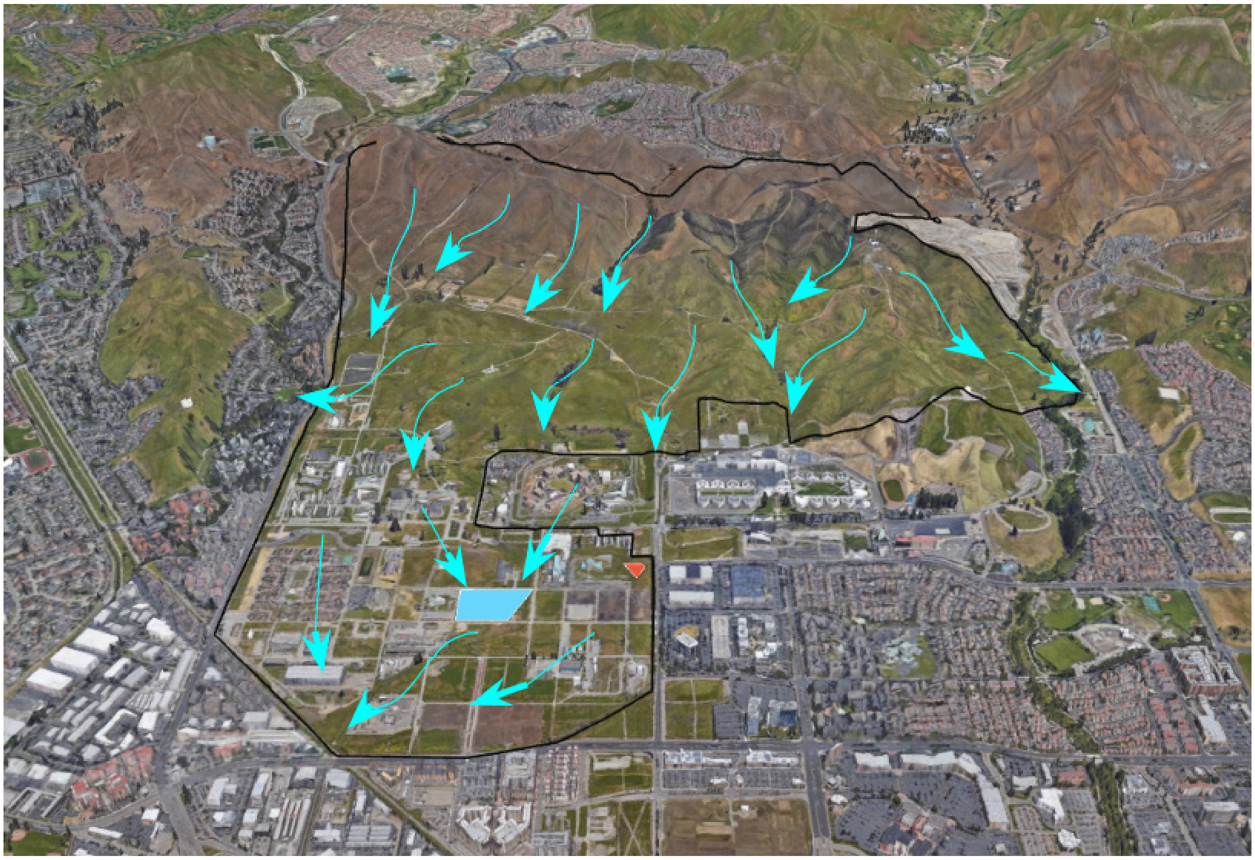
# A Resilient Camp Parks

## *Strategies for Sustainable Water and Energy Management*



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# Introduction

Camp Parks is located on the border of Contra Costa County and Alameda County, largely within the city of Dublin, California. Camp Parks was built during World War II as a Navy base and then later served as an Air Force base for training purposes. In 1959, the United States Army took over the base, and in 1973, Camp Parks became an Army Reserve training facility. Camp Parks primarily hosts a variety of training programs, as well as other important functions. The base has two distinct areas: the *cantonment* (the area developed with buildings, parking lots, etc.) and the *range* (mostly rolling, open grassland used for field training). Camp Parks is only field training facility of its kind within the largely urbanized San Francisco Bay region, so the base is extremely valuable to the military mission (Figure 1).

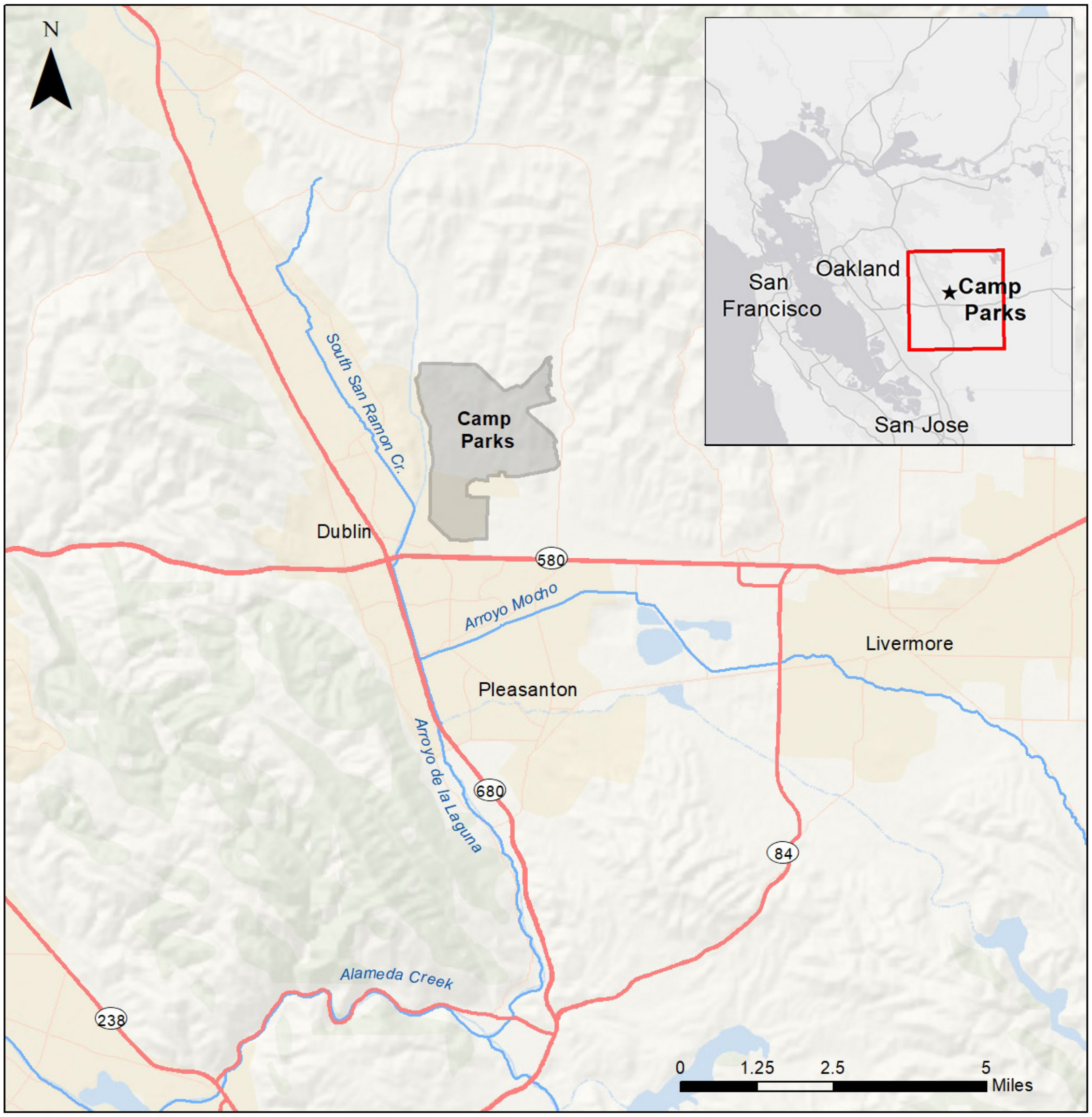


Figure 1. Camp Parks location map.

Since the mid-20th century, the population of the area surrounding Camp Parks has exploded, such that the base is now an 'island' within a suburban 'sea'. The lands of the base drain southward to Alameda Creek, whose watershed has transformed from mostly rural agricultural land and extensive wetlands (around what is now Pleasanton) into suburbs, with a concomitant increase in areas of impermeable surfaces such as rooftops, roads, and parking lots. Runoff from these impervious surfaces has resulted in higher stormflows downstream, with resultant flooding and channel erosion. The base itself has experienced flooding problems, and its impervious surfaces contribute to the regional stormwater problem, making stormwater management a critical issue, both on the base and in surrounding communities.

Additionally, Camp Parks is looking to progress towards the resiliency goals of the Army. The Camp Parks mission is "To provide quality installation services and facilities to enable Total Force readiness." Readiness implies being prepared for changes that may come in the future as well as in the event of an emergency. Important guiding codes and standards include the Energy Security and Sustainability Strategy (ES2), the Unified Facilities Criteria, and the Energy Independence and Security Act of 2007 (EISA). In ES2, the strategic goals are broken into five categories: Inform Decisions, Optimize Use, Assure Access, Build Resiliency, and Drive Innovation, as discussed further below. Camp Parks is also required be self-sufficient for at least 14 days following a major earthquake or other disruption, such that it can provide potable water for over 1000 people, electrical energy sufficient for critical base functions, and natural gas storage.

Our overall project goals were to manage runoff, through developing facilities to maintain and restore stormwater runoff, consistent with EISA, and to increase base resilience in compliance with the ES2, to anticipate, prepare for, and adapt to changing conditions and recover rapidly from disruptions. To create a plan addressing Camp Parks' mission and goals, we developed three main lines of analysis, pursued by three teams within the studio. The Watershed Analysis Team analyzed flood hazards on base and the influence of further on-base development on downstream flood hazard. The Stormwater Management Team analyzed potential for runoff reduction, and proposed measures to reduce both on-base flooding and potential increase of runoff to downstream areas. The Base Resiliency Team focused on diversifying water supply portfolio, energy and water storage for 14-day emergency, and using trees to reduce energy demand and improve working conditions for servicemen and women.

## Camp Parks Within the Alameda Creek Watershed

Camp Parks drains southward into Chabot Canal, westward into Alamo Creek, and eastward into Tassajara Creek. All three of these major streams drain southward into Arroyo de la Laguna, with Chabot Canal and Tassajara Creek flowing first through Arroyo Mocho (Figure 2). Arroyo de la Laguna flows southward to join other tributaries and become Alameda Creek, flowing westward through Niles Canyon and thence to San Francisco Bay. Urban development and channel modification have increased the 'flashiness' of runoff, exacerbating flood risk, such that managing Camp Park's on-base flood risk and its contribution to downstream runoff will continue to be critical to its mission.

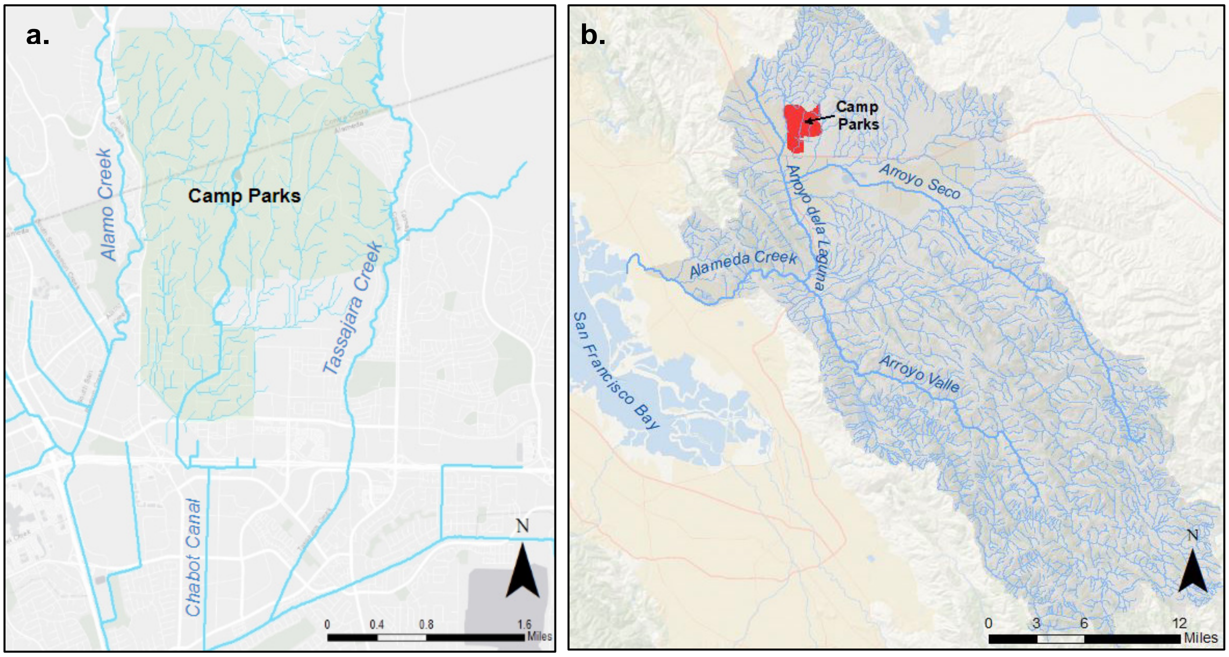


Figure 2. a. Camp Parks drainage and adjacent waterways, and b. Camp Parks situated within the Alameda Creek watershed (b).

