Haʻikū Tunnel Bulkhead Study

Presented to

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Prepared by

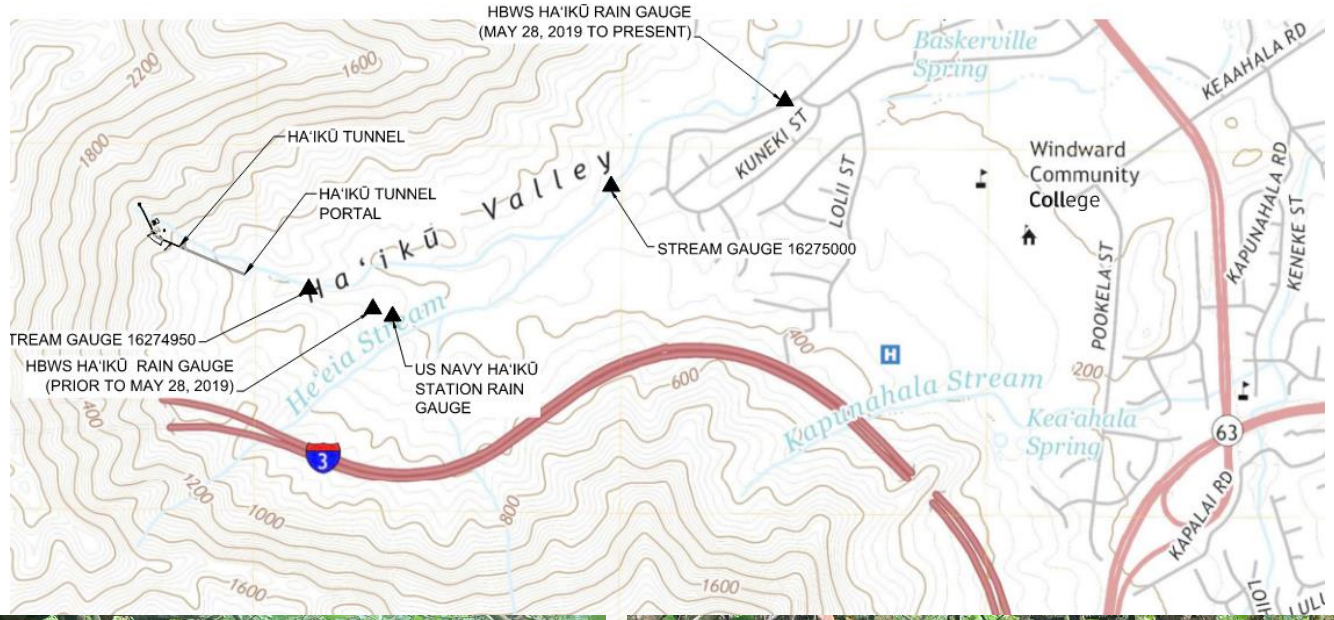
Board of Water Supply
KA ʻOIHANA WAI

BRIERLEY ASSOCIATES
Creating Space Underground

Outline

- Project Location, Purpose, Description
- Haʻikū Tunnel History
- Our Understanding of Existing Hydrogeological Conditions
- Alternatives Considered
- Feasibility of Construction Alternatives
- Conclusions and Recommendations

Project Location



Purpose

- Haʻikū Tunnel constructed c.1940
- Historic USGS reports c.1960s, 1970s - Heʻeia Stream reduced
- CWRM issued Notice of Action (Order) to HBWS June 18, 2021
  - Bulkhead Haʻikū Tunnel at furthest apparent dike location in tunnel, and reduce groundwater withdrawal rates to 0.3 MGD
  - Complete a bulkhead feasibility study and preliminary engineering design
  - Quarterly meetings with Commission and stakeholders
  - Final design and construction of bulkhead after completion of feasibility study
  - Following bulkhead installation, work with Commission to evaluate baseflow and determine feasibility of establishing numeric IFS
  - If bulkhead is not feasible, Commission staff will recommend an IIFS amendment OR, amend BWS Water Use Permit

In response to the Order, HBWS:

- Haʻikū Tunnel Water Use Permit = 1.340 MGD
- Prior to Order: Took initiative to reduce Haʻikū Tunnel flow by ~1/2 (~1.0 to ~0.5 MGD)
- August 2, 2021: Further reduced Haʻikū Tunnel flow from ~0.5 MGD to 0.3 MGD
- October 22, 2021 – April 10, 2022: "Shut-in" Haʻikū Tunnel. Shut-in tunnel pressure was ~47 psi
- Contracted with Brierley to perform a feasibility study associated with installation of a new bulkhead
- Funded USGS Cooperative Study to better understand water resources in the Heʻeia watershed
- Working with KMCBH to reduce water demand and expand recycled water usage
- Restricting building permit approvals for State Hospital and WCC until new replacement source is designed and constructed

Site Description

- Vertical dikes, created by the upward flow of magma, exist along the Koʻolau Range
- As rainwater infiltrates -> stored between dikes
- Tunneling through dikes to withdraw the water
- Bulkheads typically constructed at the dike locations to prevent loss, maintain/build storage, and control withdrawal

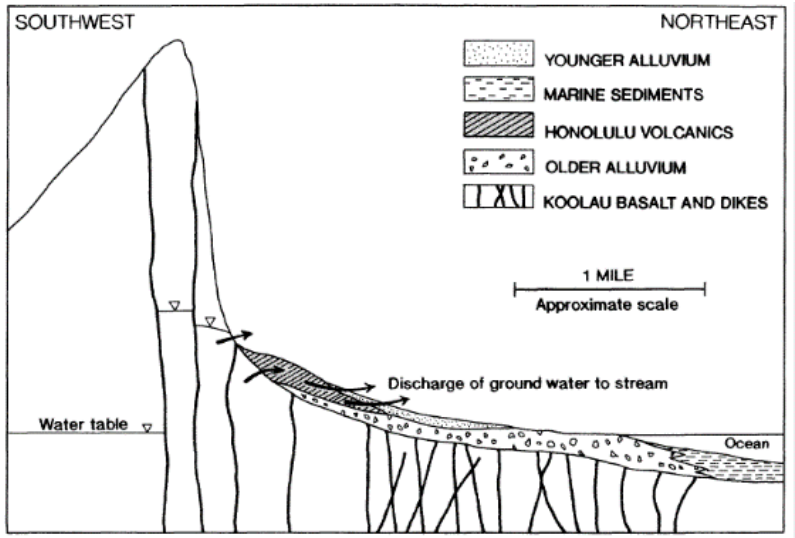
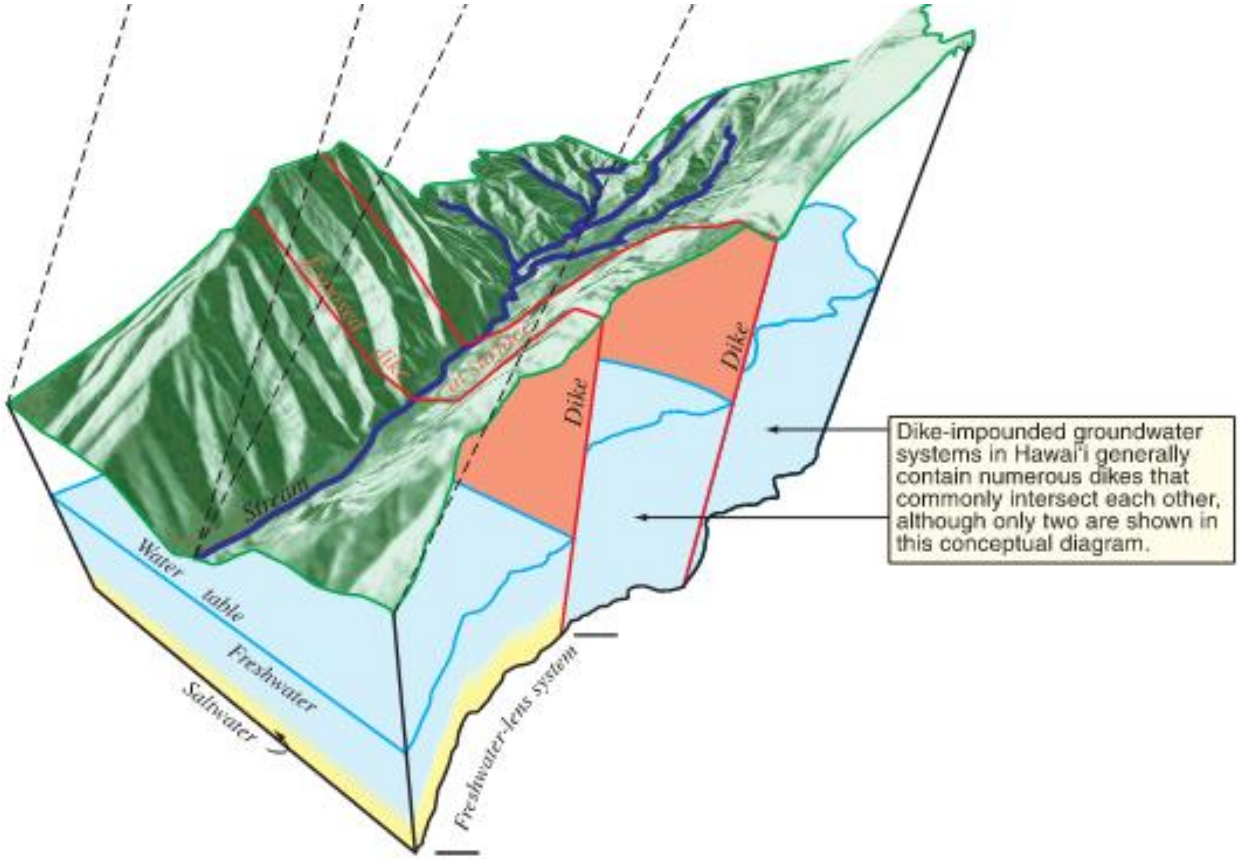


