Title

Strawberry Creek Restoration: Advancing Stewardship in the North Fork

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Strawberry Creek Restoration: Advancing Stewardship in the North Fork

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Abstract

This paper presents historical overviews and original ecological surveys on the North Fork of Strawberry Creek in Berkeley, California to better inform the Kingman Hall Creek Restoration Project. Analysis of geomorphologic changes in the North Fork of Strawberry Creek during urbanization reveals the legacy of alterations on contemporary ecology. Case studies varying in time, scale, and approach contextualize restoration efforts in the entire Strawberry Creek Watershed. The impacts of urbanization and culverting are evidenced by an ecological snapshot of current creek conditions between LBNL and the UC Berkeley Campus. Rod and level topographic surveys, ArcGIS permeability analysis, vegetation analysis, avian surveys, and macroinvertebrate counts conducted at three distinct locations along the North Fork provide a multipronged baseline survey of current conditions. Topographic surveys show a higher degree of incision below culverted stream sections. ArcGIS permeability analysis reveals a highly urbanized watershed, especially around the restoration project site. Vegetation analysis shows the prevalence of invasive species in urbanized riparian ecosystems. Avian surveys found the majority of birds in riparian areas of the North Fork to be generalist ground foragers. Finally, macroinvertebrate surveys found that the complexity and richness of benthic insects decrease after culverting, suggesting a need for further restoration work along the creek. Our surveys found that the impacts on stream health due to culverting and urbanization are beyond the scale of the Kingman Hall Creek Restoration Project. This paper is intended to provide a baseline for future research on the North Fork.

Problem Statement:

Strawberry Creek is one of many urban streams in the Alameda Watershed, with its headwaters in the hills of the East Bay and its terminus in the San Francisco Bay. For millennia, these riparian zones served as culturally significant foodways for ancestors of the Ohlone community. Over the past 150 years, Strawberry Creek has played a central role in the institutional development of the UC Berkeley campus and urban settlement of the City of Berkeley. Throughout this time, development processes imposed ecologically and geomorphologically destructive alterations upon the creek. Strategies such as serial engineering, culverting and general hardening of riparian zones were implemented to control resulting shifts in creek dynamics. In the 1980s, the success of an unprecedented citizen-led creek daylighting project shifted this paradigm from creek hardening towards more ecologically sound restoration techniques. This enthusiasm spread upstream onto UC Berkeley's campus grounds, where the student body, scientific community, and university administration would increasingly support similar restoration efforts.

Rarely have these efforts extended beyond the campus-owned watershed with the same degree of investment, stewardship, and continuity. Whereas much of the South Fork watershed on and east of campus is held under a unified property regime, the North Fork is fragmented between campus, 46 private properties, and the Lawrence Berkeley National Laboratory (Parcel Data, City of Berkeley Open Data Portal). As a result, most restoration efforts in the watershed occur in the on-campus portions of the Mainstem and South Forks of Strawberry Creek. Meanwhile, ownership, management, and access complexity have led to a dearth of research, restoration, and stewardship along portions of the North Fork beyond campus.

In the Spring of 2023, a student-led restoration effort began at the historic Kingman Hall student cooperative, renewing attention to the off-campus North Fork reach. Funded by The Green Initiative Fund (TGIF), the Kingman Hall Creek Restoration (KHCR), "seeks to stabilize a 100-foot section of Strawberry Creek's failing banks, increase native biodiversity, and foster environmental education and stewardship" (Stanton 2023, 1). This paper, authored by students leading the KHCR, will provide the historical and scientific research necessary to inform their restoration effort.

As such, the intent of this paper is threefold:

1) To situate the North Fork of Strawberry Creek within local histories of colonial settlement, urbanization, and contemporary restoration efforts.
2) To fill a gap in Strawberry Creek restoration literature by providing a foundational ecological snapshot of the North Fork on and between Campus and LBNL property.
3) To inform restoration work within and beyond the scope of the ongoing KHCR.

Situating the North Fork in Strawberry Creek History

Intro to Study Area

From the mid-1800s onward, the development of the UC Berkeley campus and environs led to the alteration of the North Fork of Strawberry Creek's ecology and geomorphology. By the mid-1900s, the North Fork exhibited many characteristics of urban waterways: stream culverting and re-routing, watershed impermeability, channel incision, bank erosion, water quality issues, and loss of biodiversity. In response to this riparian degradation, the Strawberry Creek watershed experienced a series of restoration efforts: traveling upstream from Strawberry Creek Park (SCP) (1983) to on-campus North and South Fork reaches (1988 - 1992, 2006 - present) to the off-campus North Fork watershed (2008, 2011, 2023). These included municipal involvement, citizen activism, campus support, private firm consultation, and student volunteer leadership. Throughout this, multi-party engagement has proven critical to these varying scales of restoration success. Project design and management have evolved along with advancements in urban creek restoration sciences, shifts in municipal code, evolutions in engineering and landscape architectural practice, and increases in community and student volunteership. Distinguishing between the history of *alterations* and *restorations*, the following sections delve deeper into the arc of Strawberry Creek's history to contextualize the ongoing KHCR.

Alterations: Colonization and Development

For millennia, ancestors of the Muwekma Ohlone Tribe cultivated culturally, nutritionally, and medicinally bountiful creeks in the Alameda watershed by maintaining their ecological health and integrity. Starting in the late 1700s, Spanish colonists seized indigenous land, privatizing much of the region and its watersheds (Stratton, 1858). Prior to their missionization and subsequent centuries of cultural erasure, the Ohlone community's hyper-local resource management practices, traditional ecological knowledge, and intertwined culture were integral to the health of East Bay watersheds, of which Strawberry Creek is a part (Fazeli, 22).

By the 1860s, a decade after California gained statehood, the University of California relocated from Oakland to Berkeley. Before purchasing the campus land and corresponding watershed, the Board of Trustees chartered studies to ensure Strawberry Creek could support year-round water consumption. Once confirmed, the "College Water Company" was incorporated as a financial mechanism "authorized and empowered to take and use the waters" (Willey 1887, 172). This led to one of the first documented watershed-wide alterations: conveyance systems from the headwaters to campus. In the North Fork, a single pipe brought water to "Mr. Felton's Reservoir" and "fountain" (Soule 1875). Around the same time, sections of Strawberry Canyon were cleared for livestock grazing, another ecologically damaging use (Resh et al., 294). During this time, the upper watershed rapidly transformed under continued settlement and institutional development.

Figure 1

Meanwhile, Strawberry Creek reaches on and near campus, despite being central to the university's aesthetic and design, soon became receptacles for development and waste management. Notably, while campus architects decided to spare the North and South Forks from development, "the middle fork was drained in the early 1870's" to build a running track that was eventually replaced by the Valley Life Sciences Building. (Charbonneau 1988, 9). By the 1900s, the remaining branches of Strawberry Creek proximal to campus housing became ad-hoc sewage infrastructure and trash dump sites. Figure 1 shows wooden pipes ejecting sewage into the stream centerline. The resulting stench would be used as an argument in support of creek culverting throughout the city of Berkeley, setting the stage for the next chapter of creek alterations (Charbonneau 1988, 15*)*.