In this study we conducted a hydrologic analysis of Camp Park's flood risk and the runoff it contributes to downstream channels in The Alameda Creek watershed under alternative development scenarios. Our study demonstrates that increased impervious surfaces on Camp Parks can increase flood risk downstream, but that low impact development and runoff management can mitigate these increases. We focused on identifying what areas currently flood on Camp Parks during the 100-year storm, how runoff from Camp Parks contributes to downstream flood risk, where flows exceed the capacity of downstream channels, and how increased development on Camp Parks could impact downstream flooding under alternative development scenarios.

## Hydrologic Setting

Camp Parks experiences a Mediterranean climate, with cool wet winters and hot dry summers. As a result, most streams have very low baseflows or completely dry up in late summer, but they can experience raging floods in wet winters. As illustration, the hydrograph of daily discharge for water year 2018-2019 at the US Geological Survey gauge on nearby Alamo Canal shows how flows remain low through the summer and peak sharply during the winter months (Figure 3). The Alamo Canal gauge measures flow from a 39.5-square-mile basin, which includes approximately 1.36 square miles that drain from the base. The 2019 winter saw heavy rains with corresponding peak flows, especially in mid-February, but the 2019 flows pale in comparison to flows in other recent years, such as in 2017 (Figure 4, data from USGS Water Data website). This reminds us that we must prepare for very large flows. Furthermore, climate models predict increased occurrence of extreme rain events like these (AghaKouchak et al. 2018).

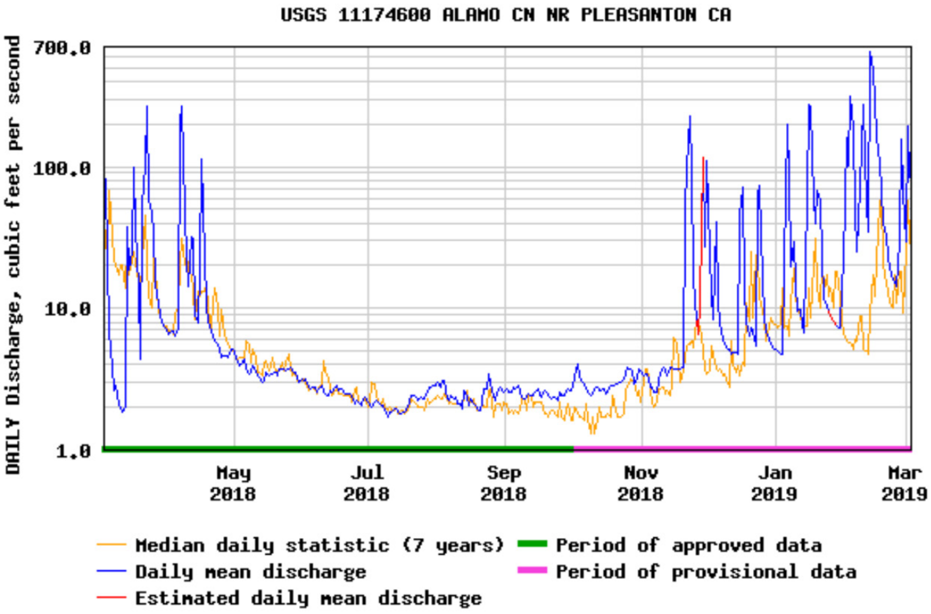


Figure 3. Hydrograph of streamflow in Alamo Canal, April 2018-March 2019. Data from US Geological Survey gauge 11174600, Alamo CN. Data available at https://waterdata.usgs.gov/usa/nwis/uv?11174600, accessed March 2019

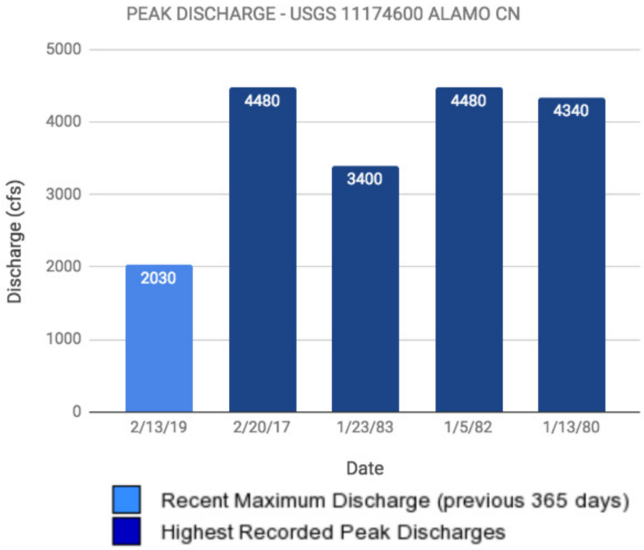


Figure 4. Bar chart showing peak flows in Alamo Canal in recent years. Data from US Geological Survey gauge 11174600, Alamo CN. Data available at https://waterdata.usgs.gov/usa/nwis/uv?11174600, accessed March 2019

As the Alameda Creek watershed has urbanized since the mid-20th century, the area of impervious surface has increased, resulting in increased peak flows for a given rainfall. These higher peak flows, along with the draining of the formerly extensive wetland near Pleasanton (which used to absorb floods from the watershed areas above) has greatly increased stream energy in Arroyo de la Laguna, which has resulted in channel incision and locally severe bank erosion. Camp Parks encompasses one of the last, large areas of open space in the watershed. Expanding the area of impervious surface on the base, without mitigating it via detention and infiltration, can increase flooding problems both on-base and downstream, and add to the high stream energy responsible for channel erosion in Arroyo de la Laguna downstream.

In this study, we analyzed the 100-year storm**,** which is the storm with a 1% chance of occurring in a given year. This is a standard scenario used for flood risk planners in the US, including for the National Flood Insurance Program. Camp Parks has already experienced damaging floods, and flood control channels in the nearby area have experienced high water in excess of some assumptions upon which structural controls were designed. For example, in the high flow of 1998 (approximately an 8-year event according to 66 years of record from nearby San Ramon Creek), the Arroyo Mocho canal near Camp Parks came close to overtopping (Figure 5) and the El Charo Ranch subdivision in Dublin was inundated (Figure 6).

Figure 5. Flooding in Arroyo Mocho Canal, 1998. (Source: Alameda County Flood Control District Zone 7)

Figure 6. Flooding El Charo neighborhood, 1998. (Source: Alameda County Flood Control District Zone 7)

We delineated distinct subbasins on the base using a digital elevation model. There are 16 outlow points where runoff exits the base, each draining a separate subwatershed (Figure 7). The largest subwatershed is 2.4 sq miles in the center of the base, which drains a small area of suburban development north of the base, then mostly undeveloped rangeland of the base, before flowing through the cantonment area and thence entering Chabot Canal to the south. A smaller but still significant set of streams drain the west side of the base westward to Alamo Creek (Figure 7), and smaller drainages drain the eastward extremity of the base, flowing into Tassajara Creek (Figure 7).

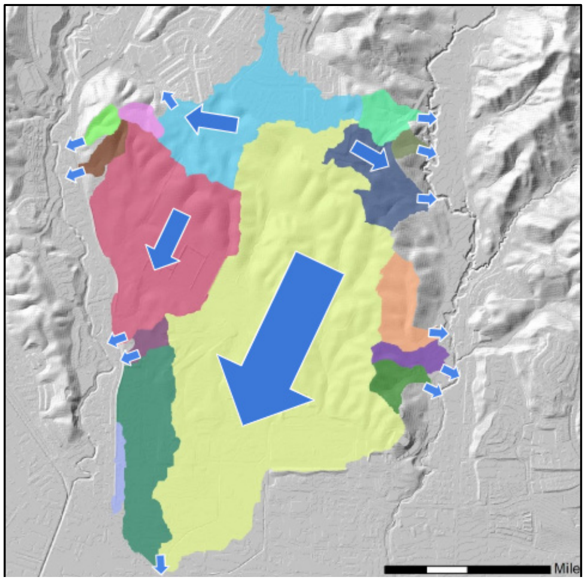


Figure 7. Drainage basin within the base, showing their contributions to stream in the surrounding landscape.

## Methods of Runoff Estimation

To evaluate how different planning scenarios may influence runoff and flooding, we used topography and rainfall data, and we leveraged two hydrology flood modeling techniques to calculate runoff in the 100-year storm for each of Camp Park's subwatersheds (Figure 8). This analysis provided insights into the range of possible flooding outcomes that accompany specific planning approaches.

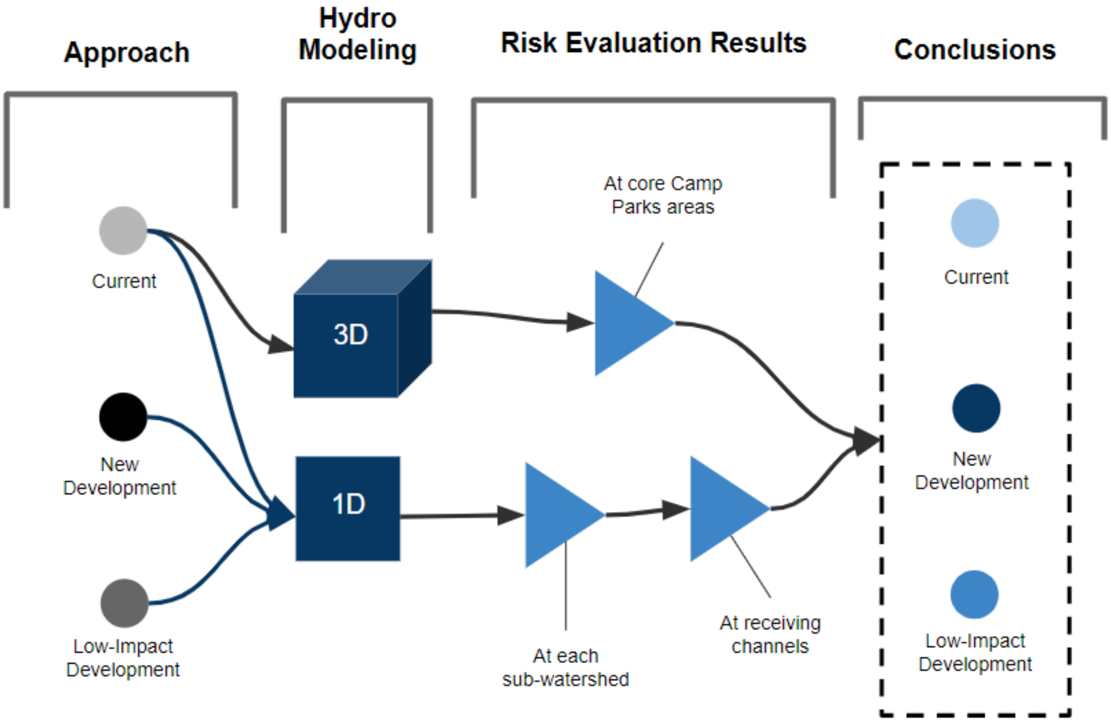


Figure 8. Flow chart of steps in the watershed analysis.

