



# Red Hill Tank Closure Plan Analysis of Alternatives & Concept Design to Close In Place

## Joint Base Pearl Harbor-Hickam, HI

Contract No. N62742-20-D-0002  
Delivery Order No. N6274222F0453  
eProjects Work Order No. 1744245

20 December 2022  
Analysis and Concept Design



Naval Facilities Engineering Command Pacific  
258 Makalapa Drive, Suite 100  
Joint Base Pearl Harbor-Hickam, Hawaii 96860



**Red Hill Tanks Closure Plan Analysis of Alternatives & Concept Design to Close In-Place,  
Joint Base Pearl Harbor-Hickam, HI**

Project No: D3430609  
Document Title Final Analysis and Concept Design  
Contract No.: N62742-20-D-0002  
Task Order No.: N6274222F0453  
eProjects Work Order No. 1744245  
Revision 2  
Date: 23 November 2022  
Client Name: NAVFAC Pacific

**Jacobs Government Services Company**

777 Main Street  
Fort Worth, Texas 76102  
United States  
T +1.817.735.6000  
F +1.817.735.6148  
www.jacobs.com

**Subconsultant**



Enterprise Engineering, Inc.  
2525 Gambell Street, Suite 200  
Anchorage, AK 99503

© Copyright 2022 Jacobs Engineering Group Inc. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright.

Limitation: This document has been prepared on behalf of, and for the exclusive use of Jacobs' client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party.

**Table of Contents**

- 1. Tank Background and Construction..... 1**
- 2. Evaluation of Alternatives .....5**
  - 2.1. Cost Evaluation .....5
  - 2.2. Schedule Evaluation .....5
  - 2.3. Engineering Feasibility Evaluation .....6
- 3. Closure Alternatives.....7**
  - 3.1. Alternative 1: Closure in Place..... 10
    - 3.1.1. Alternative 1: Cost ..... 12
    - 3.1.2. Alternative 1: Schedule ..... 12
  - 3.2. Alternative 2 Closure in Place and Preparation for Non-Fuel Reuse of Tanks ..... 12
    - 3.2.1. Alternative 2: Cost ..... 14
    - 3.2.2. Alternative 2: Schedule ..... 14
  - 3.3. Alternative 3: Closure with Fill (with inert material) ..... 14
    - 3.3.1. Alternative 3: Cost ..... 17
    - 3.3.2. Alternative 3: Schedule ..... 17
  - 3.4. Alternative 4: Remove Tank Steel Liner, and Fill ..... 17
    - 3.4.1. Alternative 4: Cost ..... 19
    - 3.4.2. Alternative 4: Schedule ..... 19
- 4. Summary of Closure Alternatives..... 20**
- 5. REFERENCES ..... 21**

## 1. Tank Background and Construction.

The Red Hill Bulk Fuel Storage Facility was constructed from December 1940 to September 1943. The facility consists of twenty underground vertical cylindrical concrete fuel storage tanks (Tanks F-1 to F-20) mined into the igneous rock formation. Each tank is 100 feet in diameter and between 238 – 250 feet high and holds approximately 12.5 million gallons of fuel.

The tank structure consists of an upper dome, extension ring, barrel section, and lower dome, with internal steel liner on all surfaces, fuel piping, and tank venting systems. Support facilities and systems include the Upper Access Tunnel, Lower Access Tunnel, and a harbor tunnel that connects the Red Hill Tank Gallery area to the Underground Pump House on Joint Base Pearl Harbor Hickam (JBPHH).

The Upper Access Tunnel provides access to the tank manholes and gauging platforms. The Lower Access Tunnel contains piping and associated infrastructure plus electrical, ventilation, control and fire suppression systems. The Lower Access Tunnel provides access to the tank multi-product common fill/issue piping and valves, tank drain, and sampling piping and valves at the bottom of the tanks. Tunnels are interconnected by two elevators: Elevator 72 is uphill of Tank 15 and Elevator 73 is uphill of Tank 17. Tunnels are accessed by six "adits" (an adit is a horizontal access to a mine).

Access to Red Hill is currently available at the manned guard shack next to Halawa Correctional Facility and through the privatized Army housing area. There are two roads: the guard house entrance is connected to the lower access road and the privatized housing area gate connects to the upper access road.

Each tank has a steel frame tower in the center of the tank extending from the floor of the lower dome to the top of the upper dome with a walkway from the manhole at the Upper Access Tunnel level (approximately 190 feet above the floor) to the tower. The center tower was used during original construction of each tank, and it remains in each tank to provide access to the tank lower dome floor via elevator. Over the years, the center towers have been retrofitted with booms and hoists with man-baskets for tank maintenance and repair. Booms are removed from tanks after repairs and not left in place.

Tanks 1 to 4 are 100-foot diameter, 238-feet 6-inches overall height, and have a container volume of approximately 12 million gallons each. Tanks 5 to 20 are 100-foot diameter, 250-feet 6-inches overall height, and have a container volume of approximately 12.7 million gallons each.

The container volume represents maximum volume. Per Navy policy, working storage volumes are less than maximum volumes to reduce risk of a release. The tops of the tanks (top of the upper dome) vary from 110 feet to 178 feet below ground. The bottoms of the tanks range in elevation from 123 feet to 151 feet above sea level. The tanks are arranged in two rows of 10 tanks, spaced 200 feet on center. Approximately 100 feet of lava rock separates the tanks from each other.

The tank construction sequence started with Tanks 1 and 2, and each crew moved to the next construction area, ending with Tanks 19 and 20. The tanks were constructed by excavating the lava rock formation of Red Hill to create a cavity for each tank, which was then lined with gunite, reinforced concrete, and a 1/4-inch-thick steel liner before pressurized injection of grout to fill voids and to "lock" the tanks into the mountain and reduce risk of damage from seismic events. A shaft from the ground surface, down to the elevation of the lower access gallery, was first excavated to serve as the excavation spoil shaft to conveyors in the Lower Access Tunnel. The upper dome was constructed next. The lava rock was excavated to create a cavity for the upper dome. The diameter of the upper dome excavation is larger than that of the tank barrel, allowing for it to be constructed on the existing rock. Steel framing and liner plates were then installed, followed by filling the cavity between the liner plates and lava rock with reinforced concrete up to 4 feet thick. This provided a structural dome permitting safe excavation of the tank below the dome and its overburden of 110 to 178 feet of vertical rock.

After the upper dome was constructed, the barrel was excavated to approximately the elevation of the Lower Access Tunnel floor. The rock face was lined with 6 inches of gunite (i.e., spray-applied concrete, a dry-mix form of shotcrete) to seal the rock face. In some locations additional grouting into the lava was required to fill voids. The lower dome was constructed next, including all tank piping between the tank cavity and lower access tunnel. The lower dome was then poured as a plug to approximately the elevation of the tank floor. A steel structure was fabricated, and concrete filled behind the plates, in lifts up to the spring line of the dome, 50 feet above the dome floor. The floor of the lower dome (20-foot diameter) is flat and consists of 1/2-inch-thick steel plates that serve as the foundation for the tower.

