Final Draft

A Royal Flush? Ecological and Social Success of Urban River Restoration on the Truckee

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Abstract

We conducted a multifaceted post-project appraisal of the Truckee River Whitewater Park at Wingfield Park in Reno, NV, evaluating the park's ecological and social benefits. A small dam removal and urban corridor revitalization project completed 15 years ago, the whitewater park was designed for recreational use with hoped-for ecological and social benefits. To compare pre and post project conditions, we quantified physical salmonid habitat heterogeneity at a reference dam site very similar in design and function to the dam that was removed in Wingfield Park in 2003 and at Wingfield Park. We also obtained design documents from and interviewed project designers, and analyzed repeat satellite imagery. We measured depth and velocity variation, substrate size distribution, and mapped facies to compare the current conditions to the reference dam site and pre-project conditions. To understand salmonid response to the project since 2003, we drew upon electroshocking fish count data provided by the Department of Wildlife. We documented an increase in physical salmonid habitat heterogeneity, which likely correlated with the measured positive response in juvenile salmonid populations. Regarding social benefits, past studies have indicated that projects designed for whitewater recreation can also provide benefits to a more diverse, non-whitewater user group. We mapped behavior, conducted a demographic study, assessed physical connectivity dimensions, and

conducted on-site interviews and surveys to compare current social interactions with the river at Wingfield Park to pre-project conditions, and to Idlewild park, which is located just upstream. Social connectivity of the river improved for a diverse local community as well as visitors, making human interaction with the river possible, and allowing park users to take a refreshing dip in the Truckee snowmelt after dipping too deep in their wallets at the blackjack table half a block away.

Introduction

Centuries of anthropogenic activities have compromised the ecological integrity of riverine ecosystem services worldwide (Wantzen et al., 2016). River restoration activities are proving to be essential towards rejuvenating the recreational, spiritual, social and environmental ecosystem services provided by rivers (Watzen et al., 2016, Vörösmarty, et al., 2010). River restoration is often defined as "repairing waterways that can no longer perform essential ecological and social functions" (Palmer et al., 2006). The successful river restoration project addresses biological and natural restorative features in landscapes. Project surveys worldwide have shown that changing hydro-morphological conditions of rivers can help in improving instream physical habitats (Bernhardt et al., 2005; Brooks et al., 2007; Nakamura et al, 2006; Leps et al., 2016).

The popularity of river restoration has increased in recent times including fights to remove hydroelectric dams, resurrect natural river processes, and create habitat for native species, but also the reconnection of an urban river to its community. An urban context presents many social and physical challenges, in many cases surpassing those of their rural counterparts.

These urban projects also present interesting human interactions and connectivity between the river and the communities they serve. The complexity and dynamic nature of restoration projects emphasize the importance of pre-project evaluation, comprehensive geomorphic and ecological evaluations, and post-project assessments for effective projects.

The Truckee River formerly supported spawning runs for anadromous salmonids including Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*), endemic to the area. Non-native salmonids have more recently been introduced including Rainbow Trout (*Oncorhynchus mykiss)*, Brown Trout (*Salmo trutta*), and Mountain Whitefish (*Prosopium williamsoni*). It is generally accepted that there were two spawning runs from Pyramid Lake (winter and spring) that would ascend the Truckee River annually (Hawks, 2018). With the Influx of European settlers in the early 1900s, significant anthropogenic changes to the system, including water diversions, over-harvest of fish, habitat alteration, reduced water quality and quantity, and introduction of non-native salmonids, led to the decline and near elimination of Lahontan Cutthroat. Today, protection of all salmonids and their habitat is the goal of many restoration projects in the Truckee.

Though located on the banks of the Truckee River, Reno has historically turned its back on the river in lieu of its indoor attractions. Reno, Nevada, “the Biggest Little City in the World”, was battered by massive flooding in 1997, followed by a weak post-9-11 economy and increasing competition from new casinos all over the U.S. The City of Reno was betting on a new plan to revive the economy that develops and promotes the region’s natural outdoor attractions. Completed in 2003, the 1.5 million-dollar whitewater park in downtown Reno was a key component in the City’s Truckee River Recreation Plan to create economic diversity and redevelop the downtown (Figure 1). The Reno Whitewater Park has revitalized a once deteriorating section of the City and become Reno's greatest outdoor attraction (Figure 3). With a dramatic increase in recreational usage and public access the whitewater park generates an estimated $18-39 million in economic output (Powers, 2004). Mayor Robert Cashell called the Reno Whitewater Park the best capital investment project he made in ten years of being mayor.

The whitewater park project at Wingfield Park involved the removal of the Arlington dam, a decommissioned diversion dam in downtown Reno. The dam was an inhibition to river navigation, posed a significant safety hazard, was unsightly, and restricted fish passage while likely creating homogeneous habitat conditions for instream salmonids. In an effort to integrate river recreation improvements with instream habitat improvements at Wingfield Park, the dam was replaced with 11 hydraulic structures in the river with natural materials. This significantly altered river flow conditions which strongly affect salmonid habitat conditions and fish passage.

Post-project appraisals for river restoration projects are rare (Rubin et. al. 2017), but post-project appraisals for whitewater parks are even more rare, and there is little research and literature regarding the effect that instream recreation design has on salmonid habitat (Kolden et al. 2015). The Reno whitewater park is no exception, with no official ecological assessment ever completed. Though instream recreation was the primary intent of this project, significant ecological benefits and social connectivity to the river were secondary goals. Thus, this appraisal was twofold: first, we examined salmonid habitat heterogeneity benefits by comparing pre and post project conditions using a reference dam site, pre-construction imagery, and original project reports; second, we analyzed social connectivity improvements at Wingfield Park by comparing social interaction conditions before and after the construction of the whitewater park and also by comparing Wingfield to Idlewild park just upstream.

Methods

ECOLOGICAL EVALUATION METHODS

STUDY SITES

In a paired site study, we used a reference dam site approximately three miles upstream of Wingfield Park to replicate the pre-project conditions in Wingfield Park's north channel. The Arlington Dam that was removed as part of this project was a diversion dam crossing the entire north channel at Wingfield Park and is shown in Figure 5. The reference dam site three miles upstream is also a diversion dam, and incorporates many of the same features as the original Arlington Dam (Figure 6). We chose two specific study sites at the dam site; a cross section just upstream of the dam and a cross section just downstream of the dam. At Wingfield Park, we studied both the North Channel and South Channel using 3 cross sections and a longitudinal profile that represented the diverse topography of the park (Figure 7).

PHYSICAL MEASUREMENTS

Our field work for this study consisted of three intensive days of measurement at the two different sites. At each study site, we surveyed cross sections and longitudinal profiles using a TopCon level, 25-foot rod, and 100-foot tape. Cross section 1 at Wingfield Park is located just upstream of the island and all designed instream features. Cross section 2 is just below the 2nd drop in the north channel, which is the site of the removed Arlington Dam. Cross section 3 is just downstream of the island at the confluence of the north and south channels. At the reference dam site, we surveyed two cross sections, one just upstream of the dam and one just downstream of the dam (Figure 8). We surveyed a 1176 ft longitudinal thalweg profile of Wingfield Park's north channel (Figure 7) and a 293 ft longitudinal thalweg profile survey of the dam site (Figure 8).

In order to achieve an accurate portrayal of the difference in flow complexity at the two sites, we measured velocities at 265 different points throughout the whitewater park and the reference dam site. We used a JDC Electronics Flowatch Flowmeter that uses an impeller to electronically calculate fluid velocities with an accuracy of ±2%. Point velocities taken every five feet were measured across each of the same cross sections that were surveyed, as well as additional cross sections containing significant features within the whitewater park. We measured point velocities along the longitudinal thalweg profiles of both the north and south channels at the whitewater park and at the dam. We measured longitudinal velocities approximately every 15 feet. The velocities were measured at 60% of the depth, which is often measured based on the assumption that this is the average velocity in a vertical column (Harrison et. al 2004).

We used the Wolman Pebble Count method and a double phi gravelometer to measure the intermediate axis of 100 pebbles at each study site site, executing random walks at each of the surveyed cross sections.

For facies mapping pre-whitewater park construction, we used Highly Rectified Orthoimagery (HRO) aerial photography from December 2002. We then identified and drew out the prominent stones diverting the flow. For current conditions, we used field observations and a DJI Mavic Pro drone to map facies and channel features.

ADDITIONAL RESOURCES

We used US Geological Service (USGS) discharge data from the Truckee River gage in Reno (USGS Gage 10348000) over a time period of 94 years to assess monthly average water discharge throughout the year as well as the daily discharge the Truckee has seen in 2019.

We interviewed the whitewater park design engineers and obtained access to drawings, pre-construction photos, design reports, and technical studies. This yielded additional information regarding basis of design, regulatory scrutiny, and ecological history as well as a deeper insight into the social and ecological setting of the site 15 years ago.

We obtained data from Nevada Department of Wildlife (NDOW) that is the result of a Memorandum of Agreement between NDOW and the Pyramid Lake Paiute Tribe dating back to 2002. As part of the agreement, annual fish population sampling has been conducted utilizing electrofishing techniques on the Truckee River since 1971. This technique utilizes the Smith Root 5.0 GPP tote barge for a single pass fish survey. It was done at 11 transects along the Truckee River in the Fall each year, and included data at Wingfield Park in 2003, 2004, 2005, and 2013. The Reno whitewater park was constructed in the Winter of 2003, so the 2003 study was completed before the project was constructed, and thus serves as pre-project data.

DATA ANALYSIS

We used simple nonparametric tests to quantify the range of variation in water depths and flow velocities, and boxplots for graphical representation of variation along with calculations of coefficients of variation (CV) for variables. We calculated median (d50) grain size at each location. We used the longitudinal profile survey data to visualize differences in bed morphology as well as determine pool area and spacing. Instream facies mapping allowed a comparison in number and area of salmonid habitat features before and after the project. We analyzed the fish count data by comparing salmonid populations and juvenile percentages from year to year as well as in various zones along the lower Truckee.