Our three scenarios varied by the extent of impervious cover on Camp Parks. The current scenario represents baseline flooding conditions. The 'New Development' scenario follows the trend of increasing development of Camp Parks and assumes an additional 20 acres of impervious surfaces. This represents increased paving of roads and building construction, but without the addition of engineered retention basins or other natural rainwater infrastructure. The 'Low-Impact Development' scenario accounts for the same additional 20 acres of development as the New Development, but 10 of those acres are permeable.

We used two hydrology modeling methods. The first method used was a time-series flood simulation using 3Di, a hydrodynamic modeling software (Stelling, 2012). This approach used the Manning equation to estimate flood depth extents for every minute for 24 hours. This method simulates the benefits of retention basins and is useful for identifying where water will pool during a large rainfall event. The second was the Rational Method calculation, which is an engineering standard for calculating discharge from open channel flow. This method assumes no water is retained on the base and represents, in our case, the upper limit of flooding impact from the 100-year storm.

Our two modeling methods used the same input data. Topography data was derived from high resolution LiDAR data (USGS, 2006). Soil data was collected from the 2019 Soil Survey Geographic Database (NRCS, 2019) and was used to derive soil infiltration rates. 2016 NAIP aerial imagery (USDA-FSA-APFO, 2016) was used to develop a land cover map, which we converted into a Manning's surface roughness coefficient map. Rainfall intensity data was derived using Contra Costa County's Verification of the District Standards (Contra Costa County Flood Control & Water Conservation District, 2019) rainfall intensity chart. The 100-year storm dumps 6.34 inches over 24 hours, with a peak rainfall of 1.3 inches (or 34 mm) in just a 30 minute period.

To investigate potential downstream impacts of changes in runoff from Camp Parks, we calculated the total runoff that flows into receiving channels from the western, central, and eastern subwatersheds on the base under current conditions, and assuming future development with and without implementation of LID.  We compared these flows with the capacity of the channels to determine if they would overtop.

### *Flood Modeling - 3Di*

3Di uses the Manning equation to estimate flood depth over time (Stelling, 2012). This software works by simulating rainfall across the landscape, where rainfall heights are calculated for each grid cell, or pixel, in a digital elevation model (DEM). The model estimates how much rainfall infiltrates the soil, and then calculates the volume of runoff to leave that pixel. If a pixel has an adjacent, lower elevation pixel, the simulation will transfer that volume of water to that neighboring pixel. If a relative minimum elevation is reached, the runoff pools and begins to flood. This process is repeated every minute over 24 simulated hours of rainfall. In this approach, we were able to account for the storage benefits of the newly constructed retention basin in the cantonment area of Camp Parks by adjusting the DEM to its dimensions.

### *Runoff Modeling - Rational Method*

The Rational Method estimates discharge for a given drainage basin using a runoff coefficient, location-specific rainfall intensity, and watershed area. The runoff coefficient, C, is based on slope, soil type and land cover data layers (USDA National Engineering Handbook).  With each of our development scenarios, the land-cover variable changes, with increased impervious surface resulting in an increased runoff coefficient. The Rational Method assumes natural waterbodies and constructed basins are at full capacity and as a such it does not account for water storage within the base. This could cause over estimation of runoff values if a rainfall event occurs when basins are not at capacity. However, large storms can occur back to back, which could create conditions in which a heavy rainfall event takes place when Camp Park's basins are full.

## Results

### *On-Base Flooding*

The simulated results for Camp Parks show the benefit of the newly constructed retention basin, which retains runoff from the central drainage basin leading into the Chabot Canal. The results also show that the Camp Parks shooting range functions as a de-facto detention basin, with water pooling to a depth nearly 1 foot.  The model also shows runoff passing through the natural pond, marshland areas, and stream, to be collected by the new retention basin. In the Camp Parks cantonment area, an engineered trapezoidal channel conveys flows between buildings. The simulation shows this channel overtopping by less than an inch, but that is sufficient to flood a nearby building. The simulation indicates this building is at risk of flooding, and in fact one building in the cantonment did flood in 2017.

### *Off-Base Runoff*

Figure 9 shows our discharge results at the subwatershed scale for the 100-year rain event under current conditions. In general, basin size is the largest factor influencing runoff, but the interactions between impervious surfaces, slope and infiltration characteristics are also important. The central drainage basin contributes the greatest discharge at 669 cubic feet per second (cfs), and large runoffs are also estimated from watersheds on the west side of the base. Smaller runoff was calculated for the eastern drainages to Tassajara Creek. These 'current condition' results represent the baseline to be compared with future scenarios.

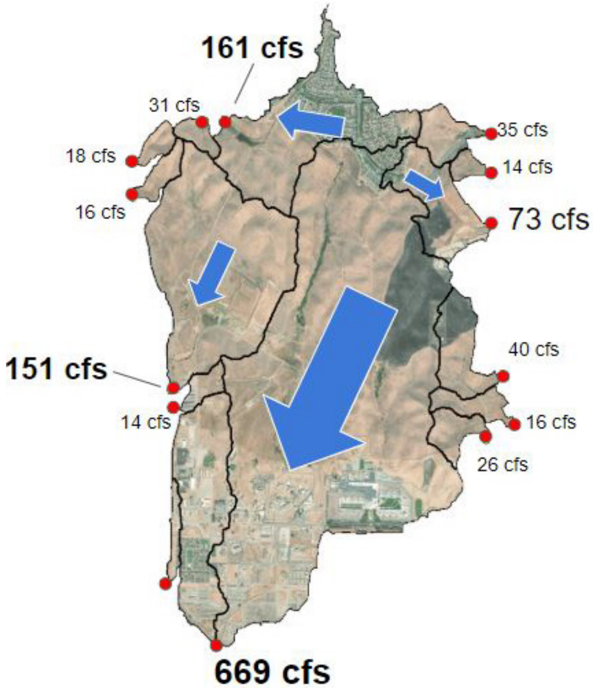


Figure 9. Runoff from base under current conditions

Figure 10 shows the estimated increase in discharge for the new development scenario. 20 acres of development was modeled in each subwatershed with locations indicated by the grey squares on the map. All subwatershed discharge values increase and the greatest total increases are

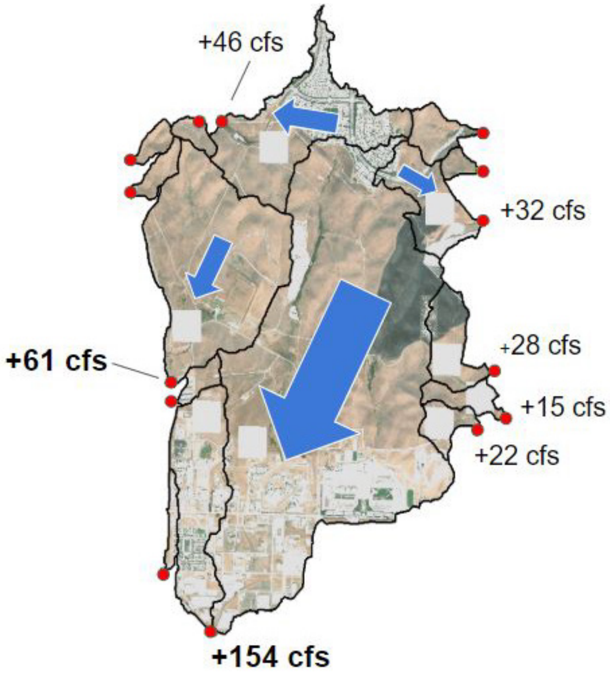


Figure 10. Increased runoff from base under increased development and impervious surface scenario.

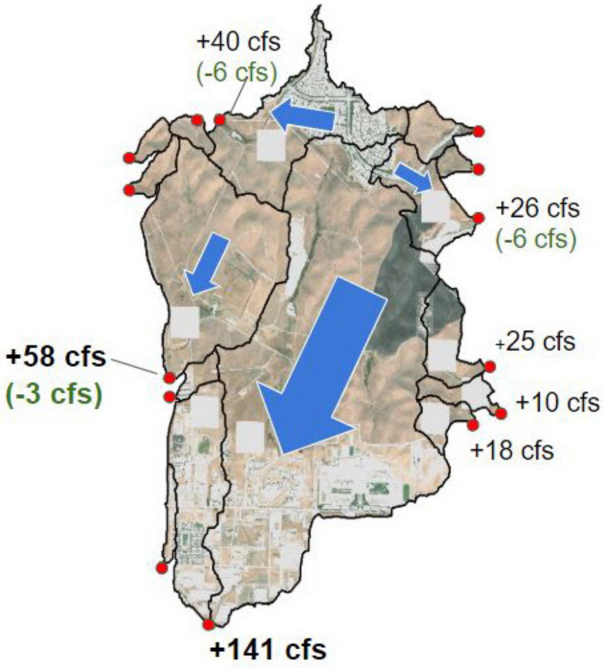


Figure 11. Increased runoff from base under LID scenario.

in the largest watersheds which are capturing the most rainfall. Figure 11 shows the estimated increase in discharge for the low-impact development scenario. This scenario assumes half of the new development consists of pervious surface such as permeable paving. The increase is smaller than the previous development scenario but still substantial. It is important to note that this scenario does not account for water retention opportunities, which are an important component of low impact development, nor for the effect of the recently completed retention pond on the base.

### *Downstream Impacts*

The Chabot Canal, into which the base's central drainage flows, has a capacity of 663 cfs (Alameda County Flood Control District Zone 7, personal communication, March 13, 2019), which is already exceeded by our calculated 100-year runoff from the base, not accounting for reduction due to the retention basin. Tassajara Creek, which receives runoff from the east drainages, has a capacity of 5,200 cfs (Alameda County Flood Control District Zone 7, 2006), which is just sufficient to convey the current 100-year runoff. Alamo Creek, which receives the western drainage, has a capacity of 9,000 cfs (Alameda County Flood Control District Zone 7, 2006), whereas the current 100-year runoff is only 8,500 cfs and thus Alamo has more than sufficient capacity (Figure 12). Under the new development scenario, increased impervious surfaces result in increased runoff, which would put Chabot Canal further over capacity, Tassajara Creek over capacity, and flows in Alamo Creek remain just below the channel capacity.

Under current conditions, the FEMA flood insurance rate maps identify a significant area subject to flooding during the 100-year event along Chabot Canal downstream of the base, affecting commercial uses (Figure 13) (FEMA, Flood Insurance Rate Map, 2009). When the FEMA maps are updated to reflect the effects of the newly constructed retention basin, it is likely that this flooding will be eliminated or at least reduced. Along Alamo Creek, farther downstream the FEMA map indicates the channel is over capacity below the confluence of a flood-prone tributary (Figure 13). If future development on the base increases runoff from the base, the potential for flooding in these areas can be expected to increase. Better coordination with Zone 7 Water Agency to share data and improve model inputs could improve model fidelity and help mitigate future flood risks.

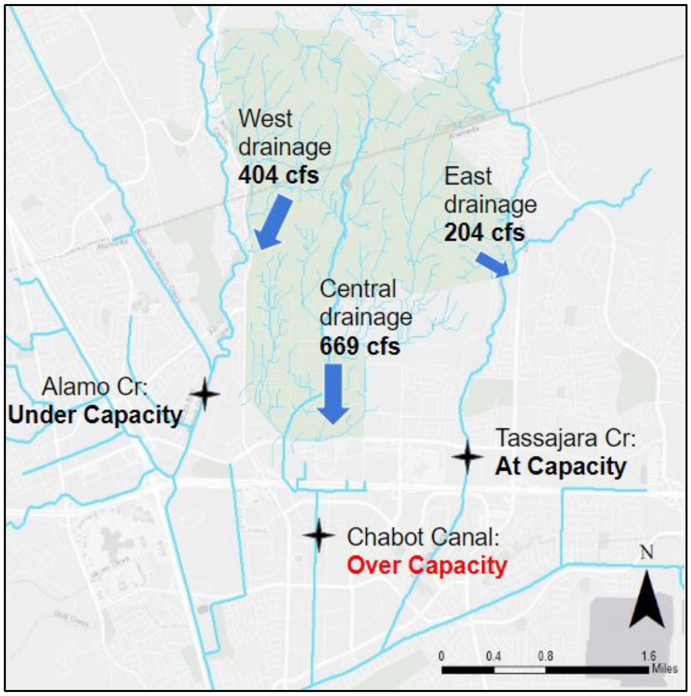


Figure 12. Estimated current 100-y flood runoff from Camp Parks compared to capacity of receiving channels downstream.