Illustration depicting dikes and water storage compartments within the Haʻikū Valley (From Takasaki and Mink, 1985)

Storage compartments



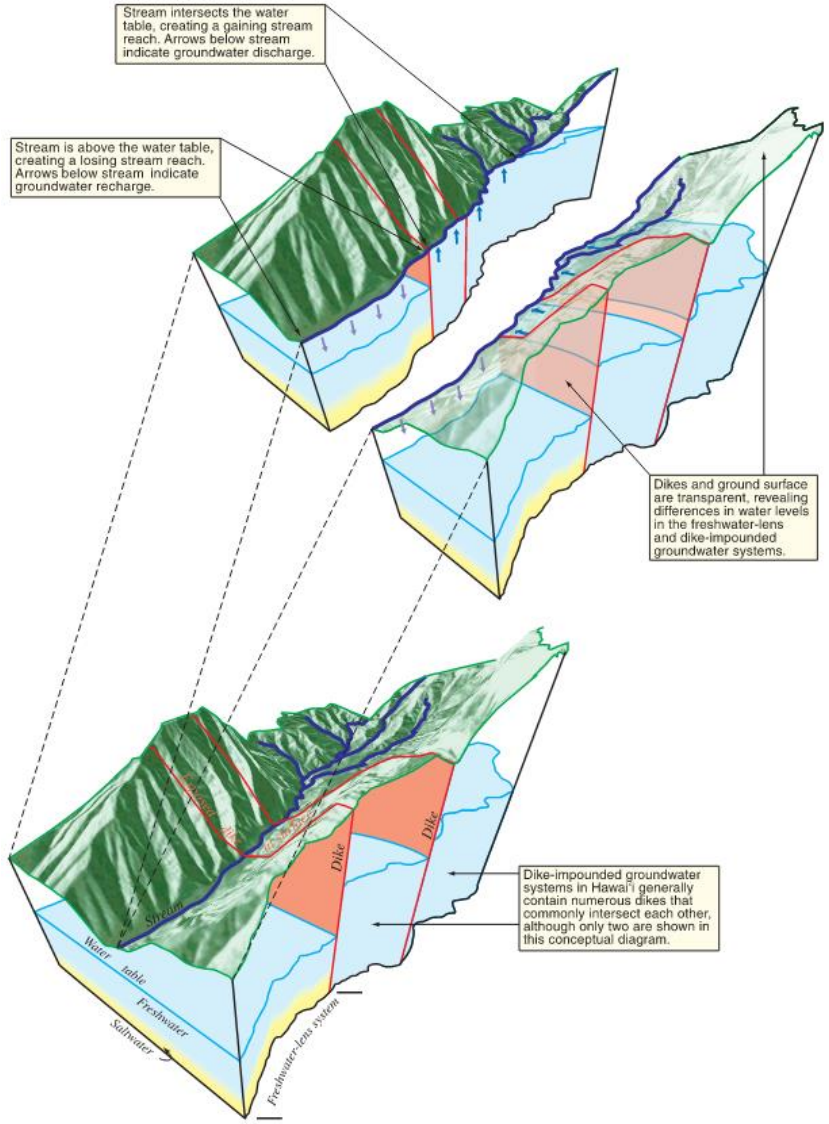


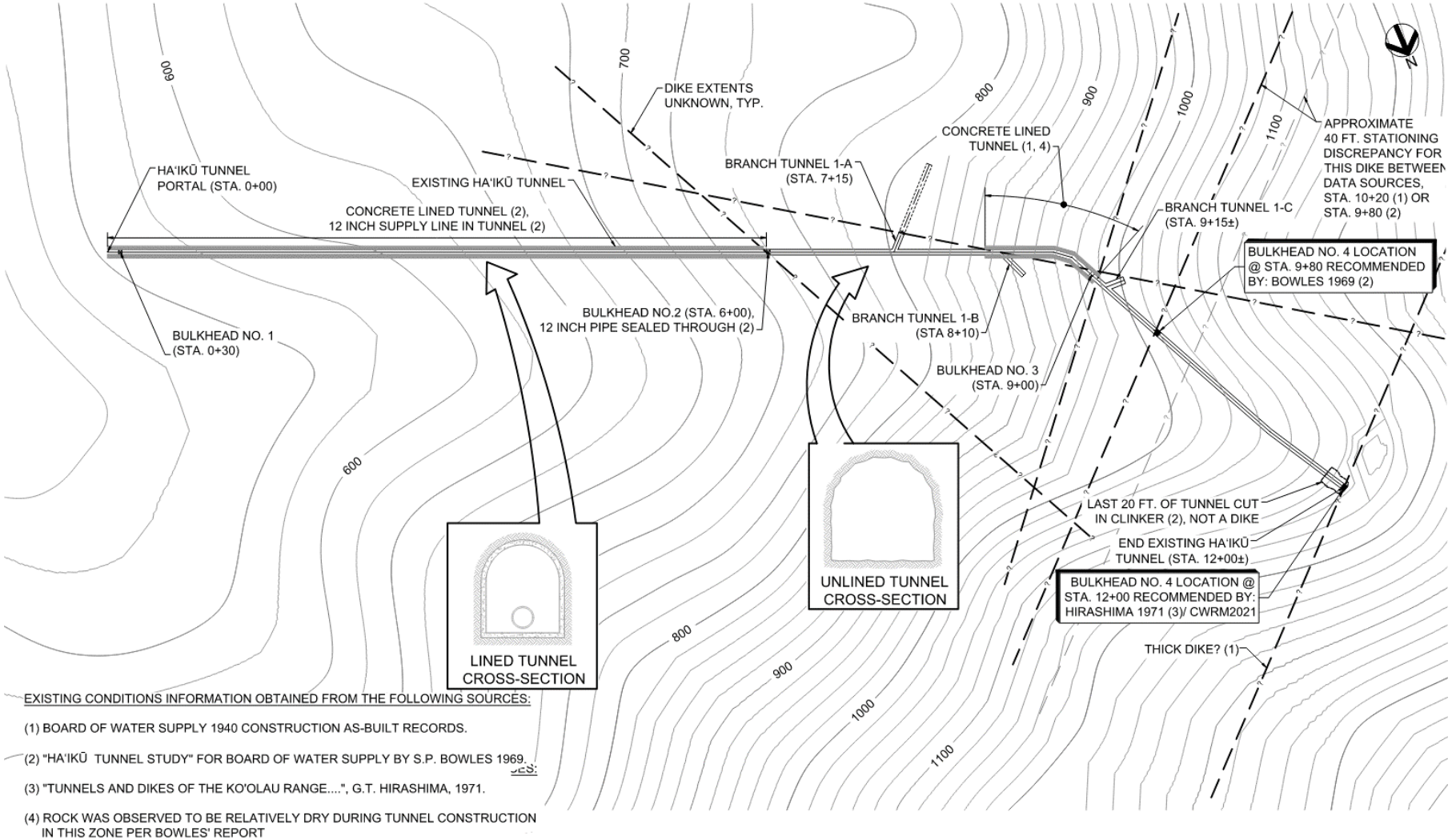
Figure 8. Conceptual diagram showing relation between surface water and groundwater within the drainage basin of a stream. The cutaway views at the top are split along the main stream.