Alterations: North-Fork Culverts and By-Passes

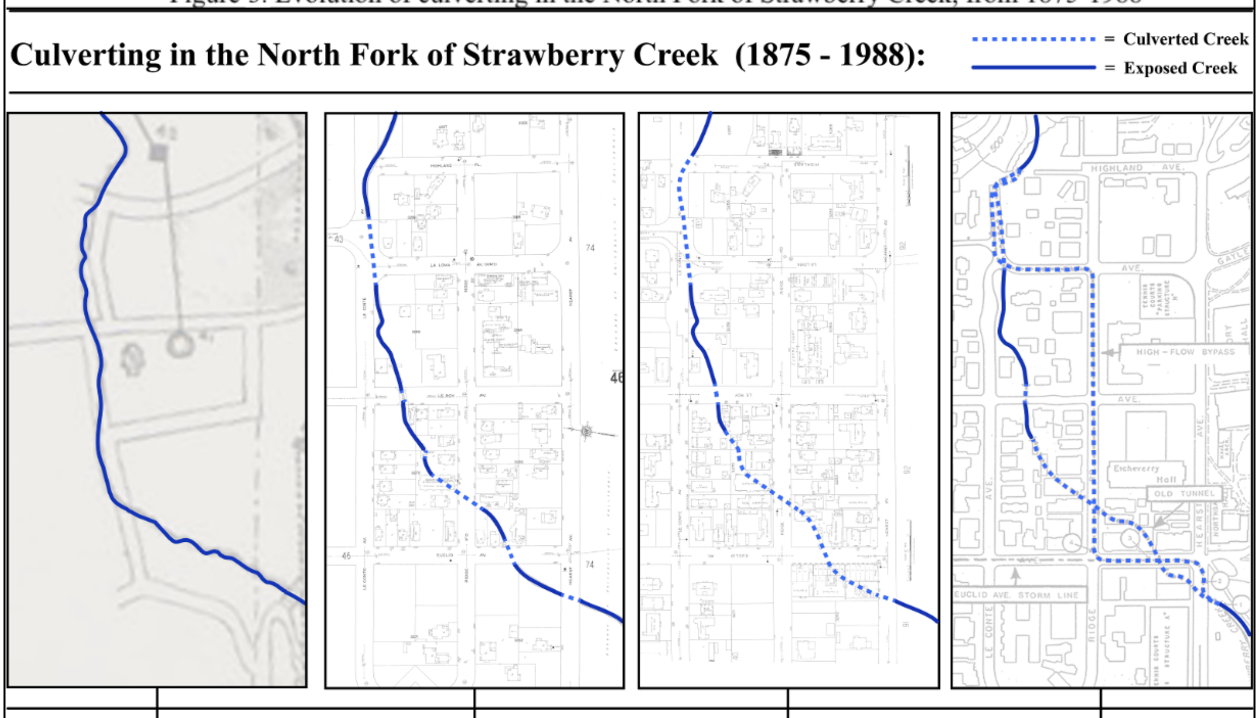
Aside from "Mr. Felton's" residence, the North Fork watershed off campus remained relatively undeveloped through the turn of the 19th century. A 1902 photograph facing east from "Holy Hill" reveals a riparian vegetation corridor unfragmented by urbanization. The only visible structure in the photograph is "at the present intersection of La Loma and Le Conte Avenues," precisely the location of the KHCR site (Figure 2). A written account from the same year speaks to the North Fork's "untamed beauty and waywardness." The creek still boasted morphological health with streambed boulders, natural hillside walls, and ample shade. The vegetation also points to creek health: native oak, laurel, willow, wild rose, blackberry, fern, creeper, scarlet columbine, and thimble-berry were all noted (1903 Blue and Gold, 4-5).

This relatively unaltered landscape did not last long. Figure 3 illustrates that by 1911, streets were laid out, and culverts were built to accommodate them. Notably, 150 feet of the creek was culverted at the intersection of La Loma and Le Conte Avenues, just upstream of the KHCR site. Culverting also occurred downstream with the creation of Le Roy Avenue, Ridge Road, Euclid Avenue, and Hearst Avenue. With the expansion of commercial and residential development in the area, the 1929 Sanborn maps omitted the creek altogether. Despite this erasure, nearly continuous culverting south of Le Roy Avenue can be inferred through extant building footprints. Back upstream, the Eastern portion of Le Conte Avenue until Highland Avenue was extended, adding another 150 feet of culverts.

Figure 2: 1902 image of North Fork of Strawberry Creek, including KHCR site

North of Campus, looking East from what is now known as "Holy Hill." Euclid Avenue will run north-south just below the hill in the immediate foreground. The trees on the right grow along the north fork of Strawberry Creek. The present intersection of La Loma and Le Conte Avenues will lie beyond the barn and to the right (c. 1902).

Figure 3: Evolution of culverting in the North Fork of Strawberry Creek, from 1875-1988



1875: Minor water distribution pipe for single residence (Soulé)

1911: Culverting, urbanization and road establishment begin (Sanborn)

1929: Continued culverting inferred from building footprints (Sanborn)

1988: Majority culverted and urbanized, high flow bypass installed (Charbonneau)

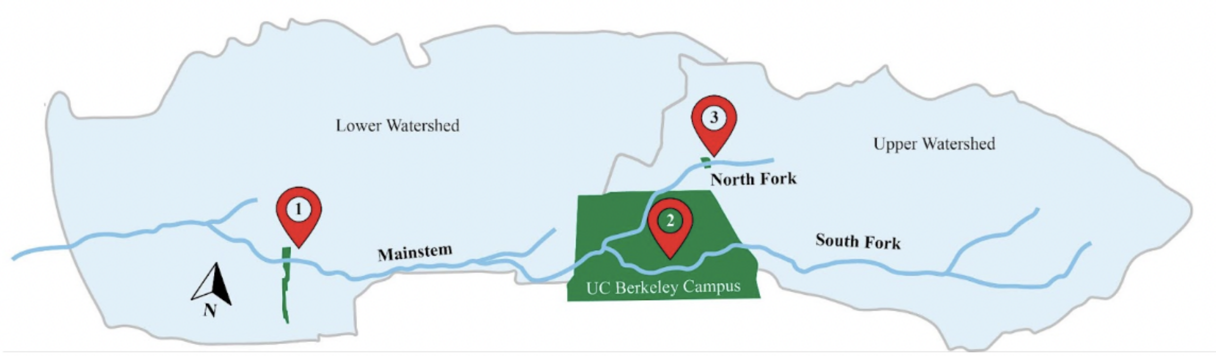
This transformational move by private developers, institutions, and the city to develop much of the North Fork of Strawberry Creek within a few decades was not without consequence to the creek's ecology. Increased watershed impermeability, culverting, and streambed confinement contributed to a "very flashy hydrologic regime" (Charbonneau 1988, 7). Furthermore, the development of the Lawrence Berkeley National Laboratory in the North Fork headwaters during the 40s led to the "obliteration" of upstream portions of the watershed. (Charbonneau 1988, 36) Subsequent serial engineering was required to negotiate these development-induced stream alterations and their associated flood risk.