SOCIAL EVALUATION METHODS

STUDY SITES

To evaluate the success of Wingfield park in bringing people to the river and to assess the social connectivity after the installation of the whitewater park, we compared Wingfield Park to Idlewild Park as they are both parks adjacent to the Truckee River and of close proximity to each other and to downtown Reno. In this paired site study, we used Idlewild park as an example of a park next to the river whereas Wingfield is a dedicated river park. Idlewild park is a 7.4 acre park that features a pond with a kids train around the perimeter, a pedestrian/bike path along the Truckee river, and a playground near the pond. Wingfield Park is a 3.25 acre urban space in downtown Reno consisting of an island in the Truckee river, with Arlington Ave running north-south. It includes the whitewater park with 11 drop structures, a shared-use path, 3 pedestrian bridges, and an amphitheater.

OBSERVATIONS OF PARK USES

We conducted field observations of park uses on Saturday, November 2nd from 12-4PM and Saturday, November 23rd from 12-4PM at Idlewild Park and Wingfield Park. Each of the observations was 10 minutes in three different locations within the two parks. Wingfield park was divided into two sections separated by Arlington Ave. We conducted the demographic study (age and gender) in a similar manner for Wingfied East/West and Idlewild parks at the same time as the behavior mapping. Five different age categories were analyzed: toddlers, kids, young adults, adults, and seniors.

We focused on the longitudinal, lateral, and vertical connectivity to the river when we observed each site. Social connectivity refers to the communication and movement of people, goods, ideas, and culture along and across rivers similar to the longitudinal, lateral, and vertical connectivity described by river hydrology and ecology connections (Kondolf & Pinto, 2017). Longitudinal connectivity refers to the major transportation or navigation route located along the river, and longitudinal pathways, sidewalks and riverside parks that facilitate longitudinal connectivity. Lateral connectivity is related to the movement across the water and embankment and bridge design, which enhances connectivity of the city with the river. The vertical connectivity is defined as the range of human activities related to the height above the water.

We used behavior mapping similar to the methods outlined in the Cosco and Moore study to record the observations at Idlewild and Wingfield parks, mapping the location of park activation, including the type of activity (biking/skateboarding, walking/running/playing, fishing/river activity, and sitting/standing/lying) in each park and the location of where these activities were taking place. We made comparisons of the behavior maps between Wingfield and Idlewild Park to understand the locations of activity types at each park. In addition, we took the photographs shown in Figures 10-12 at each park to document overall activity types/locations and pedestrian movements.

INTERVIEWS & SURVEYS

We conducted surveys and interviews to determine differences in the type of visitors to each park, but focused on Wingfield Park to conduct the majority of the interviews and surveys. We interviewed park visitors to understand how people currently interact with Wingfield Park and how it was used and viewed before the whitewater park. For the surveys, we randomly handed out 40 questionnaires to 40 people who were using Wingfield Park. The questionnaire asked questions about demographics, travel distance and method, time spent at the park, activities, and park perception.

Results

ECOLOGICAL EVALUATION RESULTS

High flows on the Truckee River recorded in Reno at USGS Gage 10348000 generally occur in the months of April through June, and drop in the late summer (Figures 13). The average monthly flows range from 262 cfs in September to 1,470 cfs in May. Mean daily flows for 2019 were considerably higher than usual, with the discharge only dipping below the 94-year median daily statistic in January and November (Figure 14).

As reflected in the longitudinal profile of the thalweg (Figure 15), the morphology of the whitewater park is consistent with the intended step-pool design, with pools as deep as ten ft and riffles as shallow as 1 ft. In contrast, the thalweg profile at the reference dam site shows monotonous bathymetry aside from the dam itself (Figure 16).

The results of the cross sectional depth analysis are reported in Figures 17-20. The whisker-box plot in Figure 17 illustrates a large difference in cross-sectional depth heterogeneity between Wingfield Park and the reference dam site. We see that the depth both upstream of the dam and downstream of the dam is between 2 and 4 feet deep the entire distance across the channel. In contrast, all 5 cross sections (including both north and south channels) at Wingfield Park had dramatic variation in depth ranging from 0 to 8 ft deep. Table 3 summarizes the depth variation data.

Figures 21-22 display the results of the 265 point velocity measurements at Wingfield Park and at the dam site. The velocity results at the 9 different cross sections measured at Wingfield Park show that the average velocities for each cross section vary significantly, indicating overall heterogeneity throughout the whitewater park. In addition, velocities measured across some of the cross sections are very heterogeneous, indicating dramatic local velocity variation in many places. In contrast, the median velocity measurements at the dam site cross sections indicate homogeneous flow throughout the reach. All three cross sections at the reference dam site are also locally homogeneous, with similar velocities measured across the current from bank to bank. A look at the velocity measurements taken along the longitudinal profiles also shows heterogeneity in flow throughout the whitewater park, with much slower velocities in the south channel than the north channel.

The results of the pebble counts at the five different locations can be seen in Figure 23. The whisker-box plot illustrates a variation in median grain size throughout the whitewater park, with d50 values of 22, 32, and 44 at the three cross sections studied. Within each cross section at the whitewater park, we observed little variation in grain size. At the reference dam site, the d50 value below the dam was 32 and the d50 value above the dam was 64. Both cross sections had a larger variation in grain size than at the whitewater park..

Figures 24-25 illustrate the difference in instream facies between the pre-whitewater park conditions and post-whitewater park conditions. With the Arlington Dam present in the pre-project conditions, as well as concrete walls on both sides of the channel and very few instream features apart from the dam itself, quantity and diversity of instream features before whitewater park construction is minimal. In contrast, Figure 25 shows current conditions with locations of current deflectors and habitat boulders throughout both channels.

Tables 4-5 summarize the electroshocking fish count reports that were provided to our research group by NDOW. The study focused on salmonid species including Brown Trout, Rainbow Trout, Mountain Whitefish, and Lahontan Cutthroat Trout. No Lahontan Cutthroat Trout were found in the study. A comparison between 2003 and 2004 shown in Figure 26 reflects a subtle increase in salmonid density between 2003 and 2004. Table 6 and Figure 28 show the results of the 2013 study comparing Wingfield Park to other sections of the Truckee, in which Wingfield has the highest salmonid density of any study site including Zone 5 that contains our reference dam site. The 2013 study also reveals a high percentage of wild salmonids in Class I. In addition, NDOW reported in 2016 that the populations at Wingfield park were again some of the highest in the Lower Truckee River (Hawks 2017).

SOCIAL EVALUATION RESULTS

SITE ANALYSIS

The redesign of Wingfield park shown in Figures 1-4 compared to the previous park layout include the addition of a pedestrian bridge on the west side of the park with an entrance plaza and sculpture garden, two new shared-use paths on both the west and east sides, and an underpass path connecting the two sides. The whitewater park integrated U-shaped drop structures lined with boulders with the removal of the dam into the park redesign.

Both Wingfield and Idlewild parks are in close proximity to the Truckee river. Pedestrian movement at Idlewild is primarily focused on the path following the river, but with a natural riparian buffer shown in Figure 12, and the main pedestrian activity is concentrated in the playground. At Wingfield, park users access the park from the surrounding downtown area using the foot bridges from the riverwalk and move through the park to the north and south while experiencing the river, the bank, and whitewater park and navigating the central paths connecting the bridges.

SITE OBSERVATIONS

There are noticeable differences when comparing the behavior mapping in Figures 28-31 for Wingfield Park and Idlewild Park. First, when observing the visitors at Idlewild park we noticed that there were no users in the river compared to five individuals experiencing the river at Wingfield Park. We also observed more activity in and around the streambank at Wingfield as there are several access points to the river from the park. The behavior map of the western portion of Idlewild Park is dominated by a playground which is closer to the interior of the park and is fenced-off making access to the river more difficult. The demographic study summarized in Figures 32-33 also revealed that there are more overall users and that there is a more diverse range of age groups enjoying Wingfield compared to Idlewild park.

SURVEYS/INTERVIEWS

From the survey conducted at Wingfield Park shown in Figure 34, the most common visitor was male (57.5%), between the ages of 21-40 (42.5%), caucasian (60%) and almost 40% of the users had an annual family income of $25000-50000. More than half of the park visitors travelled to the park from more than 5 miles away (57.5%) typically by car (70%). Over half the users (56.4%) spend less than an hour in the park and people split their time at the park alone, with family, as a couple, or with friends. 65% of the park users viewed the park as "very important" to the overall quality of life in Reno and the majority of people "always" (47.5%) or "often" (42.5%) feel safe in the park and most of those surveyed thought of the park as "excellent" (40%) or "very good" (47.5%). The activities people participate in most are enjoying the outdoors, nature, or the river (61.5%), walking, biking, running and skateboarding for exercise (46.2%). Other main activities include sitting (43.6%), meeting friends (38.5%), and dog walking (38.5%). People's priorities for the park are natural open space (50%), path or trail (35%), bridges (32.5%), activities in the river (30%), and activities on the bank (25%).

Interviewing visitors to Wingfield Park highlighted the community and social benefits of the park amenities compared to their experiences before the whitewater park was built, noting that "we didn't really walk down to the river before" and that "it was a place that was seedy and that it is safer to walk along the river now". Additional users comment they often "walk the dogs in the park" and appreciate "the cultural diversity" and "various activities" while enjoying the "nature" and "beauty" of the "river" as valuable qualities of the park. At Idlewild park visitors often commented that they "enjoy bringing the kids to the playground" and "like walking on the path next to the river" but rarely mention their perception of the river itself.

Discussion

ECOLOGICAL

The hydrologic data reported in Figures 13-14 is a significant consideration for a fish habitat heterogeneity study. The high flows in the Spring carry sediment down the river and deposit it in areas of lower velocity like pools and eddies. During high flows, species require cover and refuge areas from the high current velocities. In most years, the Truckee experiences high flows in the Spring, and low flows in the fall and winter. Any structural complexity will allow for deposition of material in low velocity locations as well as create areas of cover and refuge during the high Spring flows. We see that 2019 was not an exception, so scour and deposition in the whitewater park should be expected, and the low flows during our November 1st site visit should allow for optimal habitat conditions.

