BIOLOGICAL ASSESSMENT AND THE EFFECTS OF WATER WITHDRAWALS ON WAIKELE STREAM, OAHU AQUATIC BIOTA

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EXECUTIVE SUMMARY

The Hawaii Biological Survey (HBS) conducted a preliminary assessment of the effects of water withdrawal on Waikele Stream and the surrounding estuary area in the West Loch of Pearl Harbor. A surface water diversion of approximately 4.6 MGD in Waikele Stream has been proposed in the area of USGS Gaging Station 2130 that is immediately upstream of Farrington Highway. This study assessed the potential effects that long-term water withdrawal would have on native and estuarine aquatic biota in Waikele Stream.

Two primary impacts to the stream and estuary would occur during water withdrawals conducted in the dry season. The first would be a reduction in stream flow (of 4.6 MGD) and aquatic habitat in the Waikele Stream channel downstream of the diversion point. The second impact would be a potential increase in salinity in estuarine habitat in the West Loch of Pearl Harbor. This would potentially occur starting at the upper tidal limit of the Waikele Stream estuary (at the USGS Gaging Station weir) and extend into the West Loch of Pearl Harbor. This analysis mainly addresses the impacts of changes in salinity on estuarine biota. Other potential impacts such as changes in nutrients, phtyoplankton productivity, etc., were beyond the scope of this report.

Reductions in flow just upstream of the USGS Gaging Station weir could affect conditions in the estuary by either altering the chemical environment, primarily salinity, of the estuary or by reducing the physical space (i.e., volume of the freshwater lens). Some impacts to native estuarine biota may occur due to reduction in physical space, and some impacts may occur due to expected salinity changes. These impacts can only be considered to occur when compared to present, short-term (since diversions stopped in 1989) conditions. The proposed diversion is nearly identical to the long-term average sugar cane diversion, but much less than the maximum diversions of up to 14 MGD that commonly took place from 1951-1989. Thus, no net impacts are expected when compared to historical (pre-1989) conditions, but potential impacts may occur when compared to current, undiverted conditions.

Increases in salinity resulting from a reduction of freshwater to the estuary could affect juveniles of two native fish species: ‘ama’ama or striped mullet and aholehole. Other native marine species occurring in the Waikele Stream estuary are tolerant to varying degrees freshwater but do not necessarily prefer or select for low-salinity conditions. Although no discrete threshold has been established, juvenile ‘ama’ama appear to prefer water with salinity below 15 ppt. When salinity becomes > 15 ppt, juvenile ‘ama’ama will abandon an area (e.g., estuary) and move in search of fresher water. During this movement, juvenile ‘ama’ama become increasingly susceptible to predation and possibly reduced food availability. Salinity preferences for aholehole are less established than that for ‘ama’ama, but the seasonal use of estuaries as nursery habitat by aholehole is similar to that of ‘ama’ama, and well known in Hawaiian waters . For this analysis it was assumed that juvenile aholehole also prefer water with salinities below 15 ppt. For reference, the salinity of sea water around the Hawaiian Islands is approximately 35 ppt.

Our field survey determined that this area is currently suitable habitat for juvenile aholehole and ‘ama’ama (striped mullet). High densities of both juvenile aholehole and ‘ama’ama were captured and observed in the tidal mudflat and mangrove area where Waikele Stream enters West Loch. Similar qualitative abundances were observed during 1993 field surveys. However, because the reduction of the area of the fresh-brackish lens (with salinities of <15 ppt) due to the proposed diversion is so small, impacts may not be sufficient to affect the fishery in Pearl Harbor.

Surface salinity in Waikele stream from the upper extent of tidal influence (at the USGS concrete weir) to the Waikele Stream mouth was measured at ≤ 15 ppt. Salinity measurements taken at the Waikele Stream mouth determined a freshwater lens of ≤ 15 ppt extended to a thickness of 0.25 ft (Nance 1998). These measurements were taken during a period of no diversion and at average stream flow levels in May (13.2 MGD) and June (12.6 MGD) 1998. The surface layer of freshwater is quite small in this area, and salinity at the Waikele Stream mouth quickly goes to near sea level conditions (> 30 ppt) at 0.5 ft below the water surface.

Therefore a very thin freshwater lens (<0.25 ft in thickness) exists at the Waikele Stream mouth. This area is suitable habitat for juvenile ‘ama’ama and aholehole. During water diversion, the thickness of the freshwater lens (≤ 15 ppt) would be slightly reduced in the immediate vicinity of where Waikele Stream enters the West Loch of Pearl Harbor. According to hydrological models, the thickness of the freshwater lens would be reduced by only 0.08 ft. at the Waikele Stream mouth. This is assuming a 4.6 MGD diversion at a stream flow level that is exceeded 80% of the time (11.6 MGD).

Due to the proposed 4.6 MGD diversion, salinity at the Waikele Stream mouth would exceed 15 ppt and render a 0.08 ft. thick portion of the freshwater lens unsuitable as rearing habitat for juvenile ‘ama’ama and aholehole. This habitat loss was calculated from flows that occur in Waikele Stream at least 80% of the time.   It is difficult to assess how a reduction of 0.08 ft. of depth in the freshwater lens would influence the ‘ama’ama and aholehole fishery at the mouth of Waikele Stream. A reduction in habitat has the potential to adversely effect the ‘ama’ama fishery. The stream mouth area is a relatively small, and was 170 ft. wide at the point of the salinity profile measurements. A loss of 0.08 ft. of the freshwater lens appears to be a small amount of lost freshwater habitat compared to the overall Pearl Harbor and West Loch system. This analysis is of course an oversimplification of a very complex system. Much more research would be required to make more definitive statements on the effects of this or any other proposed diversion in Hawaiian waters. However, the hydrological models verify that that the proposed diversion will normally (80% of the time) minimally impact the physical size and salinity of the estuarine environment at the Waikele Stream mouth, or the West Loch of Pearl Harbor.

No reduction in freshwater habitat quality and quantity would occur in strictly freshwater sections of Waikele Stream due to the proposed diversion. This is because water will be taken from Waikele Stream at a point where the stream flows over the USGS weir and immediately into a tidally influenced region. Thus, only tidally influenced areas will be affected by this diversion. This diversion could therefore potentially adversely affect recruiting stream biota and native stream organisms capable of inhabiting estuarine conditions that are found here such as ‘o’opu naniha, ‘o’opu akupa, and ‘opae ‘oeha’a.