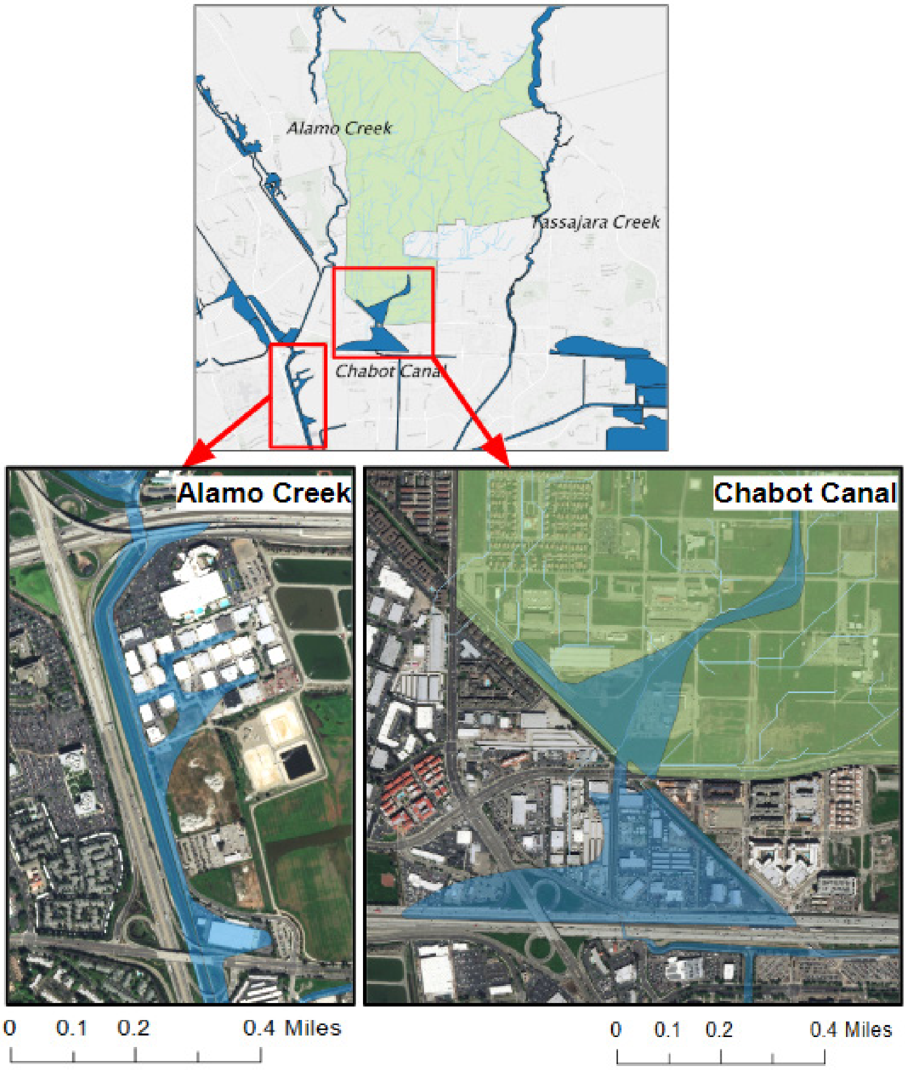


Figure 13. Current FEMA flood insurance map, showing significant area of flooding downstream of base.

## Managing Stormwater on the Base

In light of the current flooding problems on-base and the potential for future on-base development to increase runoff and flood hazard on the base and in downstream communities, we explored approaches for Camp Parks to better manage flood risk on the base, control runoff exiting the base, and identify practical and economical options for stormwater management on the base. We approached these topics in the context of the Camp Parks mission to enable "total force readiness" and relevant codes and standards.

The Unified Facilities Criteria Installation Master Planning document (UFC) was the primary resource used to highlight the most effective and appropriate stormwater management strategies for Camp Parks. The UFC defines Low impact development as the utilization of natural features to control runoff quality and quantity, instead of typical "grey infrastructure" of hardened channels and pipes designed to send water downstream as fast as possible. The UFC further specifies LID as implementing “small-scale” “hydrologic controls”, close to the source of runoff, to replicate more closely the hydrological conditions prior to development [UFC 2-2.8, pg.8]. Additionally, the Energy Independence and Security act of 2007 specifies that LID should be implemented [Section 1204]. “The use of on-site natural features to control stormwater runoff quantity and quality in lieu of traditional ‘end-of-the-pipe’ solutions is a land planning and engineering design approach termed Low Impact Development (LID).” [UFC 2-2.8, pg8]

### *LID vs Grey Infrastructure*

While LID is widely regarded as being better for the environment than conventional “grey” infrastructure, it has also been shown to produce financial savings over the long term due to lower maintenance costs (Odefey, 2012; Zhan, 2016; Davis, 2017). This is particularly evident when considering the inevitable replacement of current infrastructure as storm intensity and capacity requirements rise with climate change. The cost of updating and expanding a grey infrastructure system can become prohibitive, especially if the infrastructure has been allow to deteriorate without an ongoing program of replacement (Vineyard, 2015; Ahiablame, 2012). Recent literature on stormwater management indicates LID may yield capital cost savings between 15 - 80% over conventional “grey” infrastructure across a variety of climates and scenarios, with potential implications for Camp Parks as the base deals with potentially increased maintenance costs over time (Gallet, 2011, Sample 2018; Ahiablame, 2012; Chiang, 2015).

### *Stormwater Management Approach*

Integrating all these considerations, we explored three measures to address runoff and flood management, all specifically recommended by the UFC to increase permeable surfaces and reduce runoff [UFC 2-2.8.1, pg8]: larger detention basins located primarily in the range area, bioswales adjacent to impermeable areas in the cantonment, and permeable pavers in all new developments, along with infrastructure updates as repairs are needed.

By expanding detention and infiltration capacity of the rangeland, the runoff that reaches the cantonment via the central drainage can be reduced significantly. Consequently, this reduces risk to sensitive infrastructure potential economic losses from flooding. Daily operations would be interrupted less frequently by floods, and post-flood recovery will be faster, as transportation and outdoor facilities will remain functioning. This is particularly vital in times of crisis. A large flood affecting the surrounding area would require immediate action and support from Camp Parks, a response that may be hindered if on-base flooding is not prevented by adequate measures controlled prior to the flood. In addition to reducing the amount of runoff received by the cantonment, increasing the infiltration rate of available surfaces would reduce the magnitude of locally-generated urban flooding, improving the security of base infrastructure, operation, and personnel. In turn, reducing the runoff discharged from the cantonment avoids inadvertent impacts to surrounding communities.

## Three Measures Proposed to Treat Stormwater on the Base

### *Measure 1: Detention Basins*

Detention basins are depressions in the landscape to hold stormwater for a limited time, releasing flow through outlets sized to minimize downstream flooding. Thus, they are typically located upstream of an area to be protected from flooding or to prevent upland storm runoff from reaching a larger stream. Unlike retention basins, detention basins are designed to dry out in between floods (Nascimento et al., 1999). Because detention basins are dry most of the year they can be put to other uses when not flooded, such as playing fields for baseball or soccer, picnic areas, or for parks, thereby offering a more functional space than retention basins, with perennial water (Nascimento et al., 1999). For Camp Parks, we envision additional uses as training features: excavated soil can be molded into berms and rope courses or ziplines could cross over the detention basins (wet or dry) (Figure 14). Excavating the detention basin could offer training for heavy equipment operators.

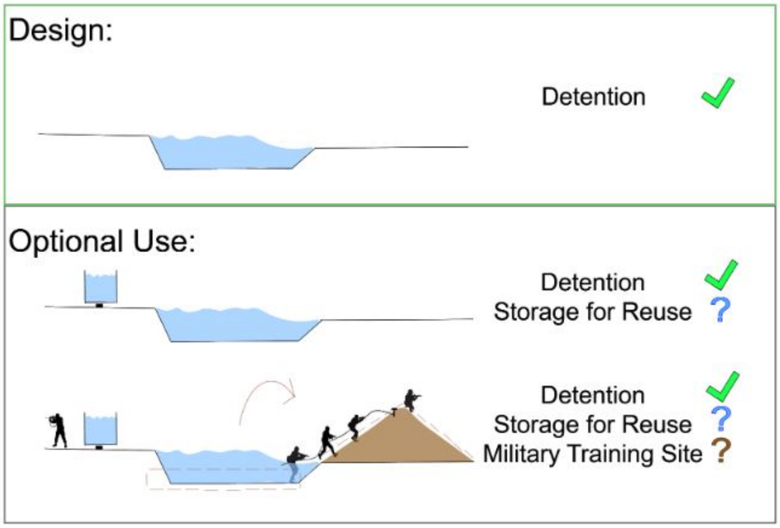


Figure 14. Detention basin design and potential uses.

The landscape of Camp Parks offers an ideal location for large-scale detention in the shooting range, which is located in a valley between two ridges (Figure 15). Because outflow from this valley must exit through narrow outlets, the valley already ponds with water and thus performs a natural detention function (Figure 16). By constructing control structures on both outlets (one towards the south, the other towards the west), the detention function could be greatly enhanced, and the site could detain significant volumes of stormwater, thereby reducing peak flows arriving in the cantonment area downstream.

Detention basins can accumulate trash and sediment, but their maintenance is relatively simple and inexpensive: raking or sweeping. Traps for bedload (the coarse sand and gravel carried by flows) or sedimentation tanks can be installed to catch solids at the entrance of the basin, simplifying removal of accumulated materials (Nascimento et al., 1999).

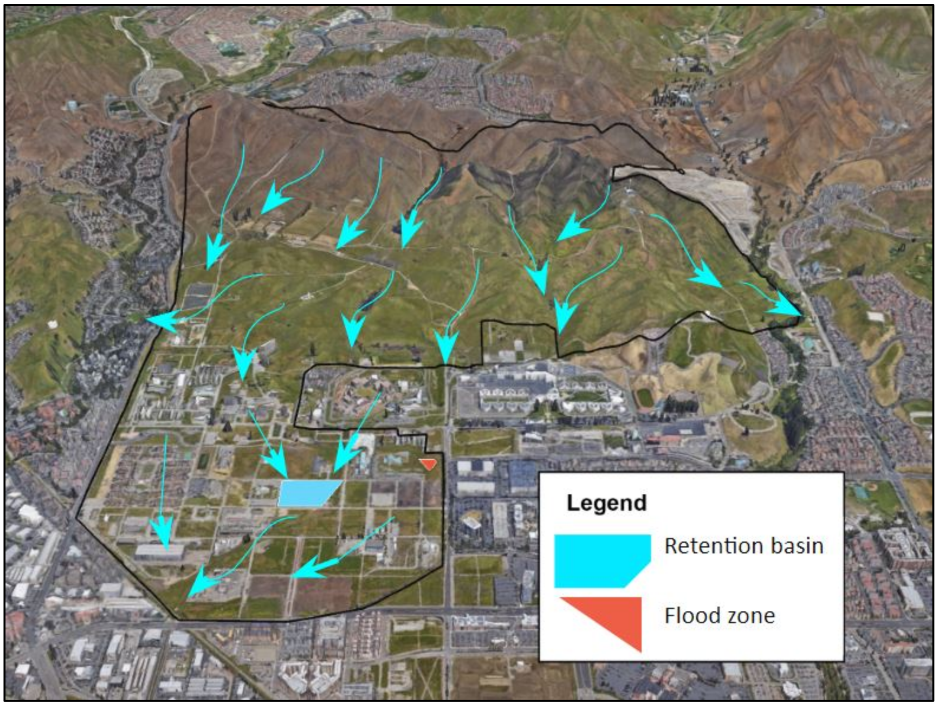


Figure 15. Oblique aerial view showing runoff patterns on base.