The barrel was constructed of reinforced concrete (2 feet-6 inches thick minimum at the top, 4 feet thick minimum at the bottom). The steel liner plates on the barrel are arranged in 5 foot tall horizontal courses that served as forms for placing concrete. Horizontal steel angles were welded to the backside of the steel plates at the top and bottom of the plates. All horizontal and vertical joints in the steel liner are butt welded plates. Reinforcing steel for concrete was then placed in the forms. The horizontal angles were then anchored to the reinforcing steel with 3/4-inch diameter anchor rods. Concrete was placed in the forms in 5 foot lifts. The barrel section was then pre-stressed by injecting grout between the reinforced concrete and gunite layer, thus compressing the barrel. Grout was injected via tubes that penetrated the steel liner and extended through the concrete to the gunite layer. Grouting pressure was monitored with strain gauges in strain gauge tubes in the barrel. The strain gauge tubes penetrate the steel liner and extend through the concrete and gunite into the lava rock. Grout tube and strain gauge tube penetrations in the steel liner were sealed with plates welded over the penetrations.

The tanks are currently vented (for fill and issue air displacement) at several locations throughout the Upper Access Tunnel areas that extend to above the surface at Tanks 2, 3 and 19, and an additional vent outside Adit 5. Various tanks vent to different locations. Most of the vent piping from the tanks is set in concrete below the floor in the upper tank gallery and has very little access for inspection or repair.

A separate fresh air ventilation system was installed to make tunnels suitable for workers. Inlet and outlet shafts were installed above Elevator 73, downhill from Tank 20 and above Adit 3. Other fresh air inlets and outlets can be found at Adit 6 and Adit 2. Ventilation fans are located at Adit 3.

Major features of a Red Hill Tank construction are shown in the following graphics:

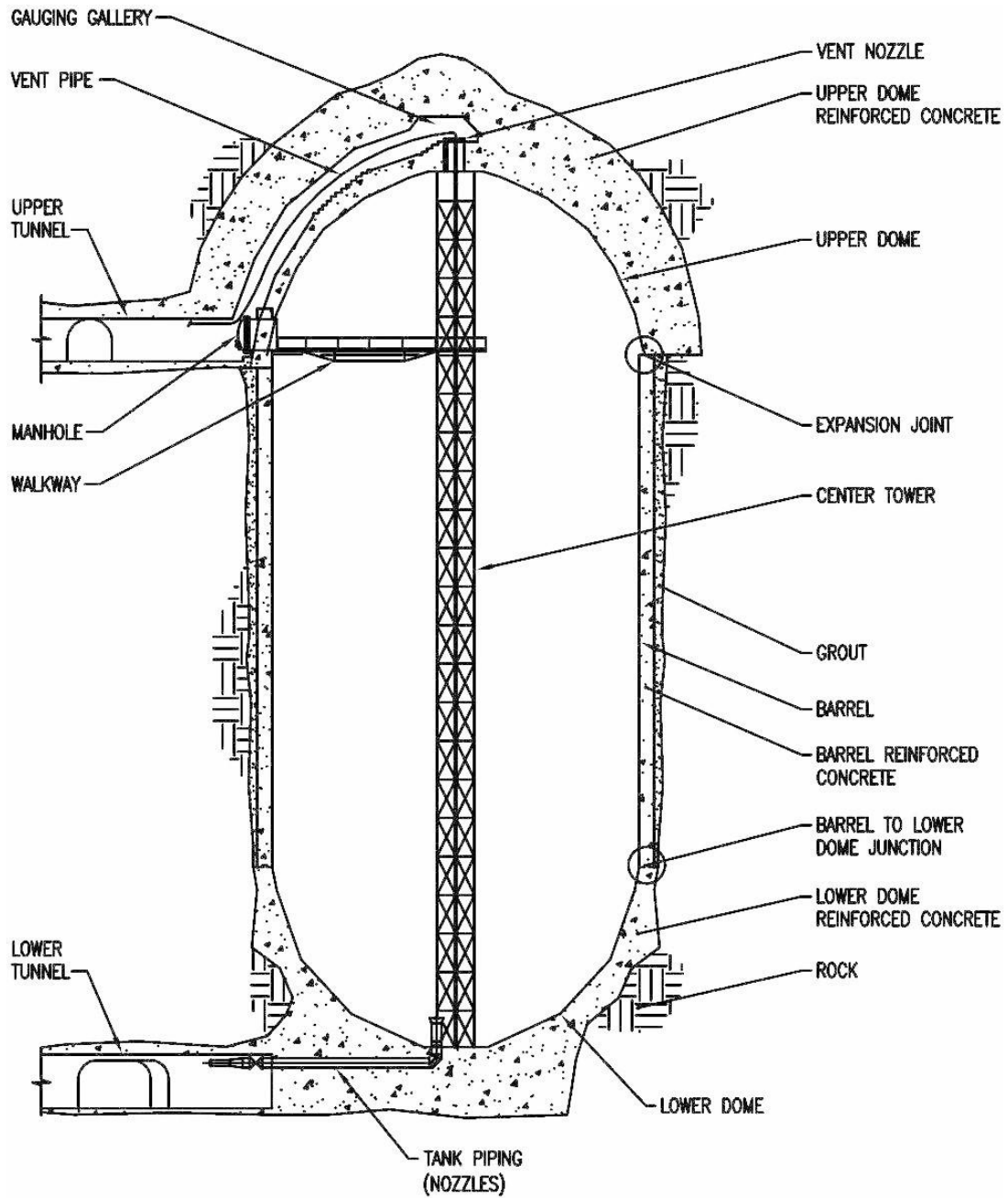


Figure 1: Existing Tanks 1-4 Elevation

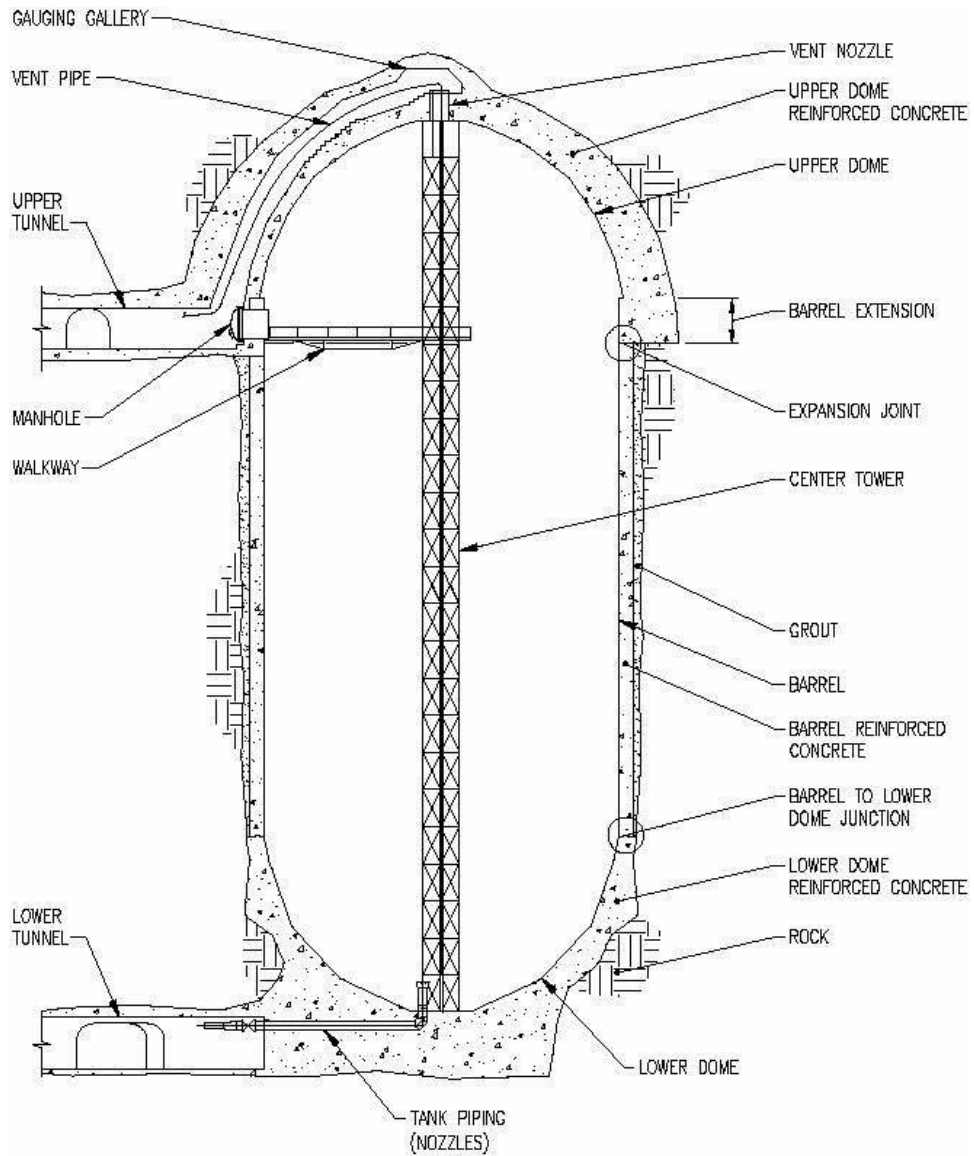


Figure 2: Existing Tanks 5-20 Elevation

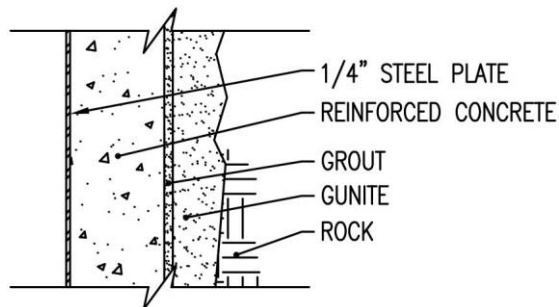


Figure 3: Existing Barrel Configuration

The four surge tanks are underground, reinforced concrete fuel storage tanks with an internal steel lining. The tanks were constructed circa 1942. Each tank is approximately 60 feet in diameter and 20 feet high. The internal steel lining is of welded construction with lap-welded and butt-welded shell plates and lap-welded floor plates. There is no floating pan. The nominal shell capacity is 10,000 barrels (420,000 gallons).

## 2. Evaluation of Alternatives

In accordance with Directive 8 of the Hawaii Department of Health (DOH) May 6, 2022, superseding Emergency Order (EO) requiring the Navy to develop the Closure Phase of the Closure Plan for the Red Hill Bulk Fuel Storage Facility (RHBFSF), and in response to DOH direction during the July 14, 2022, Meet and Confer session between DOH and Navy, this report analyzes four tank closure alternatives for the RHBFSF. Each alternative was evaluated for engineering feasibility (including worker safety and impacts to the environment and surrounding community), schedule, cost, and potential for beneficial non-fuel reuse. In addition, this report includes a summary table listing the pros and cons of each alternative. All four closure alternatives will render the tanks incapable of being used for fuel storage and will effectively eliminate any future possibility of the tanks containing fuel. Above all, **the tanks will never be used again for storage of fuel or hazardous chemicals.**

Closure alternatives were evaluated in terms of the adherence to Hawaii Administrative Rules (HAR) 11-280.1-71(c), which provides requirements for permanent closure of an underground storage tank (UST) or tank system. This HAR section states that to permanently close a UST or tank system, owners must "Remove the UST or tank system from the ground, fill the UST or tank system with an inert solid material, or close the tank in place in a manner approved by the department." However, these rules were not implemented with a facility as large as Red Hill in mind and are generally used to close USTs the size of a typical gas station (10,000 to 20,000 gallon tanks).

### 2.1. Cost Evaluation

The cost evaluation is based on notional, planning-level, rough order of magnitude (ROM) estimates for the cost to accomplish closure of the 20 USTs, four surge tanks, and associated piping and infrastructure. ROM cost estimates are to be used only for consideration and comparison of the relative magnitude of alternative effort, and are not intended for purposes of planning, programming, budgeting, and execution, or establishment of milestone schedules for the work to be performed. ROM cost estimates are estimated construction costs in today's dollars, and do not include all programmatic costs for accomplishing each alternative, including project planning, design, procurement of design and construction contracts, construction and demolition oversight, design and construction contract administration, contract incentives, project contingencies, or potential future escalation of labor and materials costs.

### 2.2. Schedule Evaluation

The schedule evaluation is based on notional, planning-level, ROM estimates for the execution time to accomplish closure of the 20 USTs, four surge tanks, and associated piping and infrastructure. Schedule ROM estimates do not include design development of closure alternatives. Schedule durations are to be used only for consideration and comparison of the relative magnitude of alternative effort, and are not intended for purposes of planning, programming, budgeting, and execution, or establishment of milestone schedules for the work to be performed. The ROM schedules are not intended to be used to lock expectations for dates of closure completion, from the date of alternative selection. ROM schedules are only estimated construction schedules from construction start to finish, and do not include front end processes for accomplishing the alternative, including project planning, historic preservation consultations, programming of funding, design, or procurement of design or construction contracts.



### **2.3. Engineering Feasibility Evaluation**

Engineering feasibility, also referred to in this report as constructability, considers using practicable construction means and methods, recognizing the difficulty in utilizing the Upper and Lower Access Tunnels for material supply or removal within the present constraints of the tunnels. In general, the construction efforts related to closure will focus on the 20 USTs, the four surge tanks, and associated piping. For all four alternatives, it is expected that the tunnels and other infrastructure will be left intact or partially intact, in order to maintain access to existing groundwater monitoring points, which are currently sampled monthly. For this purpose, electrical lighting, communication, water, power, ventilation, tunnel drainage, and ordinary fire sprinkler systems must be maintained in the tunnels.

This evaluation factor also considered worker safety and impacts to the environment and surrounding community. The Red Hill USTs are over 200 feet tall and located deep underground, with limited access through two long and narrow tunnels. Removal of the tank steel liners would create safety issues associated with lifting workers and equipment to great heights within the tanks, unbreathable fumes emitted during steel cutting, and stability of the tanks during demolition. Removal of the surrounding concrete would create additional safety concerns, including potential destabilization of the rock face and overburden, risk of catastrophic failure, and loss of life during construction.

As described below, alternatives 3 and 4 would require transport of enormous amounts of fill material, and this effort would negatively impact the environment and surrounding community due to the high volume of trucks and other heavy construction traffic for an estimated five years. Access to the top of Red Hill is currently constrained by limited roadways and steep grades, such that road improvements would be needed, including widening of the roads, roadway base improvements, and possible re-routing of the roads. In addition, the area above the tanks would be affected by clearing, grading, and site improvements to accommodate stockpiles of fill and heavy equipment for handling the material. All of these efforts would create noise, dust, vehicular exhaust, and heavy traffic for prolonged periods of time.