Under the proposed diversion of 4.6 MGD, approximately 2000 ft. of Waikele Stream from the diversion point at WP-18 (USGS Gaging Station weir) downstream to West Loch would have a reduction in freshwater and estuarine habitats during low-flow periods. According to the hydrological models, the mostly freshwater areas in the Waikele Stream channel affected by the proposed diversion would have the freshwater layer reduced by a range of 0.27 to 0.5 ft in thickness from current conditions.

The diversion impacts on stream biota in a worst case scenario, or the lowest flow day from 1989 to 1997, was also analyzed. A 4.6 MGD diversion during a nine-year low-flow of 7.1 MGD would decrease the fresh water layer from 0.13 ft to 0.05 ft. in the Waikele Stream mouth area. Thus, even in a worst case scenario, a decrease of 0.08 ft. in thickness of the freshwater lens at the Waikele Stream mouth appears to be a small reduction in overall estuarine habitat. The hydrological analysis also determined that overall salinity levels in the West Loch of Pearl Harbor would only be minimally changed by a maximum of 0.9 ppt due to the proposed 4.6 MGD diversion. There is currently no way to quantitatively assess (unless a long-term study was conducted) if native ‘o’opu nakea population in the upper reaches of Waikele/Kipapa Stream would be adversely impacted by the proposed 4.6 MGD diversion. On the other hand, impacts to salinity levels and the size of the freshwater lens even in a worst case scenario have been shown by Nance (1998) to be minimal under the proposed 4.6 MGD diversion. Impacts to ‘o’opu nakea would be far less than the former sugarcane diversions that regularly exceeded 4.6 MGD, and often were substantially greater than 10 MGD.

INTRODUCTION

The Hawaii Biological Survey (HBS) conducted a preliminary assessment of the effects of water withdrawal on Waikele Stream and the surrounding estuary area in the West Loch of Pearl Harbor. A surface water diversion of approximately 4.6 MGD in Waikele Stream has been proposed in the area of USGS Gaging Station 2130 that is immediately upstream of Farrington Highway. This study assessed the potential effects that long-term water withdrawal would have on native and estuarine aquatic biota in Waikele Stream. A biological assessment of Kapakahi Stream was also conducted in the vicinity of the old railroad grade crossing. Potential impacts on native stream fauna due to temporary pipeline construction in the streambed were also assessed. Additionally, a Waikele Stream survey conducted by the author in 1993 allowed for present comparisons to be made with conditions five years ago.

The objectives of these assessments were to 1) describe baseline distribution and abundance of native and introduced fish species both in Waikele Stream and estuary, 2) describe distribution of crustaceans, mollusks, aquatic Odonata (damselflies and dragonflies), and amphibians in the sections of Waikele Stream potentially affected by water withdrawals 3) evaluate potential environmental impacts to stream biota and estuarine fisheries associated with proposed changes in stream flow in Waikele Stream 4) evaluate potential environmental impacts to Kapakahi Stream from proposed channel dredging.

STUDY AREAS

Waikele Stream

Waikele Stream drains the leeward areas of both the Koolau and Waianae mountain ranges in central Oahu. Tributaries of Waikele Stream draining areas in the Waianae mountains are intermittent, and flow only during periods of heavy rains. However, other areas of the Waikele Stream drainage, including the major tributaries of Waikakalaua and Kipapa Streams and the areas of the main Waikele Stream have permanent stream flow mainly in upper elevation areas. These tributaries are connected to the ocean during storms and periods of wet weather.

From its origin in the Koolau mountains, the Waikele/Kipapa system flows for 17.2 mi to the Waikele Stream estuary in Pearl Harbor. Downstream from the junction of Waikele and Kipapa Streams to the southern border of the Kipapa Military reservation, water flow in the stream channel is intermittent, and the channel contains little or no water during drought periods (Englund 1993). From the Waikele/Kipapa Stream junction, Waikele Stream flows 2.0 mi to its estuary in the West Loch of Pearl Harbor. Figure 1 contains a location for each numbered sampling station.

Station 1 (sea level)

A five ft. high concrete weir ponds up Waikele Stream at the USGS Gaging Station 2130. Downstream of the weir is entirely tidal, while no tidal influence occurs in the ponded area upstream of the weir. At low tide, the stream will spill over the concrete lip of the weir into a 50 ft. wide concrete-lined channel. The bottom of the channel is lined with concrete until just downstream of the Farrington Highway Bridge footings. After the bottom concrete channel lining ends, the stream bottom becomes a typical Pearl Harbor stream with a fine silt bottom lined with concrete sides. Eventually the concrete sides end, and thick growths of mangroves line the stream banks into West Loch.

The estuary area for Waikele Stream was accessed by launching kayaks at the USGS Gaging Station 2130 weir (See Figure 1 for locations). Visual observations of aquatic biota were also made while kayaking to the tidal flats. At the Waikele Stream mouth, a large expanse of tidal mudlflats are exposed at low tide. Tree stumps, shopping carts, tires, and other urban debris are found strewn throughout this tidal mudflat area. The substrate in the tidal mudflat area consists of thick layers of fine silts, with many areas firm enough to walk on at low tide. However, in some mudlflat areas a person can sink to over 3 ft deep in the fine silt. At low tide many shallow water pockets are found in the mudflats near the mangroves, and these extend out several hundred yards into Pearl Harbor. This concentrated the aquatic biota into shallow, isolated pools and allowed for ideal and effective sampling conditions.

Dense growths of mangroves (*Rhizophora mangle*) line the shoreline of West Loch at the point where Waikele Stream enters Pearl Harbor. According to an analysis by Tom Nance of Tom Nance Water Resource Engineering, mangroves have extended their growth significantly in the West Loch region of Pearl Harbor (Nance 1998). Between the time of the last USGS Waipahu quad map field check (1982), and aerial photographs taken in 1989 and 1994, mangroves appear to have grown seaward at the Waikele Stream mouth at least several hundred feet in some areas (Nance 1998).

Figure 1. Sampling stations in Waikele and Kapakahi Streams, May-June 1998.