In October 1962, a heavy rain event brought these flood risks to the fore: extreme erosion pushed small boulders, mud, and gravel into the culvert system, leading to plugging and overflow of the inlet at the eastern end of Le Conte Avenue (Kuntz 1980, 2-3). In response, the campus Consulting Engineer BF Lennert called for installing and integrating an auxiliary 60" high-flow bypass into the extant culvert system. Additionally, in 1966 five check dams were built in Blackberry Canyon just upstream of the bypass to dissipate stream energy coming off of LBNL property (Kuntz 1980, 6). This post-1962 storm engineering response uses the "high-flow bypass tunnels" to redirect instances of flashy hydrology from Blackberry Canyon straight to a campus outlet at Hearst Avenue, notably circumventing all downstream open reaches on private property, including the KHCR site (Figure 3, Charbonneau 1988, 11). It should be noted that the reach upstream of the La Loma culvert inlet in Blackberry Canyon, the KHCR reach, and the reach downstream of the Hearst Avenue outlet are surveyed and analyzed later in this paper.

Figure 4

Case Studies of Restoration in the Strawberry Creek Watershed (1983-2023):

	1) Strawberry Creek Park	2) Strawberry Creek (on-campus)	3) Kingman Hall (off-campus)
Dates Studied	*1983*	*1988 - 1992, 2006 - present*	*2008, 2011, 2023*
Length	*200'*	*2,000'*	*75'*
Ownership	*Public*	*Institutional*	*Private*
Parties	*Berkeley Parks Commission* *Wolfe Mason Associates* *Berkeley Youth Alternatives* *Community leaders*	*Office of Environment Health & Safety* *Lawrence Berkeley Laboratory* *Phillip Williams & Associates* *City of Berkeley* *Student groups*	*Berkeley Student Cooperatives* *Student-residents* *Neighbors*
Funding	*Land & Water Conservation Fund* *Measure Y*	*UC Berkeley Facilities Services* *Chancellors Community Partnership Fund* *The Green Initiative Fund*	*Berkeley Student Cooperatives* *Chancellors Community Partnership Fund* *The Green Initiative Fund*
Approach	*Daylighting* *Revegetation* *Community maintenance*	*Stabilization* *Student revegetation/maintenance*	*Student revegetation/maintenance*



Restoration Case Study #1: Strawberry Creek Park

For nearly two centuries, colonial land management, campus boards, residents, and engineers contributed to the decline of the Strawberry Creek watershed ecology. A preliminary survey of this history reveals drastic changes in riparian corridor geomorphology: increased bank hardening, impermeability, and culverting. The former oak savanna became overgrown, and the last run of salmon and steelhead fish in Strawberry Creek ceased by the 1930s (Schwartz). By the mid-20th century, these ecological losses weighed on the psyche of Berkeley residents and campus community members, especially those involved in a growing wave of national environmental awareness.

Fueled by this cultural context, the 1983 creek daylighting project at Strawberry Creek Park (SCP) was an inflection point for Strawberry Creek and watersheds nationwide. Located roughly 1.5 miles downstream (west) of the North Fork, the future parkland was an industrial lot containing a 200' culverted reach of the main stem of Strawberry Creek. As the second urban creek daylighting in US history, the SCP project was up against deep-seated civic fears, financial constraints, and the limits of the then-nascent stream restoration sciences. To garner support, the Berkeley Parks Commissioner, landscape architects, and other conservation leaders engaged skeptics through educational town halls, invited trusted community leaders to speak on behalf of the effort, and leveraged internal advocates to push the project through city bureaucracy; multi-party engagement that proved critical to the project's success.

Unlike contemporary stream restoration projects, there was "no record of any hydrology or hydraulics evaluations for guiding the project design," nor were there any legal requirements to do so (Riley, 66). Furthermore, cost-saving measures necessitated the creative reuse of on-site concrete for enhanced control channels in the daylit creek. This less impervious structure, while still using concrete, departs from traditional concrete channel enforcements, a theme that will only continue in restoration approaches throughout time. With four decades of perspective on the project, however, some have come to critique the ecological performance of these concrete channels citing increased erosion (Riley 2016, 58).

Restoration Case Study #2: Strawberry Creek (on-campus)

Despite its debated restoration approach, Strawberry Creek Park's historic success profoundly impacted urban creek restoration practice. Many landscape architects, city officials, and environmental activists involved went on to advance the ensuing four decades of ongoing local creek restoration efforts. Many of these occurred upstream on the UC Berkeley campus and were spearheaded by then-environmental planning master's student Bob Charbonneau (Charbonneau 2000, 20). Informed by engagement with the City of Berkeley's "Urban Creeks Council" and with the support of concerned environmental science professors on campus, Charbonneau compiled a comprehensive Strawberry Creek Management Plan for his master's professional report (Riley 2016, 63).

The report famously established the impacts of urbanization on the Strawberry Creek watershed: increased storm runoff and decreased water table levels. His archival research patched together a foundational history of the urban creek, which was then cross-referenced with geological, hydrological, and ecological assessments. Notably, investigations into point source pollution identified major failures in campus environmental management, including sewage leaks into the watershed (PWA 1988, 82). Management strategies and recommendations provided a roadmap that Charbonneau implemented after graduating in 1988 as an employee of the campus Office of the Environment, Health and Safety (EH&S).

Charbonneau's efforts led to the creation of a multi-party committee that included representatives from major watershed property owners: the Berkeley city government and the Lawrence Berkeley Laboratory (Charbonneau 2000, 22). Broader community engagement strategies included educational visits across departments, signage near creek storm drains flowing into the creek to raise public awareness and discourage pollution, and informational mailing campaigns to property owners within the watershed.

As a design strategy, Charbonneau sought to implement soil bioengineering solutions that are "more durable, cost-effective, and environmentally compatible than a concrete wall" (Charbonneau 2000, 23). In 1989, a swath of legislative protections were incorporated into the Berkeley Municipal Code that aligned with Charboneau's restoration approach. In addition to pollution control measures, the code explicitly prioritizes "bank stabilization using vegetation or combination revegetation construction (soil bioengineering)" (BMC, 17.08.060 E). Therefore, some campus restoration efforts under Charbonneau's purview were one of the earliest adopters of these municipally recommended soil bioengineering strategies. For example, to address "serious erosion problems" near Stevens Hall, plans for constructing a crib retaining wall were outlined and implemented (PWA, 1988, 28). Unlike concrete walls or even the enhanced control channel of SCP, this intervention provided bank stabilization using only natural materials, employing wood and live vegetation for structural integrity.