Habitat requirements often vary with life stages of salmonids and depend on the season. For this reason and others, depth heterogeneity is important (Binns 1994). The results from this preliminary fish habitat study determine that the whitewater park dramatically increased the variation in depth in the urban stretch through downtown Reno. Assuming the Arlington dam had characteristics similar to our upstream reference dam site, the depth conditions near the dam were monotonous with no deep pools or concentrated deposition areas. A close look at Wingfield Park's Cross Section 2 (Figure 17), which is located in the pool where the Arlington Dam was located, reveals a deep pool, cobble bar, and small side channel.

The study of velocity heterogeneity within the whitewater park was the principal focus of our field work. Increased complexity in flow patterns and characteristics influence fish habitat in many ways, by creating cover, influencing oxygen availability, influencing the quality and quantity of available food sources, regulating water temperature, reduce pool stagnation, shaping channel morphology, and aid in the re-establishment and maintenance of secondary flow channels (Poff et al, 1997). The riffle where the Arlington Dam was in the whitewater park is characterized by shallow depth with high velocities flowing over deposited cobble as well as some slow velocities created by habitat boulders in the riffle. The pool at the Arlington site has two large eddies downstream of the wings with low velocities with high velocities in the main current at the center of the river. We see the most variation in velocity at the deflector cross section due to its large eddies and pinched main channel.

In general, spawning occurs in coarse gravel substrate with swiftly-flowing water that delivers oxygen to and removes waste products from incubating eggs. (Armstrong et al. 2003, Hendry et al. 2003, Hunter 1991, Mitchel et al. 1998). However, substrate requirements of salmonids differ with life stage (Kondolf 2000). Usually, silt or fine sand is not preferred for spawning because of instability with the flow and lack of refuge areas for very small fish. The results from our Wolman Pebble Count shown in Figure 23 indicate variety in substrate size throughout the whitewater park. The median grain size (d50) at the three cross sections examined in the whitewater park were different, indicating different conditions in different locations, as required by salmonid in different life stages. The results at the dam site indicate two different median grain sizes, however, we know that this is a direct result of the obstructing dam between the two cross sections.

Deep pools provide cover for fish during high flows and create habitat during very low flows (Binns, 1994). Pool area is a key component of habitat-improvement projects in the USA (Larscheid and Hubers, 1992). Figures 15-16 illustrate the step-pool channel bathymetry that is consistent with the whitewater park's design goals (404 Permit App 2002). The whitewater drops incorporated into the channel allow for natural scouring and create deep pools with low velocities that create cover. The drops also create flow complexity and habitat diversity, aerate the water, and provide grade control and flow control for the channel (McGrath 2003). Prior to the construction of the whitewater park, there were no pools in this reach of the Truckee (Figure 24). The longitudinal profile survey of the reference dam site supports this conclusion.

Structural variety of habitat is one of the most important conditions for the existence of well-balanced aquatic communities (Lelek and Lusk 1965, Hynes 1968, Sheldon 1968, Karr and Schlosser 1978). Channel features and structures increase flow complexity and aquatic habitat heterogeneity by allowing natural scouring, secondary eddy currents, velocity refuges, and cover. Current deflectors reduce bank erosion and undercutting while also providing cover (McGrath 2005). Placement of boulders in the channel increases habitat heterogeneity for fishes, offering protective cover for juvenile salmonids, and provides resting areas during high flows, and creates energetically efficient feeding areas for drift feeding fish (Armstrong et al. 2003). The facies and features mapping that we conducted in this study supports the conclusion that structural variety in the channel has increased due to the construction of the whitewater park. This is not surprising because this was a direct goal of the design (404 permit app).

To validate the relationship between fish habitat heterogeneity and actual salmonid presence in the project area, we referenced fish count reports provided to us by NDOW. The results from the 2003 and 2004 studies shown in Figure 26 indicate that the initial construction of the whitewater park was not detrimental to salmonid populations. Ten years after the project was completed, the 2013 study reveals higher salmonid population density in Wingfield Park than any other studied zone in the Lower Truckee (Figure 28). The 2013 study also indicates a large percentage of wild trout in Class I (juveniles) for both brown and rainbow trout (Table 5). This evidence supports the conclusion that there was no negative initial impacts with the construction of the whitewater park, and that long term response has also been positive. The high percentages of juvenile found in 2013 indicate that salmonid spawning habitat exists at the whitewater park.

SOCIAL

The whitewater park design enhanced social connectivity to the river at Wingfield park in three dimensions by improving longitudinal, lateral, and vertical connectivity. The structural changes have improved access and circulation within the park and also created a recreational space by attracting more users directly to the river itself and facilitating activities in and along the river. The addition of a pedestrian bridge and two pedestrian/bike paths allow for visitors to move easily from the downtown riverwalk and experience the interior of the park, the amphitheater, special events, and the whitewater features.

The longitudinal social connectivity was enhanced by a new underpass trail beneath Arlington Ave. This allows movement between the east and west section of the park without crossing the busy road and provides for consistent proximity to the water as users travel along the path. The previous bank with more canalization and flood protection walls reduces the two other levels of social connectivity as well. Moreover, the underpass, the new ramps along the river, new pedestrian bridge form a circulation network allowing for better connection to the larger trail system, which interact people with the river more and make them experience the natural environmental in city.

The lateral connectivity of people and the river were improved after the redesign of Wingfield park. The establishment of a pedestrian bridge and entrance plaza in the west section of the park ensures better lateral connectivity between the northern riverwalk and streambank to the center island. Also, multiple paths were created in the central green space of the park that connect with the old and new bridges, which provide for better circulation and pedestrian and cyclist networks. The green space in the center was activated as a new urban space for people and the new foot bridge and paths are far away from the existing road offering safe crossing points and movement to the waterfront. To make stronger lateral connectivity, riparian corridors and floodplain areas could be developed with embankment design along the park to accommodate flooding which also offer additional public space and further enhance the vertical connectivity.

The vertical dimension of social connectivity is related to various human activities at different heights in the river from instream to the top of the bank. Uses at the top of the bank include sitting, walking, running, picnicking, biking, skateboarding, fishing and event celebrating. Activities in the river include swimming, whitewater rafting, kayaking and river tubing. Improvements to uses at the top of the bank were achieved by the installation of boulders which create visual access to the river and develop open space on the bank with the opportunities for recreation and leisure. In-stream activity enhancement were the result of the removal of the hazardous low-head dam, the installation of step pools, the improvement of water quality and the physical access created by the stepped banks with drop structures allowing free movement to the river.

While there are opportunities to access the river near Idlewild Park, visitors often have to navigate through vegetation to get close to the river, perhaps explaining why there was no one seen interacting with the river at the time of the study. The use of step pools in the whitewater park not only allow various activities in the river but also enable visitors along the bank to interact with the river at various depths that are not daunting. The ease of access to the river and the various activities in and along the river at Wingfield Park can perhaps explain why there was a more broad range of age groups and more people using the park compared to Idlewild park. Also, from our interviews local residents typically use Idlewild compared to both the local community and visitors as far away as LA who come to visit Wingfield.

Conclusions

Salmonid fishes have a very fragile life-cycle that is heavily dependent on specific physical conditions in the river reach in which they are attempting to live and spawn. They require different conditions in various life stages and thus, habitat heterogeneity is desirable. Initial results of this investigation indicated that the instream conditions at Wingfield Park 15 years after the construction of the whitewater park are much more heterogeneous than the site conditions before the project. The salmonid community showed an increase in population after the instream improvements were constructed as well as an increase in juvenile spawning measured many years after the construction. Human interference in the Truckee has led to long term negative impacts on salmonid populations, and fluctuation in the Truckee's hydrology has many short term impacts on fish, but with the amount of adequate salmonid habitat increasing as certain sections of river are restored, a balanced fish community is re-establishing.

From our observations and studies, the social connectivity to the river at Wingfield Park significantly improved with the implementation of the whitewater park. The activation of Wingfield park in and near the river and streambank enhanced by the whitewater park's structural changes improved the connection of various users to the river through multiple dimensions. The previous channelized riverbank provided flood protection but eliminated opportunities for vertical and lateral social connectivity. Based on the land use of the areas surrounding Wingfield park, recreation and leisure are important economic drivers. Increased foot traffic and improved interactions with the surrounding businesses has contributed to the social success of the project. The accessibility of the Truckee river in Wingfield park has provided an invaluable asset to the city of Reno, allowing for diverse groups of people to enjoy the park and adjacent riverwalk in addition to the desired instream activities

River restoration projects in urban settings must be multi-objective. As a result, these projects can be critiqued from various perspectives. Many urban river projects with social benefits as the primary objective often fall short when critiqued from the pure ecological restoration perspective. In parallel, a river restoration project in which ecological habitat is the main concern can be critiqued from a social point of view, as many ecological projects disconnect the river from society and oftentimes create hazards to instream use. For this reason, a combined ecological and social study is important as it uniquely incorporates both perspectives. As a socially integral part of Reno's downtown and an improvement to aquatic habitat, Wingfield Park's whitewater park exemplifies the convergence of these two perspectives, striving for the proper balance between the often conflicting goals.

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Tables

Table 1: Summary of ecological evaluation methods.

Information Collected	**Methods to Collect**	**Analysis / Outcome**
Discharge Data	USGS Historical Flow Gauge	Compare 2019 and Average
Depth Variation	Cross section and profile surveys	Variation in Depth
Local Velocity Variation	Flow Meter	Variation in Velocity - 3-D
Substrate Size Distribution	Pebble Count	Variation and Median
Bed Morphology	Long Profile Survey	Plot elevations w/ Water Depth
Facies / Feature Mapping	Photos and Field Observations	Pre and Post Comparison
Maximum Velocities	Flow Meter	Fish Passage Ability
Interviews	Persistent phone calls	Understand opinions and methods in design
Concept Drawings	Sourced from Designer	Compare intended and current
Design Reports	Sourced from Designer	Understand intended outcomes and design constraints
Fish Count Data	NDOW	Compare different years and locations

Table 2: Summary of social evaluation methods.