Station 2 (5 ft elevation):

This station began at the Waipahu Street Bridge and extended downstream through the Waipahu Cultural Plantation Village, ending immediately upstream of the USGS Gaging Station 2130 concrete weir. Stream habitat in this area consisted largely of a series of backwater pools formed by the concrete weir, with the pools extending upstream nearly to Waipahu Road. Pools ranged in depth from >3-4 ft deep to 1-3 ft deep, and were connected by deep, slow-velocity runs. Substrate at this area consisted of find sand/silt in the deep pools, and small cobble in the limited run habitats. Pools with fine, silty substrate comprise the majority of habitat in Waikele Stream in the vicinity of the Waipahu Plantation Cultural Village. Underwater visibility was quite variable, but in late May 1998, visibility was quite good due to decreasing flows, and was high as 7-8 ft. Riparian vegetation consisted entirely of a dense growth of California grass (*Brachiaria mutica*) growing several feet into the stream channel.

Station 3 (18 ft elevation):

This station started slightly downstream of the H-1 highway upstream to the boundary of the Upper Kipapa Military Reservation. Except for some private property on the west bank of Waikele Stream near Waikele Springs, the current property owner in this area is Amfac JMB Hawaii. In 1998, approximately 200 yds downstream of H-1 highway a large set of springs emerged on the east side of the banks of Waikele Stream, through an old tunnel. The springs dramatically change the character of Waikele Stream, and also influence stream water chemistry (see Nance Hydrology Report). Upstream of these springs Waikele Stream is more turbid, warmer and sluggish. The spring discharge is completely clear and cooler, and water clarity in Waikele Stream improves significantly below the emergence of Waikele springs. Thick growths of aquatic macrophytes line the streambed where Waikele Springs emerge. California grass partially obscures the groundwater tunnel where the springs emerge. Taro (*Colocasia esculenta*) was also growing on both sides of Waikele Stream in the vicinity of the springs, but was more abundant on the west side (near the houses) of the stream.

At low baseflow these springs contribute 80% of the water flow to the lower Waikele Stream (Nance 1998). Up through July 1989 a well and pump system for sugar cane irrigation was operated by Oahu Sugar Company in the vicinity of these springs. These irrigation wells extracted variable but often significant amounts of water during periods of low stream flow from Waikele Stream (Nance 1998). Stream habitat in the vicinity of the most upstream (and largest) of the emergent Waikele Springs consisted of high velocity shallow runs 1-2 ft deep connecting shallow pools 0.75 -2.0 ft in depth. Downstream of the springs, the streambed gradient gradually decreases, and fine substrate predominated in the pool habitats.

Upstream of the spring area the stream gradient increases, with larger gravels and cobbles predominating. In contrast to the 1993 survey, a significant amount of water flow was observed in Waikele Stream close to the border of the Kipapa Military Reservation. In 1998, this area was above the influence of the Waikele Springs, and streamflow here was comprised of mainly surface water runoff (See Nance 1998), and was thus more turbid and warmer than below Waikele Springs. In 1993, stream flow above Waikele Springs was not continuous, as sections of dry streambed containing intermittent pools were observed approximately every 200 yds. above the last Oahu Sugar pump station on Waikele Stream (near the border of Kipapa Naval Reservation). Riparian vegetation in this area was exclusively California grass, with an overgrowth of mainly Chinese banyan (*Ficus microcarpa*) and some mango (*Mangifera indica*)

Kapakahi Stream

Kapakahi Stream begins as a 0.5 MGD spring emerging underneath the Shiro's Food parking lot immediately north of Farrington Highway (Nance 1998). Visible water flow for Kapakahi Stream begins on the north side of Farrington Highway, and terminates into an indistinct set of channels flowing through thick stands of mangrove approximately 0.75 mi downstream into the West Loch of Pearl Harbor. Kapakahi Stream has been channelized but is not lined with concrete. In the area of Farrington Highway the stream channel is shallow and very silty. Houses are situated on the west side of the streambanks from Farrington Highway to the old railroad grade and petroleum pipeline. An auto dealership and other industrial properties lined the east side of Kapakahi Stream. Kapakahi Stream is also adjacent to a City and County refuse pickup station next to the Chevron petroleum pipeline crossing. Water clarity is surprisingly good for such a disturbed urban stream, but the channel and banks are lined with trash. A trash 'dam' has built up underneath the old railroad trestle supporting the Chevron petroleum pipeline.

The banks of Kapakahi Stream are bare dirt from Farrington highway to the pipeline, and appear to be frequently sprayed with herbicide. California grass starts appearing in the area of the Chevron pipeline. Approximately 100 yds downstream of the pipeline mangroves start to line the channel. Mangrove growth eventually becomes so dense that further access to the stream channel is impossible.

METHODS

GENERAL METHODS

Field work for this study was conducted in May and June of 1998. Sampling was conducted under generally clear weather conditions. Representative sampling stations (see STUDY AREA) were established on Waikele Stream and its Pearl Harbor estuary, and Kapakahi Stream. Aquatic macrofauna (fish, crustaceans, mollusks, and amphibians) was assessed at each station. Sampling areas were somewhat dependent upon the constraints of vegetation and local terrain.

Composition of the riparian vegetation and stream substrate were evaluated at each sampling station. Habitat condition for native aquatic organisms was evaluated both within sampling stations and throughout the sections of stream sampled. Altitude at each sampling station was determined by using a combination of USGS topographic maps and a hand-held Casio altimeter. Stream distances were measured with a planimeter on USGS quads.

Fish, Crustacean, and Mollusk Sampling

Fine-mesh fish nets (seines) were the main sampling technique used to assess introduced fish abundance. We used a 15 x 4-foot seine with a $^{1}/_{16}$-inch mesh. Seines are only marginally effective at capturing native ‘o’opu but were useful to quantify the abundance and size distribution of other native and nonnative fish species. Seines used in Waikele Stream were effective and used in slow-water habitats such as pools and deeper runs. Area sampled for each seine haul was determined by measuring the length and width of each sample. Maximum depth was recorded for each seine haul. Small hand seines (‘opae nets) and aquatic dip nets were also used to collect and assess fish and other aquatic invertebrates.

Due to poor water visibility in some sections of Waikele Stream, and the entire Kapakahi Stream, snorkeling and above-water observation were only used in Waikele Stream upstream of the USGS Gaging Station 2130. Visual underwater and above water observations were possible in Stations 2 and 3 of Waikele Stream. We did not use electroshocking equipment to collect fish, and likely did not catch some of the more secretive introduced fish species.