### 3. Closure Alternatives

Closure of underground storage tanks is typically conducted according to American Petroleum Institute (API) Recommended Practice 1604, "Closure of Underground Petroleum Storage Tanks," as supplemented or amended. The API recommended practices specifically address underground petroleum storage tank systems at service station facilities, though the principles outlined may be applied to similar systems at other petroleum storage facilities. However, for the large bulk-storage mined and field-erected tanks at Red Hill, there is no direct precedence or regulation that provides guidance.

In accordance with the HAR, the following alternatives (ALT) were considered for permanent tank closure at Red Hill:

ALT 1: Closure in Place

ALT 2: Closure in Place and Preparation for Non-Fuel Reuse of Tanks

ALT 3: Closure with Fill (with inert material)

ALT 4: Remove Tank Steel Liner, and Fill (with inert material)

The alternatives are conceptual in nature. The analysis of each alternative is based on an original construction report (Contractors Pacific Naval Air Bases), the repair and maintenance history of the Red Hills tanks, plus information on current tank inspection and repair methodology including Tank Inspection Repair and Maintenance (TIRM) Report (October 11, 2016). Thus, this evaluation identifies some of the many challenges and potential unanticipated consequences of each alternative. There are also minor construction differences and repair histories for each of the tanks, which will necessitate further refinement of an individual tank's specific requirements. The alternative discussions do not attempt to highlight these differences, except for points critical to understanding the overall issues.

The alternatives discussions include issues that will affect ongoing tunnel use or maintenance of the utilities. In addition, consideration is given to post-closure monitoring of any water that may infiltrate the tanks.

General overarching considerations:

1. **Base and internal Red Hill access:** Past Red Hill tank repair projects have been subject to extensive security requirements and facility access restrictions, to the point that a labor force is difficult to obtain and maintain. Once the fuel is removed from Red Hill, the Navy needs to determine if any significant restrictions will remain.
2. **Beginning of closure activities:** The alternative analysis assumes that the closure process begins after the tanks have been emptied of recoverable fuel, leaving only the "tank bottoms," which may include some amount of residual fuel, waste, sludge, and water. As part of the tank closure process, the Navy will characterize, remove, and dispose of the tank bottoms in accordance with federal, state and local regulations.
3. **Surge Tanks:** The surge tanks are relatively small compared to the 20 large USTs (the volume of one surge tank is approximately three percent of the volume of a single Red Hill UST). Due to their small size, the surge tanks have no potential non-fuel reuse, and they can be filled with inert material without causing significant impact to the environment or surrounding community. Therefore, regardless of the alternative chosen for the 20 large USTs, this report recommends closing the surge tanks by filling with structural concrete.

4. **Gallery and Harbor Tunnel Piping:** Approximately 5% of the piping between the surge tanks and the Red Hill tank farm may contain asbestos. In addition, the coatings of the pipes and approximately 750 pipe supports are known to contain levels of lead. For the purpose of this analysis of alternatives, it is assumed that the piping will be closed in place rather than removed.
5. **Tank Ventilation and Cleaning:** Prior to cleaning, each tank will be ventilated to make it safe for worker occupancy. The interior of each tank will be cleaned by application of an environmentally acceptable cleaning solution, typically done with a power washer, followed by rinsing with fresh water. The cleaning solution and fresh water rinsate shall be collected into Department of Transportation (DOT) approved containers, characterized, marked and labeled, accumulated and disposed of at an appropriate waste management facility in accordance with Federal, State and Local requirements and regulations. Depending on the conditions inside each tank, the cleaning processes will vary, which may affect the overall implementation schedule of the alternatives. For example, some tanks may have sufficient cleaning performed from the center tower "basket," while others may need tower booms installed to allow for more rigorous cleaning. Some level of repair may be needed to the towers and catwalks to provide safe access. For each alternative, these preparation and cleaning costs are included in Appendix A.
6. **Execution strategy - scheduling and sequencing of tanks for defueling or construction:** The scheduling of each alternative depends on the defueling schedules, and for the purpose of this analysis, it is assumed that no closure actions will occur concurrent with defueling.
7. **Utilities (power and water):** Availability of power, water, and other sanitary facilities for construction activities at Red Hill has been an ongoing issue. The alternatives consider the power and utility requirements. It is expected that the closure contractor will have to install temporary utilities not tied to Navy systems. The costs for temporary utilities have been included in the cost estimate (Appendix A) for each of the alternatives.
8. **Laydown/storage areas:** There are limited parking, laydown and storage areas within the Red Hill facility. Work on top of the hill may require additional site work to allow for laydown areas.
9. **Site access:** Site access to Red Hill is either via Halawa gate or through a residential neighborhood. Depending on the needs for site access, road improvements at the site may be required. Access to the top of Red Hill is further constrained by limited access ways and steep grades. Costs for road improvements have been included in the alternatives that require significant heavy vehicle traffic (Alternatives 3 and 4).
10. **Tank venting versus tunnel ventilation:** Tank venting is specific to the tank in-breathing and out-breathing during filling and draining. Tunnel ventilation is a separate system that provides fresh air to allow for human occupancy. Care and attention should be given to differentiate between the two separate systems when considering construction features. The condition of the current tank venting system is unknown, and this unknown condition adds an element of uncertainty to this analysis of alternatives.
11. **Continued use and maintenance of tunnels:** Each of the alternatives has various considerations with respect to ongoing use of the tunnels and tunnel maintenance. Routine, long term use of the tunnels will be required following all closure alternatives, so there will need to be maintenance of the electrical service, tunnel ventilation, fire protection systems, and systems for collection, processing, and disposal of water that may enter the tanks or tunnels.

12. **Future environmental considerations:** There are existing groundwater monitoring access points in the Lower Access Tunnel. Currently these wells are sampled monthly. Access to these monitoring wells must be maintained.
13. **General versus tank specific solutions:** Each of the alternative discussions is general in nature and applies to most of the tanks. There are some minor tank-specific design features that may require slight modifications to the alternatives.
14. **Current Tank 18 conditions:** Tank 18 was recently in the process of a Clean, Inspect, and Repair (CIR) procedure, but the work was stopped due to the Red Hill tank closure initiative. During this CIR process, the original tell-tale leak detection system was removed, leaving over 750 two-inch diameter openings in the steel liner from the top to the bottom of the tank, thereby exposing the concrete substrate. During tank closure, these openings will need to be welded shut, as would have occurred during completion of the CIR process.
15. **Tunnel access limitations:** Any construction work at Red Hill will encounter physical access limitations that may become an integral part of the construction process, including the following:
  - a. There are few access points to the upper and lower tank galleries
  - b. The size of load movement in the tunnels is restricted by physical size of the tunnels or other utilities and piping
  - c. The lower tank gallery and tunnels have bulkheads that further restrict movement
16. **Fire Protection:** There is currently an Aqueous Film Forming Foam (AFFF) system within the lower access tunnel. The AFFF system will be addressed in accordance with the requirements of the National Defense Authorization Act (NDAA) for Fiscal Year 2020 applicable to Department of Defense facilities. Once all fuel has been removed from the facility, the Navy will remove the AFFF as directed in the NDAA, and subsequently evaluate the water fire suppression system in context of the future beneficial non-fuel reuse of the facility. Therefore, the AFFF system is not included in this analysis of alternatives.
17. For Alternative 4, removal of the tank steel liner would likely meet DOH requirements for permanent tank closure. However, DOH may consider the surrounding concrete to be part of the tank, such that removal of the concrete, gunite, and grout would also be required for tank closure. These additional removals are not recommended for the following reasons:
  - a. The original construction of each tank followed a very set process where the upper dome was first constructed, followed by the excavation of the rock below the upper dome. The reinforced concrete upper dome, spanning the 100 foot diameter tank, is a required structural feature, and its removal would potentially destabilize the overburden.
  - b. Safely removing concrete overhead, with a 250 foot cavity below, is not a simple task, and the entire process would depend on safely protecting the center tower from damage during the process. Also, the center tower depends on the upper dome connection for stability, and removing the dome takes away this feature.
  - c. Concrete and grout are likely tightly adhered to the rock strata, and removal may require blasting, with attendant unforeseen consequences. Given the large voids associated with each tank, blasting would potentially destabilize the rock face and surrounding structures.
  - d. Regardless of the removal method, there are extreme safety concerns associated with the removal of the concrete, gunite, and grout, with a risk of catastrophic failure due to