Private firms like Phillip Williams and Associates (PWA) brought professional technical oversight to the erosion mitigation elements of the management plan. Their 1988 report focuses on "bank and channel erosion problems on the campus portions of the North and South Forks of Strawberry Creek" (Phillip Williams and Associates 1988, 3) and suggested actionable interventions to improve these creek conditions. Despite the notable Stevens Hall crib wall project, many of the recommendations under PWA's 1988 and 1991 reports still include hard solutions like concrete aprons, box culverts, bridge abutments, retaining walls, and more. (1991) Conceptual recommendations with more "natural" materials like rock, log, and gabion check dams were also mentioned (PWA 1988, 27-28). These recommendations point to the shifting prominence of hard solutions in Strawberry Creek restoration and management.

In collaboration with UC Berkeley faculty member Vincent Resh, Charbonneau conducted a post-implementation appraisal of these early interventions using similar indicators from his management plan. Water quality in the urban downstream reaches of both the North and South Forks appeared to improve compared with pre-restoration conditions (Resh Table 1, 297). Water clarity and aesthetic value noticeably improved on the central campus, indicated by decreases in downstream suspended solids, turbidity, nutrient levels and fecal bacteria concentrations (Resh, 302). Additionally, there were documented increases in family richness of macroinvertebrates, upstream migration of crayfish, establishment of various fly communities, and successful re-establishment of native fish populations (notably the three-spine stickleback) (Resh, 303). With some hindsight, this post-project appraisal spoke to the necessity of the multi-party engagement process for successful implementation of the 1988 management plan, much like the SCP project.

While recommended interventions involving heavy machinery, skilled labor, and professional consultation were completed within a few years of Charbonneau's plan, other campus creek restoration efforts would continue well into the future. The focus of these restoration efforts shifted from erosion control and stream-bed interventions to vegetation management. In a 2014 interview Charbonneau recalls that "trying to restore native vegetation really lends itself quite nicely to getting students involved." (Cherbowsky, 8) Volunteer student involvement in invasive species management rapidly increased from 2002 - 2006 under campus environmental specialist Tim Pine. Starting in 2007, The Green Initiative Fund further bolstered student involvement in vegetation management with the financial support of nearly a dozen related projects between 2007 and 2014 (Cherbowsky, 9).

Restoration Case Study #3: Kingman Hall (off-campus)

Off-campus restoration efforts in the North Fork remain largely undocumented and less frequent than on campus. However, students living at Kingman Hall have conducted and documented minor efforts through course projects over the past two decades, providing valuable insight into small-scale private property restoration on the North Fork. The earliest documentation found includes a 2006-2007 Chancellor's Community Partnership Fund project that provided $15,000 to implement the Kingman Hall Creekside Amphitheater Restoration Project. By 2008, the project accomplished a community redesign and refurbishment of the primary amphitheater gathering space (namely the terraced stone seats), enabled vegetation management and native re-planting work days, and conducted tree maintenance (Chancellor's Community Partnership Fund Community Report 2009, 3).

A 2011 creek restoration research paper conducted by then Kingman Hall Garden Manager, Sara-Rose Tannenbaum, reports that many of these plants were killed during construction of seismic retrofits at Kingman Hall in 2010. (Tannebaum, 6). Her paper also includes ecological notes and data on bank grade, canopy cover, and vegetation distribution as of 2011. She went on to lead a series of workdays in collaboration with downstream homeowners, including Tellefson Hall, in order to manage invasive species in the reach. Over a decade later, student and Kingman Hall resident Natalie Grivalja conducted a geological survey of the KHCR reach where she recorded creek longitudinal profiles, grain sizes, hydraulic radius, and bank profiles (Grivalja, 2022).

Started in 2023, the Kingman Hall Creek Restoration can be seen as an extension of the student-led and TGIF-funded on-campus efforts and Tannenbaum's research. Tim Pine, Bob Charbonneau and Sara-Rose Tannenbaum all provided preliminary consultation and support for the project in the Spring of 2023. Like us, Tannenbaum was motivated to conduct her research due to the restoration challenges associated with the North Fork's "residential urban landscape and multiple stakeholder properties" (Tannenbaum, 5). Furthermore, we agree that the Kingman Hall co-op's social infrastructure can be leveraged to ensure successful restoration: "an intentional community with already established modes for communication and education is a great asset and source for momentum" (Tannenbaum, 3). The remainder of this paper provides the ecological surveys required to successfully implement the Kingman Hall Creek Restoration after centuries of harmful development and four decades of restoration efforts.

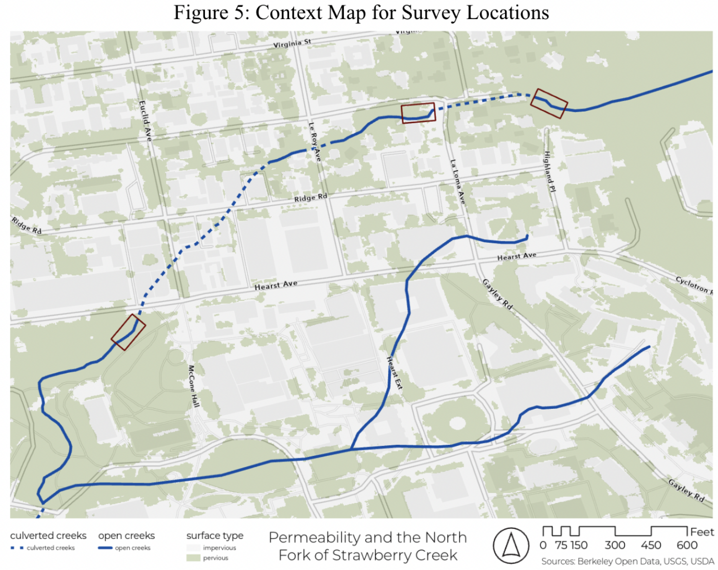
Methods

Study Area and Survey Introduction

We surveyed three sites along the North Fork of Strawberry Creek to compare and understand the factors that impact stream health (Figure 5). We hope that by surveying three distinct sites, we might inform further work on the North Fork addressing its lack of documentation.

The North Fork faces unique challenges: mixed property ownership, inconsistent stream conditions from intermittent culverting, and lack of longitudinal connectivity from culverting and property lines. The three sites we surveyed reflect this heterogeneity. The headwaters of the North Fork are near the Lawrence Berkeley National Lab (LBNL) (ArcGIS stream data, Berkeley Open Data Portal). We selected a 75-foot reach of Blackberry Canyon above the high-flow bypass in this stretch as our "reference site" because it is largely undeveloped.

Figure 5: Context Map for Survey Locations



The North Fork flows from LBNL property through Blackberry Canyon into a culvert and high-flow bypass east of the end of Le Conte Ave. The creek flows 350 ft through an underground culvert before returning to its original channel at Kingman Hall's property, where our next study site is. We are interested in studying this 75-foot reach of the creek to better inform the ongoing KHCR. This site is privately owned and in close proximity to houses and streets.