Aquatic Insect Sampling

Aquatic insect sampling was conducted according to Polhemus (1995a) and Englund and Filbert (1997a). Collections of both immature and adult specimens were conducted with aerial sweep netting, dip nets and benthic samples. Visual observations of aquatic insects were also conducted around the stream channel. In addition, the sampling of damselflies and dragonflies (Odonata) was emphasized. Six species of *Megalagrion* damselflies are currently held as candidate Threatened, Endangered, or Species of Concern on the Federal Register. Moreover, native Hawaiian damselflies give an indication of the relative 'health' of a stream system; they do not typically occur in highly disturbed areas. The number and species of native damselflies observed during hikes both upstream and downstream were also recorded, and native damselfly catch (or observations) per unit of time was noted.

All insect specimens were stored in 75 percent ethanol and subsequently transported to the Bishop Museum Entomology laboratory for curation and identification. Voucher specimens are currently housed in the Bishop Museum collections.

RESULTS AND DISCUSSION

Waikele and Kapakahi Stream Sampling Effort

Data were collected in Waikele and Kapakahi Streams in May and June of 1998. Sampling was conducted at three stations within Waikele Stream, and the entire Kapakahi Stream. The mudflat area surrounding the Waikele Stream mouth was sampled with seines, dipnets, and aerial nets. Numerous aquatic dip net, opae net, and aerial net samples were used in other sampling stations at Waikele Stream and Kapakahi Stream. Approximately 250 yds of Waikele Stream was snorkeled by two observers up and downstream of the USGS Gaging Station weir upstream of the Farrington Highway bridge. Sampling effort by station and gear type are shown in Table 1.

Table 1. Sampling effort, by gear type and method, for Waikele and Kapakahi Stream, Oahu during May-June 1998 (X = method used).

Station	Seine (m^2)	Kick Net/ Dip Net	Aerial Net	Visual
Waikele 1 (Estuary)	109	X	X	X
Waikele 2 (USGS)	Hand Seine	X	X	X
Waikele 3 (Springs)	104	X	X	X
Kapakahi	Hand Seine	X	X	X

Quantitative seine hauls, approximately 213 m^2, were conducted in Waikele Stream, and numerous other qualitative seines (both 'opae nets and larger 15 ft. seines) were also taken. Visual assessments were made within each sampling station and along the stream corridor as we hiked between stations.

Aerial, kick nets, and ‘opae nets (small hand seines) were used at all stations, primarily for collecting insects. Kick nets were also effective in capturing fish in areas we could not effectively seine, such as riffles.

Distribution of Aquatic Biota

Waikele Stream

Three new species of introduced aquatic macrofauna were recorded from Waikele Stream In 1998, compared to 1993 surveys conducted by the author (Table 2). The present survey found fifteen native aquatic species and thirteen introduced aquatic species in Waikele Stream (Table 3). This excludes riparian species such as isopods and spiders, and species with an uncertain identification (amphipods) or geographic status. Most of the observed native species were marine and estuarine species observed in the Waikele estuary area. Important food fish species such as the native aholehole (*Kuhlia sandvicensis*) and ‘ama’ama or striped mullet (*Mugil cephalus*) were abundant up to the concrete barrier formed by the USGS Gaging Station weir. However, tilapia (*Sarotherodon melanotheron*) dominated this area both numerically and in biomass. Large schools of tilapia were ubiquitous from Waikele Springs downstream to the marine and estuarine portions of West Loch.

Table 2. New aquatic species found in Waikele Stream in 1998, and introduced since 1993 (compared to Englund 1993).

Species	Location
Atyid shrimp (*Neocaridina denticulata*)	USGS weir and upstream
Scarlet skimmer dragonfly (*Crocothemis servilia*)	Taro fields, USGS weir and upstream
Apple snail (*Pomacea canaliculata*)	Taro fields, at Plantation Village

Only three of the five native ‘o’opu species were captured or observed. Neither ‘o’opu nopili (*Sicyopterus stimpsoni*) nor ‘o’opu alamo’o (*Lentipes concolor*) were encountered during this survey, or during previous surveys. Fish species composition during this study is consistent with results of a 1993 assessment of Waikele Stream (Englund 1993). Somewhat surprisingly, no new alien fish species were observed in the surveyed areas of Waikele Stream as compared to the 1993 surveys. Additionally, a 1997 survey of Kipapa Stream (a major tributary to Waikele Stream) from 280-300 ft elevation level also found no new alien fish or crustacean species (Englund 1997). The 1997 survey was conducted above Kamehameha Highway, and was not far upstream of Station 3 at Waikele Springs. In Kipapa Stream in 1997, only four species of alien fish were observed, all of which were found in the lower Waikele Stream (Englund 1997). In 1998, several alien fish species known to exist in the lower Waikele Stream area such as the Chinese catfish (*Clarias fuscus*) and the rice paddy eel (*Monopterus albus*) were not observed. This is likely due to their secretive habits and because we did not use electroshocking equipment to collect fish.

‘O’opu nakea (*Awaous guamensis*) and ‘o’opu naniha (*Stenogobius hawaiiensis*) may have declined in lower Waikele Stream since 1993. In 1993, high densities of post-larvae (hinana) of both of these species were observed below the USGS weir. No post-larval ‘o’opu were observed during extensive sampling conducted in May and June 1998, and only one ‘o’opu nakea was observed and collected in lower Waikele Stream. Native fish were not observed In the vicinity of Waikele Springs (Station 3). This contrasts with ‘o’opu nakea commonly found at this station in 1993 when numerous ‘o’opu nakea were observed and netted. A wide range of size classes of ‘o’opu nakea were found in 1993, including relatively recent recruits as small as 24 mm.

Introduced bristle-nosed or armored catfish (*Ancistris* sp.) were extremely abundant in faster water run and riffle areas in Station 3. Densities were especially high above the influence of cold-water Waikele Springs, but were also high below the spring input area. Bristle-nosed catfish densities appeared to be similar to that found in Manoa Stream near Manoa Elementary (i.e., very high), and may be a major factor contributing to the complete lack of ‘o’opu nakea in this section of stream in 1998. Although not uncommon in 1993, bristle-nosed catfish numbers appeared to have increased markedly since then. More intensive sampling over a longer time period would likely find a few more ‘o’opu nakea in lower Waikele Stream. However, extremely high densities of introduced fish are undoubtedly impacting native ‘o’opu through factors such as predation, competition for food resources, disease, and other factors.