destabilization of the substrate. The consequences could be high, especially since the Red Hill facility is adjacent to a residential neighborhood.

- e. Overall, there would be a high risk for catastrophic events and loss of life during construction.

### 3.1. Alternative 1: Closure in Place

Closure in Place implies a tank is eliminated from service, left in the ground, and not filled with inert material. The purpose of Closure in Place is to eliminate the tank from being used for fuel purposes. The Closure in Place alternative will involve tank ventilation to allow workers to enter and clean the inner walls of the tanks. The tanks will then be isolated from the tank vent system, the piping system in the lower access tunnel, and the tank openings in upper access tunnel and gauger's gallery. Unneeded electrical systems will be disconnected. Access tunnels will remain in place to provide water drainage and to provide electrical lighting, communication, water, power, ordinary fire sprinkler systems, and access to existing groundwater monitoring points, which are currently sampled monthly. No fill will be introduced into the 20 large tanks and pipes. Vents will be left in place and capped. Closure in Place will commence after tank defueling is complete.

This analysis includes a general assessment of the structural integrity of the access platform, center tower, and booms for holding equipment and workers. Appendix A includes estimated costs for structural repairs, expected based on past CIR efforts, that would provide for structural integrity and worker safety.

The following items must be addressed for Closure in Place:

1. **Venting:** The tanks have venting to the outside, with combined ductwork to the outside vent. Each tank's vent must be isolated from the system and used during the tank closing process. At the conclusion of work, the vent should be closed off to the outside. As part of future maintenance, some degree of ventilation may be required to prevent any condensation or organic growth from occurring inside the tanks. This issue will be evaluated in a separate document addressing the long term structural integrity of the tanks.
2. **Secured access:** The tank center structure tower and platform to the access manhole at the 190-foot level must be secured to prevent unauthorized access or use.
3. **Water accumulation:** Given the properties of water and the nature of its movement underground, it is expected that water and/or condensation will eventually intrude into the tank cavities. This liquid should be monitored and removed periodically from the bottom of each tank. Some tanks do not have gravity drains at the very bottom of the tanks, so new drains may have to be installed through existing tank nozzles, which will require slight modifications inside the tanks and minor piping changes on the exterior of the tanks. Costs for these activities are included in Appendix A.
4. **Electrical disconnect:** Disconnect the tank electrical connections (primarily gauging and level alarms). The existing gauging provisions, including nozzles and gauge tubes, can be left in place since the structural stability of these items is not a concern to the overall integrity of the concrete tank and liner.
5. **Access Tunnels:** Lower and Upper Access Tunnel access to the tanks would be required. The electrical lighting, communication, water, sewer, electrical power, ordinary fire sprinkler systems, fresh air tunnel ventilation systems, and tunnel dewatering systems would have to remain in place and be maintained. The cost for these future maintenance activities is not included in this report.
6. **Ongoing evaluations for structural integrity:** Some level of ongoing inspections will be required to ensure the long term integrity of the tank structure and steel liner. A cursory visual examination of the

tanks should be performed every 2 years from the catwalk and from the piping in the lower tunnel. Based on current CIR schedules, a structural assessment should be performed every 20 years. The 20-year assessment would need to include extensive hands-on efforts requiring the use of the booms and baskets. The 2 year and 20 year intervals may need to be adjusted in the future, depending on the results of the inspections. These future inspection costs are not included in the current cost estimate.

If closed permanently as described above, the tanks are not expected to deteriorate in the next 50-100 years. This conclusion is based on observations of the current condition of the tank steel linings and structural assessments of the visible anchors in the tank. While the tanks have generally contained fuel over the years, Tanks F-1 and F-19 have been empty for the past 25 years and have shown no signs of structural deterioration during that time. In addition, during normal operations the tanks are never filled to the top of the upper dome, so portions of the upper dome of all tanks have been exposed to air/vapor mixtures for the past 80 years. These exposed areas do not currently demonstrate corrosion or deterioration, again suggesting long term stability of the tank steel liners, even for empty tanks. These issues will be evaluated further in a separate document addressing the long term structural integrity of the tanks.

The Closure In-Place alternative will require coordination of a venting system and development of a plan for isolation of each tank or specific quantity of tanks that will enable safe and efficient work activities. In addition, the Navy must develop a system to monitor potential water infiltration into the tanks and determine how the water will be removed. The removal of the water in the tanks is required to prevent mold growth and corrosion, which would negatively impact the non-fuel reuse of the tanks.

Alternative 1 would require ongoing site access and continued maintenance of roads, tunnels, ventilation systems, water-based fire protection system, electrical service, and systems for collection, processing, and disposal of water that may enter the tanks or tunnels.

Alternative 1 will support the beneficial non-fuel reuse of the tanks; however, the future reuse has yet to be determined, so the estimated cost (Appendix A) and schedule do not include any activities related to non-fuel reuse. Regardless of any future reuse, the tanks will never be used again for storage of fuel or hazardous chemicals under this closure in place alternative. This prohibition is ensured by the regulatory UST closure and regulatory approval process.

Table 1 lists the pros and cons of ALT 1.

Table 1: Pros and Cons for ALT 1: Closure in Place

Pros	Cons
<ul style="list-style-type: none"> <li>• Supports beneficial non-fuel reuse of the tanks, with potential for local economic benefits.</li> <li>• Provides a hardened and secure site for non-fuel reuse.</li> <li>• Tank closure tasks are well defined, with minimal uncertainty.</li> <li>• The estimated schedule is significantly shorter than any other alternative.</li> <li>• Materials are readily available to complete this alternative.</li> <li>• The need for major efforts and logistics on top of Red Hill are minimized or eliminated.</li> <li>• Least costly alternative.</li> </ul>	<ul style="list-style-type: none"> <li>• Would require ongoing maintenance of systems for tunnel ventilation, fire protection, electrical, tunnel dewatering and water collection from the tanks.</li> <li>• Would require ongoing site access and maintenance of roads.</li> <li>• Would require an internal assessment of the tanks' structural integrity over time.</li> </ul>

**3.1.1. Alternative 1: Cost**

- The ROM estimated cost of alternative ALT 1: Closure In-Place is \$119,000,000. See Appendix A for details.