Figure from: SIR 2010-5011 (USDOI/USGS)

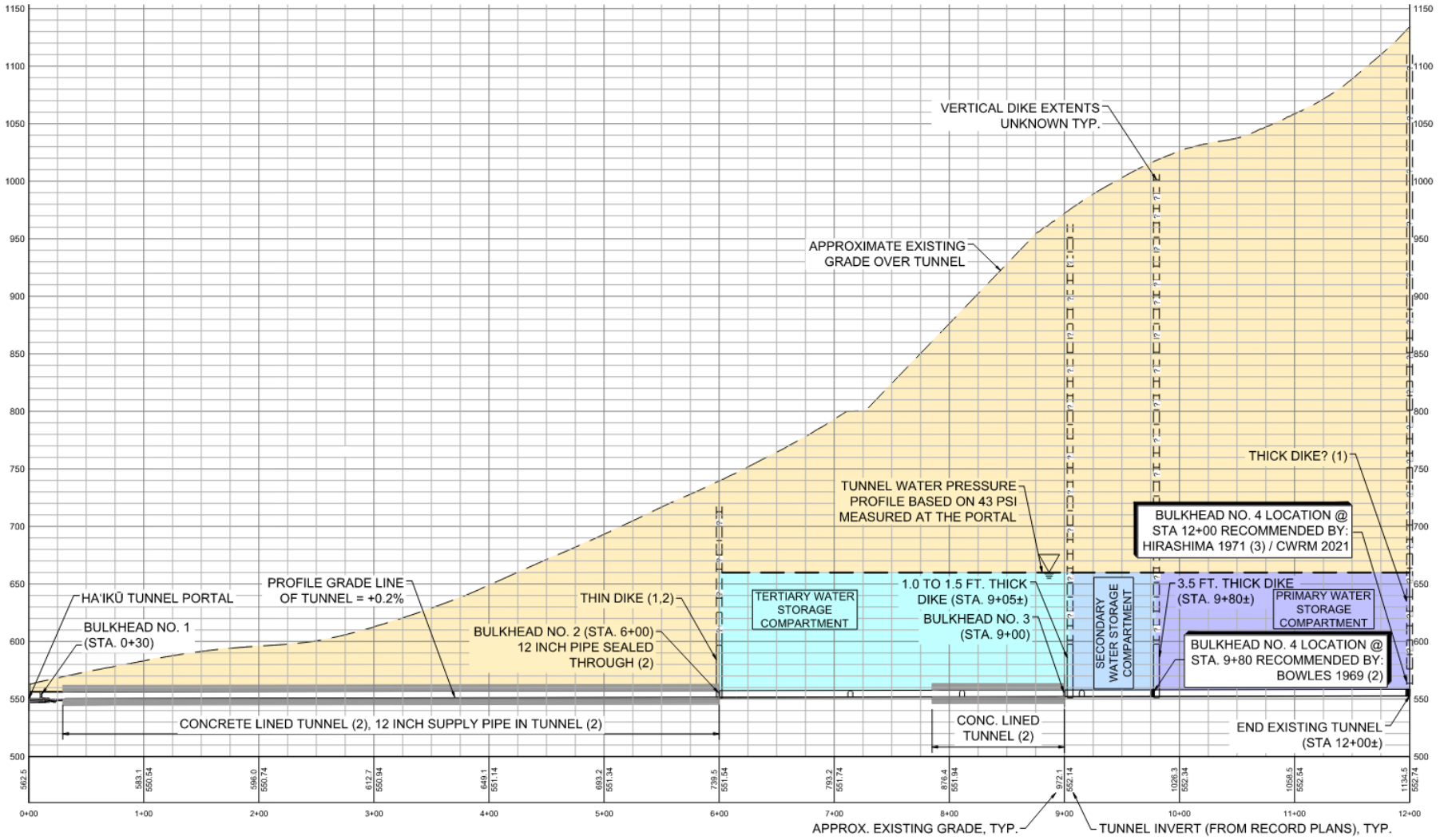
Haʻikū Tunnel

- Constructed windward side of Oʻahu 1939-1940
- Approximately 1,200 feet long with 3 bulkheads
- Bulkheads were installed at STA 0+30 (Bulkhead No. 1), Sta 6+00 (Bulkhead No. 2) and STA 9+00 (Bulkhead No.3)
- Tunnel is concrete lined between Bulkhead No. 1 and Bulkhead No. 2 to mitigate loss
- 12” pipeline extends from the portal through Bulkhead No. 1 and Bulkhead No. 2
- 36” access pipe through Bulkhead No. 3 - open
- As-built maps show dike locations, lined sections, bulkhead locations and Branch Tunnels
- Total groundwater inflow plotted with tunneled distance, where about 55% of the inflow was shown to be attributed to the last 50-ft of tunnel

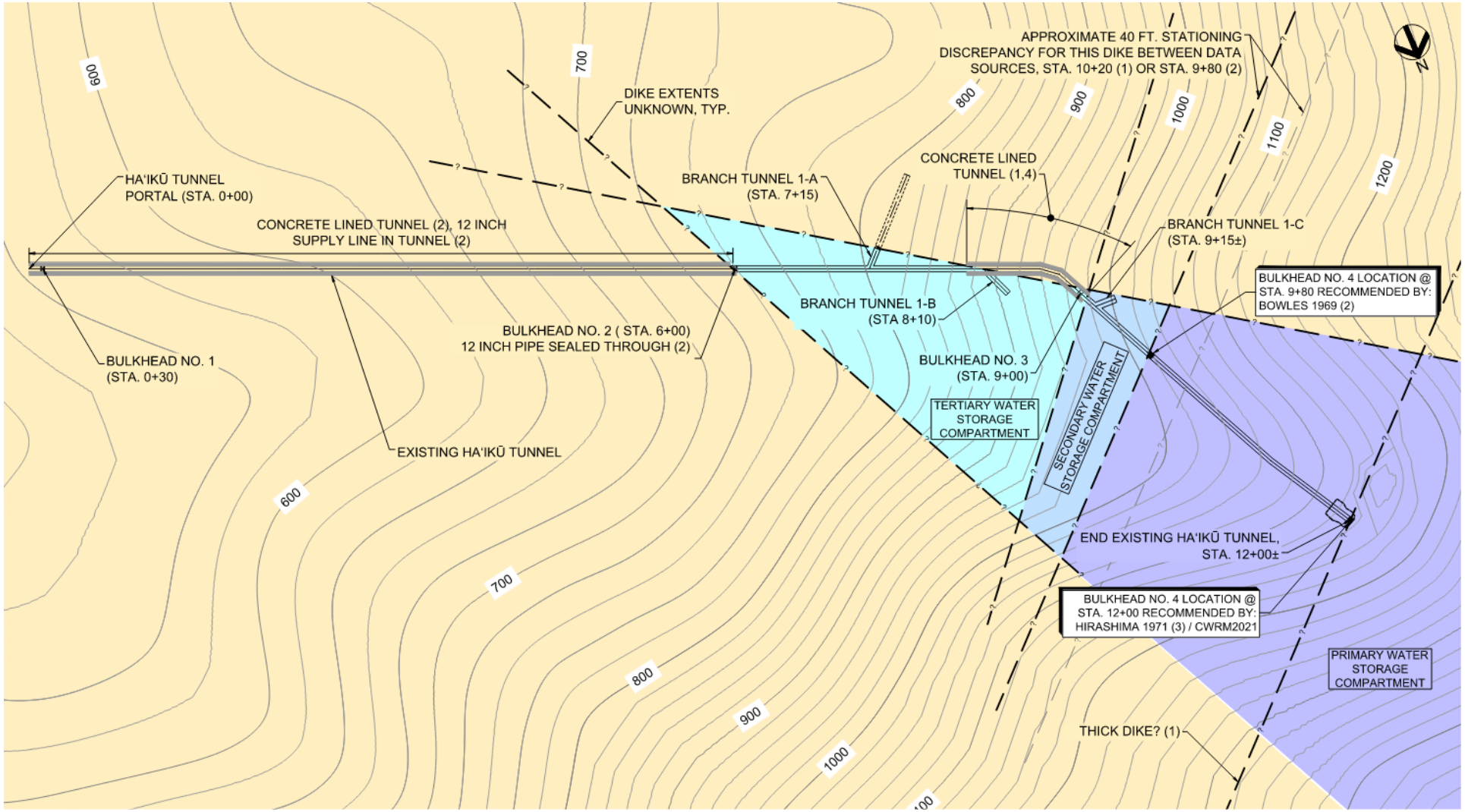
Haʻikū Tunnel – Interpreted Plan



Haʻikū Tunnel – Interpreted Profile



Haʻikū Tunnel – Water Storage Compartments



Haʻikū Tunnel – Literature

- George Hirashima, USGS, authored or co-authored several papers about the Haʻikū Tunnel
  - 1962: “Effect of the Haiku Tunnel on the Kahaluu Stream, Oahu, Hawaii”
  - 1963: “Influence of Water-Development Tunnels on Streamflow-Groundwater Relations in Haiku-Kahaluu Area, Oahu, Hawaii”
  - 1969: “Water Resources of Windward Oahu, Hawaii,” USGS Water Supply Paper 1894
  - 1971: “Tunnel and Dikes of the Koolau Range, Oahu, Hawaii , and Their Effect On Storage Depletion and Movement of Groundwater”
- Recommended that a new bulkhead be constructed near the end of the tunnel ~STA 11+78 based on the assumption that a thick dike is present (1971)
- Hirashima’s 1962 and 1963 papers concluded that construction of the Haʻikū Tunnel also resulted in reduced flow in the Kahaluʻu Stream located ~2.5 miles away