Although not assessed during this survey, high elevation areas of Waikele/Kipapa Stream only accessible by helicopter contained a significant population of large, ‘o’opu nakea (Englund 1993). In contrast to the lower reaches of Waikele Stream, only one introduced species of fish (mollies) was found to co-exist with ‘o’opu nakea at elevations above 1200 ft. in Waikele/Kipapa Stream. It is unknown whether recruitment continues to occur in high elevation areas of Waikele/Kipapa Stream, as these refugia from alien fish species have not been resurveyed since 1993.

For the present study, greater effort was placed on sampling aquatic insects in the lower and estuarine reaches of Waikele Stream than in the 1993 assessment. Consequently, a few more aquatic insect species were captured in the lower Waikele Stream and estuary in 1998. The aquatic insect fauna in Waikele Stream was dominated by native and introduced dragonflies and introduced damselflies. Native *Megalagrio*n spp. damselflies were not observed in lower Waikele Stream. The scarlet skimmer dragonfly (*Crocothemis servilia*), a recent introduction to the State of Hawaii, was a notable introduced species absent from Waikele Stream in 1993, but common in 1998. These dragonflies were first collected in Hawaii by R. Englund around taro fields in Waiahole Valley in December 1994 (Polhemus 1995b).

As estuarine shrimp identification is uncertain and problematic in Hawaii, shrimp specimens from the Waikele Stream and estuary were identified in May 1998 by Dr. Brian Kensley of the Smithsonian Institution. A new species of introduced freshwater shrimp (*Neocaridina denticulata*) in the Atyidae family, not present in Waikele Stream in 1993 (Englund 1993) was exceedingly abundant in 1998. *N. denticulata* was found from the USGS Gaging Station upstream to the upper limits of this survey at the border of the Kipapa Naval Reservation. This freshwater shrimp is an apparent aquarium introduction, and its native range is Taiwan, Ryukyu Islands, Korea, mainland China, and Vietnam (Hung et al. 1993). *N. denticulata* has also apparently been found in several windward Oahu streams for the past several years. This is the first definite identification of this freshwater shrimp on Oahu, and the first record from a leeward Oahu stream. Introduced atyid shrimp densities were extremely high, with up to several hundred shrimp captured in one aquatic dip net in the Waikele Springs area. Additionally, *Neocaridina denticulata* were not found in Kipapa Stream in 1997, which is upstream of Waikele Springs (Englund 1997). Indigenous estuarine shrimp identified by the Smithsonian Institution include *Palaemon debilis* and *Perclimenes (Harpilius*) sp. Native crenulated blue crabs (*Thalamita crenata*) were abundant in the Waikele tidal mudflat area.

Estuarine biota such as ‘ama’ama, aholehole, shrimp, and crabs were not observed above the USGS Gaging Station weir at Farrington Highway. This five ft. high concrete weir apparently serves as an effective barrier for organisms lacking the ability to climb over barriers, such as some of the native and introduced ‘o’opu. Additionally, ‘o’opu akupa (*Eleotris sandwicensis*), the native eleotrid and the introduced goby *Mugilogobius cavifrons* were not observed above the weir. *M. cavifrons* was abundant in Waikele Stream from the concrete weir to the tidal flats at the stream mouth.

Apple snails (*Pomacea canaliculata*) were not observed within the confines of the lower Waikele Stream channel area in both 1993 and 1998. Large quantities of taro were observed growing in and along the streambed in the area of the emergent Waikele Springs just downstream of H-1. Apples snails and their bright red egg cases were not observed on any of these taro plants, or any other riparian vegetation in the Waikele Springs of stream area in June 1998. However, extremely high densities of adult and immature apple snails were observed in the large taro field area of the Waipahu Plantation Cultural Village in May and June 1998. Apple snails will undoubtedly soon spread to the Waikele Stream riparian corridor as the taro fields are spring fed and immediately adjacent to Waikele Stream. Red apple snail egg masses were observed on up to 25% of all taro plants in these taro fields, and many taro stalks were observed to be damaged by the adult snails.

Kapakahi Stream

‘O’opu akupa was the only native species of fish found in Kapakahi Stream and was uncommon, while eight species of introduced fish were found (Table 3). Introduced fish species were dominant in Kapakahi Stream and included tilapia, *Mugilogobius cavifrons*, and numerous species of livebearing fish (Poeciliidae). Despite its short length of <0.75 mi, Kapakahi Stream contains more species of introduced fish than many Oahu streams. Excluding amphipods and isopods, only one species of introduced crustacean, *Procambarus clarki*, was found in Kapakahi Stream. Nine species of aquatic insects were collected at Kapakahi Stream. Several species of native indigenous dragonflies such as the common green darner (*Anax junius*) and the wandering glider (*Pantala flavescens*) were abundant, as were the introduced scarlet skimmer (*Crocothemis servilia*), and roseate skimmer (*Orthemis ferruginea*) dragonflies. Native damselflies (*Megalagrion* spp.) were not observed, but Rambur’s forktail (*Ischnura ramburi*) and the fragile forktail (*Ischnura posita*) were common. Several species of introduced aquatic beetles were also collected in Kapakahi Stream.
Kapakahi Stream also has the unfortunate distinction of being the first stream in the Pearl Harbor area in which apple snails were found. Apple snails are a serious pest to island agriculture, and cause serious economic damage to wetland crops such as taro and watercress (*Nasturtium microphyllum*) (Eldredge 1994, Cowie In Press).

Overall, aquatic habitat conditions were quite poor in this short stream, and native stream biota (with the exception of the common indigenous dragonflies) was almost non-existent.

Table 3. Distribution of native and introduced aquatic animals in Waikele and Kapakahi Streams, Oahu, May-June 1998.