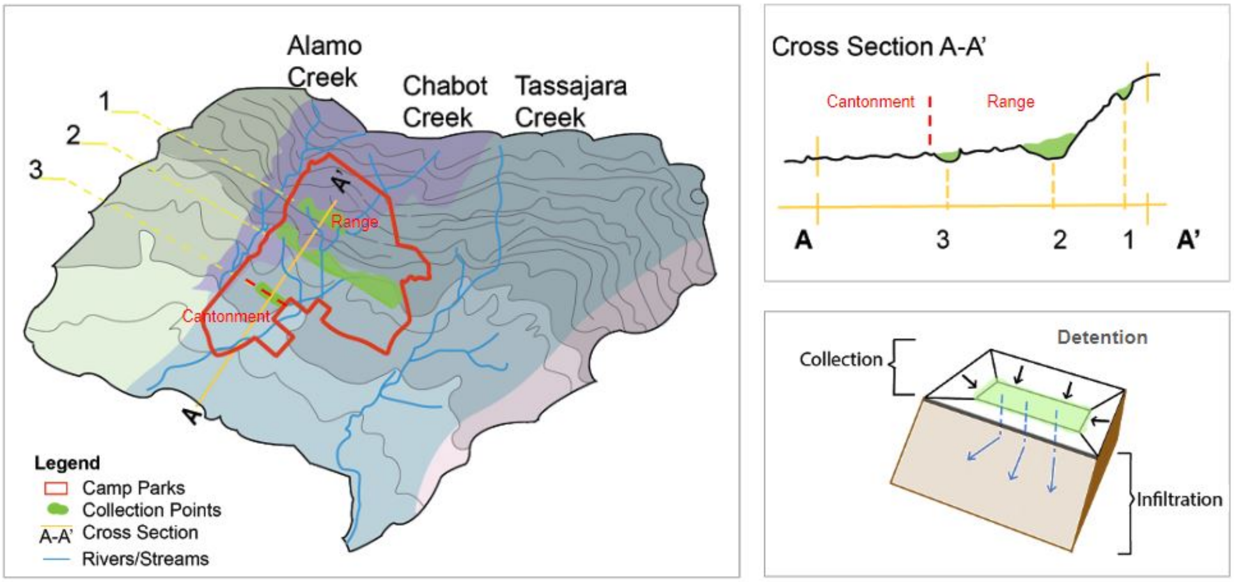


Figure 16. Block diagram showing approximate placement of detention basins

### *Measure 2: Bioswales*

Although much smaller than detention basins, bioswales allow for 88% runoff reduction and up to 95% solid pollutant removal through mediums like coarse grain pebbles (Xiao and McPherson, 2009). Pollutants removed include "nutrients, metals, organic carbons, solids, gas, diesel, and motor oil" (Xiao and McPherson, 2009). Other materials could include sand, loam, or lava rock that creates crevices for water to filter pollutants (Xiao and McPherson, 2009). The top layer is the initial filter and has the largest pore space, with each successive layer of filters being smaller to effectively filter out the pollutants. Including short grasses creates additional adsorption surfaces for pollutions like lead and copper to adhere to (Figure 17). In the cantonment, bioswales could be placed where they can filter runoff from discrete areas. For example, a 5m$^2$ swale could treat runoff from a 200m$^2$ parking lot, or an area about half the size of a basketball court. Bioswales are essentially mini detention basins that receive smaller inflows of water and have more emphasis on micropollutant removal.

Figure 17. a. Bioswale cross sectional diagram and b. and proposed placement map.

***Measure 3: Permeable Pavers***

The third measure is to install permeable pavers to decrease total impervious surface area. Permeable pavers allow filtering of heavy metal pollutants, commonly found in parking lots, so the target locations would be similar to those of bioswales (Figure 18). In terms of pollutant treatment, permeable pavers are capable of reducing chemical oxygen demand by 89%, suspended matter by 50%, lead by 95% (Balades et al., 1995). Permeable pavers can be cleaned by sweeping, suction, or high pressure water jets, which can be accomplished efficiently since clogging is limited to the first 2cm (Balades, et al., 1995).

Our suggested implementation does not require permeable pavers to replace all existing parking lots, but rather pavers should be phased in as replacements when existing paving requires renewal, and used in future parking lots and low-traffic access roads. As pavers are a more specialized type of impermeable surface it will cost more than the bioswale both to implement and upkeep. However, each method has its unique function. Bioswales redirect a moderate amount of stormwater into a nearby detention basin, while the permeable pavers simply make an impervious parking lot surface to be pervious, decreasing the total runoff.

## Stormwater Design Strategy for Camp Parks

The physiography of the base (Figure 14) suggests an overall strategy to manage stormwater: Place a large detention basin in the shooting range to detain and control the largest floods, thereby minimizing the peak runoff that reaches the cantonment downstream. Place smaller basins detention basins at strategic points around the base (Figure 19). Within the cantonment, install bioswales to receive runoff from parking lots and roads, and to convey stormwater to small detention basins within the cantonment, and as repaving becomes necessary gradually replace conventional paving with permeable pavers in areas that receive only light traffic, such as parking lots and lightly-used driveways. Through these measures, flooding on-base can be reduced or eliminated, and the base can avoid increasing peak flows that leave the base and flow into Chabot Canal (and can likely decrease them).

Assuming an average water storage depth of 5 ft, approximately 126 acres of detention basin would be needed to reduce discharge from the 100-year, 24-hour storm down to the level of a 2-year 24-hour storm. This detention basin area could be achieved in many ways, one of

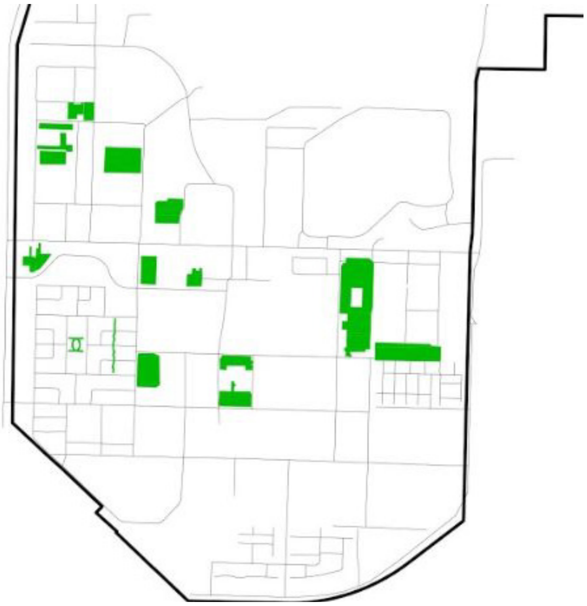


Figure 18. Proposed placement of permeable pavers

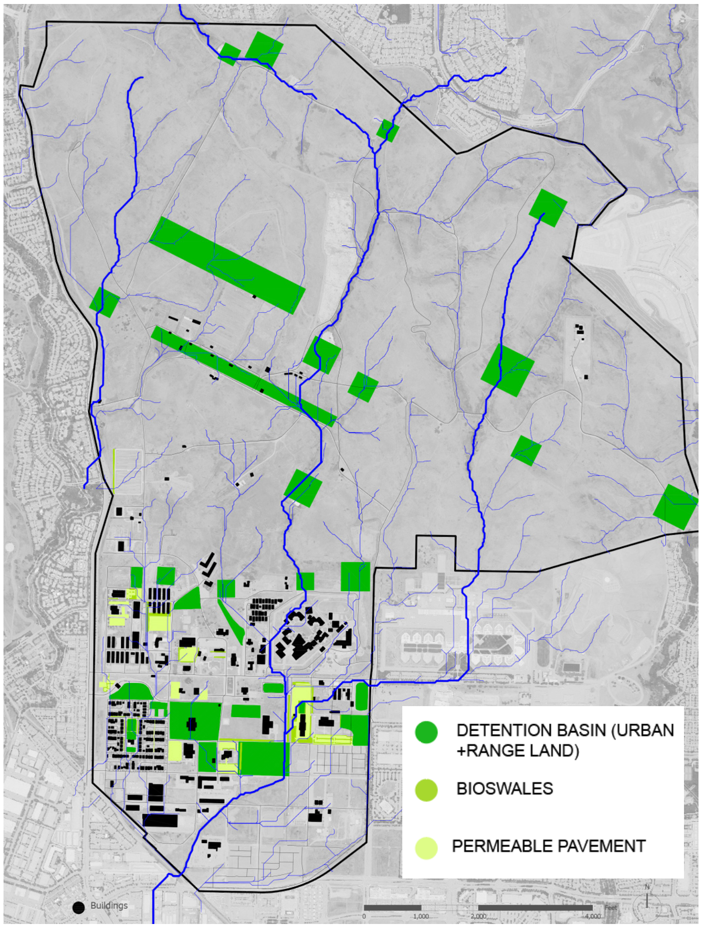


Figure 19. Proposed placement of detention basins, bioswales, and permeable pavers in Camp Parks

which is schematically proposed in Figure 19, which features detention in the shooting range and another large area in the range. The shooting range drains both to the central drainage flowing through the Cantonment (and thence into Chabot Canal) and also westward into Alamo Creek, so detention here would reduce flood flows into Alamo Creek as well as to the Cantonment and Chabot Canal. Various other sites could be evaluated across the base landscape. Within the Cantonment, accounting for the extent of structures, increasing permeable surfaces is the most realistic strategy to respond to local runoff, through bioswales adjacent to impermeable areas, as well as a phasing towards pervious pavement across the base. While larger undeveloped spaces are more limited in the cantonment, there are still several opportune locations to implement additional detention to enhance security against floods (e.g., track/proposed track, baseball field, existing outflow points, accidental flooding parking lot). The proposal in Figure 19 includes generalized schematic locations of potential detention storage within the cantonment, but specific sites would require more detailed analysis. In addition, if water depths can be increased, such as in the shooting range area, the total area required to meet the volume target may be lower.

The proposed mix of detention pond storage, bioswale storage/infiltration, and permeable paver infiltration would be expected to accommodate nearly 29 million ft$^3$ of stormwater, in excess of the 27.2 million ft$^3$ target needed to reduce the discharge from a 100-year, 24-hour storm to that of a much less destructive 2-year storm (Table 1). The detention basins in the range are the workhorse. This illustrates how Camp Parks can play such an important role in reducing downstream flooding and channel erosion from excess energy. So much of the rest of the watershed has already been developed, there are relatively few opportunities to enact such large - but relatively simple and low-cost – solutions, not only to prevent flooding in the cantonment but also to benefit the wider area.

**Table 1. Proposed detention and infiltration in detention ponds, bioswales, and pervious pavers**

| **Measure** | **Area (ft$^2$)** | **Avg depth (ft)** | **Total volume (ft$^3$)** |
|---|---|---|---|
| Detention basins | 5,700,000 | 5 | 28,500,000 |
| Bioswales | 850,000 | 0.5 | 425,000 |
| Permeable pavers | 890,000 | 0.08 | 73,870 |
| Total detained/infiltrated | | | 28,999,000 |
| Target detention volume (reduce 100-yr 24-h flood to 2-yr) | | | 27,192,000 |

## Increasing Base Resiliency

The imperative to increase overall resiliency of Camp Parks stems directly from the Camp Parks mission statement: “To provide quality installation services and facilities to enable Total Force readiness.” Resilience and readiness go hand-in-hand. The Base Resiliency group delved into what key factors need to be addressed for greater resilience to emergency situations, for which Camp Parks plays a critical role, and greater resource resilience, all while maintaining a pragmatic perspective on the feasibility of these goals. The main areas we explored were how to expand water sources to meet the 14-day emergency requirements, how to improve energy efficiency at Camp Parks, and potential added benefits of water and energy resiliency.

For resiliency, the ES2 document describes optimizing use and assuring access. To optimize use, ES2 calls for *decreasing resource demand* via improved building technologies, *increasing resource efficiency* via holistic integrated approaches for optimal solutions, and supporting *resource recovery* via strategies to “increase the beneficial use of each gallon of water.” To assure access, ES2 calls for *diversifying and expanding resource supply* by having multiple sources to improve resource availability, *maximizing flexibility in system design and use,* and *reducing vulnerability and risks,* both cyber and physical security.

