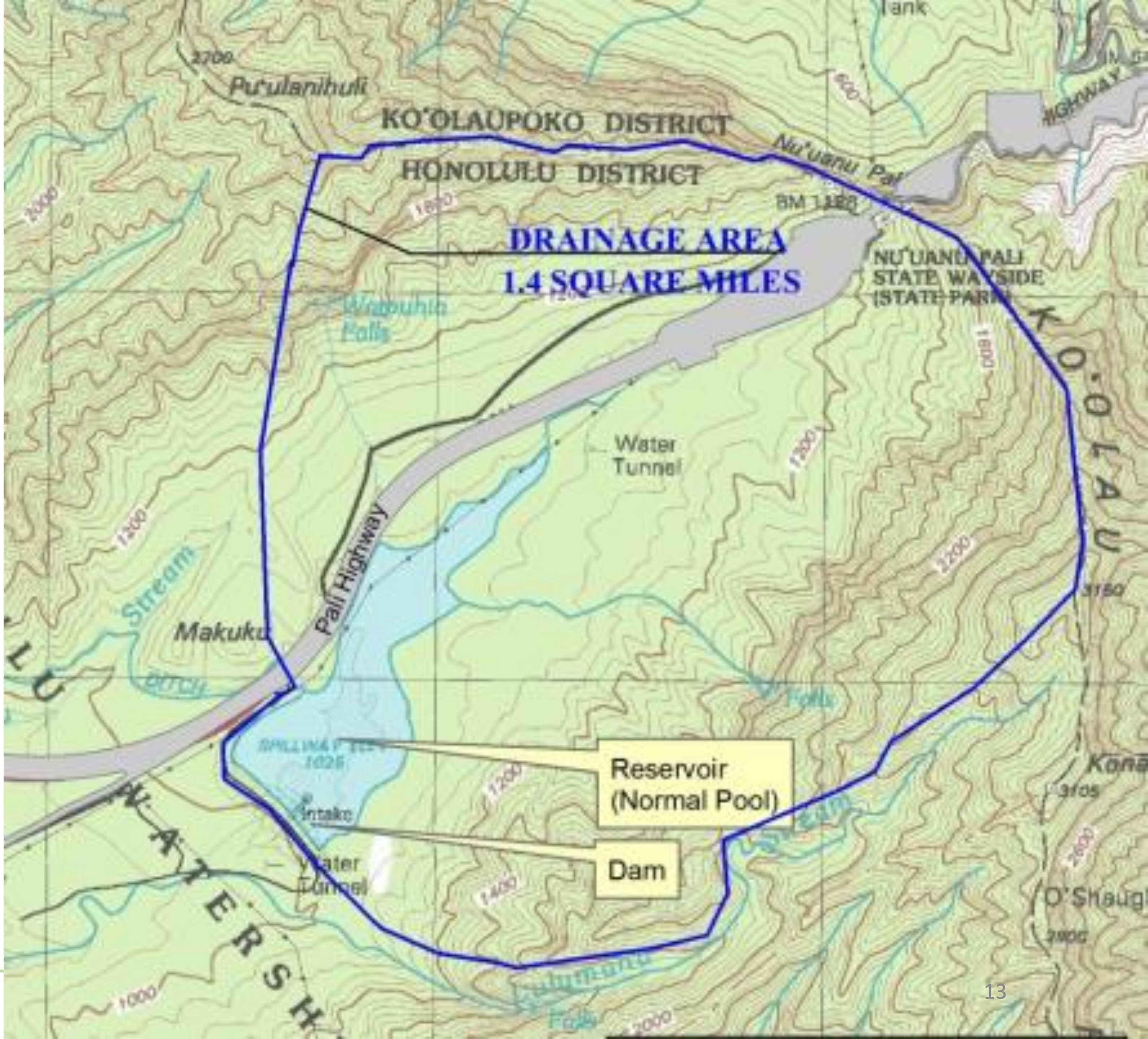
Longitudinal is the right direction

High permeability is sufficient for 1-2 mgd recharge

Inject below the alluvium and above the groundwater table to allow insitu treatment

Reservoir #4 Water Quality

- Reservoir #4 feeds into the Nu'uanu Stream
- Up until 1919, the Reservoir was a surface water drinking reservoir
- Watershed to the Reservoir is ~1.4 square miles
- Undeveloped, forested condition
- Inflow is as much as an average daily flow of 6 cfs (3.3 mgd).
- Reservoir #4 was recently dredged to remove silt build-up around the intake tower.