	Waikele[A]				
Taxon	1 Estuary	2 USGS Gage[B]	3 Waikele Springs	Kapakahi Stream	Geographic Status
Fish					
‘O’opu nakea (*Awaous guamensis*)		X	X		Indigenous
‘O’opu naniha (*Stenogobius hawaiiensis*)		X	X		Endemic
‘O’opu akupa (*Eleotris sandwicensis*)	X	X		X	Endemic
Goby (*Mugilogobius cavifrons*)	X	X		X	Introduced
Aholehole (*Kuhlia sandvicensis*)	X	X			Endemic
‘Ama’ama (*Mugil cephalus*)	X	X			Indigenous
Mullet (*Moolgarda engeli*)	X				Introduced
Barracuda (*Sphyraena barracuda*)	X				Indigenous
Lizardfish (*Saurida gracilus*)	X				Indigenous
Armored catfish (*Ancistris* sp.)		X	X		Introduced
Blackchin tilapia (*Sarotherodon melanotheron*)	X	X	X	X	Introduced
Guppy (*Poecilia reticulata*)		X	X	X	Introduced
Shortfin molly (*P. mexicana*)[1]	X	X		X	Introduced
Sailfin molly (*P. latipinna*)				X	Introduced
Cuban topminnow (*Limia vittata*)[1]				X	Introduced
Western mosquitofish (*Gambusia affinis*)	X	X	X	X	Introduced
Platy (*Xiphophorus maculatus*)[1]				X	Introduced
Green swordtail (*Xiphorphous helleri*)		X	X		Introduced
Crustaceans					
‘Opae ‘oeha’a (*Macrobrachium grandimanus*)		X	X		Endemic
Crayfish (*Procambarus clarki*)		X	X	X	Introduced
Tahitian Prawn (*Macrobrachium lar*)		X	X		Introduced
Atyid shrimp (*Neocaridina denticulata*)		X			Introduced
Marine shrimp (*Periclimenes (Harpilius)* sp.)	X				Indigenous?
Marine shrimp (*Palaemon debilis*)	X				Indigenous?
Crenulated blue crab (*Thalamita crenata*)	X				Indigenous
Scuds (Amphipoda)					
Hyalelella azteca (prob.)		X		X	Indigenous
Gammaridae	X				Unknown
Sow Bugs (Isopoda) (riparian)					
Armadillidae		X	X	X	Unknown
Ligia hawaiiensis		X	X	X	Endemic
Mollusks					
Corbicula fluminea		X	X	X	Introduced
Apple snail (*Pomacea canaliculata*)		X[2]		X	Introduced
Snail (Thiaridae)		X	X	X	Introduced
Hirudinea (leeches)					
Myzobdella lugubris		X	X	X	Introduced
Aquatic Insects					
Damselflies/dragonflies (Odonata)					
Rambur’s forktail damselfly (*Ischnura ramburi*)	X	X	X	X	Introduced
Fragile forktail damselfly (*Ischnura posita*)	X	X		X	Introduced
Familiar Bluet (*Enallagma civile*)		X	X		Introduced

[A]See study area for description of locations. [B]Includes area above and below USGS gage. [1]Taxonomic status in Hawaii currently under review. [2]Apple snails in taro field next to stream, but not yet in stream channel (see Results).

Table 1 (cont.). Distribution of native and introduced aquatic animals in Waikele and Kapakahi Streams, Oahu, May-June 1998.

	Waikele[A]				
Taxon	**1 Estuary**	**2 USGS Gage[B]**	**3 Waikele Springs**	**Kapakahi Stream**	**Geographic Status**
Damselflies/dragonflies (Odonata) - cont.					
Wandering glider (*Pantala flavescens*)		X	X	X	Indigenous
Common green darner dragonfly (*Anax junius*)	X	X	X	X	Indigenous
Scarlet skimmer dragonfly (*Crocothemis servilia*)	X	X	X	X	Introduced
Roseate skimmer dragonfly (*Orthemis ferruginea*)		X	X	X	Introduced
True flies (Diptera)					
Chironomidae					
Orthocladius sp.		X			Unknown
Chironomus hawaiiensis		X			endemic
Culicidae					
Mosquito (*Aedes albopictus*)		X	X	X	Introduced
Dolichopodidae	X	X			Unknown
Ephydridae					
Scatella sexnotata	X				Indigenous
Tipulidae (*Limonia advena*)			X		Introduced
Aquatic Coleoptera (Hydrophilidae)					
Enochrus sayi				X	Introduced
Tropisternus lateralis		X			Introduced
Tropisternus salsamentus		X		X	Introduced
Trichoptera (Caddisflies)					
Cheumatopsyche pettiti			X		Introduced
Spiders (riparian)					
Tetragnathidae (*Tetragnatha mandibulata*)		X			Introduced
Amphibians					
Giant marine toad (*Bufo marinus*)		X	X	X	Introduced
Bullfrog (*Rana catesbeiana*)		X	X	X	Introduced

[A]See study area for description of locations. [B]Includes area above and below USGS gage.

ECOLOGICAL REQUIREMENTS OF STREAM ‘O’OPU

Five species of native ‘o‘opu occur in streams in the Hawaiian Islands. Four species (*Stenogobius hawaiiensis, Awaous guamensis, Lentipes concolor, Sicyopterus stimpsoni*) are in the family Gobiidae (goby) and one species (*Eleotris sandwicensis*) is a member of the family Eleotridae (sleeper). Hawaiian ‘o‘opu have recently been reclassified: four species are now considered endemic, and one species ‘o’opu nakea (*A. guamensis*) is considered indigenous (Watson 1992).

‘O‘opu have an amphidromous life cycle; they migrate to and from the sea but do not use the ocean for reproduction (Meyers 1949). ‘O‘opu spend their entire adult lives in freshwater streams. They reproduce in the stream, laying their eggs on the upper surfaces of rocks and hatch within 48 hours (Ego 1956). Larvae then drift out to the ocean and spend up to 160 days in a planktonic state. Returning post-larval ‘o‘opu, called hinana, may ascend randomly to streams and at times in great numbers.

Species such as ‘o’opu nakea, ‘o’opu nopili (*Sicyopterus stimpsoni*), and ‘o’opu hi’ukole (*L. concolor*) are capable of climbing waterfalls and areas of rapids. ‘O’opu hi’ukole is the strongest climber and is capable of ascending very large waterfalls. Individuals have been reported to ascend single waterfalls as high as 1000 ft (Englund and Filbert 1997b).

‘O’opu nakea is known to migrate downstream to spawn on riffles located just upstream of the ocean (Kido and Heacock 1991). Downstream spawning runs are believed to be triggered by the first large rainstorm in the fall. However, postlarvae have been found throughout the year, indicating that some degree of spawning occurs throughout the year.

A major ecological requirement for ‘o‘opu is the need to pass through a stream mouth at two times during the individual’s life (Kinzie 1990). The most important factor for the existence of endemic ‘o‘opu in streams is that access to and from the ocean is maintained. Stream channelization and diversions can eliminate or significantly limit native fish populations within a stream.

‘O’opu hi’ukole is listed as a Candidate species on the Federal Register, and was considered ‘threatened’ by the American Fisheries Society (AFS) (Deacon et al. 1979). ‘O’opu nakea and ‘o’opu nopili were considered to be species of special concern by the AFS (Deacon et al. 1979).