The base is already decreasing resource demand though improved building technologies.
We focused on increasing resource efficiency with a holistic integrated approach, while supporting resource recovery with the goal to increase the beneficial use of each gallon of water, therefore extending the current potable water use. For assuring access, we focused on diversifying resource supply so that Camp Parks is not just reliant on a single source to maximize flexibility in the design so that Camp Parks can better adapt to the needs of the future in addition to those in the event of an emergency. The goal is for Camp Parks to be able to quickly shift from everyday function to emergency functioning conditions without losing critical facilities.

Army Directive 2017-07 addresses the 14-day emergency contingency requirement, calling for “redundant and diverse sources of supply, including renewable energy and alternative water” and that landholding commands will “plan, program, budget, and execute energy and water projects that close energy and water security gaps and reduce risk.” For a 14-day emergency, Camp Parks needs a water supply for at least 1000 people (an estimate that may be low in light of the critical role anticipated for the base within the broader region), a 14-day supply of electricity for continued operations, and a 14-day supply of natural gas.

Resilience is more than just ensuring the continued operations of Camp Parks infrastructure. Resilience also extends to servicemembers’ health and readiness to fulfill their orders. Directives from the Department of Defense, including Operation Live Well and Healthy Base Initiative, seek to improve the health and fitness of servicemembers, and a Camp Parks resilience plan can meet these directives as well.

### Water Security

To improve water security and management at Camp Parks, expanding on current infrastructure improvement efforts, diversifying the water portfolio and increasing on-site storage could greatly improve base resilience. We explore incorporating a onsite non-potable water system, rainwater capture, both potable and non-potable water storage for 14-day emergency supply, and also groundwater potential for emergency situations. Current water usage at Camp Parks averages 14,200 centum cubic feet (CCF) per year (29,100 gallons/day). According to the Water Research Foundation's chart of typical water use, there should be about 42% of reusable greywater potential and about 44% applicable end uses for recycled water (Figure 20).

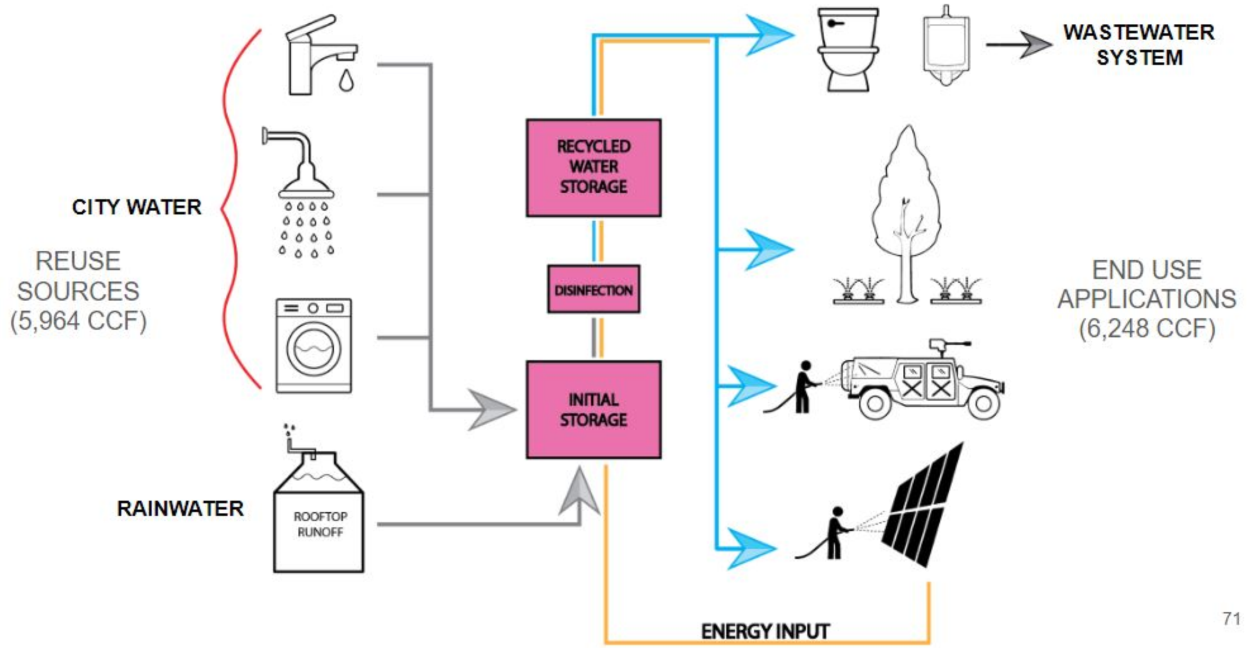


Figure 20. Onsite non-potable water system diagram.

The non-potable water system could also incorporate rainwater collected from roofs, diverted to a non-potable treatment system. The water would initially be collected and stored, then go through a disinfection process which includes UV and biological treatment. It would then be stored as recycled water, then allocated for flushing toilets, irrigation, and outdoor construction and maintenance. These uses typically make up about 6000 CCF/yr for Camp Parks, so the potential supply of reusable water matches closely the anticipated end-use application.

According to data compiled by the Pacific Institute, a non-potable water system for Camp Parks would cost between $20,000 and $29,000 to install (Cooley, 2016) (Table 2), a relatively small cost compared to expected savings of over $55,000 a year from reduced potable water use and diversions from wastewater. It would substantially diversify the Camp Parks water portfolio, and thereby making the base more resilient.

Rainwater is another potential source to be integrated into an onsite non-potable water system. Although this source must be kept separate from the potable water system, rainwater can be tied easily into a greywater treatment system. Rainwater can also be used directly for irrigation for new tree plantings or for outdoor washing. Rainwater collection is a great opportunity to implement now on existing buildings, as greywater reuse is not feasible on existing buildings until buildings are replaced or fully renovated over time.

**Table 2. Cost estimates for non-potable reuse systems from the Pacific Institute (2016)**

| Small project <10,000 AFY (Camp Parks = 32.6 AFY) | Non-potable reuse facility | | | Total cost of non-potable reuse | | |
|---|---|---|---|---|---|---|
| | **Low** | **Med** | **High** | **Low** | **Med** | **High** |
| $/AF | $550 | $590 | $1,200 | $1,500 | $1,500 | $2,100 |
| $/CCF | $1.26 | $1.35 | $2.75 | $3.44 | $3.44 | $4.82 |
| Cost for capacity of maximum potential reuse at Camp Parks | $7,530 | $8,078 | $16,430 | $20,537 | $20,537 | $28,752 |

Groundwater is another source that could be key for emergency purposes. The first step would be to initiate discussions with the Dublin San Ramon Services District, which currently manages groundwater under the base. Many now inactive wells exist on the base (Figure 21), which should be evaluated for potential re-activation, followed by a suitability analysis to determine best location for new wells. We would likely look towards the alluvial bottomland along Tassajara Creek as an initial well locations.

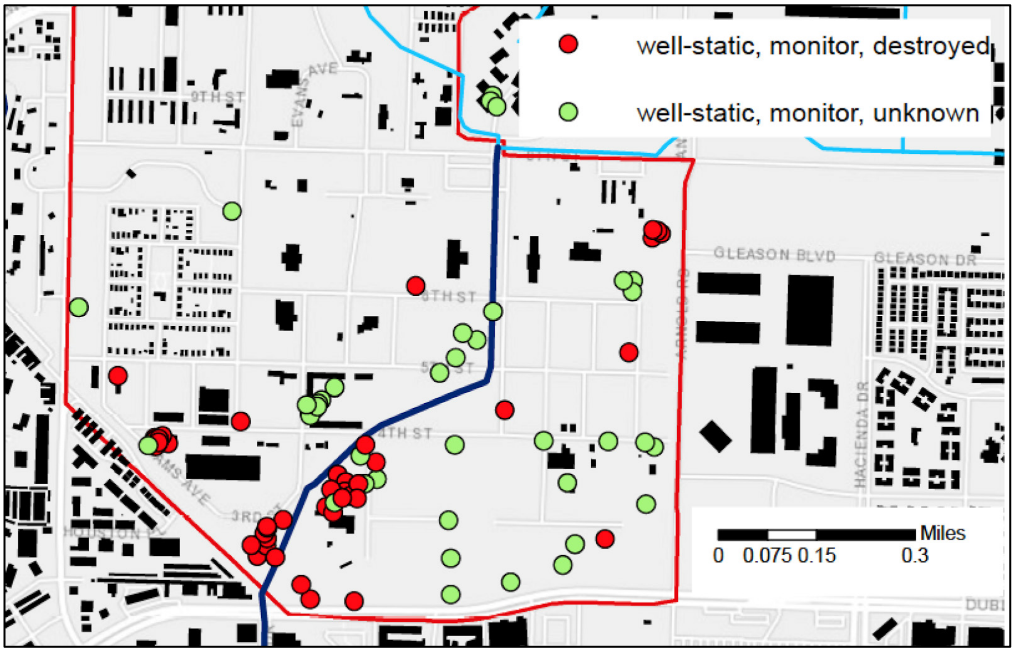
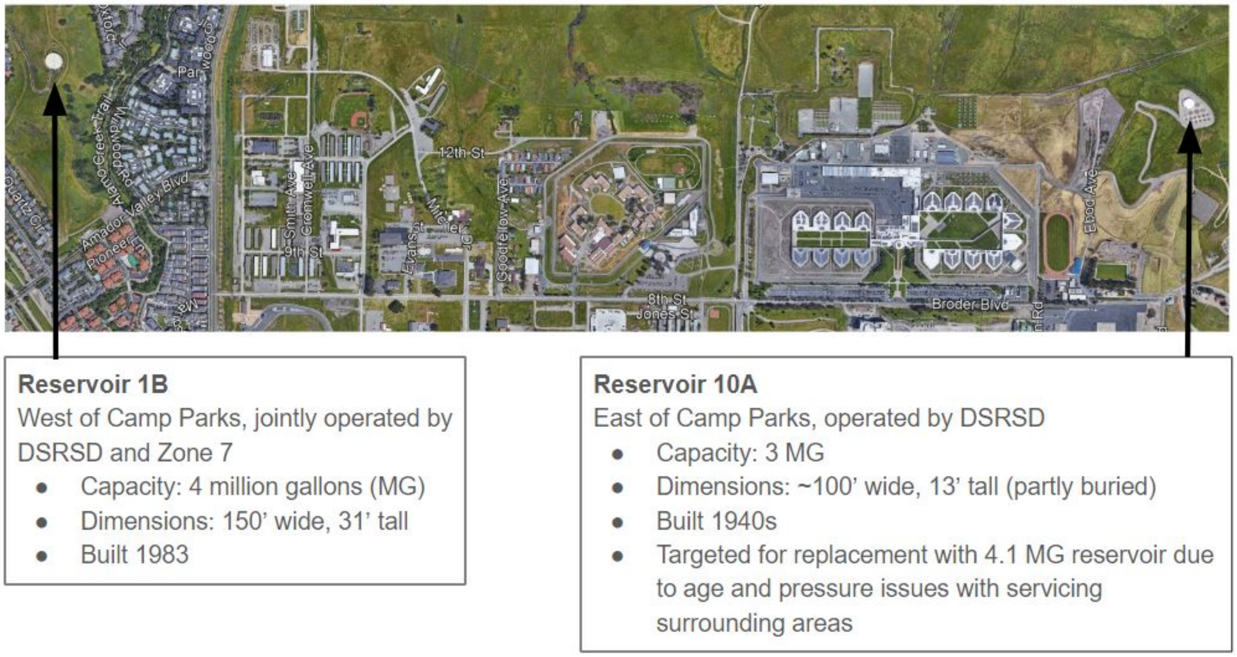


Figure 21. Map of existing wells in part of the cantonement area of the base.

To meet the 14-Day emergency directive, Camp Parks should increase on-base water storage capacity by construction of a large reservoir (tank). Storing water makes possible Camp Parks' self-sufficiency and ability to support emergency operations post-disasters, when the base may be isolated and must be self-reliant. We recommend moving potable water from DSRSD to a new Camp Parks reservoir, from which it can be distributed across the base, keeping it moving to prevent stagnation.