From the Kingman Hall culvert, the creek flows approximately 380 ft through private property, going underground at Le Roy Ave and surfacing for 120 ft before being culverted again. It flows roughly

810 ft through this culvert before letting out at the Chancellor's Mansion near Hearst St. The final third site is a 75-foot stretch on this property, just below the Hearst Street culvert. It is more developed than the Blackberry Canyon site but less developed than the Kingman site.

In order to create baseline data for future restoration and stewardship of the North Fork, we performed a variety of surveys to build a snapshot of geomorphic and biological conditions. Along with our historical research on the North Fork, this "portfolio approach" (Rubin et al., 2017) is essential to "quantify the range of natural variability" (Rubin et al., 2017). Our surveys were also informed by a previous restoration proposal and research performed by Sara Rose Tannenbaum. Her research combines topographical sketches with vegetation identification and canopy cover estimations of each site (Tannenbaum, 2011).

Topographic Surveys

Longitudinal and cross-sectional surveys compare the geomorphic characteristics of our three study sites. Longitudinal connectivity is important for fish migration, and the transport of sediment and nutrients (Kondolf et al. 2019, 36). Cross sections show lateral and vertical connectivity, important for understanding silt deposition, inundation, social connectivity, and nutrient and surface/groundwater exchanges (Kondolf et al. 2019, 36). These surveys can be used with other methods to indicate stream health.

ArcGIS Analysis

We conducted visualization and analysis through ArcGIS Pro to depict the open and culverted segments of the North Fork and how they relate to the landscape around them. We calculated the North Fork's watershed using flow direction data derived from a digital elevation model (DEM) of the area (Figure 6). Then, using the "classification wizard" tool, we calculated the percent of permeable land within this boundary. We also calculated the permeability in a 100-foot buffer of each reach for more site-specific permeability data (Figure 7). We drew inspiration for the size of the buffer from the EPA EnviroAtlas map (EPA 2018, 1). Impervious surfaces can be used as an environmental indicator (C.L and Gibbons 1996, 245). As "impervious cover increases, the velocity and volume of surface runoff increase" as well, carrying with them pollutants and sediment (C.L and Gibbons 1996, 245). Streams with less than 10% surrounding impervious cover are considered "protected," 10-30% of cover are "impacted," and over 30% of cover are "degraded" (C.L and Gibbons 1996, 245). We classified each stream section and greater watershed according to these parameters.

Figure 6: North Fork Watershed Boundary

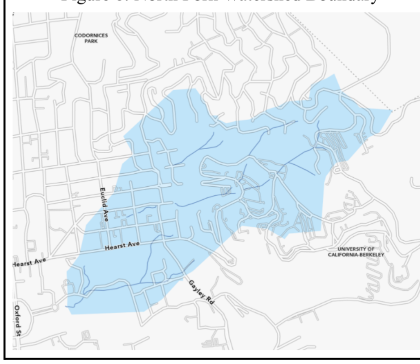


Figure 7 : North Fork open (solid) and culverted (dashed) channel. 100ft buffers around each site. Permeable surfaces shown in green, impervious surfaces shown in grey.

Plant Survey

As a measure of biodiversity, we recorded the vegetation surrounding each site. As native species provide habitat and food sources for local insects, birds, and mammals, we roughly classified natives and non-natives. We also analyzed the vegetation cover and structure, as plant shade over streams can help reduce water temperatures and produce organic matter that create a more hospitable environment for aquatic invertebrates and fish (Knight and Bottorff 1981, 160).

We recorded species within a 15-foot buffer of the stream channel to the species level when possible. We then qualitatively displayed rough plant cover and type for each site. This survey builds off the permeability analysis to provide more detail.

Bird Survey

From late October to early November, we ran four aviary bioblitz surveys conducted within three hours of sunrise, using the point count method for standard data collection. To mitigate inaccuracies, we enlisted the help of local Audubon chapters and used the Cornell Lab of Ornithology's database to confirm sightings.

During each survey, we visited the study sites along the North Fork of Strawberry Creek, within five meters of the stream and the riparian zone. We considered the short distance of one survey site to another by limiting the counting time to 5 minutes for each site (per the recommendation of the USGS & US Forest Services bird count standards, (Ralph et al., 1995)). During the surveys, we used the Grinnell method for field notes and a riparian bird count procedure sheet used by the CA Water Resources Control Board. Our identification of the counted taxonomic families was made primarily through calls and was supported by the Merlin Bird ID mobile app in the field and by audio recordings taken during count time. Our visual identification in the field was aided by binoculars and notes we took describing the specimens' distinguishing traits.

One notable aspect of our aviary studies was the order in which we performed the surveys. Adjusting to low sightings, poor weather, and time change, the first two surveys started at the Blackberry Canyon site and went downhill to the Kingman Hall site, then the Hearst site. We ran the final two surveys in the opposite direction (downhill to uphill) to mitigate the potential bias of survey timing. To process our data, we sorted our results by site and noted the amount of each species. We then looked at the following categories of each species: preferred habitat, diet, and food behavior to determine the amount and distribution of these factors per site.

Invertebrate Survey

For the last aspect of our ecological survey, we sampled for benthic macroinvertebrates at each site using an aquatic d-net to catch the organisms we dislodged from a square foot of riffle habitat upstream the net. We used elutriation to remove larger and heavier pieces of inorganic matter and ran the samples through a fine mesh net to filter out the smallest sediments/creek water. We stored our samples in bottles with ethanol, labeled them, and transported them to the lab. Once in the lab, we split the sample into two using Folsom Plankton Splitter equipment to reduce sample size and decrease processing time (selecting a half of our sorting sample by a randomized coin toss). Our sample halves were then processed under a microscope. We selected the macroinvertebrates and categorized them in groups to order level. We then focused on the three insect orders present across at least two sites: Diptera, Odonata, and Trichoptera and identified them at the family level. Our decision to identify only these groups to a lower taxonomic level was due to time constraints and identification skills. After processing all the samples, we multiplied the results by 2 to replicate/estimate the total amount of invertebrates within each.

We then organized and reviewed our data to examine the distribution of individuals across each order to understand the evenness of the communities we sampled. As macroinvertebrates act as bioindicators of water quality, we also applied several indexes of biotic integrity to our results to calculate and identify each site's creek conditions. We first calculated Simpson's Diversity Index (SDI), which measures community diversity by taking into account both species richness and abundance of each site on a scale of 0-1. We then looked at the amount of EPT taxa present at each site. This measurement system relies on the three orders: Ephemeroptera, Plecoptera, and Trichoptera, as they are reported to be significantly sensitive to pollution and poor water quality (Rief 2002, 1). Lastly, we applied Hilsenhoff's biotic values (FBI) to the identified insect families to further describe the site's water quality, as the FBI is recommended for deciding whether watersheds should be studied further and intended for rapid field procedures (Hilsenhoff, 1988).