**3.1.2. Alternative 1: Schedule**

- The ROM schedule for alternative ALT 1: Closure in Place is approximately 3 years from the start of construction to completion.

**3.2. Alternative 2 Closure in Place and Preparation for Non-Fuel Reuse of Tanks**

Alternative 2 includes all the Closure In-Place activities performed in Alternative 1. In addition, Alternative 2 includes a minimal level of advanced preparation for a beneficial non-fuel reuse of the tanks. Because the non-fuel reuse has not yet been determined, the scope of Alternative 2 is based on the assumption that the tanks will be used to store products other than fuel. Thus, Alternative 2 involves the installation of a protective coating over 100% of the tank internal surfaces and nozzles. The coating would meet industry criteria for the storage of other products besides fuel. If a different reuse is ultimately selected, the coating proposed under this alternative may not be needed. As a result, there is significant uncertainty in the schedule and level of effort for this alternative.

Depending on the ultimate non-fuel reuse of the tanks, some or all of the items below may need to be addressed. Because the reuse option has not yet been determined, these items are provided for future information only and are not currently included in the cost estimate (Appendix A) for Alternative 2: Closure in Place for Potential Non-Fuel Reuse.

1. **Life Safety:** If the reuse is for purposes that would involve personnel physically accessing the tank container, a rigorous "Life Safety" code analysis, perhaps similar to assessing guidelines on mining

activities, would be required. Access, egress, and ventilation are not trivial matters in an underground complex such as Red Hill. The analysis would take into consideration whether the activity would be for mostly unoccupied use, such as document storage, or occupied use, with daily personnel access. Such a life safety assessment is beyond the current initiative.

2. **Tank Venting:** The tanks have atmospheric venting to the outside (needed for tank filling and withdrawal), with combined ductwork to several outside vent structures on top of Red Hill. Each tank’s vent must be isolated from the tank vent collection system, and used during the cleaning, assessment, repair, and coating process. This present system most likely would not satisfy any degree of ventilation for human occupancy without major redesign and upgrade. In addition, consideration of venting the tunnels or tanks will be required, depending on the degree of future use.
3. **Tank Repair:** Depending on the intended reuse, the tanks will have to be inspected and repaired, perhaps extensively as provided in the current “Tank Inspection, Repair and Maintenance (TIRM)” report, dated 11 October 2016. Some tanks will need more extensive repair than others. Tanks 5, 13, 14, and 17 were recently repaired in accordance with the TIRM document.
4. **Accessory Removal:** All the existing gauging, electrical, and level alarms will have to be demolished and removed from the tanks.
5. **Additional items:** Once the repairs and coatings (if appropriate) have been completed, the following items will need to be considered:
  - a. The tank ventilation systems will need to be repaired or replaced depending on the actual non-fuel reuse. If the tanks are reused in combination with the tunnels, a new ventilation system will have to be designed and installed
  - b. Proper ventilation through the tank will be needed to maintain the integrity of the coating and tower.
  - c. The tunnel ventilation, access, electrical, drainage, and fire protection will require proper maintenance.

The Closure in Place and Preparation for Non-Fuel Reuse alternative will require coordination of a venting system and development of a plan for isolation of each tank or specific quantity of tanks that will enable safe and efficient work activities. In addition, the Navy must develop a system to monitor potential water infiltration into the tanks and determine how the water will be removed.

As with Alternative 1, Alternative 2 would require ongoing site access and continued maintenance of roads, tunnels, ventilation systems, fire protection system, electrical service, and systems for collection, processing, and disposal of water that may enter the tanks or tunnels. Table 2 lists the pros and cons of ALT 2.

Table 2: ALT 2 Closure in Place and Preparation for Non-Fuel Reuse

Pros	Cons
<ul style="list-style-type: none"> <li>• Supports beneficial non-fuel reuse of the tanks, with potential for local economic benefits.</li> <li>• Provides a hardened and secure site for non-fuel reuse.</li> </ul>	<ul style="list-style-type: none"> <li>• Tank closure tasks involve significant uncertainty due to the assumption that the tanks will need a protective coating. If this assumption is incorrect, the schedule and level of effort will change significantly.</li> </ul>



Pros	Cons
<ul style="list-style-type: none"> <li>Materials are readily available to complete this alternative.</li> <li>The need for major efforts and logistics on top of Red Hill are minimized or eliminated.</li> </ul>	<ul style="list-style-type: none"> <li>Would require ongoing maintenance of systems for tunnel ventilation, fire protection, electrical, tunnel dewatering and water collection from the tanks.</li> <li>Would require ongoing site access and maintenance of roads.</li> </ul>

### 3.2.1. Alternative 2: Cost

- The ROM estimated cost of alternative ALT 2: Closure in Place and Preparation for Non-Fuel Reuse is \$223,000,000. The cost estimate may vary significantly based on actual reuse.
  - The driving factors in this ROM cost estimate are the cleaning of the tanks and re-coating of the tank(s) with an epoxy coating liner.

See Appendix A for details.

### 3.2.2. Alternative 2: Schedule

- The ROM schedule for alternative ALT 2: Closure in Place and Preparation for Non-Fuel Reuse is approximately 4 years from the start of construction to completion.

## 3.3. Alternative 3: Closure with Fill (with inert material)

The closure steps identified for Alternative 1 also apply to this alternative. Subsequent to cleaning and isolation of the vents, this alternative entails closure of the tanks by completely filling them with inert material. The tank concrete and steel liner will remain in place. There are several options for selection and placement of fill material, and these options are described below. In estimating environmental and local area impacts, schedule, and cost, this analysis assumes the fill material will be aggregate obtained at the local quarry, trucked to the site, and placed through borings drilled from the top of Red Hill to the gauger's gallery at the top of each tank.

The options for completely filling the 20 large USTs with inert material include:

- Aggregate material
- Flowable fill or lean concrete mix
- Composite cellular concrete mix
- A combination of the above, based on availability and cost

Based on the container volume of the 20 USTs, it is estimated that 1.2 million cubic yards of material will be required to fill all tanks, regardless of the type or source of material. The availability of sufficient quantity of aggregate on the island needs to be determined and, if insufficient for this purpose, the additional cost of transporting fill material from off-island must be considered. The following critical issues must be addressed for Alternative 3:

- Ability to use heavy construction vehicles to safely access and stage equipment and materials on top of Red Hill, where access is currently very limited
- Impact to surrounding community due to high volume of construction traffic and transport of enormous amounts of fill material
- Prevention of fugitive emissions to ensure compliance with air quality standards during filling process

Additional items that must be addressed for Alternative 3 include:

1. Prior to filling the tanks, the manways, vents and nozzles will have to be secured or reconfigured for appropriate use during the filling process (i.e., venting and air displacement).
2. The existing tower and internal appurtenances may remain in place, but any internal platforms on the tower or walkways should be removed to allow for ease of filling.
3. Regardless of the source of the material, there will be extensive local vehicular traffic for a prolonged period.

The three options for fill material are described below.