There are two potable water storage reservoirs near the cantonment area of Camp Parks (Figure 22). Reservoir 1B, west of Camp Parks is jointly operated by the Dublin San Ramon Services District and Zone 7 Water Agency. It has a capacity of 4 million gallons and measures 150 feet wide by 31 feet tall. Reservoir 10A, east of Camp Parks, is operated by the Dublin San Ramon Services District (DSRSD) and stores 3 million gallons. Built in the 1940s, it is scheduled for replacement.



**Reservoir 1B**
West of Camp Parks, jointly operated by DSRSD and Zone 7
- Capacity: 4 million gallons (MG)
- Dimensions: 150’ wide, 31’ tall
- Built 1983

**Reservoir 10A**
East of Camp Parks, operated by DSRSD
- Capacity: 3 MG
- Dimensions: ~100’ wide, 13’ tall (partly buried)
- Built 1940s
- Targeted for replacement with 4.1 MG reservoir due to age and pressure issues with servicing surrounding areas

Figure 22. Map showing nearby water supply reservoirs.

The Universal Facilities Criteria 3-230-01 “Water Storage and Distribution” calls for sufficient water storage on a military base to meet at least half the daily domestic requirements for 14 days, plus industrial demand that cannot be shut off during a fire or emergency, and additional water storage for firefighting efforts. UFC 3-230-01 also explicitly recommends using elevated or above ground tanks. Underground tanks are least preferred option due to their high cost and limited technical advantages for water storage.

Following these requirements, we recommend the construction of a water storage reservoir on a small hill above the Cantonment area (near the former site of the base commander residence). Based on average residential water usage rates, this reservoir would need a capacity of at least 1.2 million gallons to supply 1,000 people for 14 days, plus any additional storage for camp operations and fire suppression. DSRSD recently estimated the cost of replacing Reservoir 10A at $7.6 million, which we can use as an estimate for the cost of a new reservoir on Camp Parks.

Water use at Camp Parks can be diversified to improve resiliency and extend the potable water supply on the base for everyday use and during emergency operations (Figure 23). Currently the water supply is made up of only potable water. An Onsite Greywater System would allow Camp Parks to increase the beneficial use of each gallon of water. This would allow for more storage of potable water, and replace a portion of the stored potable water with a stored non-potable water supply. In the 14-day emergency situation, the stored potable water would be the source of drinking water for the base and the recycled water will be able to extend the water supply for operations that do not require a high level of treatment, such as firefighting operations. A groundwater agreement with DSRSD should be considered to allow the base to pump water in emergency situations. Diversifying the Camp Parks water portfolio can provide adequate water supply for 14-days and increase the overall resiliency of the base.

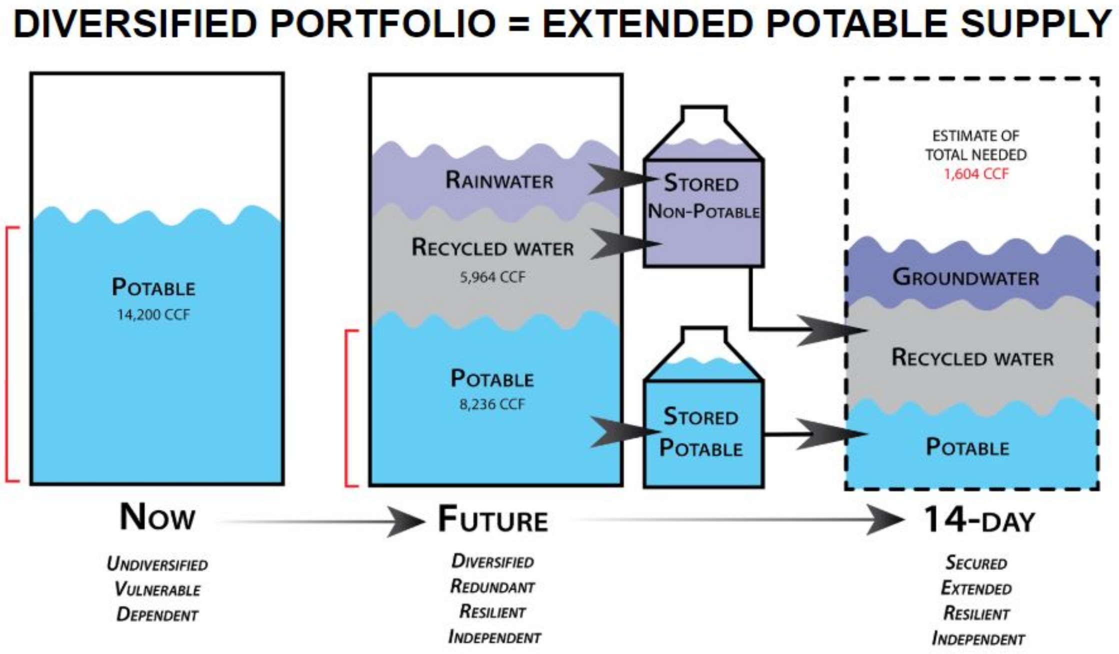


Figure 23. Diversified portfolio to extend water supply

## Energy

The base has constructed a large solar array (located along the west side of the base, north of the cantonment area, which (once integrated into the grid) will provide sufficient power to meet all the needs of the base, although due to the intermittency of solar panels, additional battery storage may be required. The solar array is a key step towards energy independence and resiliency. To complement the increased supply of electrical power, we explored options to reduce demand, notably cooling demand in hot summer months.

It is well established in the scientific literature that strategically located trees can significantly reduce the urban 'heat island effect' and air-conditioning demand of individual buildings by shading buildings, roads, and parking lots. We applied the I-Tree tool suite, an analytical tool developed by the US Forest Service that uses input data from satellite imagery of land cover and temperature data to calculate effects of urban trees on energy demand, air quality, etc (i-Tree Software Suite). From the army code of regulations we identified reducing heat islands and maximizing positive environmental effects of interventions such as the CO2 removal as key elements in the landscape code for army bases, and we used the specified guidelines to help determine our tree criteria, factoring in compatible soil, energy conservation properties, drought tolerance, suitability for urban environments, low maintenance requirements, and high resistance to insects and diseases to estimate performance of urban trees over a 60-year lifespan. Using I-Tree Species, we searched for taller trees, as well as trees with low allergenicity, high interception of water, high uptake of CO2, high wind reduction and high air cleansing properties. We checked the identified trees with the Water Use Classification to rule out species with high water demand, trees on a list species to avoid in light of future temperature predictions for Pleasanton, and trees which were prone to diseases. Taking all these factors into account, the top choice was European Hackberry, which stands at 40-70-ft tall and has a lifespan of 50-150 years (Figure 24). It's a deciduous tree that will be able to provide shade in the summer to help cool, but will lose its leaves in winter, so can then let the sun in to minimize heating costs. Our second and third choices were River Sheok and the Deodar Cedar (Figure 24). The European Hackberry has been heavily planted in the region and has been grown with great success locally (Figure 25). We then calculated and modeled the possible benefits of planting European Hackberry in various locations in terms of costs saved, air quality, kilowatt hours of electricity saved, gallons of water intercepted, and carbon dioxide stored.

1.European Hackberry 2. River Sheoak 3. Deodar Cedar

Figure 24. Tree species recommendations for Camp Parks. Source of images: Pinterest.com

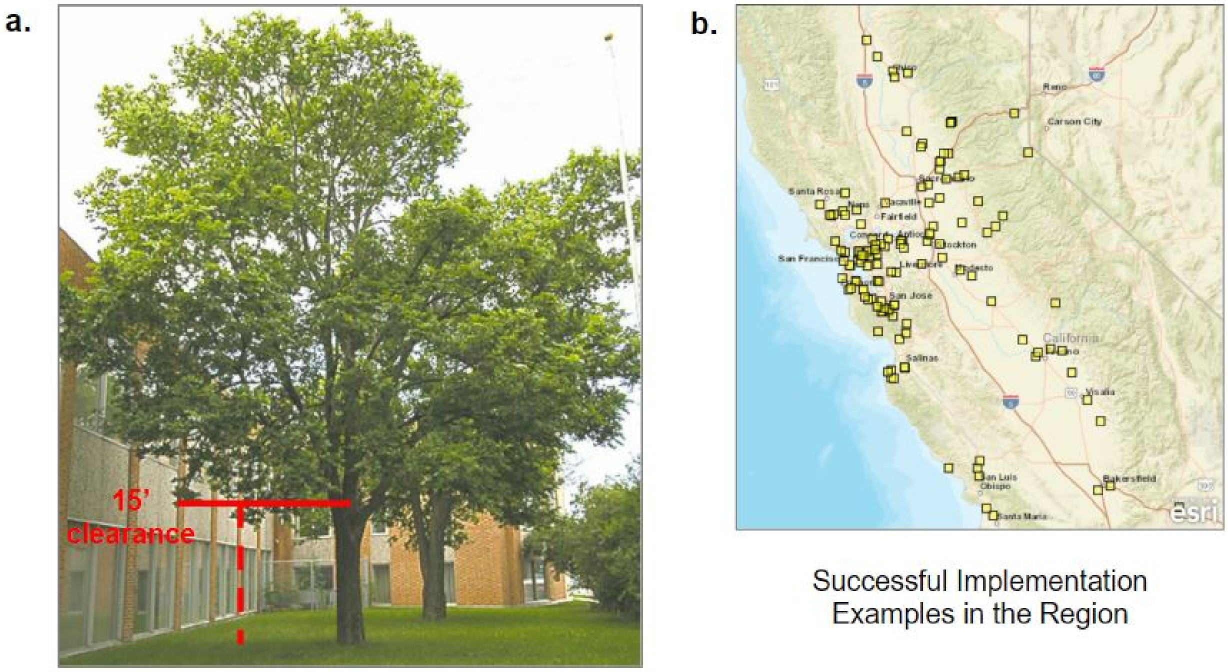


Figure 25. a. Use of European hackberry near buildings. b. Map of successful plantings of European hackberry in region. (source: https://selectree.calpoly.edu/tree-detail/celtis-australis )

Our general modeling approach was to place mature trees (>3 inches in diameter, with their first branches >10 feet above the ground), along the southwest corner of every building, 20 feet away from the building (Figure 26). We started with three to five trees per building, and also modeled increased and decreased density. We assumed each building was post-1980 construction with both heating and air conditioning. (Actual benefits might be great for older, less efficient buildings.) Our model results indicated that, over 35 years, planting European Hackberries around the southwest corners of buildings on Camp Parks could save an estimated 724,500 Kilowatt hours of electricity, cut CO2 emissions by an estimated 3.4 million pounds, intercept an estimated 16.7 million gallons of water, save an estimated $62,000 due to healthier air, and save an estimated $574,000 total (Figure 27). The trees have a longer life-span than 35 years, so the benefits would continue to accumulate over time.

Sufficient trees to shade walking routes between frequently used buildings (such as between classrooms and mess hall) could encourage walking in lieu of driving, and thereby contribute to improving the health of servicemembers, a goal of DoD's 'Operation Live Well' adopted in 2017. Increasing exercise and fitness is a critically important issue, as failure to meet weight standards is a leading cause of involuntary separation from the military.