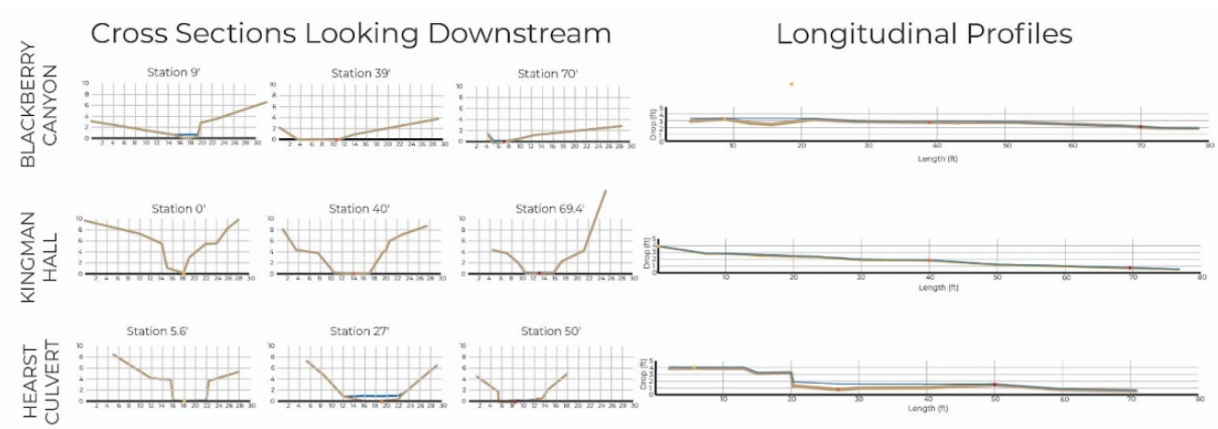
Results and Discussion

Topographic Survey

Figure 8 compares cross-sections and longitudinal profiles for each site. The steepest channel gradient was 5.86% outside the Hearst culvert, which we attribute to the concrete check-dam structure near its opening. Kingman Hall was the next steepest at 4.41%, and this slope has little variability along its longitudinal profile. The Blackberry Canyon site had the gentlest gradient of 1.3% and more riffle-pool formations than the Kingman site.

We can see from the cross sections that the banks of Kingman are steeper than banks at the other two study sites. There appears to be a high degree of incision at the Kingman and Hearst sites and consequent floodplain disconnectivity. Concrete culverts have a Manning's Roughness Coefficient of 0.012, whereas natural stream beds have a coefficient of at least 0.030—over two times more than the culvert (Engineeringtoolbox.com). Water in the culverts is confined to a narrower space and has less friction from the bed, and therefore, flows with more velocity than in its natural bed. Our understanding of stream morphology and topographic surveys suggest that culverting is a factor in the scouring, incision, and floodplain disconnectivity of the stream beds at the Kingman and Hearst sites.

Figure 8: Blackberry Canyon, Kingman Hall, and Heart Culvert Cross Sections and Longitudinal Profiles



ArcGIS Analysis

Our ArcGIS watershed and permeability analysis (Figure 7) determined that the North Fork watershed is 37.96% impervious. Within their respective 100-foot buffers: the Blackberry Canyon site is 3.16%, the Kingman site is 40.83%, and the Hearst site is 11.27% impervious. The percentage of impervious surfaces is likely higher in the overall watershed than within the buffers because the riparian areas within the buffers generally support more vegetation. Using the classification system mentioned in *Methods*, the Blackberry Canyon site is considered "protected," the Hearst site is "impacted," and the Kingman site, as well as the North Fork watershed are "degraded."

Because the North Fork of Strawberry Creek is affected by pollution from watershed-scale imperviousness, restoration projects aiming to improve in-stream conditions should include watershed-level interventions. While native plants are crucial for habitat restoration, solely planting natives along stream banks or restoring aquatic vegetation does not match watershed-level pollution factors and cannot single-handedly improve in-stream ecological conditions (Walsh et al. 2005, 690). In addition to these strategies, there should be a focus on increasing the permeability of catchments, specifically adjacent to the creek and around stormwater drainage pipes that direct water into the creek (690, 702).

Plant Survey

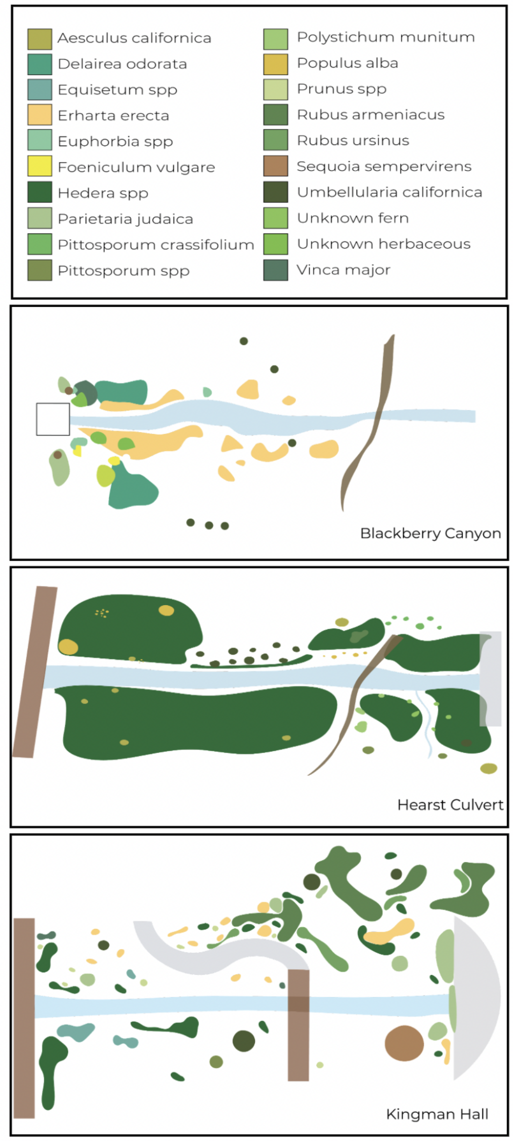
We saw the greatest plant species and structure diversity at the Hearst site (Figure 9). A large fallen log with *Hedera canariensis* (Canary Island Ivy) shaded the stream. There were numerous mature and adolescent trees along this site: a stand of *Umbellularia californica* (California bay trees), *Populus alba* (white poplar), *Aesculus californica* (California buckeye), and *Pittosporum spp*. Many of these trees overhang the stream, dropping leaf litter and providing shade. The banks were densely covered with Canary Island ivy. Ferns and small herbaceous plants were scattered near a small water inlet.