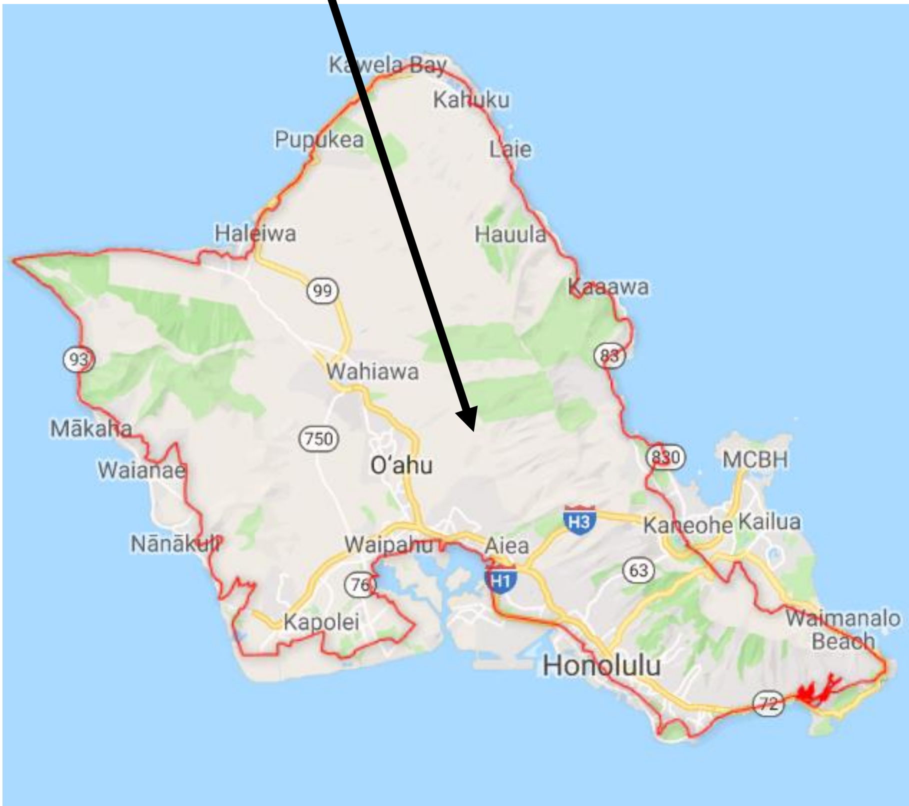
UIC Regulations

High risk — Low risk

Subclass A → Subclass E

- This will be a Class V subclass C injection well, gravity driven.
- Injection above the underground source of drinking water aquifer
- Anticipate the aquifer is basalt (low in TOC) with a confined layer above.
- Required Tests for UICs
  - Chloride concentration
  - TDS
  - Coliform – Total. If found, then fecal and streptococcus

Area inside red is drinking water aquifer



Water Quality Sample Results and Notes

Surrogate for coliform

June 28 2020 Water Quality Sampling Results

Constituent	TOC (mg/L)	Dissolved Organic Carbon (mg/L)	Total Dissolved Solids (mg/L)	Alkalinity Total (mg/L as CaCO3	Turbidity (NTU)	Chlorides (mg/L)	Iron (mg/L)	Manganese (mg/L)	pH	Heterotrophic Plate Count (HPC) (CFU/ml)
Surface Water (6/28/20 sample)	12.2	7.56	96 ok	24	11	10.7 ok	0.796	0.086	7.02 ok	1,150
National Primary and Secondary Drinking Water Regulations (Maximum Contaminant Levels)	n/a	n/a	500 (secondary)	n/a	0.3*	250 (secondary)	0.3 (secondary)	0.05 (secondary)	6.5 – 8.5 (secondary)	500