1. **Aggregate Material.** Filling the tanks with aggregate material may require boring a 36 inch diameter hole from the top of Red Hill to the gauger's gallery at the top of each tank at distances between 110 feet to 178 feet below ground. Alternatively, a conveyor system could be installed in the upper gallery to move material to the tank manholes, but this method would be difficult to implement, given the limited size and restricted layout of the tunnels. In addition, a major stockpile and material handling yard would be needed, and ultimately, the conveyor system would not allow complete filling of the tanks. For these reasons, the borehole method is recommended and evaluated below and in Appendix A. The following should be addressed:
  - a. Road improvements to the top of the hill areas to allow for extensive heavy vehicular access. This may require widening of the roadways, roadway base improvements, and possible re-routing of the roads.
  - b. Removal of the concrete structures at Tanks 2, 3, and 19, which are currently a part of the tank ventilation. These concrete structures were designed to withstand heavy artillery bombing and are formidable structures. Borings will also need to consider the existing vent structure at the top of these tanks. An evaluation can be performed to determine whether the concrete can be repurposed.
  - c. At the top of each gauger's gallery for the remainder of the tanks, there is a 20-foot concrete plug that was installed during original construction.
  - d. Borings will need to have protections including removable covers and grating or extending the casing about the surface to keep equipment and personnel from falling into the boring, and to protect the borehole from damage.
  - e. Once a sufficiently large boring is complete, the top of each tank will need site improvements for material storage and material handling for the aggregate from stockpile areas to the boring. A vacuum pump system or a conveyor belt to the boring hole will be required.
  - f. Some methods of dust control at the top of the hill and within the upper tunnel areas will have to be designed and implemented as part of the process.
  - g. Borings will need to be filled and capped after filling of the tank.
2. **Flowable Fill.** Filling the tanks with flowable fill would be performed by the installation of pump and hoses from Adits 4 or 5 to the respective gauger's gallery at the top of each tank. For the purpose of the present evaluation, flowable fill is not the chosen approach because the procedures for filling such large

spaces are unknown and may require special sequencing, as noted below. The following considerations apply to flowable fill:

- a. If the volume of flowable fill required (1.2M cubic yards) is not available locally, it would have to be brought by barges or ships to Oahu.
  - b. The procedures for filling a 250-foot tall, 100-foot-wide void with flowable fill are unknown and may require specific sequencing for filling.
  - c. An onsite batch plant may be required to mix and place the large amount of flowable fill into the tanks. There is a local supplier of concrete mixes within one mile of the entrance to the facility, but trucking mixed flowable fill to the site would be cumbersome, costly and time consuming.
  - d. Transporting ready-mixed concrete to the top of Red Hill is very challenging and pumping in lieu of truck traffic may be considered.
3. Cellular Concrete Mix. Filling tanks with a cellular concrete mix has been previously accomplished on Department of Defense cut and cover tanks in San Pedro, California. However, for the purpose of the present evaluation, cellular concrete mix is not the chosen approach because the filling of the large Red Hill tanks would require more research and design, as noted below. The following considerations apply to cellular concrete mix:
- a. The San Pedro tanks were 122 feet in diameter and 24 feet tall (50,000 barrels), much smaller than the Red Hill tanks. Filling a large Red Hill tank with this type of product will require careful consultation with the product suppliers and more research and design analysis to determine feasibility.
  - b. Like the other material options, whether or not sufficient quantity of the fill material can be obtained on-island must be considered, or the cost will need to be adjusted to include transport by barges or ships to Oahu.

Consideration for any concrete or grout closures from below would require bringing in material through the main tunnel from Adit 3 to the lower access tunnel. The tunnels are very congested and only limited size containers can negotiate the tunnels. Considerations for any concrete or grout closures from above could utilize Adit 4 or 5 to the Upper access tunnel for smaller quantities.

The contractor must confirm if fill materials (such as lava rock or crushed lava rock) are readily available on island. The contractor must also determine the actual logistics and processing impacts from the origin of each fill material and the travel distances to the site.

The contractor should use the local quarry (or other source) with a combination of logistic types to process, carry or move fill material. For example, trucks may be used to carry fill to an intermediate dump point or tunnel opening, followed by conveyors or other material transporting system over high grades or through existing tunnels. This combination of transportation minimizes dependency of restructuring existing roads or impacting neighboring community from vehicular traffic.

This alternative would involve a high volume of construction traffic for an estimated five years, during which time approximately 56 large dump trucks per day would travel the local roads, thereby causing severe, negative impacts to the local environment and surrounding community. The estimate of 56 dump trucks per day is based on 1,644,325 tons of gravel, 1.4 cubic yards (CY) per ton, 16 CY per dump truck, 260 work days per year, for 5 years. The contractor must have a maintenance of traffic (MOT) plan in place for all vehicles and transport of materials.

Filling the tanks with inert material would meet DOH requirements for permanent tank closure.

Alternative 3 would eliminate the need for continued maintenance of the tanks; however, it would require ongoing site access and continued maintenance of roads, tunnels, ventilation systems, fire protection system, electrical service, and systems for collection, processing, and disposal of water that may enter the tunnels. Table 3 lists the pros and cons of ALT 3.

Table 3: Pros and Cons for Alternative 3: Closure and Fill

Pros	Cons
<ul style="list-style-type: none"> <li>• Possibly adds long term stability to the tank structure, but a structural analysis would be required.</li> <li>• Meets DOH requirements for permanent closure of the tanks.</li> <li>• Eliminates the need for tank maintenance, but all aspects of tunnel maintenance would still be required (road access, ventilation, fire protection, electrical service, water collection).</li> </ul>	<ul style="list-style-type: none"> <li>• Eliminates the possibility of beneficial non-fuel reuse of the tanks</li> <li>• Requires enormous amounts of fill material, with uncertainty associated with on-island availability</li> <li>• Creates heavy local traffic in area with low accessibility</li> <li>• Lengthy estimated schedule</li> <li>• High cost</li> <li>• Dust, vehicular exhaust, and environmental concerns with site preparations on top of Red Hill and transporting fill materials</li> <li>• Would require ongoing maintenance of systems for tunnel ventilation, fire protection, electrical systems, and tunnel dewatering.</li> <li>• Would require ongoing site access, with maintenance and repair of roads.</li> </ul>

**3.3.1. Alternative 3: Cost**

The ROM estimated cost of ALT 3: Closure with Fill is \$443,000,000. The driving factors in this ROM cost estimate are the large amounts of fill material, along with the site preparations needed to perform the fill procedure. See Appendix A for details.

**3.3.2. Alternative 3: Schedule**

The ROM schedule for alternative ALT 3: Closure and Fill is approximately 5 years from the start of construction to completion.

**3.4. Alternative 4: Remove Tank Steel Liner, and Fill**

The closure steps identified for Alternatives 1 and 3 also apply to this alternative. In addition, this alternative will include steps to demolish and remove the tank steel liner, leaving the concrete barrel, imbedded structural steel, gunite, and grout in place. As the removal of the tank steel liner will undermine the structural integrity of the

surrounding rock, the tank voids cannot remain empty. Therefore, this alternative includes removing the demolished materials and components, and then filling the space with inert material.