Information Collected	**Methods to Collect**	**Analysis**
Study Sites	Review of previous studies; observation; and interviews.	Compare activity types and locations at Wingfield Park and Idlewild Park
Observation of Park Uses	Observe the age and gender, their activities in multiple locations; behavior mapping	Analyze the activities related to three dimensions: longitudinal, lateral and vertical
Interviews & Surveys	Face to face surveys and interviews of park visitors at Wingfield Park	Compare visitors perception of Wingfield Park before and after the redesign. More in depth demographic and activities analysis

Table 3: Standard deviation, coefficient of variance, and Average depth for each cross section and longitudinal profile.

	WP 1	WP 2 N	WP 2 S	WP 3 N	WP 3 S	D 1	D 2	WP LP	D LP
Avg. (m)	1.47	1.52	1.56	1.66	0.92	2.54	3.18	3.40	2.30
SD (m)	0.90	2.06	1.52	0.87	1.44	0.51	0.66	0.62	1.20
CV	61.30	134.88	97.40	87.26	95.03	20.39	20.94	18.44	52.50

Table 4: Summary of the NDOW fish counts in the North Channel at Wingfield Park

Wingfield Park North Channel													
	2003			2004			2005			2013			
	Fish/Mile	Avg. Size (mm)	Size Range (mm)	Fish/Mile	Avg. Size (mm)	Size Range (mm)	Fish/Mile	Avg. Size (mm)	Size Range (mm)	Fish/Mile	Avg. Size (mm)	Size Range (mm)	% Class I
Brown Trout	587	155	55-515	746	130	83-300	225	160	94 - 457	631	122	2.4-17.5	86
Rainbow Trout	1310	120	31-477	1535	109	58-227	84	147	94 - 275	291	96	52-415	96
Cutthroat Trout	10	223											
Mountain Whitefish	988	139	75-340	352	148	104-178	422	151	130 - 175	49	281	90-405	6
Sculpin	10	98											
Redside Shine	352	73	62-85							129			
Speckled Dace	29	73	65-79	42	46	41-52				23			
Mountain Sucker	1828	91	28-190	352	100	47-139	14	98		94			
Tahoe Sucker	362	105	68-200	352	119	75-185	197	119	80 - 175	25			
Green Sunfish	68	90	65-130	28	88	75-100				8			
Pumpkinseed Sunfish	10	86											

Table 5: Summary of NDOW fish counts in the four zones shown in Figure 27.

2013																
	Zone 2				Zone3				Zone4 - Wingfield Park				Zone5			
	Fish/Mile	Avg. Size (mm)	Size Range (mm)	% Class I	Fish/Mile	Avg. Size (mm)	Size Range (mm)	% Class I	Fish/Mile	Avg. Size (mm)	Size Range (mm)	% Class I	Fish/Mile	Avg. Size (mm)	Size Range (mm)	% Class I
Brown Trout	60.5	266	205-478	0	116	224	168-349	0	206	122	2.4-17.5	86		217	84-682	50
Rainbow Trout	60.5	254	99-436	19	313	177	89-450	42	449	96	52-415	96		230	72-370	51
Cutthroat Trout	0						0		0							
Mountain Whitefish	0						0		32	281	90-405	6		185	52-390	75
Total Fish/mile	**121**				**429**				**970**				**768**			

Figures

Figure 1: A drone photo we took during our November 2nd site visit depicting Wingfield Park's urban setting.

Figure 2: Concept drawing sourced from the project design engineer (Recreation Engineering and Planning). The Truckee River Master Plan's crown jewel was the downtown Reno whitewater park that reconnected the community to its river.

Figure 3: Photo from 2007 of the action the whitewater park sees during the Reno River Festival every Spring. Photo sourced from Recreation Engineering and Planning.

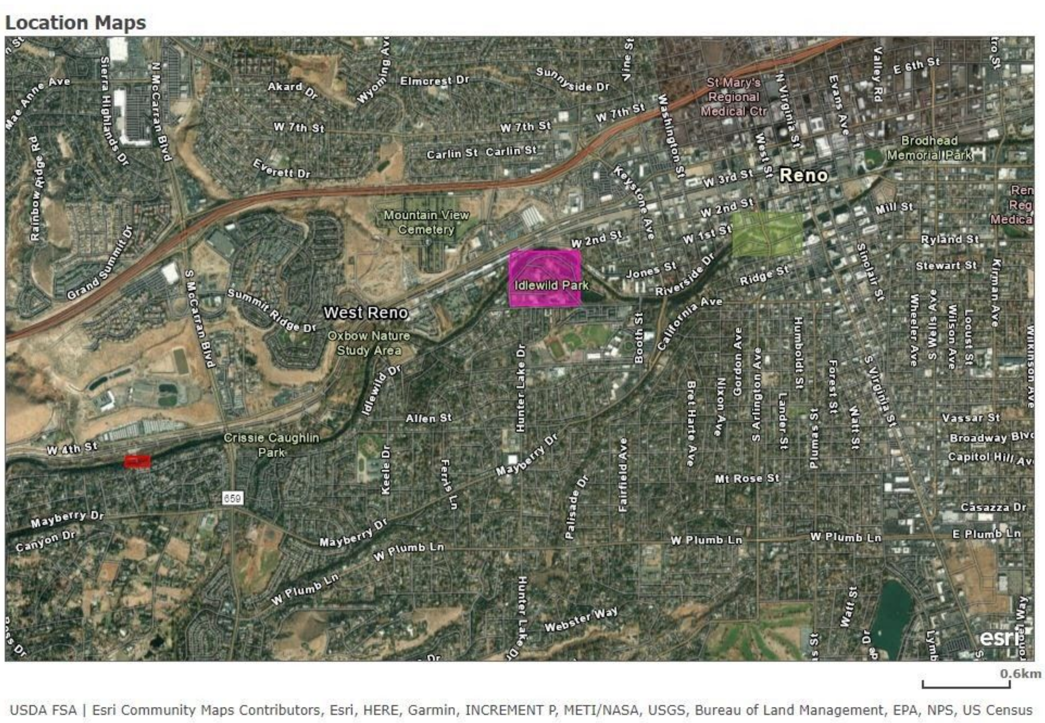


Figure 4: Satellite imagery sourced from Google showing the site locations of Wingfield Park (green), Idlewild Park (magenta), and the upstream reference dam site (red) along the Truckee River in Reno, NV.

Figure 5: The Arlington Dam severely restricted fish passage and eliminated habitat heterogeneity in the North Channel at Wingfield Park. A similar diversion dam three miles upstream was measured in this study to replicate pre-project conditions in the North Channel. Photo sourced from Recreation Engineering and Planning.

Figure 6: A drone photo we took during our site visit of the diversion dam approximately 3 miles upstream of Wingfield Park that was used as a reference site in this study. The conditions at the dam site are comparable to the pre-project conditions at the Arlington Dam shown in Figure 3.

Figure 7: Map of Wingfield Park showing the 3 cross sections surveyed and the surveyed north channel longitudinal profile. Imagery sourced from Google.

Figure 8: Map of the reference dam site three miles upstream showing cross sections and longitudinal profile surveyed. Imagery from a drone flight during our site visit.

Figure 9: Surveying the dam site was exciting!