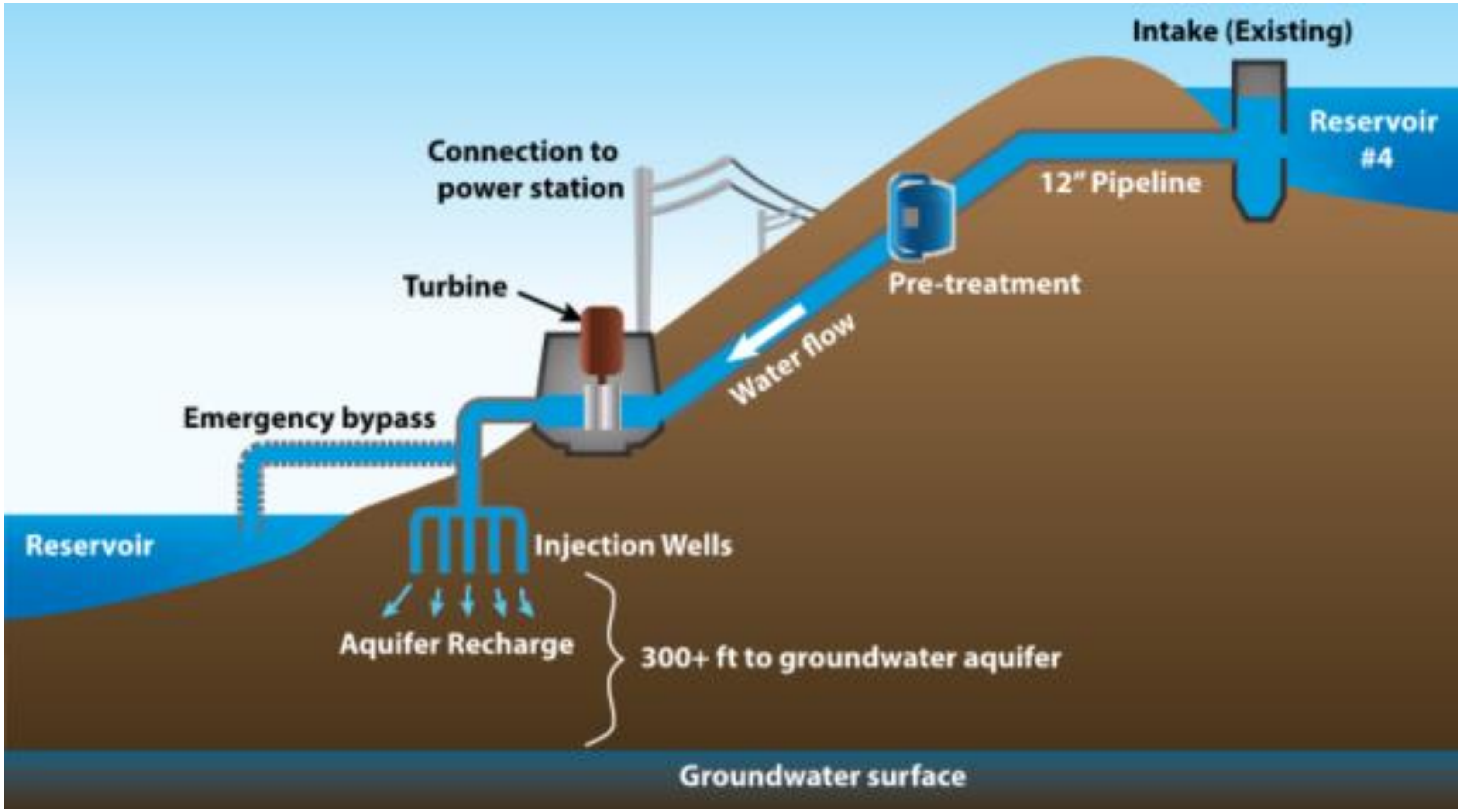
Screen and pre-treatment will be needed to remove large particles and prevent plugging of the well

Reduce <5 NTU to prevent plugging

These standards are based on aesthetics. Concern with scaling, fouling, or bacterial growth to prevent plugging