The following must be considered:

1. For each tank, booms will have to be designed and installed for load handling. The center tower of the tank is critical to the removal of the steel plates and will have to remain in place to allow for boom installation. Once mechanical life safety equipment is installed, there will be ongoing maintenance of the equipment, which increases the overall cost and schedule.
2. In its existing state, the tower in each tank can only support two booms, which will limit the number of personnel working on a tank at one time. Only two people maximum can work in a boom basket. Handling of the steel needs to be considered in the total weight capacity of the boom basket.
3. The tower will also be used to provide additional installed platforms and staging to access the last two shell courses of the upper dome, as these shell courses are not accessible with the booms.
4. The plate removal will start at the bottom of the tank and progress upwards. Based on access limitations and tower stability, there will be limited lifting capacity to remove the steel from the tank. This limitation will add time to the removal process and will most likely require a special structure or equipment to be added to the access manhole for extraction of plates from the tank.
5. The process of cutting the steel plates will result in excessive unbreathable gases and dust, which will increase the ventilation requirement and create the need for air filtration. These requirements will further limit the number of tanks that can be worked on concurrently. Old coatings of lead-based paint or adhered lead dust may also be an issue, depending on which tank is under demolition.
6. The steel plates have been in place with concrete behind the plates and steel ties imbedded in the concrete. Based on recent experience, the plates are well adhered to the concrete structure and will probably be difficult to remove.

The contractor would need to establish a plan to remove construction debris from the work area and determine if the demolition material would be categorized as hazardous material and require Hazmat guidelines for disposal and confirm whether materials would need to be transported off-island. The contractor would also need to consider if the steel and other materials could be recycled. Contractor would need to develop and secure a staging area to store construction debris and materials in a safe manner as part of the process of disposal.

Alternative 4 would eliminate the need for continued maintenance of the tanks; however, it would require ongoing site access and continued maintenance of roads, tunnels, ventilation systems, fire protection system, electrical service, and systems for collection, processing, and disposal of water that may enter the tunnels. Table 4 lists the pros and cons of ALT 4.

Table 4: Pros and Cons of ALT 4: Remove Tank Steel Liner, and Fill

Pros	Cons
------	------

<ul style="list-style-type: none"> <li>• Likely to meet DOH requirements for permanent closure of the tanks, but additional removal of concrete, gunite, and grout may be required.</li> <li>• Eliminates the need for tank maintenance, but all aspects of tunnel maintenance would still be required (road access, ventilation, fire protection, electrical service, water collection).</li> </ul>	<ul style="list-style-type: none"> <li>• Eliminates the possibility of beneficial non-fuel reuse of the tanks</li> <li>• Requires enormous amounts of fill material, with uncertainty associated with on-island availability</li> <li>• Creates heavy local traffic in area with low accessibility</li> <li>• Dust, vehicular exhaust, and other environmental concerns with site preparations on top of Red Hill and transporting fill materials</li> <li>• Would require ongoing maintenance of systems for tunnel ventilation, fire protection, electrical systems, and tunnel dewatering.</li> <li>• Would require ongoing site access, with maintenance and repair of roads.</li> <li>• Longest schedule compared to other alternatives, with increased closure durations per tank</li> <li>• High safety concern with rigging and lifting, fumes, and stability.</li> <li>• High cost.</li> </ul>
--	---

#### 3.4.1. Alternative 4: Cost

- The ROM estimated cost of ALT 4: Remove Tank Steel Liner, and Fill is \$581,000,000.
  - The driving factors in this ROM cost estimate are the large amounts of fill material and the removal of the steel liner in each of the tanks.

See Appendix A for details.

#### 3.4.2. Alternative 4: Schedule

The ROM schedule for alternative ALT 4: Remove Tank Steel Liner, and Fill is approximately 7 years from the start of construction to completion.

## 4. Summary of Closure Alternatives

The recommended tank closure alternative for the Red Hill Bulk Fuel Storage Facility is **Alternative 1: Closure in Place**. This option has the safest approach, quickest schedule, the least impact on the environment and local community, and no significant constraints on engineering feasibility. Tank closure tasks are well defined, with minimal uncertainty, unlike Alternative 2. Alternative 1 would also support beneficial non-fuel reuse of the tanks, unlike Alternatives 3 and 4.

**Alternative 2: Closure in Place and Preparation for Non-Fuel Reuse** adds work (installation of a protective coating) as an early measure to support beneficial non-fuel reuse of the tanks. The proposed protective coating is based on the assumption that the tanks will be reused as storage for products other than fuel. However, since the non-fuel reuse has yet to be determined, the additional of a protective coating is speculative and may not be needed if a different reuse is ultimately selected. Therefore, this alternative involves significant uncertainty. Compared to Alternative 1, Alternative 2 requires a longer schedule and increased level of effort, and is subject to greater uncertainty. Since Alternative 1 also supports beneficial non-fuel reuse, the additional work under Alternative 2 does not create any added benefit. For these reasons, Alternative 2 is not recommended.

**Alternative 3: Closure with Fill** requires the transportation and placement of enormous amounts of fill material, which may not be available on-island. This alternative involves a high volume of construction traffic for an estimated five years, during which time more than 50 large dump trucks per day would travel the local roads, thereby causing severe, negative impacts to the local environment and surrounding community. Significantly, this alternative does not allow beneficial non-fuel reuse of the tanks. For these reasons, Alternative 3 is not recommended.

**Alternative 4: Remove Tank Steel Liner, and Fill** includes all of the concerns associated with Alternative 3. In addition, the removal of the steel plates involves safety concerns for workers and may destabilize the surrounding geology. Significantly, this alternative does not allow beneficial non-fuel reuse of the tanks. For these reasons, Alternative 4 is not recommended.

Alternative	Venting & Cleaning Cost	Closure Cost	Total ROM Cost	ROM Schedule	Engineering Feasibility
ALT 1: Closure in Place	\$60,000,000	\$59,000,000	\$119,000,000	3 years	Constructible
ALT 2: Closure in Place and Preparation for Non-Fuel Reuse	\$60,000,000	\$163,000,000	\$223,000,000	4 years	Constructible
ALT 3: Closure with Fill	\$60,000,000	\$383,000,000	\$443,000,000	5 years	Possibly Constructible
ALT 4: Remove Tank Steel Liner, and Fill	\$60,000,000	\$521,000,000	\$581,000,000	7 years	Possibly Constructible

Note(s):

1. All ROM Cost Estimates rounded up to the nearest million and ROM Schedules are rounded to the nearest approximate year. ROM cost estimates and ROM schedules are rough order of magnitude (ROM); and are intended only for relative comparison between alternatives.

## 5. REFERENCES

1. NAVFAC EXWC. Red Hill Facility Tank Inspection, Repair and Maintenance Report 2 *blog.verint.com*. [Online] October 9, 2016.
2. API RP 1604 - Fourth Edition. Closure of Underground Petroleum Storage Tanks . February 2021.
3. Department of Defense. *Unified Facilities Criteria (UFC) 3-460-01 Operation and Maintenance of Petroleum Fuel Systems*. April 11, 2016.
4. Contractors Pacific Naval Air Bases. "Technical Report and Project History, Contacts, NOy3550 and NOy4173," Chapter XV, Red Hill, in Appendix A. Typescript report on microform, from library of Naval Facilities Engineering Command, Pacific. [1945].



## **Appendix A. Cost Details**

See Enclosures 1, 2, 3, and 4.