Haʻikū Tunnel – Bowles Report

- Unpublished HBWS report “Haʻikū Tunnel Study” by Stephen P. Bowles, April 1969
- Bowles physically entered the tunnel and mapped dike locations
- Bowles indicated that *“the last 20 feet of tunnel is cut in clinker; Apparently, the sudden contrast in permeability and rapid increase in flow gave the impression that a dike compartment had been tapped.”*

Haʻikū Tunnel – Bowles Report

"View looking towards portal at about 1000-feet in Haʻikū Tunnel showing saturated rock in foreground and dike at STA 9+80" (Bowles, 1969)

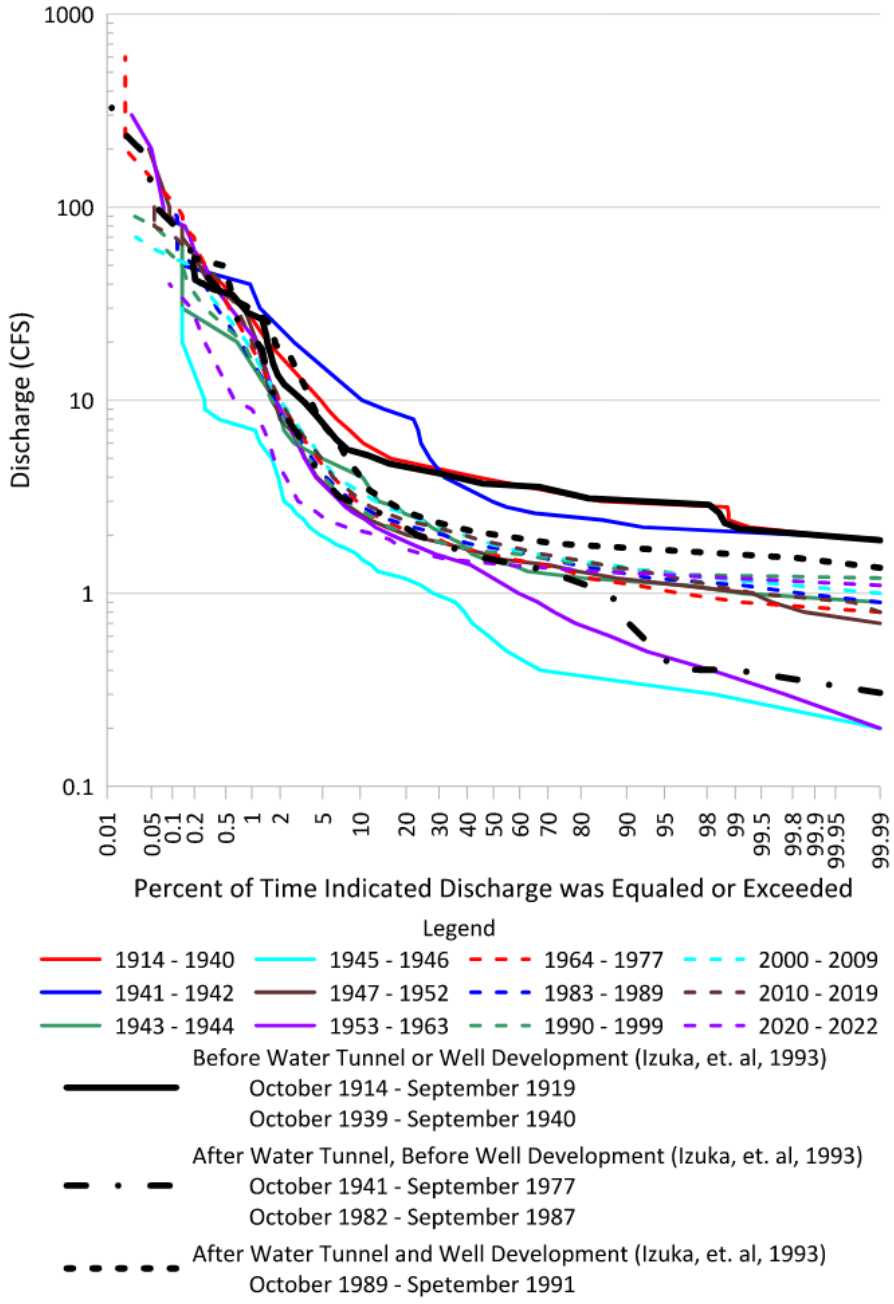
"View of Haʻikū Tunnel heading, majority of discharge is from drill holes in clinker" (Photograph from Bowles, 1969)

Haʻikū Tunnel – Recorded Flow

- 1940: Tunnel shut in: pressure 90 to 95 psi, 11.9 MGD flush flow when opened
- May 2, 1969: After the 1969 inspection, valves at Bulkhead No. 2 were closed and the tunnel was allowed to recharge. Bowles states: “Leakage to the Haʻikū stream was well established at a tunnel pressure of 25 psi or 58 feet of water.”
- Bowles stated “Following construction of the tunnel it was found that at pressures of 20 to 25 psi, Heʻeia Stream would begin to flow in a manner similar to that recorded by the USGS in 1938” (Bowles, 1969). However, stream flow data corresponding to that tunnel pressure at that time was not provided.

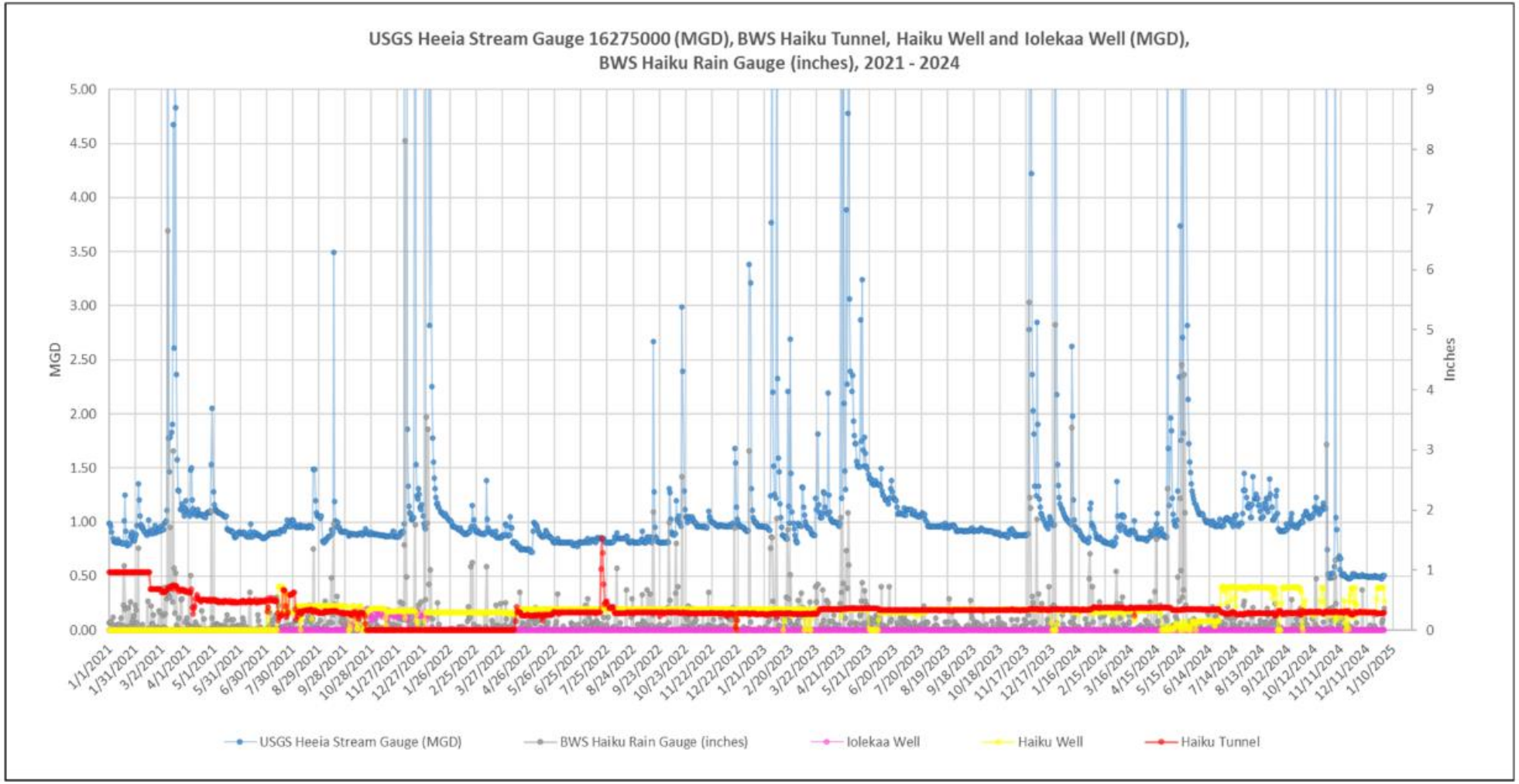
He‘eia Stream – Historical Flow Discharge Curves