Insitu treatment to kill bacteria and inactivate virus

Treatment Flow Diagram

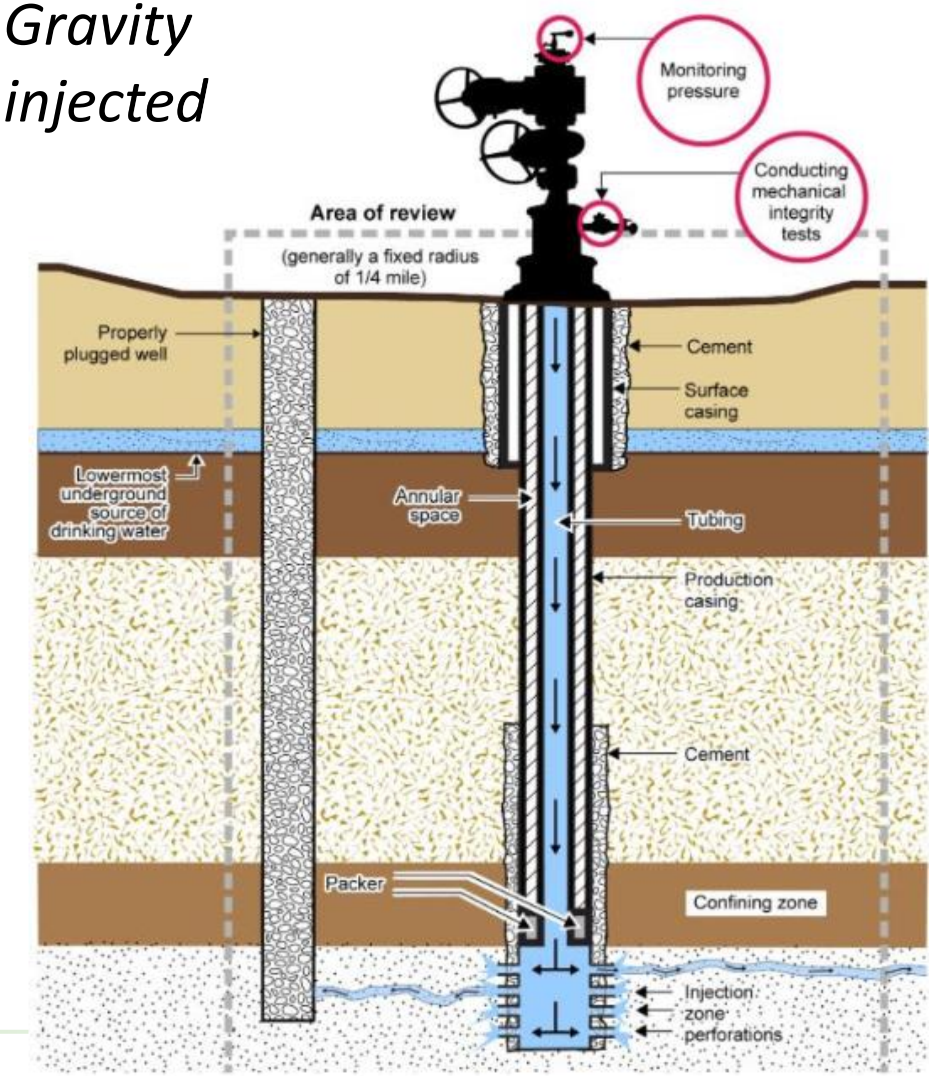


- Screening
  - Fish bypass
  - Floatables and sediment removal
- Pre-Treatment (particle removal):
  - Cartridge or Bag filters – 1 micrometer
  - Chlorine, light residual for preventing microbial growth in well and pipeline