Kingman Hall and Blackberry Canyon were similar in their diversity levels. Trees at the Kingman site included California Bay, *Pittosporum spp*., *Prunus spp*., and an established *Sequoia sempervirens* (redwood). The banks were largely unvegetated with several *Equisetum spp.* (horsetail) scattered near the water. *Parietaria judaica* (pellitory), *Rubus ursinus* (California blackberry), and *Rubus armeniacus* (Himalayan blackberry) are also higher up on the slope.

The Blackberry Canyon site had several fallen California bay trees, as well as other bay trees overhanging. *Ehrharta erecta, Delairea odorata* (cape ivy), *Parietaria judaica* (pellitory), and *Vinca major* (periwinkle) formed a semi-dense ground cover near the drop basin (an area with relatively less shade cover). Much of the floodplain was unvegetated, and there was little shrub-level vegetation.

A number of factors contribute to the vegetation cover of our sites. Development and human preferences for plant species (e.g., the redwood planted at Kingman) heavily impact the landscape around the Kingman and Hearst sites. Mature bay trees dominate the landscape around the Blackberry Canyon site, potentially shading out other vegetation. All sites face pressures from invasives, a common issue in urbanized riparian zones (Stella et al. 2012, 302).

Figure 9: Vegetation maps for each site with key.



Bird Surveys

In total, we observed 57 individual birds at the site in Blackberry Canyon, 58 at Kingman, and 57 at the lower campus site, within 19 species (Table 1). The most dominant species we observed at all sites was the Corvus brachyrhynchos (American Crow), with 102 sightings in total. The high number of American Crow is attributable to a roost site noted to be closest to Blackberry Canyon. The species richness at each site did not vary much, with 14 species at the Kingman site, 13 at the Hearst Avenue site, and 10 at Blackberry Canyon. We acknowledge that the season and weather conditions likely impacted our surveys. Because of this major limitation, we encourage a continuation of aviary surveys for our sites along the North Fork. While our sample size and number of bird surveys limit us from drawing further details about the bird community (per the nature of an ecological snapshot), we can still notice trends in the habitat and foraging selection of the counted individuals.

Table 1: List of Each Site's Species

	Bird Survey - Counted Species		
	Blackberry Canyon	**Kingman Hall**	**Hearst Avenue**
1	Black Phoebe/Sayornis nigricans	Oak Titmouse/Baeolophus inornatus	American Crow/Corvus brachyrhynchos
2	Hermit Thrush/Catharus guttatus	Chestnut-backed Chickadee/Poecile rufescens	Chestnut-backed Chickadee/Poecile rufescens
3	American Crow/Corvus brachyrhynchos	Anna's Hummingbird/Calypte anna	Anna's Hummingbird/Calypte anna
4	Chestnut-backed Chickadee/Poecile rufescens	American Crow/Corvus brachyrhynchos	Lesser Goldfinch/Spinus psaltria
5	House Finch/Haemorhous mexicanus	Steller's Jay/Cyanocitta stelleri	Nuttall's Woodpecker/Dryobates nuttallii
6	California Scrub-Jay/Aphelocoma californica	California Scrub-Jay/Aphelocoma californica	Red-breasted Nuthatch/Sitta canadensis
7	Steller's Jay/Cyanocitta stelleri	American Robin/Turdus migratorius	House Finch/Haemorhous mexicanus
8	Oak Titmouse/Baeolophus inornatus	Dark-eyed Junco/Junco hyemalis	American Robin/Turdus migratorius
9	Northern Flicker/Colaptes auratus	Bewicks Wren/Thryomanes bewickii	Ruby-crowned Kinglet/Corthylio calendula
10	California Towhee/Melozone crissalis	House Finch/Haemorhous mexicanus	California Towhee/Melozone crissalis
11	-	Townsend's Warbler/Setophaga townsendi	Dark-eyed Junco/Junco hyemalis
12	-	Red-breasted Nuthatch/Sitta canadensis	Townsend's Warbler/Setophaga townsendi
13	-	Ruby-crowned Kinglet/Corthylio calendula	Hermit Thrush/Catharus guttatus
14	-	Northern Flicker/Colaptes auratus	-

The overall results of our bird survey show a strong presence of generalist species that can exist and adapt to multiple habitats along the North Fork. This is consistent with the results of a study on avian community turnover on the UC Berkeley campus. This study showed that further urbanization and removal of perennial habitats led to specialist species decreasing "while other, less sensitive species have been able to increase with the additional habitat."(Shultz et al. 2012, 8). In total, 73.7% of our counted individuals are considered generalists in habitat selection. The remaining 26.3% were identifiable as specialists, meaning they rely on a specific food source and require a certain habitat. Despite having the lowest number of bird sightings and species types, we found that the Blackberry Canyon site had 4 specialist species, while the Kingman site had only 2, and the Hearst site had 3. This observed trend correlates with the results of our permeability study and history of development in this area, as Blackberry Canyon had the least urbanized features and Kingman the most—alluding to a far less available natural/vegetational habitat for birds.

We also found that species that ground forage in open woodland ecosystems dominated our survey, comprising 47% of our total species. The presence of shrubbery, healthy soil, and a higher canopy height in their visited habitat is crucial to protect ground foragers and host an ample food source within the topsoil. The historical removal/decline of native habitats/plants and increasing impermeability along the North Fork connect to this by demonstrating the pressures on the bird community to adapt to changing and decreasing food grounds. Additionally, the diet types of the birds we observed support this strong presence of foraging behavior: 57% of total individuals were insectivores, 21.1% consumed seeds, and 15.8% were omnivores, all of which are accessible to birds in topsoil. The diet types observed also speak to the importance of preserving open spaces and native flora. An increase of green spaces with open canopies and shrubbery would provide more habitat and likely encourage the populations of specialist birds that we observed during surveys, such as the Baeolophus inornatus (Oak Titmouse) and Melozone crissalis (California Towhee).

Our results from the aviary surveys are regrettably too limited in scope to make any further site-specific or community inferences. A larger-scaled data set would draw much firmer conclusions and a more accurate representation of the community structure/conditions of these sites. We hope our surveys provide a basis for such future endeavors.

Invertebrate Survey/Substrate Survey

We sampled 2,043 aquatic organisms from the benthic zone of the North Fork: 313 in the Blackberry Canyon Site, 1,076 in Kingman, and 654 from the Hearst Avenue site. Although significant, the difference in the number of individuals observed at Kingman compared to the other two sites does not necessarily indicate a healthier community. Of the 5 orders: Diptera, Odonata, Trichoptera, Mollusca, and Terrestrial/Misc, we found the Kingman Hall Site had the highest number of Mollusca with 85.50% of its individuals sorting of that category (Table 2). Most snails sampled were identified to be in the Lymnaeidae (a pond snail) family. A recent study finds these snails to be “resistant or resilient taxa" to pollution (Tampo et al. 2021, 8). Since these snails use pulmonary absorption to respirate, they are able to exist in low-oxygen environments, which are indicative of high levels of pollution. The results from our application of the Simpson's Diversity Index (SDI) also confirmed that the Kingman Site was the least diverse in species abundance: It scored 0.26, significantly lower than Blackberry Canyon at 0.52 and Hearst at 0.55.