- Developed from He‘eia stream flow data - USGS SG 16275000
- Stream flow gradually reduced after tunnel construction from 1941 to 1944
- Between 1945 and 1946 and between 1953 and 1963 significant reduction in stream flow was recorded
  - 1946 Kahalu‘u Valley Tunnel Construction by Honolulu Board of Water Supply
  - 1954 to 1955 Waihee Valley Tunnel Construction by Suburban Water System
- In 1964 stream flows increase and have been relatively steady with fluctuations appearing to follow total rainfall
  - Since 1964, Q90 has generally been between 1.0 MGD and 2.0 MGD



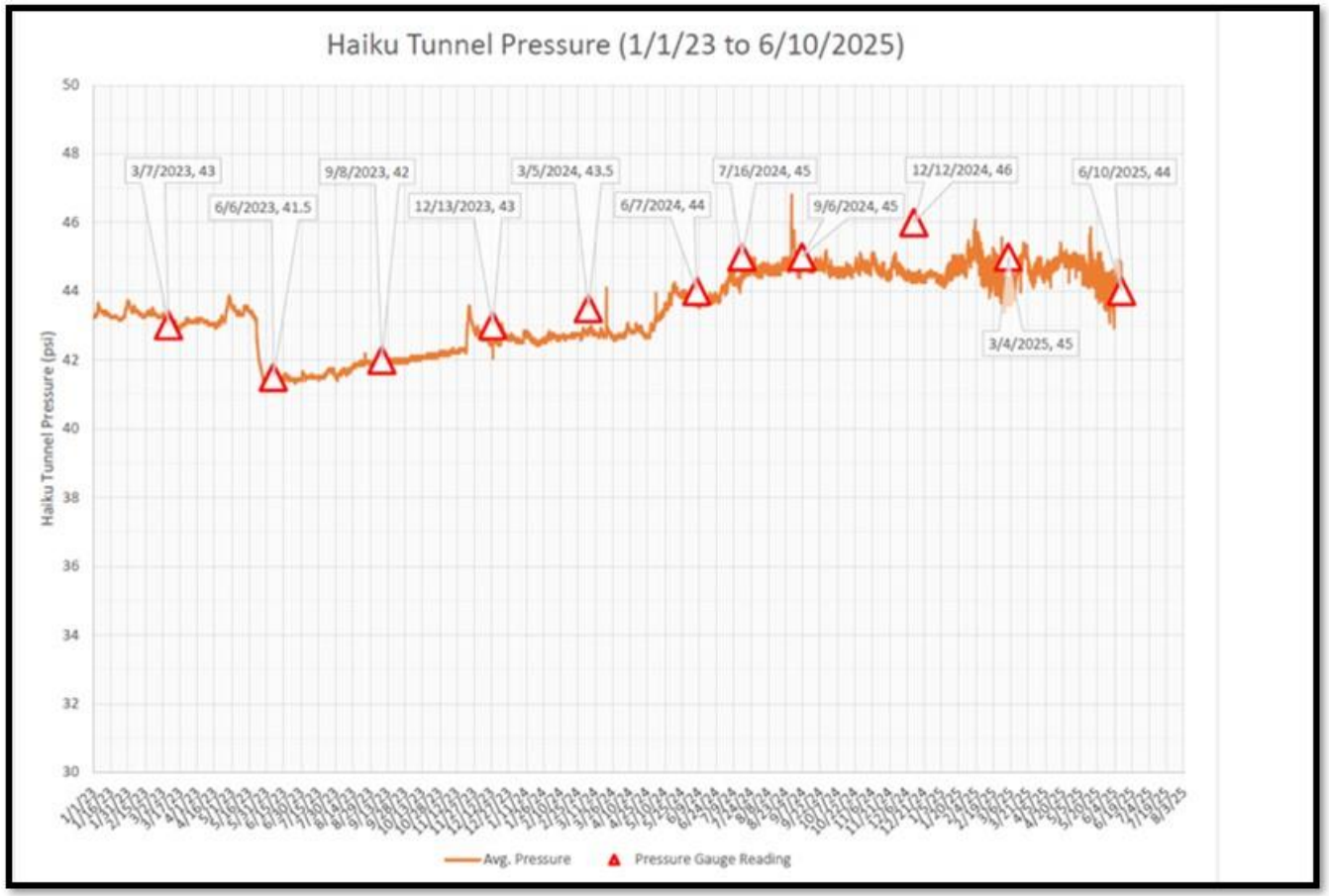
Haʻikū Tunnel vs. Heʻeia Stream Flow

The primary correlation for streamflow changes is associated with rainfall events



Haʻikū Tunnel – Available Pressure Data

- Effects since the water withdrawal from the Haʻikū Tunnel was restarted on April 11, 2022 at approximately 0.3 MGD
- Remained relatively steady at about 43 psi +/- between April 2022 and May 2023
- Began slow increase to 44-46 psi thereafter
- Increasing pressure indicates dike storage is increasing with existing bulkheads. Therefore, continue long-term monitoring