Injection Well

Typical injection well

Gravity injected

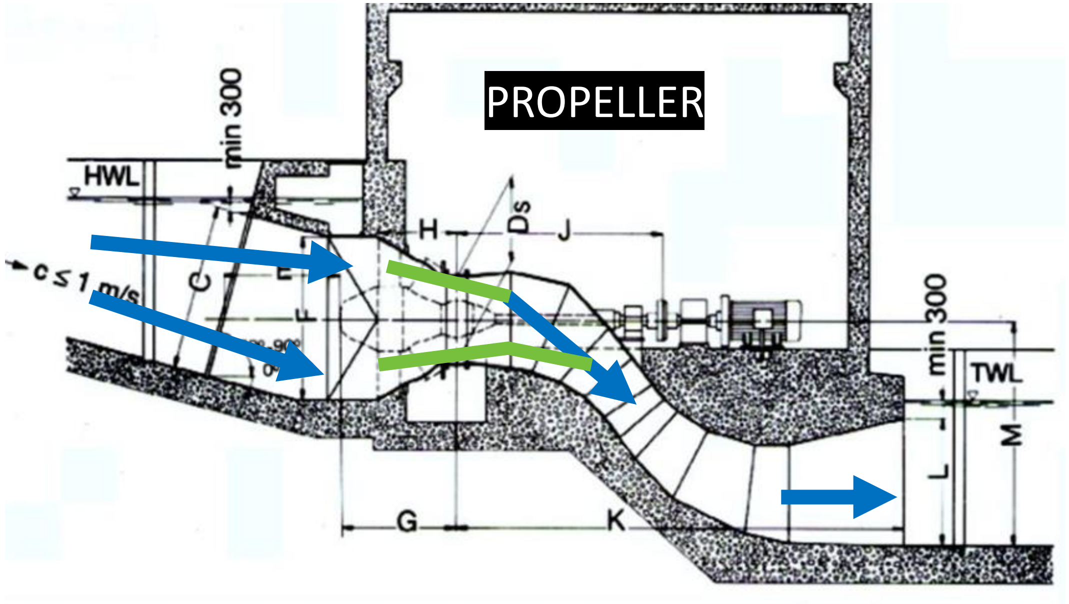


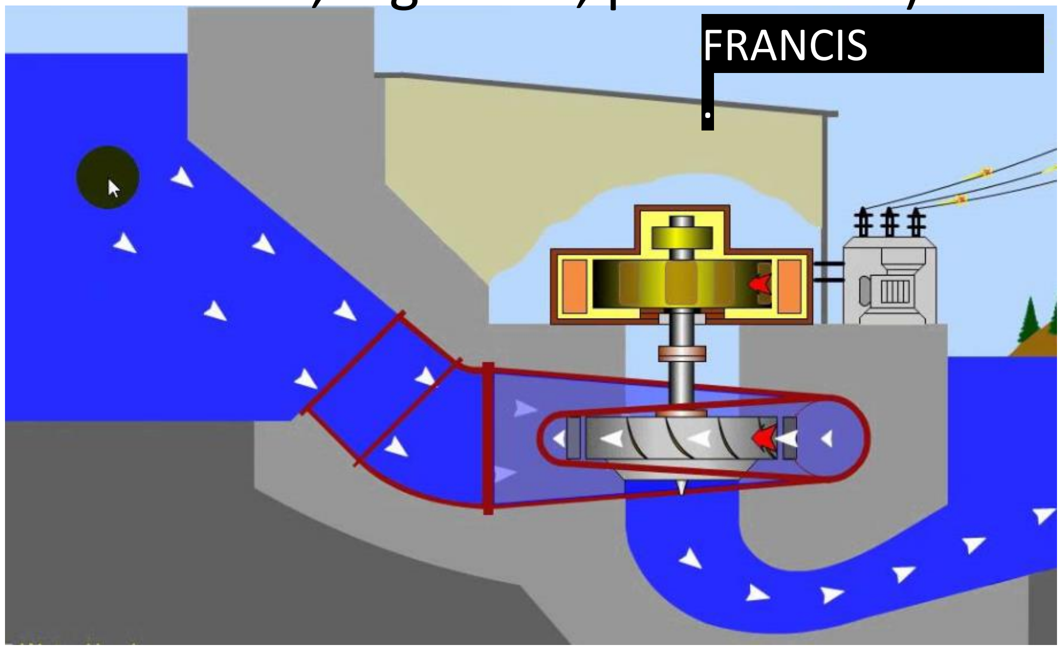
Considerations:

1. Multiple injection wells may be needed
2. Light chlorine residual is needed to prevent microbial growth/plugging
3. Disinfection byproduct formation can happen if residual is too high
4. Pre-treat to reduce soluble organic carbon
5. Differences in pH and reduction-oxidation potential may cause arsenic, iron, manganese, or radionuclides present in rock to dissolve
6. Carbonate precipitation in carbonate aquifers can clog wells if the injectate is not sufficiently acidic