While the Hearst Avenue and Blackberry Canyon survey locations had lower amounts of Mollusca (54.13% and 17.89% of their total population), they both had a large percentage of Dipterans. This order comprised 81.15% of the Hearst site’s sample and 65.81% in Blackberry Canyon. The higher percentage at the Hearst site indicates unhealthy water conditions as dipterans are “classified as tolerant or indifferent taxa" (Tampo et al. 202, 9).

Reviewing the Dipteran families we identified from the three sites, all three (Stratiomyidae, Simuliidae, and Chironomidae) have an FBI of 6 or 7. This means that they are fairly tolerant to polluted water and therefore are able to live within the whole range of conditions of North Fork. Two families were present for the Odonata: Aeshnidae (FBI of 3) and Coenagrionidae (FBI of 9). It is important to note that the far more sensitive of the two was found only at Blackberry Canyon, while Conegrionidae was present at each site. This indicates the water quality becomes poorer below the first site, parallel to increased human presence and suspected impermeable surface runoff further down the creek.

Table 2: Summary of Macroinvertebrate Order Abundance Across Site Samples

North Fork of Strawberry Creek 227 Invertebrate Samples - Abunance of Orders						
	Blackberry Canyon			Kingman Hall		Euclid Culvert
Insect Order Type:	# Counted	% of Population	# Counted	% of Population	# Counted	% of Population
Diptera	206	65.81%	96	8.92%	254	81.15%
Odonata	33	10.54%	46	14.70%	42	13.42%
Tricoptera	12	3.83%	6	0.56%	0	0%
Other Invertebrate Order:						
Mollusca	56	17.89%	920	85.50%	354	54.13%
Misc	6	1.92%	8	0.74%	4	0.61%
Total:	313		1076		654	

Finally, we looked at the percentage of EPT taxa present at each site. This system of measurement relies on the three orders: Ephemeroptera, Plecoptera, and Trichoptera, as their nymphal stages are known to be significantly sensitive to pollution and their presence within an aquatic ecosystem means healthier conditions and lower water pollution levels (Rief 2002, 1). The Hearst site had 0% EPT taxa present, the Kingman site had 0.56%, and the Blackberry Canyon site had 3.83% EPT taxa. This shows a linear correlation between the creek's health in terms of water quality pollution and complexity of invertebrate communities, and the amount of urban impact as the creek descends in elevation. The trichoptera families we identified were Hydropsychidae and Polycentropodidae, which hold FBI rankings of 4 and 6, respectively, with Polycentropodidae found at Blackberry and Kingman. An interesting point of note is that while there were more tricopterans at Blackberry, the most sensitive family was found at Kingman.

This prompts our recommendation that further sampling and work must be done at this site to examine this contrary data further.

From our benthic sampling, we are able to determine the impacts of the increasing presence of urban structure, impervious surfaces, and culverts on the macroinvertebrate communities of the North Fork through both Shannon's Diversity Index and pollution sensitivity of the taxa present at each site. The higher quality of water found at Blackberry Canyon can be linked to the relatively low level of human disturbance and the more consistent flow (due to a lack of immediate culverting/bypass). These aspects have allowed for a more complex and rich invertebrate community to be established, which in turn may also be connected to the stronger presence of specialist birds there. Our survey shows that the Kingman site's low flows resulting from water diversion due to the high-flow bypass also greatly influence the poorer habitat structure and health of the macroinvertebrates. Furthermore, the absence of EPT taxa in the Heart Avenue sample, paired with the higher percentages of mollusca and dipterans, alludes to strong impacts from the urban slobber and the culvert that exists directly above this site.

Conclusions/Proposal for Future

To this day, we see the downstream effects of physical creek alterations from as early as the 1870s. We have traced the evolution of Strawberry Creek restoration approaches from concrete culverts and hardening channels to daylighting and bioengineering. With these changes in physical restoration techniques, there is also an increased emphasis on community engagement and involving a greater scope of collaborators in stream restoration projects. We also see the importance of post-restoration monitoring as a measure of restoration success.

The culverting and development of the North Fork of Strawberry Creek directly influences the inconsistent geomorphic and ecological conditions we see at each site. Benthic macroinvertebrate surveys highlight how altered hydrology (via successive culverts and the high-flow bypass) have detrimentally impacted riparian ecology in the North Fork and affected aquatic insects. Bird surveys likewise display further specialization and habitat preferences for more open and less anthropogenically impacted spaces. Topographic surveys demonstrate how culverts have altered stream flow and contributed to stream incision. ArcGIS permeability analysis shows how property regimes affect urbanization; residential areas tend to have more urbanized riparian zones, and the creek functions as a landscape feature more than an ecological hotspot.

Our historical research, data collection, and analysis help build a body of knowledge on the North Fork to ultimately inform the Kingman Hall Creek Restoration (KHCR). Studies of previous restoration efforts also help advise our planting lists. Post-restoration monitoring at the Strawberry Creek Park project revealed that long-term survivors were generally trees, namely "redwoods, sycamore, alders, cottonwoods, buckeyes, and willow" (Riley 2016, 62). There is also a larger trend in stream restoration projects that fail to establish new vegetation in shady conditions (personal communication with Ann Riley 2016, Oct 2023). For example, the First Annual Monitoring Report for the West Circle Crib Wall states that plants on the bank adjacent to the Eucalyptus Grove are more shaded and in clay soil, therefore having a lower survival rate (Pine 2022, 2). This justifies our canopy management plan, where we removed diseased and invasive trees and allowed more sunlight onto the slopes. We will also prioritize planting in areas with more sun and gentle slopes to maximize survival.

We recognize that stream health is a watershed and process-level issue that cannot be improved solely through the planting of native species and site-specific bank stabilization. Based on our findings from the permeability study, we recommend large-scale interventions to enhance the permeability of the wider watershed, especially around storm drains. It is widely recognized that culverts have "very low residence time, ecological benefit, and land requirements" (Serra‑Llobet et al. 2022, 20). Daylighting culverted sections of the North Fork would potentially result in more complex levels of invertebrates and improve the water quality along certain creek reaches. However, it should be noted that such a daylighting project is unlikely given the costs and density of urban development on the North Fork. Based on strategies from historically successful SCP and on-campus restoration efforts, we recommend multi-party engagement with institutions like the LBNL for these large-scale and long-term projects. LBNL's Long-Range Development Plan for the next 20 years comes out in 2025 and is an opportunity for increased awareness on the North Fork.

Beyond ecological benefits, urban stream restoration projects "can provide positive reinforcement and a sense of empowerment to local groups. In many respects, the greatest benefits to restoring local urban creeks are the social benefits that accrue through the process of community building and the public environmental education achieved" (Kondolf et al. 2008, 43) In this spirit, we aim to continue fostering environmental education and stewardship through the Kingman Hall Creek Restoration.

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