Figure 10: Wingfield Park West

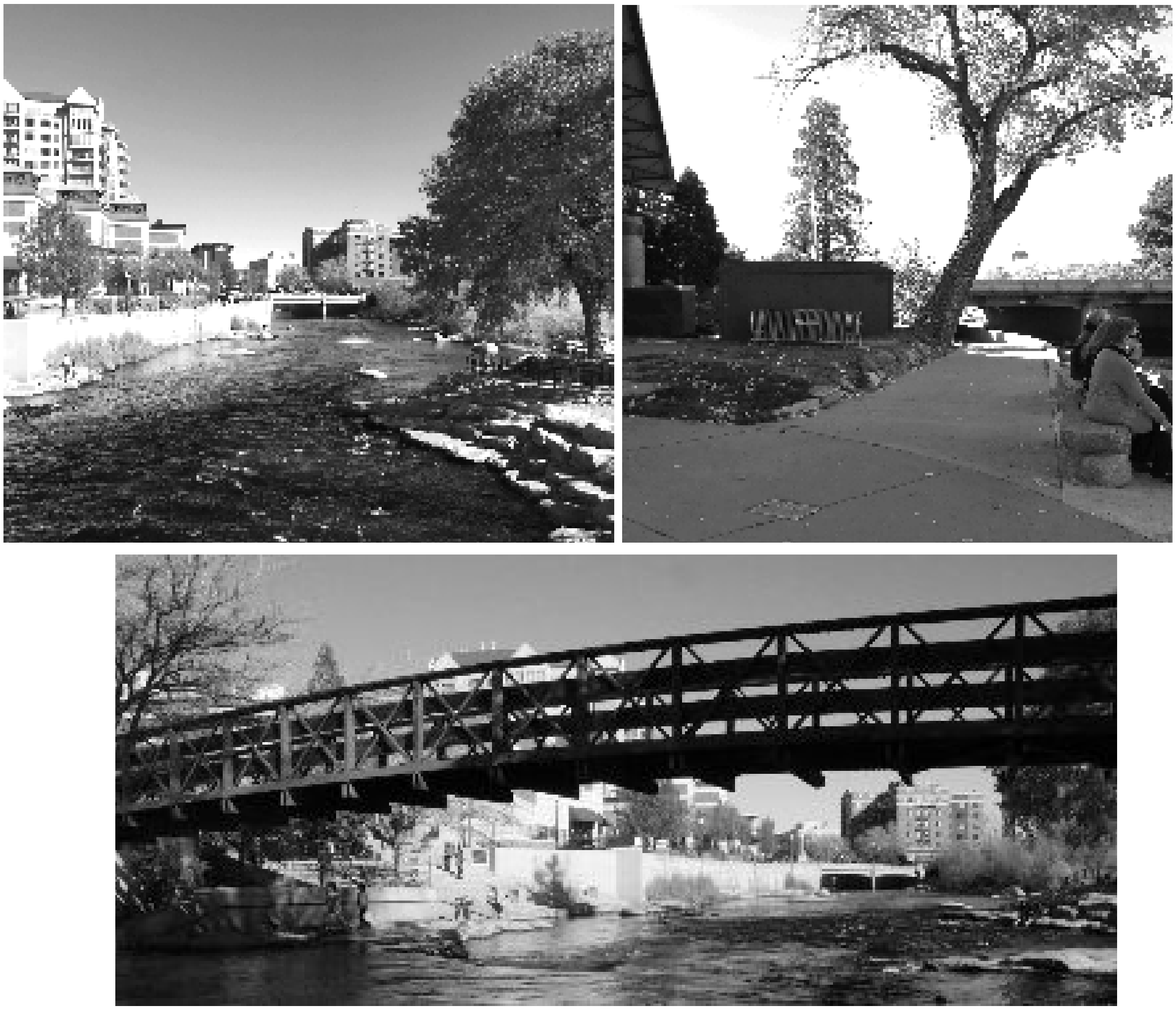


Figure 11: Wingfield Park East

Figure 12: Idlewild Park

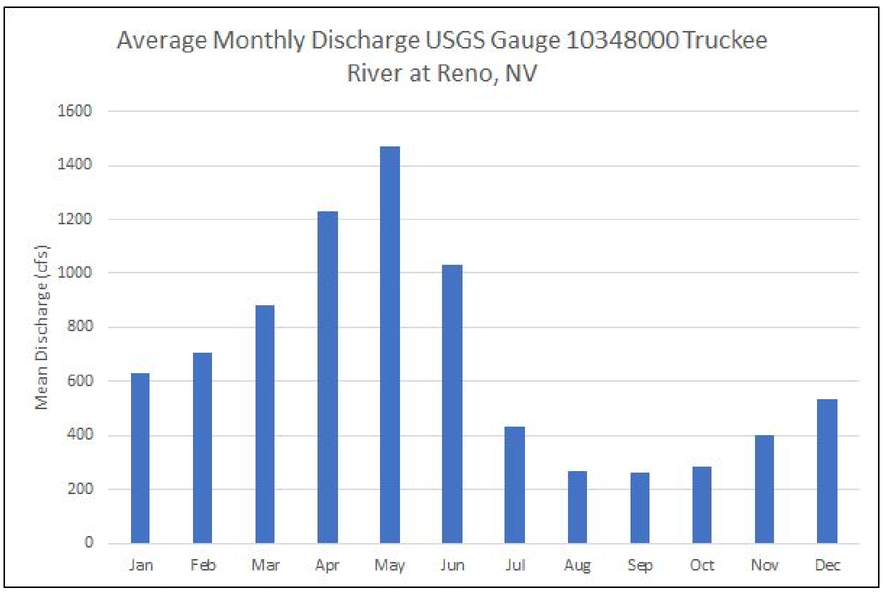


Figure 13: Mean Monthly Discharge at USGS Gage 10348000 Truckee River at Reno, NV (Source waterdata.usgs.gov, period of record 1906-2019, drainage area 1,067 square miles). High flows in the Truckee River in Reno generally occur in the months of April through June, and drop in late summer. Average monthly flows range from 262 cfs in September to 1,470 cfs in May.

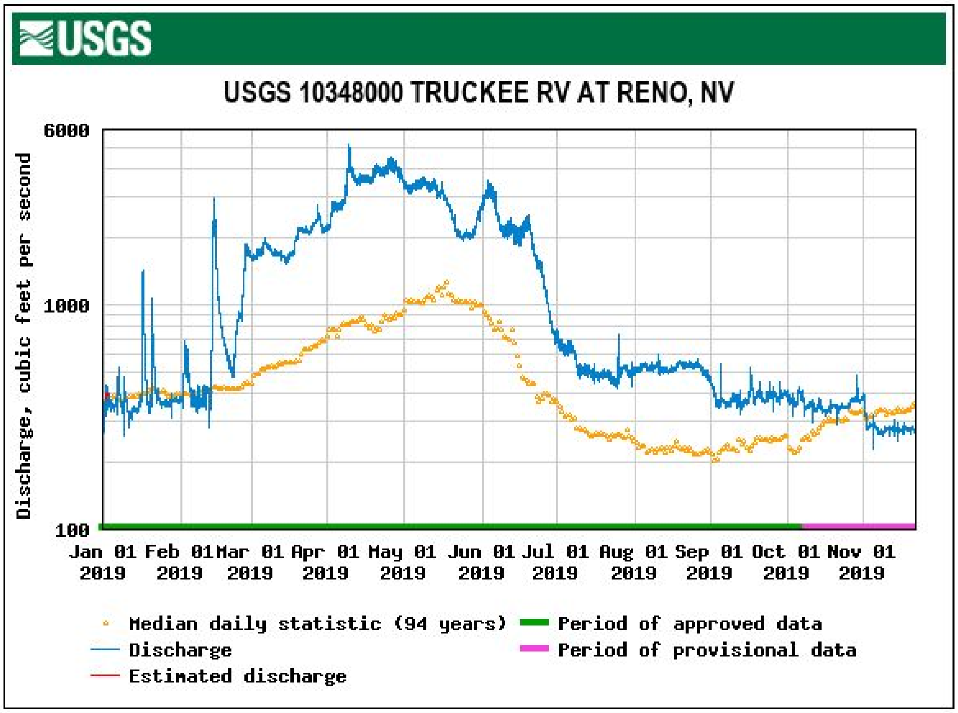


Figure 14: Daily Discharge for 2019 plotted with median daily statistic over the 94 years of data at USGS Gage 10348000 on the Truckee in Reno, NV. The gage recorded above average flow rates for almost the entire year to date, with the discharge only dipping below the mean in January and November.

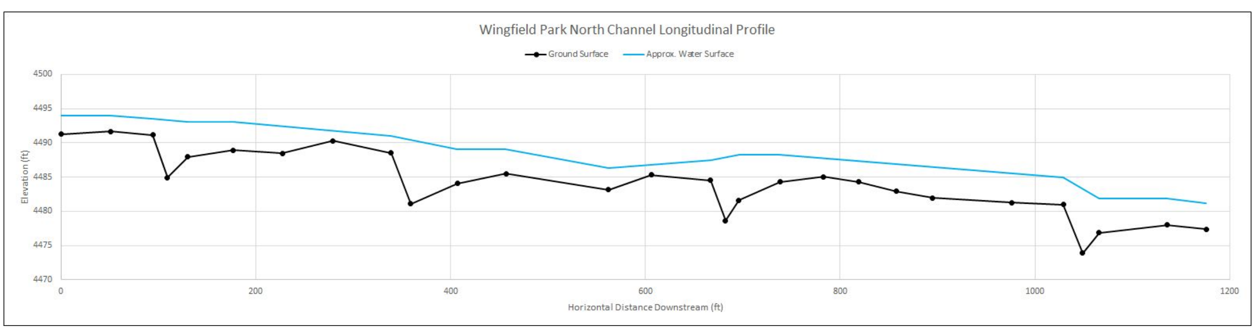


Figure 15: The longitudinal thalweg profile survey results of Wingfield Park's North Channel exhibit the step-pool morphology that was a design goal of this project. The flow features along the thalweg in the north channel consist of riffles, drops, and very deep pools.

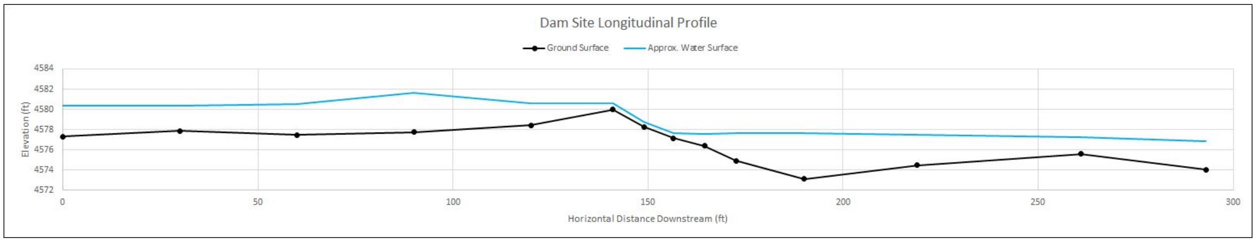


Figure 16: The longitudinal thalweg profile survey results at the dam site show an expected lack of heterogeneity that is supported by on-site physical observation.

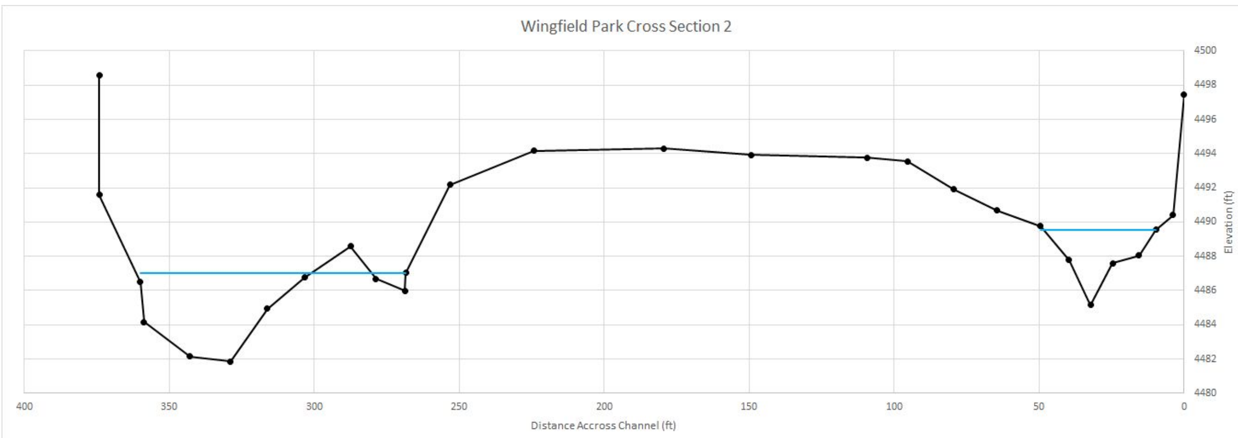


Figure 17: Cross section 2 at Wingfield Park depicts the depth heterogeneity in the channels.