Adjacent Tunnels to Haʻikū

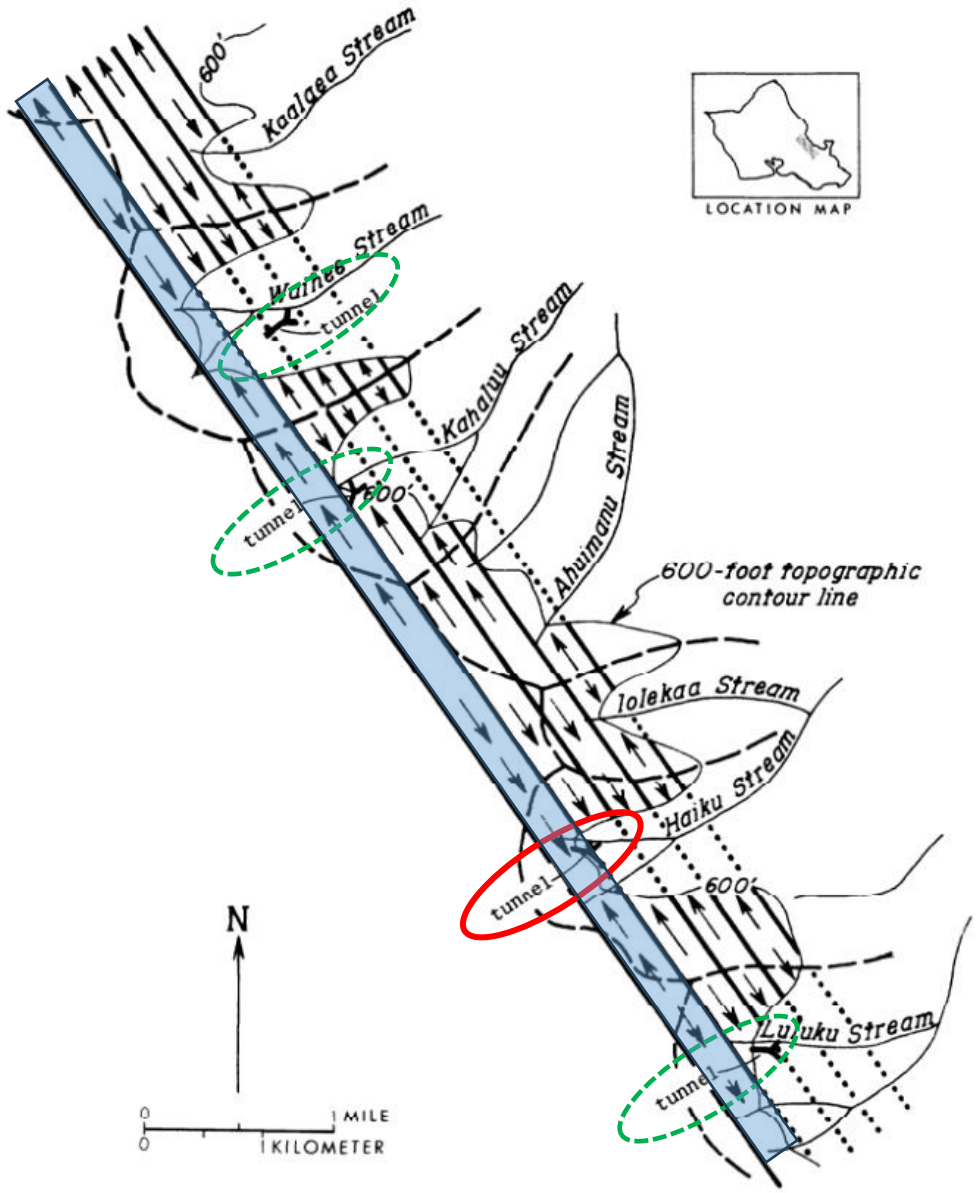


Figure 21. Sketch showing the probable directions of ground-water movement between parallel dikes above an altitude of 600 feet in the area between Luluku and Kaalaea Streams. Solid and dotted lines show the general trend of the dikes. Dashed lines mark the crests of ridges.

Dike-Impounded Water in the Koolau Range 43

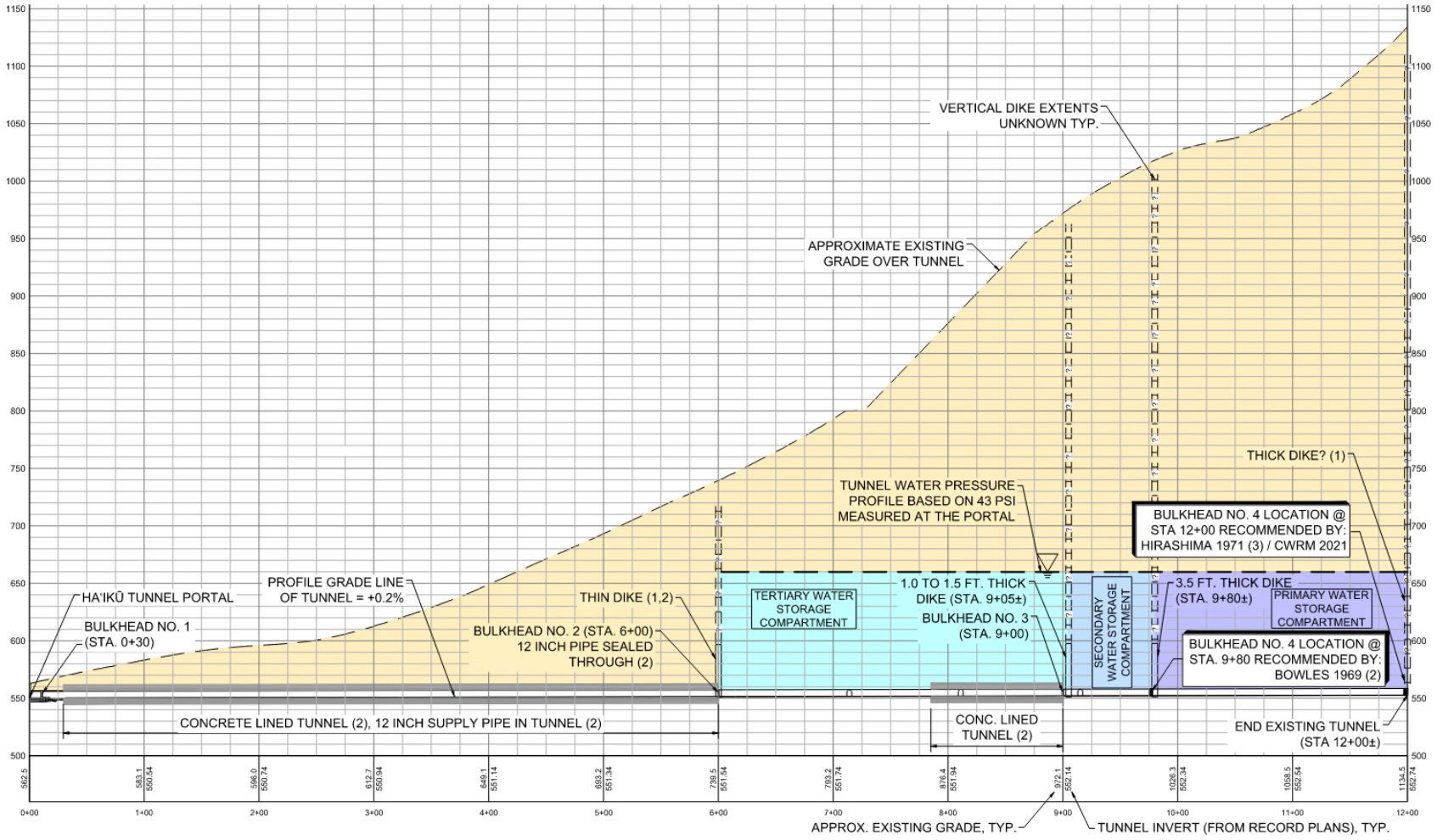
Figure from: USGS WS-2217

Rehabilitation Alternatives Evaluated

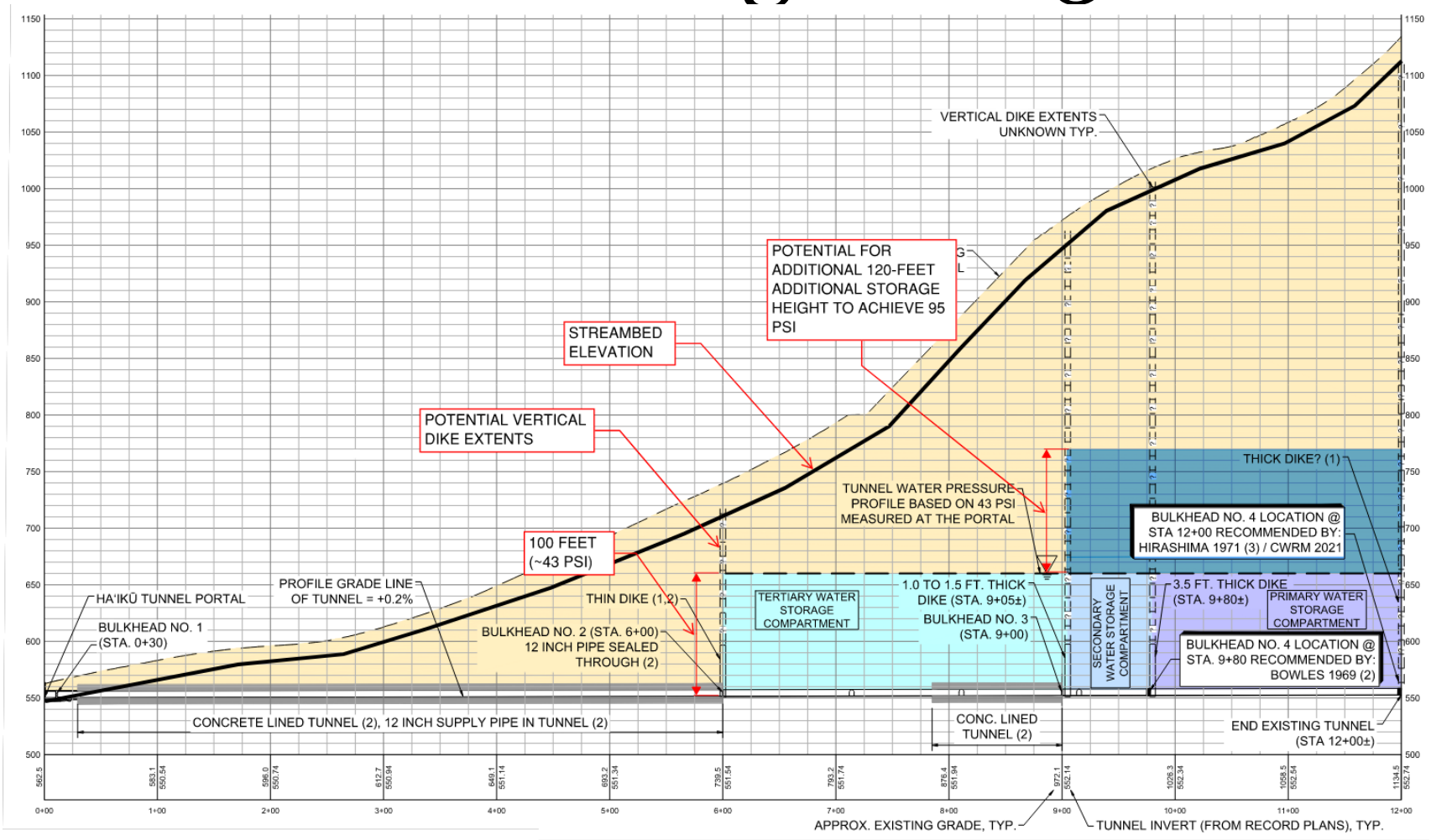
1. Installation of a bulkhead at ~STA 11+78 (CRWM)
2. Installation of a bulkhead at STA 9+80 (Bowles)
3. Installation of pipe from Bulkhead No. 2 through No. 3
4. Construct a new horizontal tunnel
5. No Build/Future Build