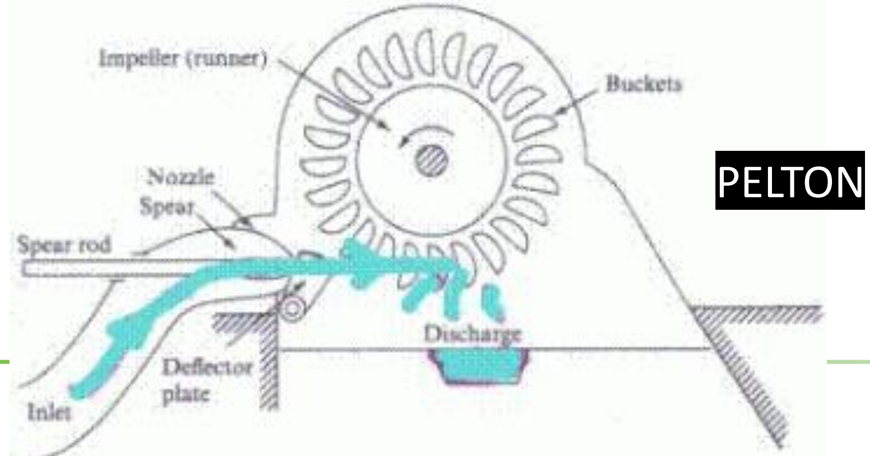
Hydropower

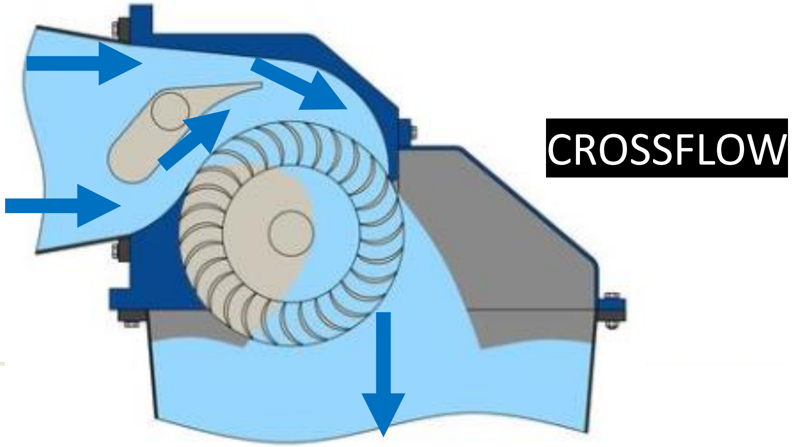
- Reaction turbines (directly in water stream, lower head, high flow, pressurized)





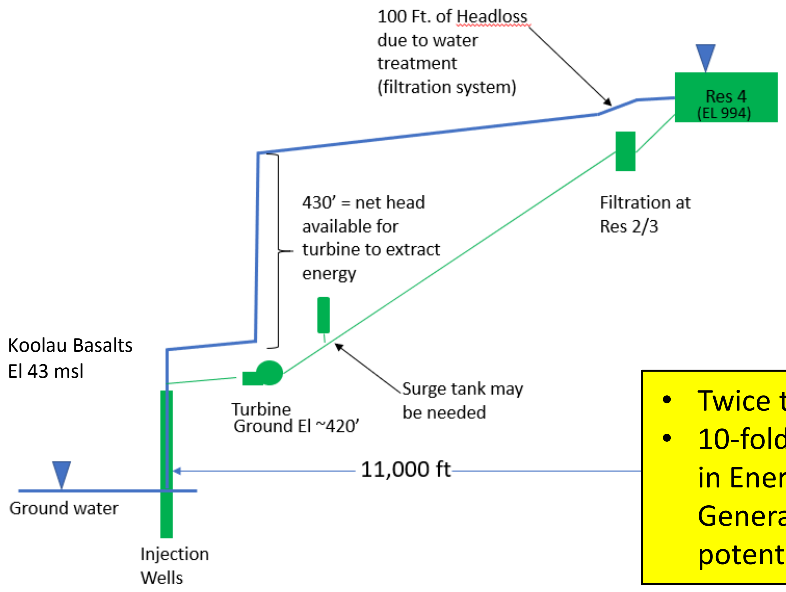
- Impulse turbines (jet velocity spins runner, higher head, low flow, discharges to atm)