POTENTIAL ENVIRONMENTAL CONSEQUENCES

Waikele Stream

As described in the INTRODUCTION section of this report, the proposed location of the water diversion in Waikele Stream is located immediately upstream of the concrete weir at the USGS Gaging Station above Farrington Highway. A detailed hydrological analysis is contained in a report prepared by Tom Nance Water Resource Engineering (Nance 1998). Biological impacts associated with water withdrawal from Waikele Stream are based on projections contained in the hydrology report. Impacts are based on changes in base-flow conditions, because that is when maximum water withdrawal from Waikele Stream would likely occur. From 1951 to 1989 (during diversions) flow in Waikele Stream averaged 26.2 MGD. After stream diversions ended in July 1989, flow averaged 27.0 MGD from August 1989 to 1997 (Nance 1998). Although this is only a 0.8 MGD difference in the average post diversion flow rate, the cessation of diversions did influence Waikele Stream flows. For example, during times of lowered precipitation minimum stream flows were higher in the last eight years than from 1951-1989 (Nance 1998). The higher minimum flows still occurred even though the period from 1989 to 1997 was substantially drier on average when compared to 1951-1989. This is reflected in the pre-1989 average streamflow of 30.5 mgd (including diversions), which is 3.5 MGD more than the undiverted 27.0 MGD average from 1989 to 1997 (Nance 1998). Thus, the proposed diversion of 4.6 MGD at the WP-18 pump station would reduce average Waikele Stream flow (based on 1989 to 1997 data) to 22.4 MGD.

The following impact analysis is divided into two sections: native amphidromous biota (stream fisheries) and estuarine fisheries. This impact analysis is predicated upon current conditions in Waikele Stream. Historical diversions such as the stream diversions by Oahu Sugar until July 1989 are not considered. Previous impacts to stream and estuarine biota would have been on a much greater and long-term scale as historical diversions were often greater than the presently proposed diversion. From 1951-1989, a highly variable average of 4.3 MGD (which is nearly the same as the 4.6 MGD proposed diversion) was diverted from Waikele Stream (Nance 1998). However, diversions of greater than 14 MGD also occurred from 1951-1989. The historical diversions were frequently greater than the proposed 4.6 MGD diversions, especially during dry periods (see Nance 1998).

Two primary impacts to the stream and estuary would occur during water withdrawals conducted in the dry season. The first would be a reduction in stream flow (of 4.6 MGD) and aquatic habitat in the Waikele Stream channel downstream of the diversion point. The second impact would be a potential increase in salinity in estuarine habitat in the West Loch of Pearl Harbor. This would potentially occur starting at the upper tidal limit of the Waikele Stream estuary (at the USGS Gaging Station weir) and extend into the West Loch of Pearl Harbor. This analysis mainly addresses the impacts of changes in salinity on estuarine biota. Other potential impacts such as changes in nutrients, phtyoplankton productivity, etc., are beyond the scope of this report.

Estuarine fisheries

Reductions in flow just upstream of the USGS Gaging Station weir could affect conditions in the estuary by either altering the chemical environment, primarily salinity, of the estuary or by reducing the physical space (i.e., volume of the freshwater lens). Some impacts to native estuarine biota may occur due to reduction in physical space, and some impacts may occur due to expected salinity changes. These impacts can only be considered to occur when compared to present, short-term (since diversions stopped in 1989) conditions (see below). As stated previously, the proposed diversion is nearly identical to the long-term average sugar cane diversion, but much less than the maximum diversions of up to 14 MGD that commonly occurred between 1951-1989. Thus, no net impacts are expected when compared to historical (pre-1989) conditions, but potential impacts may occur when compared to current, undiverted conditions.

Our field survey determined that this area is currently suitable habitat for juvenile aholehole and ‘ama’ama (striped mullet). High densities of both juvenile aholehole and ‘ama’ama were captured and observed in the tidal mudflat and mangrove area where Waikele Stream enters West Loch. Similar qualitative abundances were observed during 1993 field surveys by Englund (1993). However, because the reduction of the area of the fresh-brackish lens (with salinities of <15 ppt) due to the proposed diversion is so small, impacts may not be sufficient to affect the fishery in Pearl Harbor.

Increases in salinity resulting from a reduction of freshwater to the estuary could affect juveniles of two important native fish species: ‘ama’ama or striped mullet (*Mugil cephalus*) and aholehole (*Kuhlia sandvicensis*). Other native marine species occurring in the Waikele Stream estuary are tolerant to varying degrees freshwater but do not necessarily prefer or select for low-salinity conditions. Although no discrete threshold has been established, juvenile ‘ama’ama appear to prefer water with salinity below 15 ppt (Blabber 1987, Dr. Ken Leber, Mote Marine Lab, Sarasota, Florida, personal communication). When salinity becomes > 15 ppt, juvenile ‘ama’ama will abandon an area (e.g., estuary) and move in search of fresher water. During this movement, juvenile ‘ama’ama become increasingly susceptible to predation and possibly reduced food availability. Any adverse effects on juvenile fish can translate into a reduction in Pearl Harbor (and Oahu) fisheries. Salinity preferences for aholehole are less established than that for ‘ama’ama, but the seasonal use of estuaries as nursery habitat by aholehole is similar to that of ‘ama’ama, and well known in Hawaiian waters (Filbert and Englund 1995, Tate 1997). For this analysis I have assumed that juvenile aholehole also prefer water with salinities below 15 ppt. For reference, the salinity of sea water around the Hawaiian Islands is approximately 35 ppt.

Surface salinity in Waikele stream from the upper extent of tidal influence (at the USGS concrete weir) to the Waikele Stream mouth (see Station 7 *in*: Nance 1998) was measured at ≤ 15 ppt. Salinity measurements taken at the Waikele Stream mouth determined a freshwater lens of ≤ 15 ppt extended to a thickness of 0.25 ft (Nance 1998). These measurements were taken during a period of no diversion and at fairly average stream flow levels in May (13.2 MGD) and June (12.6 MGD) 1998. The surface layer of freshwater is quite thin in this area, and salinity at the Waikele Stream mouth quickly goes to near sea level conditions (> 30 ppt) at 0.5 ft below the water surface.