Alternatives 1 & 2: New Bulkhead Construction

- The dike at STA 9+80 and the dike at STA 11+78 [if present] have the potential to extend to much higher elevations than the currently bulkheaded dike at STA 6+00



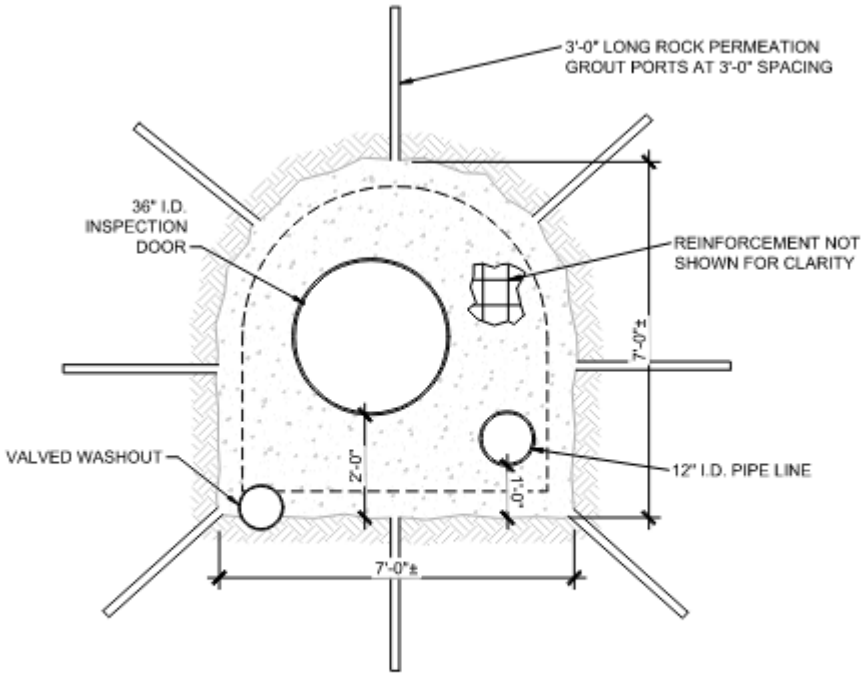
Alternative 3: Installation of Pipe from Bulkhead No. 2 through No. 3



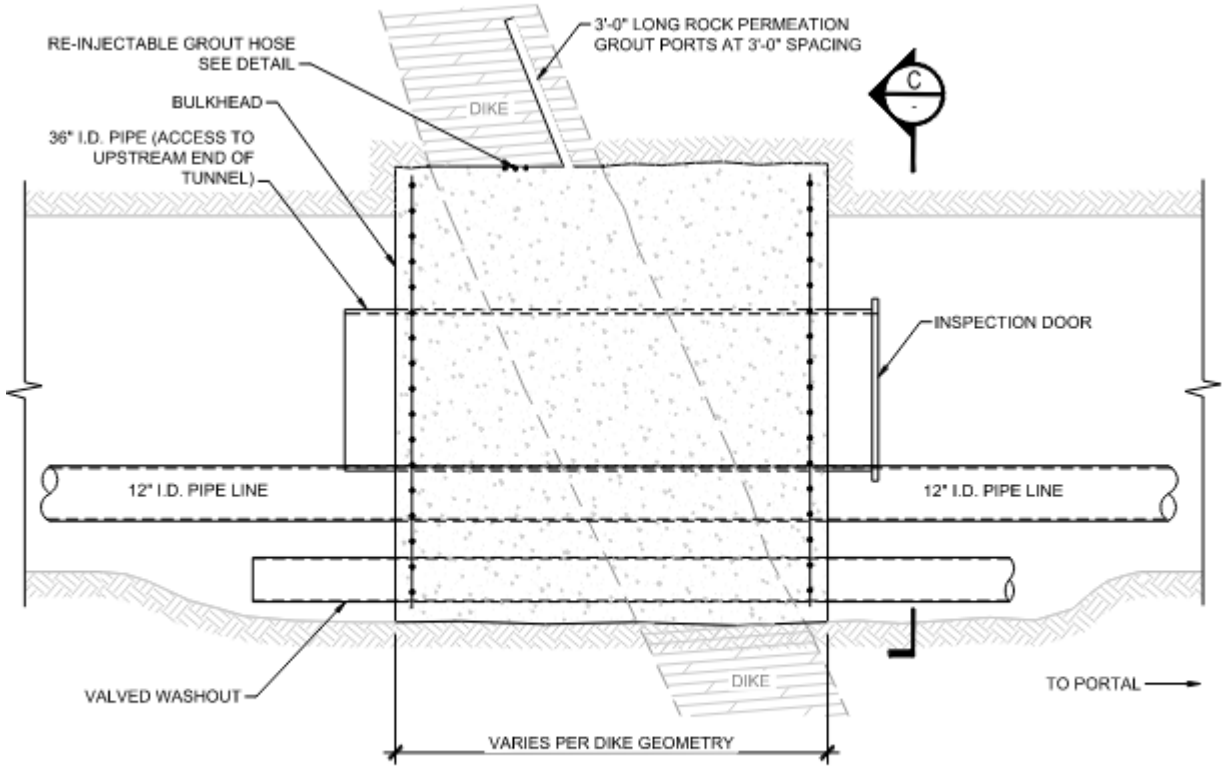
Alternative 4: New Horizontal Tunnel

- New water tunnel ~ 2,200 LF long sized to transmit up to 2.0 MGD
- Portal would be near the existing accessible area near Haʻikū Well and extend to highly permeable clinker bed encountered at the end of the Haʻikū Tunnel
- Horizontal Directional Drilling, MicroTunneling or DirectPipe Technologies
- Understanding ground and groundwater flow conditions, developing site access are challenges
- Alternative:
  - Significantly more expensive than rehabilitation, requires decommissioning of existing.
  - Production yield for a new tunnel is unknown, and risks to dike compartments and any other areas fed by them unknown
  - Reduces contamination risk

Feasibility of 4th Bulkhead (Alternatives 1 and 2)



C -- PROPOSED BULKHEAD No. 4 SECTION
SCALE: NTS



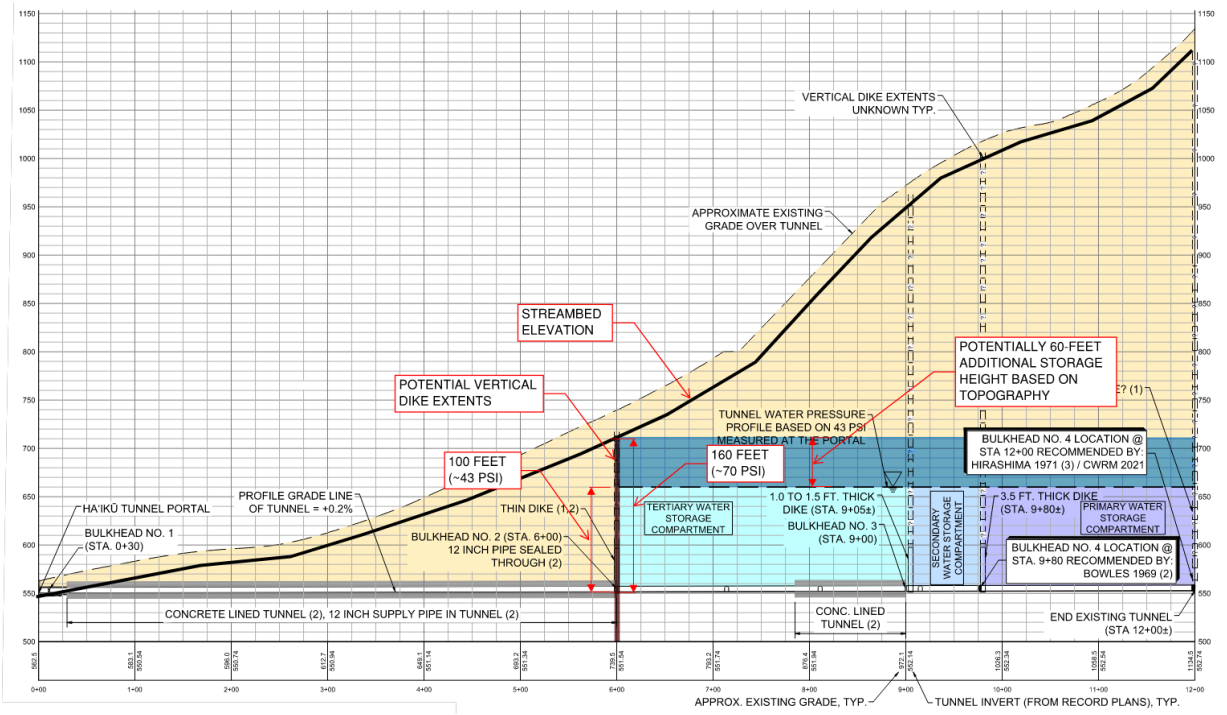
2 -- PROPOSED BULKHEAD No. 4 ELEVATION
SCALE: NTS