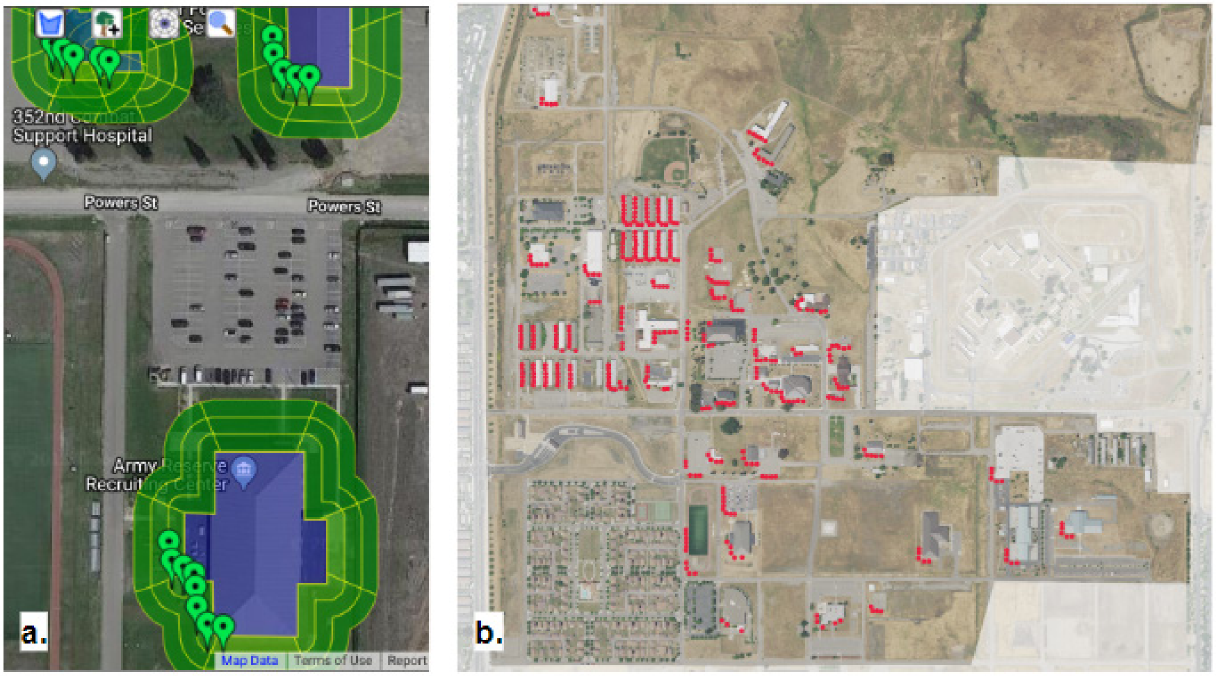


Figure 26. Map showing placement of European hackberry trees around southwest corners of buildings used to model potential benefits of urban forestry on the base.

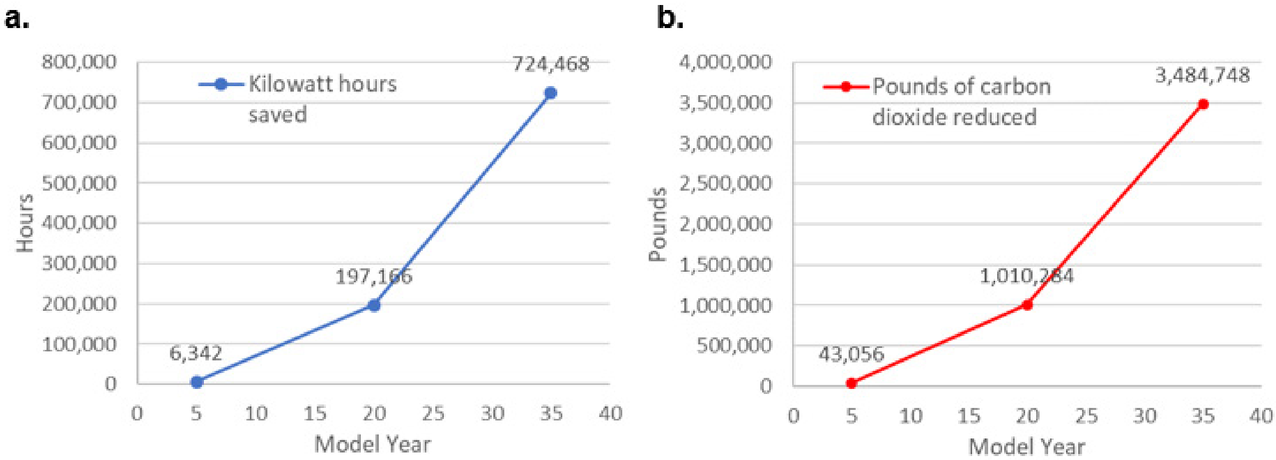


Figure 27. a. Plot of kilowatt hours saved, and b. CO2 emissions reduced, due to reduced cooling demand from trees shading buildings. Benefits calculated using US Forest Service I-tree model.

# Conclusion

By virtue of its strategic location within the San Francisco Bay region, accessible from urban areas across central and northern California, Camp Parks is an exceptional asset to DOD as a centralized training facility, whose functions would be impossible to replicate elsewhere. In response to a request by Base Commander Nolan, we explored ways to increase base resiliency in terms of water supply, energy conservation, and flood management. Two critical characteristics of the base guided our approach: first, that its range is the last open, undeveloped land upstream of an urban area with flood risk and ongoing severe riverbank erosion from increased runoff, and second, that the base cannot now meet its 14-day emergency supply requirements for water supply and power.

In response to the issue of stormwater management, we first evaluated the broader watershed context, on-base flooding, and how the base is currently contributing to downstream runoff. Using data sets from two modeling approaches, we tested several runoff scenarios with future development on Camp Parks property. We then proposed several solutions to slow and detain stormwater on Camp Parks - through large detention basins on the range to take the peak off of downstream flow in large storms and through smaller-scale bioswales and permeable pavement to treat water and increase infiltration in the cantonment. We tailored these strategies to adhere to U.S. Military standards per the requirements of the Unified Facilities Criteria, and we proposed solutions that would minimize cost and maintenance, maximize utility for training, and reduce flooding on-base and downstream.

In response to the issue of the 14-day emergency supply and, more broadly, resilience preparation, we focused on two pillars of base resilience laid out in Army Directive 2017-07 and the ES2 Strategy: water supply and energy independence. For water supply, we proposed diversifying the base's water sources to include greywater, rainwater and, in the case of an emergency, groundwater. We also proposed increasing on-base storage to help meet the 14-day emergency supply and ensure that the base is prepared to meet its own requirements and act as a staging ground for relief efforts. For energy independence, we proposed tree planting to increase efficiency, which would also provide continued energy cost savings for decades to come.

Our stormwater modelling confirms past experience that Camp Parks is vulnerable to on-base flooding and also demonstrates that further development on the base has the potential to increase downstream runoff to already-stressed river channels. We propose stormwater management solutions on the base based on the physical characteristics of the base and application of the US military code, primarily the Unified Facilities Criteria - Installation Master Planning, which guided our design strategy and ensured that our proposal adhered to Army regulations and would enhance the base's operation. Our proposed low-impact development measures could achieve the project's stormwater management goals: decrease runoff to reduce flooding, maintain Camp Parks' day-to-day function, and mitigate the base's impact on its downstream neighbors without impacting training capacity.

To expand water sources and storage to meet 14-day emergency requirements, and to increase resiliency overall, we recommend 1) building a reservoir (an appx 3-million gallon water tank) on-base, to be supplied by Dublin-San Ramon Service District, from which daily water needs would be drawn (keeping water in circulation) but whose storage is sufficient to supply water to the base in an emergency water supply, and 2) diversifying water sources with onsite recycled water, rainwater, and groundwater.  To improve energy efficiency, we recommend reducing demand for cooling by planting trees around southwest corners of buildings for shade, which our application of a US Forest Service model demonstrates could provide significant benefits in terms of reduced air-conditioning demand, concomitant with reduced CO2 emissions and overall savings in operational costs.  Water and energy resiliency can be further enhanced by urban designs to promote walking to meet DoD health directives for service members, reduced water and energy costs, and reduced storm runoff.

The approaches we recommend here have precedents on military bases elsewhere. At Joint Base Lewis-McChord, Washington, a 1.5 mile stretch of Pendleton Avenue was redesigned with permeable paving and rain gardens (Figure 28). Four lanes for through traffic are separated from parallel local traffic lanes with rain gardens and trees. This combination manages and infiltrates 100% of stormwater runoff. A local access lane has trees large enough to provide shade to nearby buildings (Figure 29). At Fort Belvoir, Virginia, buildings frequented by service members were concentrated into hubs to promote walking and physical activity on base with the aim of improving retention, readiness, and resilience of servicemembers.

Our recommendations to manage future stormwater and flood risk, increase water supply, and conserve energy, are summarized in Figure 30.

Figure 28.  Pendleton Avenue on Joint Base Lewis-McChord, Washington, was redesigned with permeable paving and rain gardens, and now infiltrates 100% of runoff from the road.  Source of image: 2019 Cascade Design Collaborative.

Figure 29. Local access lane on Joint Base Lewis-McChord, Washington, with large trees shading nearby buildings. Source of image: estormwater.com

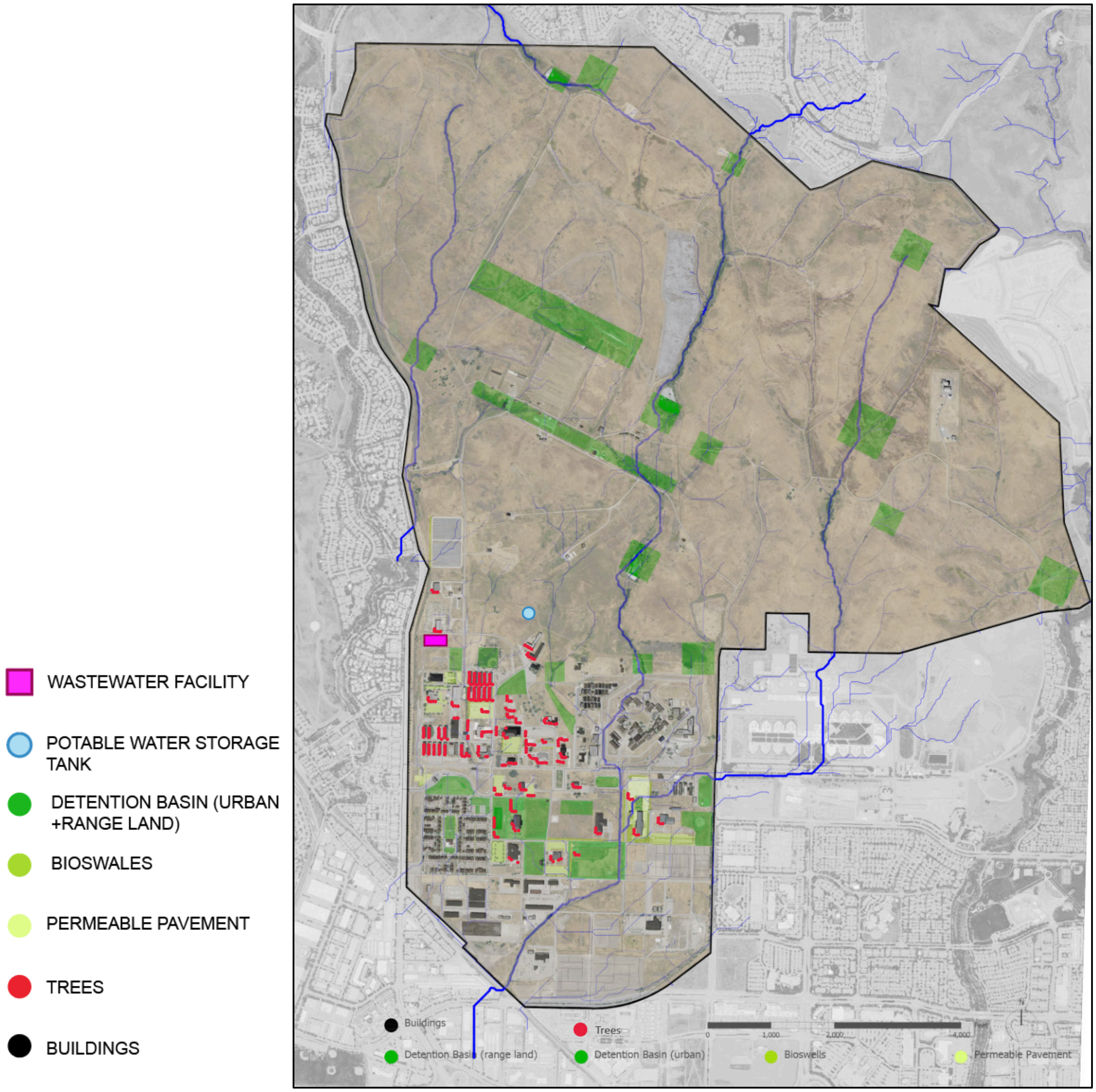


Figure 30. Final plan incorporating results of watershed analysis, stormwater management, and base resiliency planning, as developed by the graduate students in the Environmental Planning Studio.

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The team of graduate students in the Environmental Planning studio class and their advisors. Photo taken on UC Berkeley campus after presention of project results to staff of Camp Parks. Photo courtesy of Camp Parks staff.