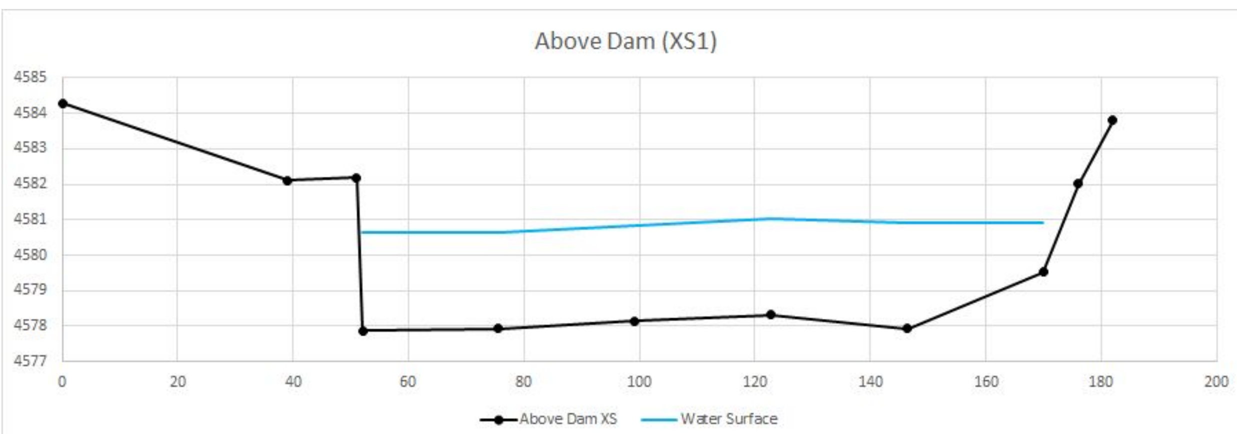


Figure 18: Cross section 1 at the dam site is the same depth most of the distance across the channel.

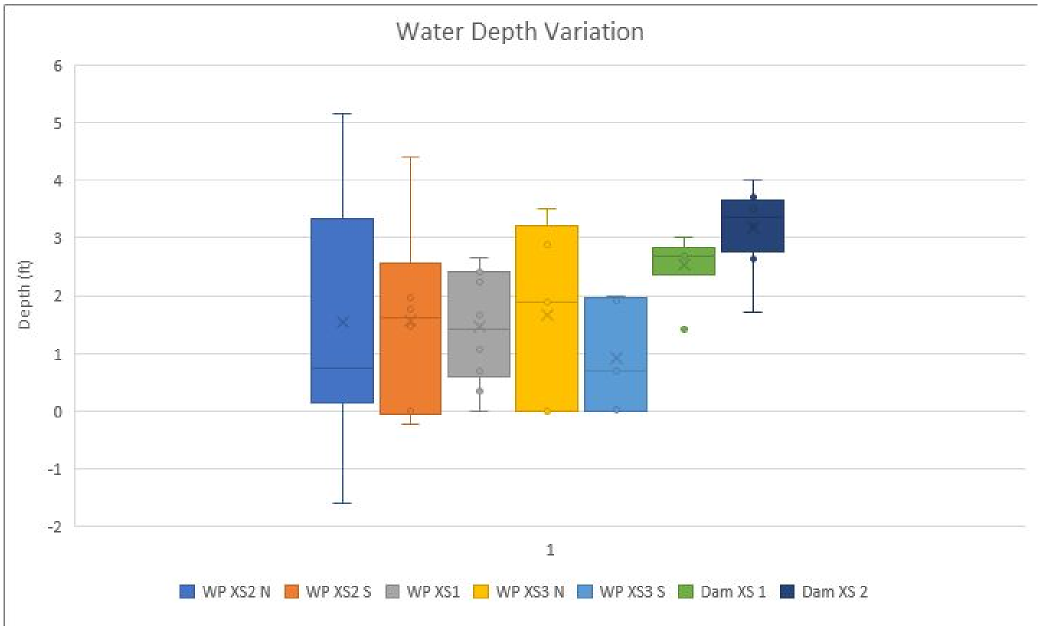


Figure 19: Depth Variation in Cross Sections. The limited variation in depth both above and below the dam at the dam site is very visible.

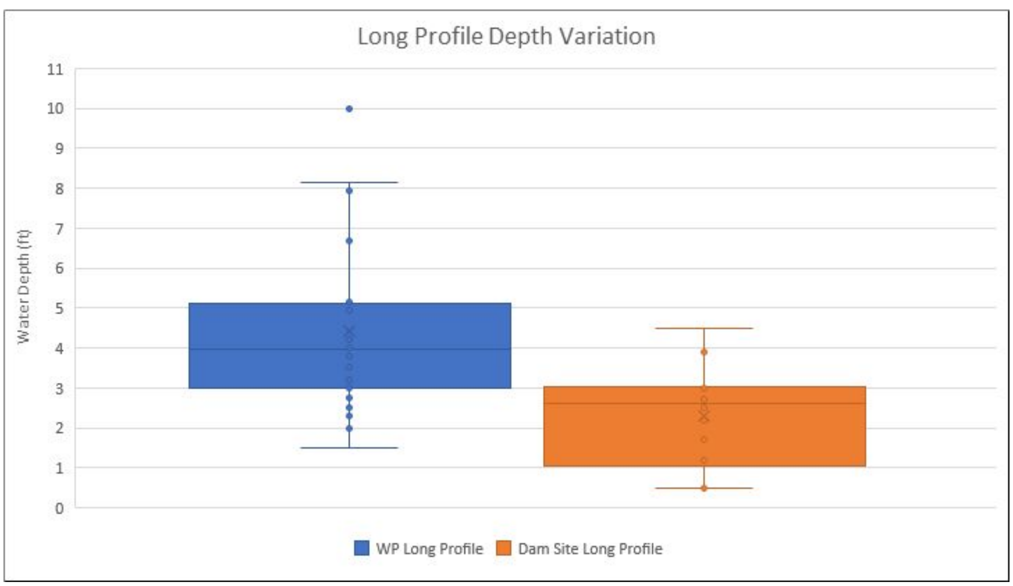


Figure 20: Box-whisker plot showing the depth variation resulting from the longitudinal profile surveys in Wingfield Park's North Channel and the reference dam site.

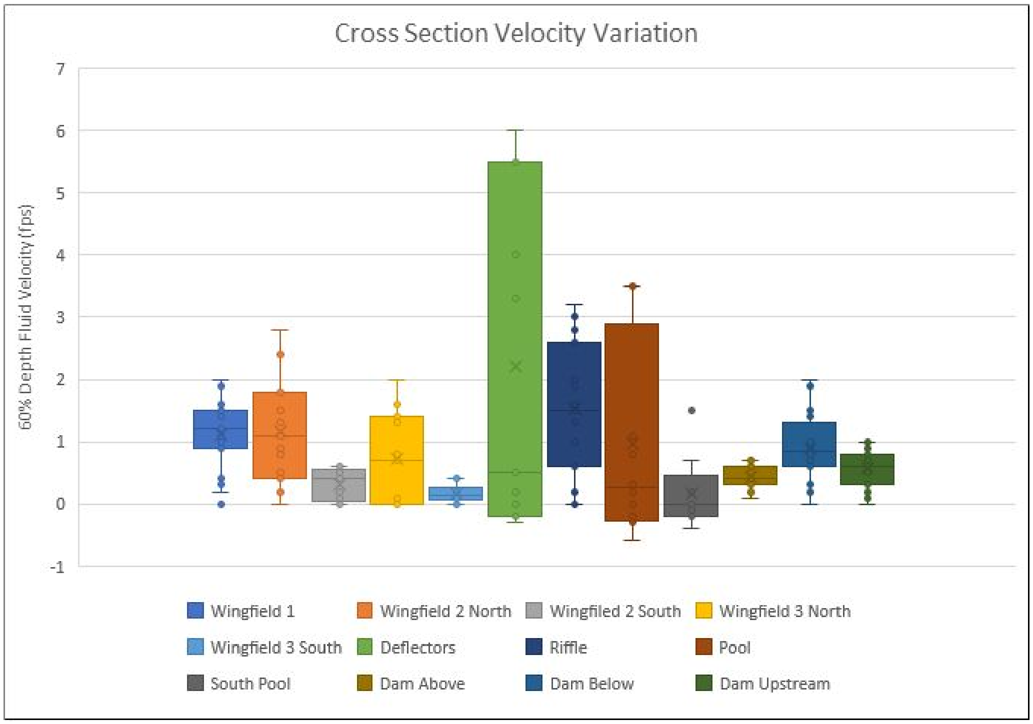


Figure 21: Velocity Variation at cross sections and long profile.

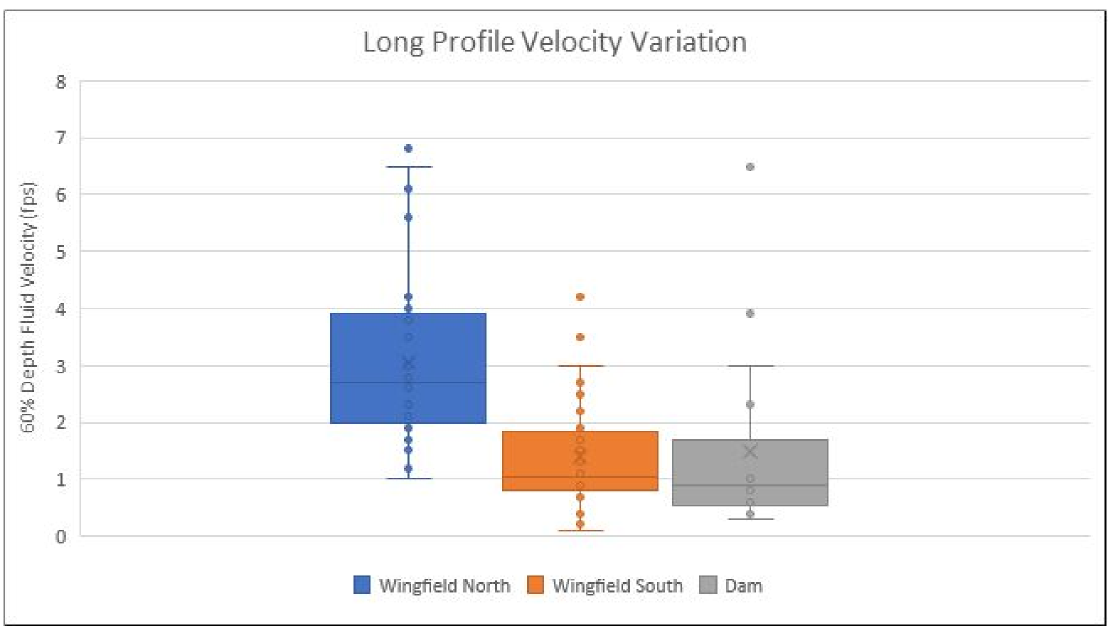


Figure 22: Velocity along the longitudinal profiles. Point velocities taken approx. every 15 ft.