Feasibility of Installation of Pipe Between Bulkhead No. 2 and No. 3 (Alternative 3)

- Requires Tunnel Drainage & Assessing Conditions
- Installation of ventilation and power
- Removal of existing piping between portal and BH No. 2
- Bulkhead No. 3 requires modifications for receiving the piping
- The flange at Bulkhead No. 2 may require modification if the groundwater stored in the dike compartment between Bulkhead No. 2 and No. 3 is to be tapped
- Installation of new piping

Construction Risks

- Tunnel Condition and Safety: Current stability unknown
- Tunnel Contamination: Microbiological contamination could cause Safe Drinking Water Act violations
- Groundwater Storage Depletion: As the tunnel freely flows (drains) during construction, storage used by other water sources and supply to streams in other valleys would be affected
- Additional bulkhead effectiveness questionable: Existing bulkheads appear effective and can likely store more water, monitoring will continue to verify



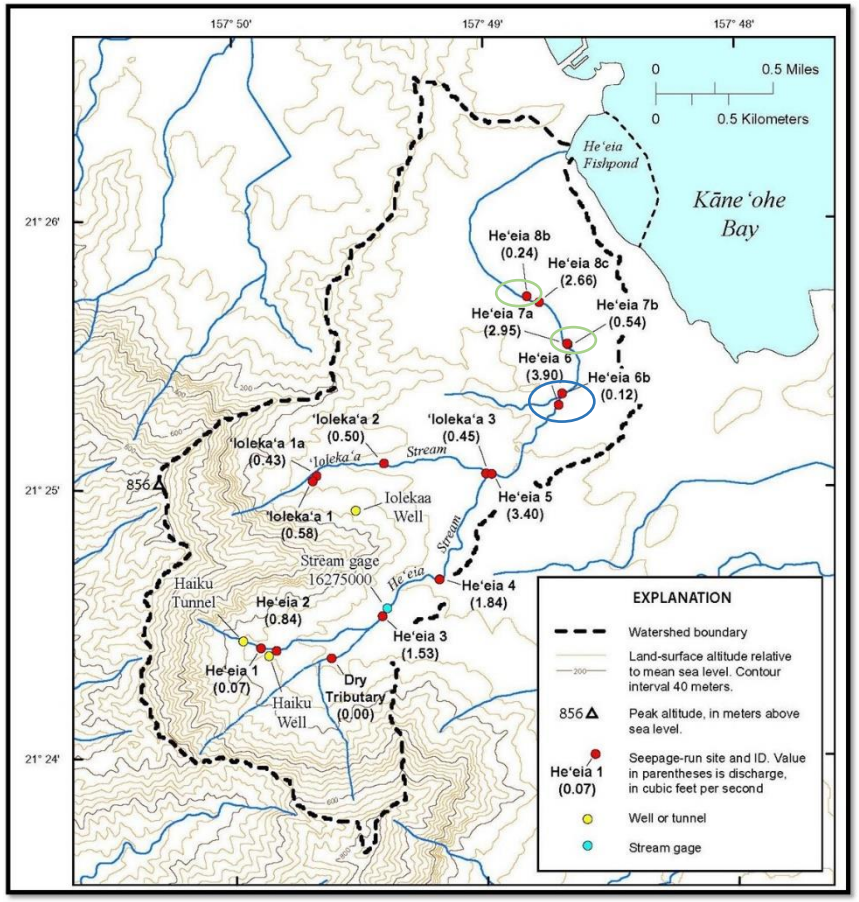
Conclusions and Recommendations

- Dike compartments are interconnected across adjacent valleys.
- Five bulkhead alternatives were evaluated. Installation of 4th bulkhead is not very feasible due to cost and risk of contamination, and is not needed because existing bulkheads are effective and can store more water
- Bulkhead storage is increasing to 46 psi or 106-feet July-Dec 2024 with Haʻikū Tunnel at 0.3 mgd. Records indicate 90 psi could be stored however, dikes levels cannot be restored to pre-tunnel conditions because of adjacent tunnel withdrawals.
- Continue hydrologic monitoring and allow additional time for recharge to restore dike levels, then reevaluate

Conclusions and Recommendations

- BWS Haʻikū 500 system capacity has been impacted. Restricting building permit approvals for State Hospital and WCC until a new replacement source is designed & constructed
- Next steps for CWRM Order:
  - Reduce Haʻikū Tunnel PU from 1.3 mgd to 0.3 mgd and transfer unused Permitted Use to new hospital well and other Koolaupoko sources, or revoke, as warranted
  - Install pipe within Heʻeia wetland to increase efficiency of Heʻeia stream water to auwai before CWRM assesses amendments to IIFS

Improve Auwai Diversions



		9/8/2021	11/15/2021	3/23/2022	8/9/2022
Map_indentifier	Station_name	*Calculated - Discharge MGD*	*Calculated - Discharge MGD*	*Calculated - Discharge MGD*	*Calculated - Discharge MGD*
He'eia 1	Heeia Str 350 ft bl tunnel nr Kaneohe, Oahu, HI	0.01	0.01	0.10	0.05
He'eia 2	Heeia Stream DS of Haiku Tunnel, Oahu, HI	0.54	0.56	0.61	0.54
Dry Tributary	Upper R trib Heeia Str on Haiku Rd, Oahu, HI	ND	0.00	0.00	0.00
He'eia 3	Heeia Stream 150 ft US of gage 16275000, Oahu, HI	0.90	0.84	ND	0.99
He'eia 4	Heeia Str .58mi US Haiku Plantations Dr, Oahu, HI	1.04	1.03	1.26	1.19
He'eia 5	Heeia Stream at Haiku Plantations Dr., Oahu, HI	2.02	1.98	2.79	2.20
He'eia 6	Heeia Stream 770 ft US of Alaloa St., Oahu, HI	2.53	2.27	2.88	2.52
He'eia 6b	Trib to Heeia Str 500 ft US of Alaloa St, Oahu, HI	ND	0.09	0.21	0.08
He'eia 7b	Wing Wo Tai Ditch nr Heeia Str, Oahu, HI	ND	0.59	0.45	0.35
He'eia 7a	Heeia Stream DS of Wing Wo Tai Div., Oahu, HI	ND	1.76	2.49	1.91
He'eia 8c	Heeia St 350 US Hop Tuck Ditch, Oahu, HI	ND	ND	2.57	1.72
He'eia 8b	Hop Tuck Ditch nr Heeia Str, Oahu, HI	ND	0.18	0.34	0.16
'Ioleka'a 1	Upper Iolekaa, US of unnamed div., Oahu, HI	0.28	0.38	0.35	0.37
'Ioleka'a 1a	Iolekaa Stream near Heeia, Oahu, HI	ND	0.28	0.35	0.28
'Ioleka'a 2	Iolekaa Stream US of Heeia conf., Oahu, HI	0.21	0.27	0.30	0.32
'Ioleka'a 3	Iolekaa Stream 55 ft US of Heeia conf., Oahu, HI	0.29	0.30	0.47	0.29

- Average total He‘eia Stream flow below ‘Iolekaa Stream confluence (blue circle) ~ 2.7 MGD
- Average total Wing Wo Tai and Hop Tuck Ditch diversions (green circles) ~ 0.7 MGD
- Remaining He‘eia Stream flow below Wing Wo Tai and Hop Tuck Ditch diversions ~ 2.7 – 0.7 = 2.0 MGD
- I.e., ~ 0.7 / 2.7 = 26% of He‘eia Stream flow below ‘Iolekaa confluence is diverted to stakeholders’ taro fields; remainder goes to “wetland” (not all native vegetation)/ocean

Questions?