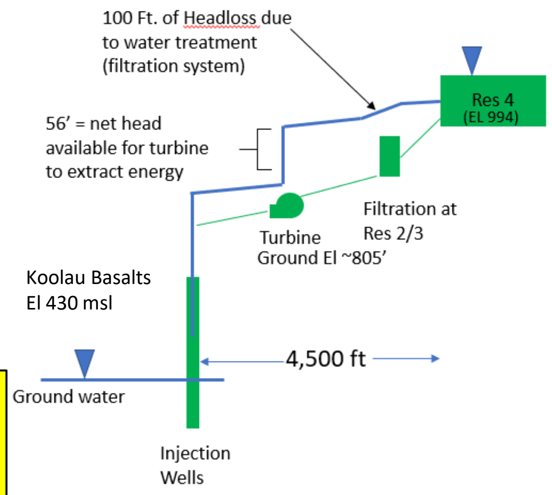




Hydraulic Grade line Figures

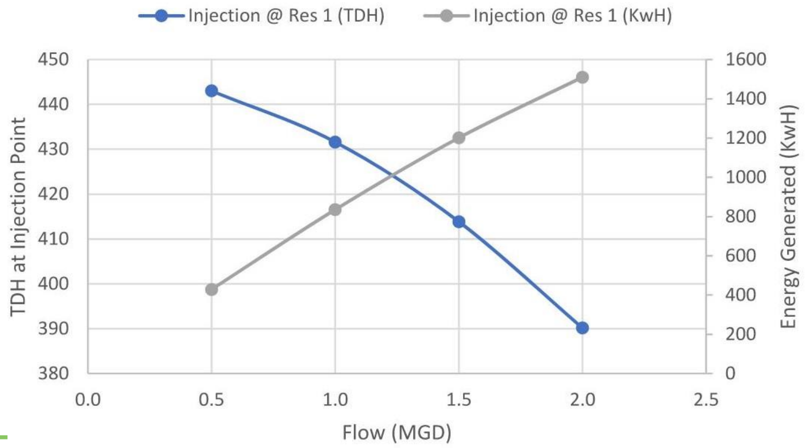
Reservoir #1 Location	Reservoir #2/3 Location

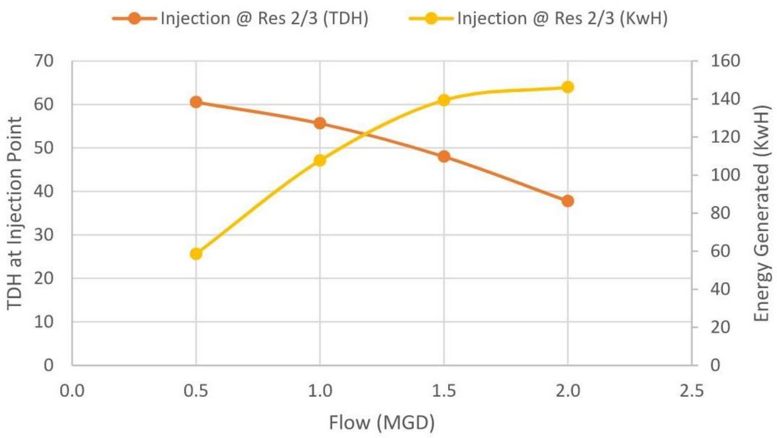




- Twice the distance
- 10-fold difference in Energy Generation potential

600 ft
static head
0.14 MW
(24 hrs)





200 ft
static head
0.05 MW
(24 hrs)

Siting of Injection Wells

Location Proximity	Property Owned by BWS	Location for bypassing flow	Achieves both Injection and Hydro-electric?	Cost	Hydro-electric potential	Distance between confinement and Groundwater Table
Reservoir 1	Yes, shared with City Parks	To Reservoir	Yes	$$$	Payback covers capital cost	~25 ft
Reservoir 2/3	Yes	To Reservoir	Yes	$$	Covers operating costs	~400 ft

Monitoring and Control

- Influent: TSS, pH, conductivity, temperature
- Influent: Flow rate
- Filtrate: TSS, pH, temperature
- Turbine: pressure
- Injectate: Flow rate
- Injectate: pressure

Preventative Measures and Safeguards to Prevent Accidental Contamination

- **Cascade control** - to prevent air binding and avoid introducing oxygen into an anoxic zone could oxidize and mobilize metals
- **Flow rate and shutoff control** - to prevent injection water levels daylighting or rising above agreed level
- **Injection interval stability**– open hole completion versus screened interval (e.g., slotted casing)
- **Turbidity control** – online turbidity meter with auto-shutdown settings
- **Control bio growths** - likely will occur due to source water nutrient levels. Add ~ 5 ppt chlorine residual disinfectant
- **Monitoring the Operation** – water levels, pH, temperature, flow rates, daily WQ sampling of chloride, TDS, Coliform
- **SOP** - for emergency shutdown if there's a major surface spill in the area (tanker turnover)
- **Phasing of well construction** – would allow BWS to gather more data and learn from a single fully operational well

What We're Doing Now

- Conducting a boring and hydraulic aquifer tests near Reservoir 2/3
- Environmental Review
- Preliminary Design

Schedule Status

- Field work complete in February 2026
- Complete pre-design by Sept 2026

Questions?