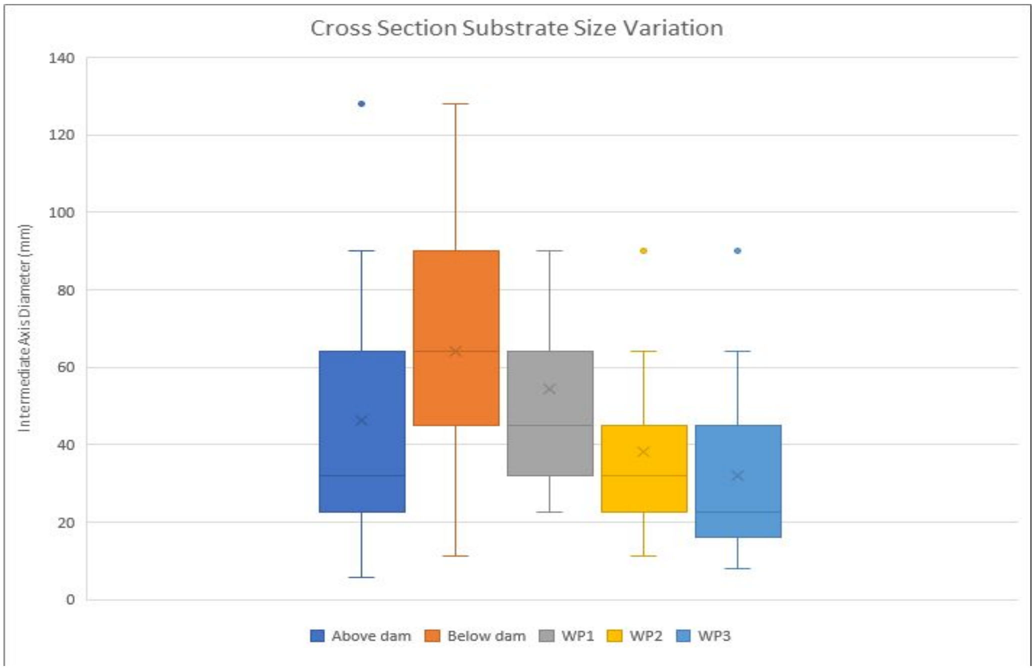


Figure 23: Pebble count results are displayed on a box-whisker plot. The plot demonstrates a smaller median substrate size above the dam than below the dam. We also see that median substrate size is different at all three locations studied in the whitewater park.

Figure 24: Facies Map of Pre-Project Conditions (taken in 12/2002 by High Resolution Orthoimagery). Instream features are highlighted in red.

Figure 25: Facies Map of Post-Project Conditions (taken in 11/2019 by DJI Mavic Pro Drone). Instream rock features are highlighted in red.

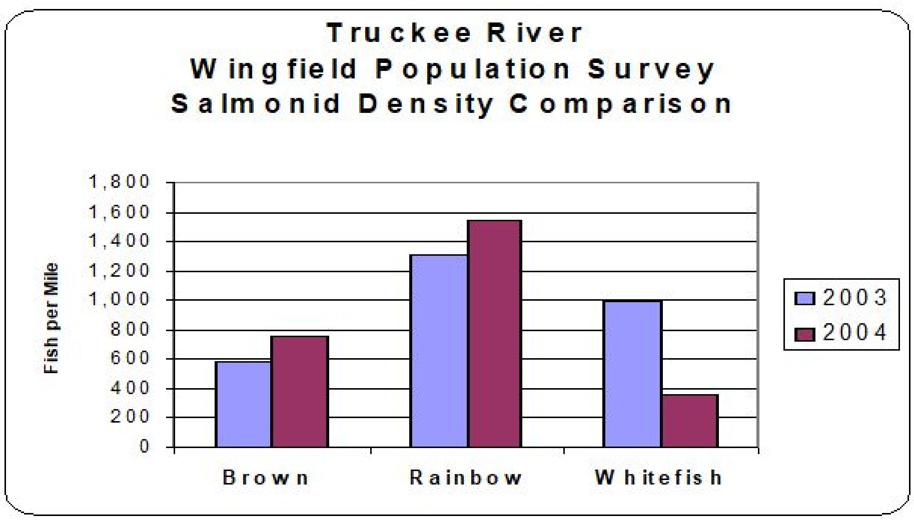


Figure 26: 2003 and 2004 NDOW salmonid count results in Wingfield Park's north channel. These results indicate that the construction of the whitewater park in 2003 did not have a negative effect on salmonid populations. (Tisdale 2004).

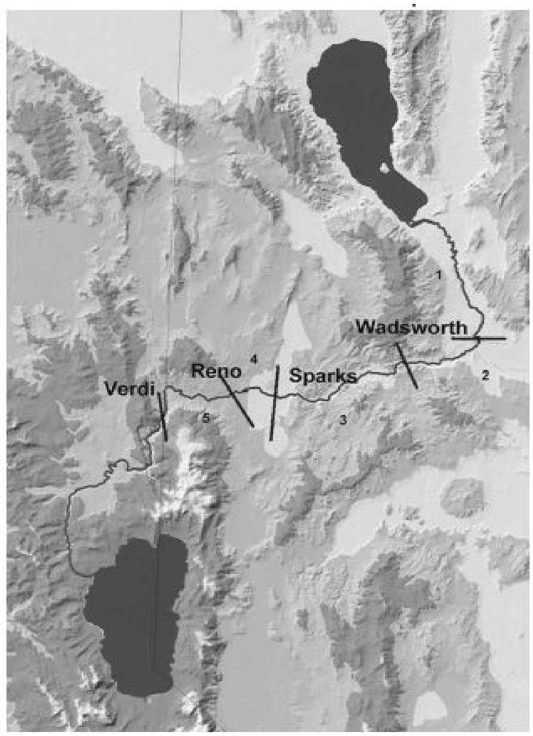
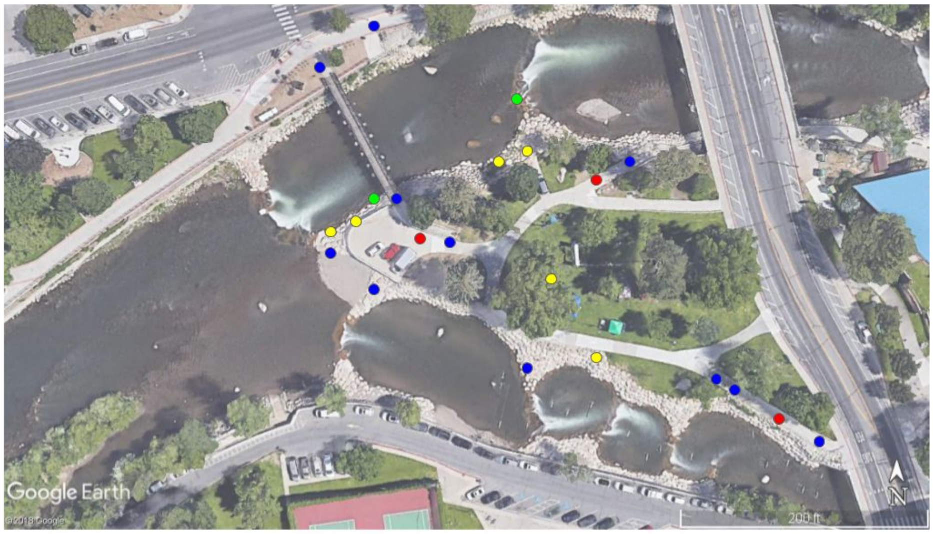


Figure 27: Regional map showing Zones 2-5 where the electroshocking fish counts were completed in 2013. Wingfield Park is in Zone 4 and the reference dam site is in Zone 5. Map sourced from NDOW report (Crookshanks 2014).

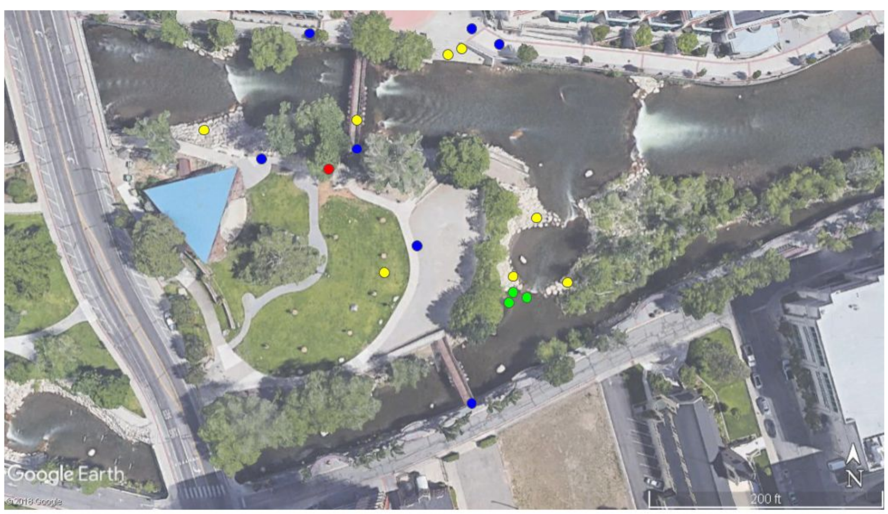
Figure 28: Results of the 2013 DOW fish count by zone in the lower Truckee. In 2013, Wingfield Park was the only location surveyed in Zone 4.



- Biking/Skateboarding
- Walking/Running/Playing
- Fishing/River Activity
- Sitting/Standing/Lying Down

Wingfield Park - West	Count	%
Biking/Skateboarding	3	14
Walking/Running/Playing	11	52
Fishing/River Activity	2	10
Sitting/Standing/Lying Down	6	29

Figure 29: Activity Map - Wingfield Park West



- Biking/Skateboarding
- Walking/Running/Playing
- Fishing/River Activity
- Sitting/Standing/Lying Down

Wingfield Park - East	Count	%
Biking/Skateboarding	1	5
Walking/Running/Playing	7	37
Fishing/River Activity	3	16
Sitting/Standing/Lying Down	8	42

Figure 30: Activity Map - Wingfield Park East

Biking/Skateboarding
Walking/Running/Playing
Fishing/River Activity
Sitting/Standing/Lying Down

Idlewild	Count	%
Biking/Skateboarding	3	12
Walking/Running/Playing	12	48
Fishing/River Activity	0	0
Sitting/Standing/Lying Down	10	40

Figure 31: Activity Map Idlewild Park

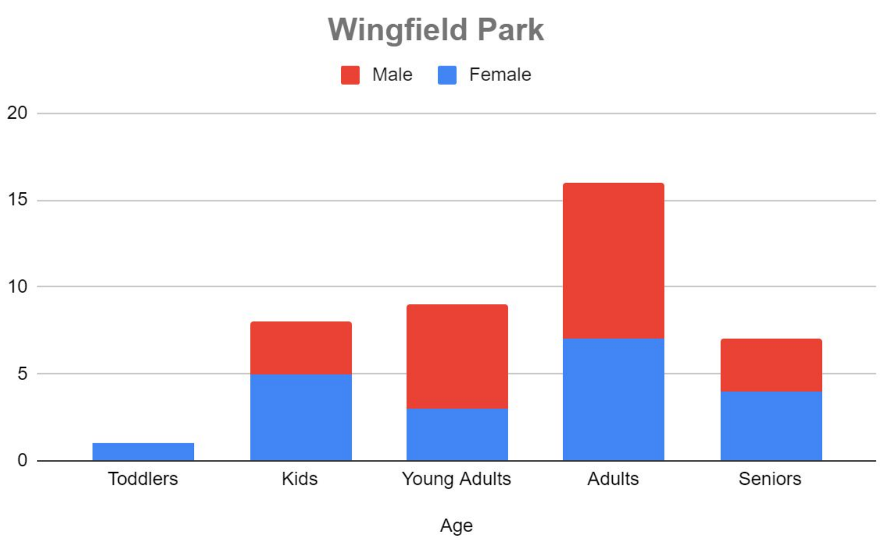


Figure 32: Wingfield Park Demographic Counts

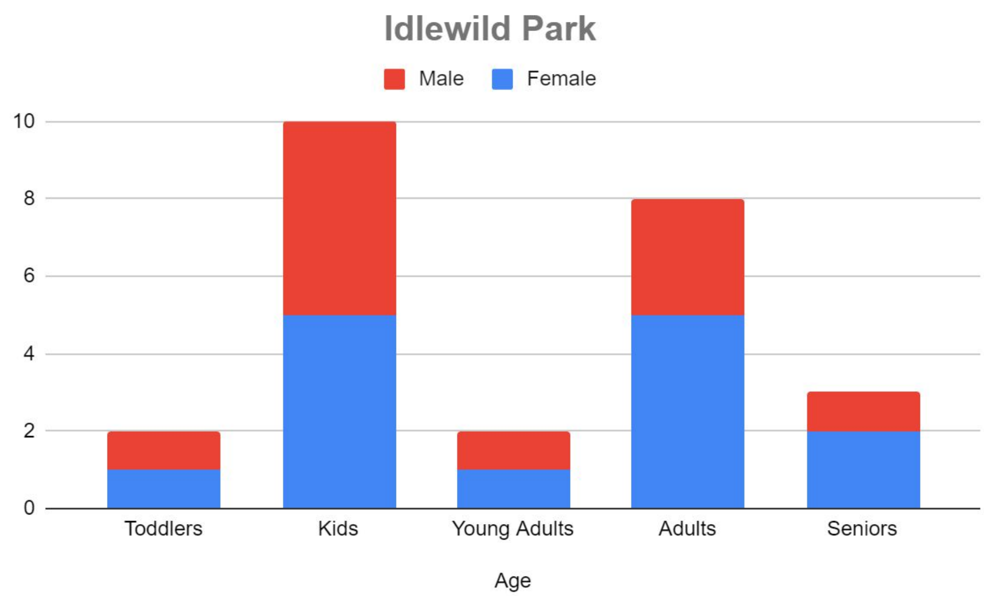
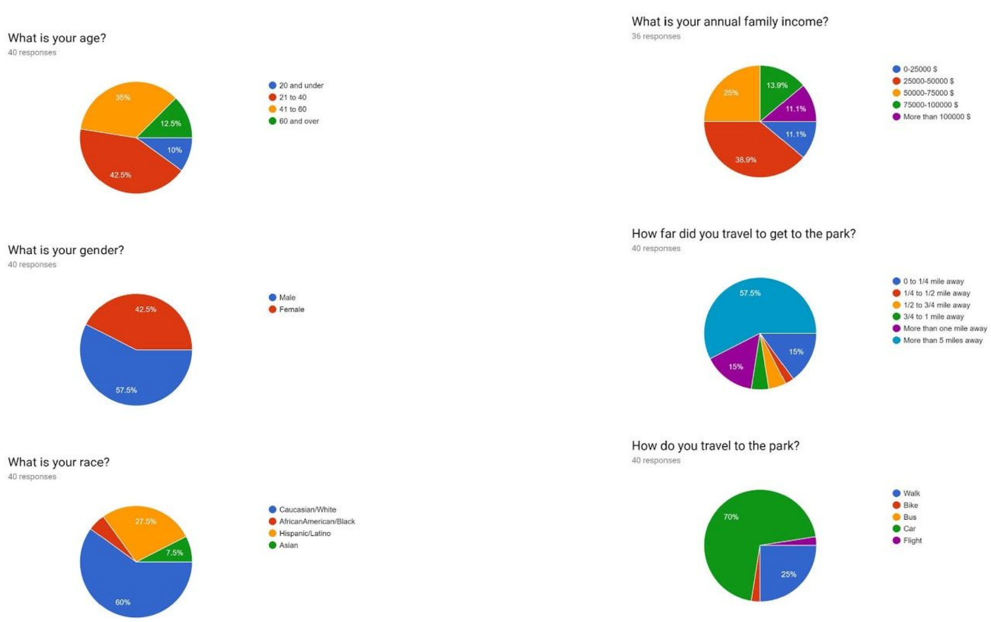


Figure 33: Idlewild Park Demographic Counts



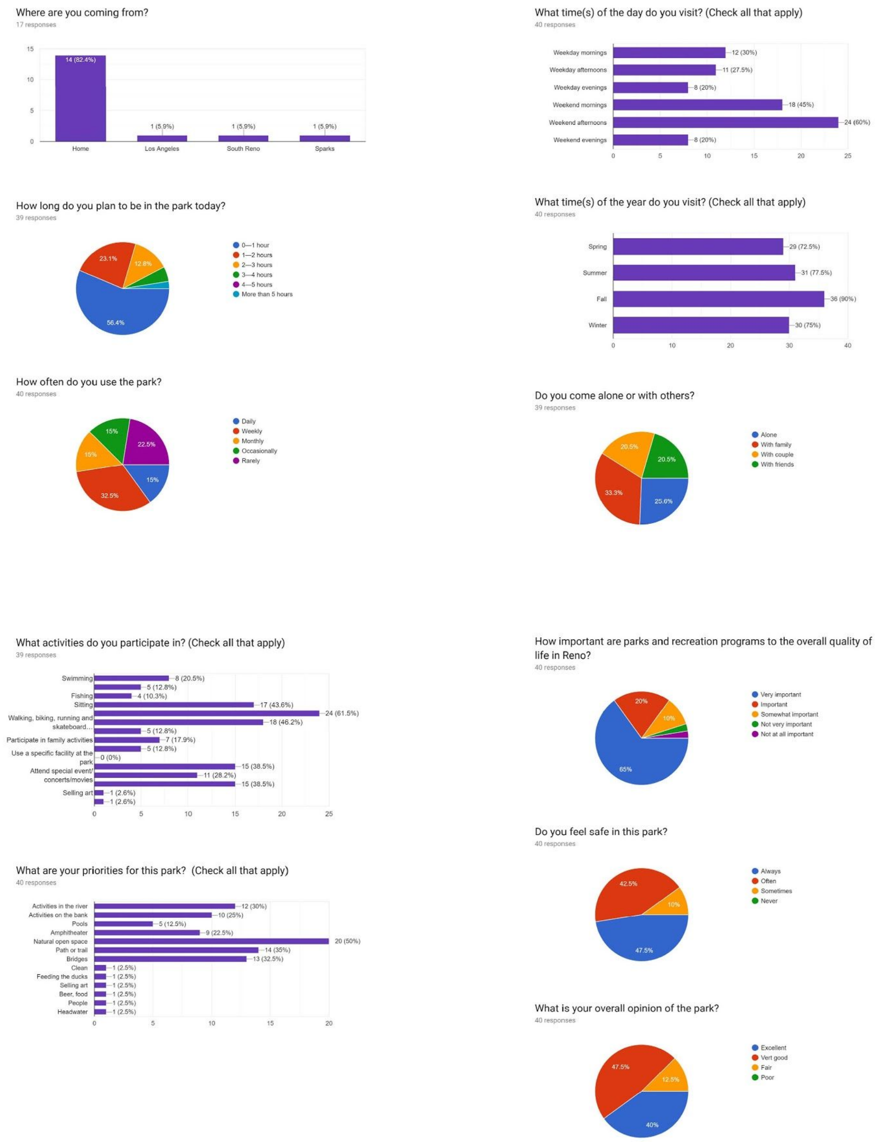


Figure 34: Wingfield Park In Person Survey Questions and Results