A very thin freshwater lens (<0.25 ft in depth) exists at the Waikele Stream mouth (Site 7 in Nance (1998)). This area is suitable habitat for juvenile ‘ama’ama and aholehole. During water diversion, the depth of the freshwater lens (≤ 15 ppt) would be slightly reduced in the immediate vicinity of where Waikele Stream enters the West Loch of Pearl Harbor. According to hydrologic models (see page 38, Tables 9 and 10, Nance 1998) the thickness of the freshwater lens would be reduced by only 0.08 ft at the Waikele Stream mouth. This is assuming a 4.6 MGD diversion at a stream flow level that is exceeded 80% of the time (11.6 MGD).

Due to the proposed 4.6 MGD diversion salinity at the Waikele Stream mouth would exceed 15 ppt and render a 0.08 ft. thick portion of the freshwater lens unsuitable as rearing habitat for juvenile ‘ama’ama and aholehole. This habitat loss was calculated from flows that occur in Waikele Stream at least 80% of the time. It is difficult to assess how a reduction of 0.08 ft of depth in the freshwater lens would influence the ‘ama’ama and aholehole fishery at the mouth of Waikele Stream. The stream mouth area is a relatively small, and was 170 ft. wide at the point of the salinity profile measurements. A reduction of 0.08 ft. in the depth of the freshwater lens appears to be a small amount of lost freshwater habitat compared to the overall Pearl Harbor and West Loch system. This analysis is of course an oversimplification of a very complex system. Much more research would be required to make more definitive statements on the effects of this or any other proposed diversion in Hawaiian waters. However, the hydrological models verify that that the proposed diversion will normally (80% of the time) minimally impact the physical size or salinity of the estuarine environment at the Waikele Stream mouth, or the West Loch of Pearl Harbor.

Additional impacts to changes in salinity in the upper north end of the West Loch of Pearl Harbor, and not only the very limited region of the Waikele Stream mouth, were also addressed by Nance (1998). The area modeled encompasses the portion of West Loch from the Laulaunui Fishpond north to the Waikele and Kapakahi Stream mouths. Surface salinities within West

Loch, including inputs from Honouliuli and Kapakahi Streams, were computed to increase as a result of the proposed diversion from 0.22 to 0.89 ppt, and ranged from 31.44 to 31.82 ppt (Nance 1998). This is likely not a major or even noticeable biological change to the West Loch estuarine system. Strong winds often push the freshwater input of Waikele Stream to the western side of West Loch, thus any slight reduction in surface salinity due to the proposed diversion will often be masked by the mixing effect of strong winds.

Although difficult to assess, a reduction of the freshwater lens by 0.08 ft. in thickness due to the 4.6 MGD proposed diversion may provide little negative impacts to native estuarine fish at the Waikele Stream mouth area. Changes in salinity due to the proposed withdrawal may not adversely impact physical habitat for juvenile estuarine fish such as aholehole and ‘ama’ama, as less than one-tenth of a foot (in depth) of critical habitat will be lost. Cumulative impacts of the numerous wells and diversions in the watershed, along with the effects of urbanization have undoubtedly reduced the fisheries of Pearl Harbor in the past 100 years. The proposed diversion is far less than diversions of over 14 MGD that occurred on a regular basis during sugarcane cultivation. Thus, any adverse impacts would be far substantially less than what occurred during periods of recent diversions.

Native Amphidromous (Stream) Biota

There are two ways in which withdrawal of water from Waikele Stream could affect native amphidromous biota: reduction of habitat quality and quantity within the stream, and diminished freshwater signature (due to reduced freshwater flow) in the West Loch of Pearl Harbor. The freshwater plume, or signature, attracts native post-larval amphidromous biota to stream mouths so that they can migrate upstream and recruit to the adult population. Amphidromous refers to organisms that migrate between the ocean streams to complete their life cycles (see Ecological Requirements of Stream ‘O’opu). Native amphidromous organisms include not only ‘o’opu, but ‘opae ‘oeha’a (*Macrobrachium grandimanus*), ‘opae kuahiwi (*Atyoida bisulcata*), hihiwai (*Neritina granosa*), and hapawai (*Theodoxus vespertinus*). Under present, non-diverted conditions, estuarine nursery fish habitats are available at the Waikele Stream mouth and lower stream channel area. In Waikele Stream we collected native post-larval stream fish and crustaceans such as ‘o’opu naniha, ‘o’opu akupa, and ‘opae ‘oeha’a that were attracted to the stream due to the freshwater plume.

No reduction in freshwater habitat quality and quantity would occur in strictly freshwater sections of Waikele Stream due to the proposed diversion. This is because water will be taken from Waikele Stream at a point where the stream flows over the USGS weir and immediately into a tidally influenced region. Thus, only tidally influenced areas will be affected by this diversion. This diversion could therefore potentially adversely effect recruiting stream biota and native stream organisms capable of inhabiting estuarine conditions that are found here such as ‘o’opu naniha, ‘o’opu akupa, and ‘opae ‘oeha’a.

Under the proposed diversion of 4.6 MGD, approximately 2000 ft. of Waikele Stream from the diversion point at WP-18 (USGS Gaging Station weir) downstream to West Loch would have a reduction in freshwater and estuarine habitats during low-flow periods. According to the hydrological models, the mostly freshwater areas in the Waikele Stream channel (Sites 1-4 in Nance 1998) affected by the proposed diversion would have the freshwater layer reduced by a range of 0.27 to 0.5 ft. in thickness from current conditions. The model is based on periods of ‘normal’ flows occurring >80% of the time. Although there would be stream flow over the USGS weir and into the concrete channel section virtually all the time, a reduction in estuarine, tidally influenced habitats would nevertheless occur under the projected withdrawal scenario. At low tide, the stream normally flows as a thin layer of completely fresh water to just downstream of the Farrington Highway Bridge. With the proposed diversion this freshwater layer (Site 1 in Nance 1998) would be reduced from 1.05 ft. in thickness to 0.78 ft. This would be a reduction in the thickness of the freshwater lens by 0.27 ft. in the area of the Farrington Highway Bridge. Waikele Stream maintains its integrity of freshwater surface flow downstream to the Chevron petroleum pipeline crossing area (Site 4 in the Nance report). This area would have the freshwater layer reduced in thickness by 0.3 ft. due to the proposed diversion.

A reduction in habitat potentially could adversely affect amphidromous biota that occupy the lower portion of the stream such as ‘o’opu naniha, ‘o’opu akupa and ‘o’opu nakea. Overall impacts to native amphidromous biota due to reduction in available estuarine/tidal habitat or the freshwater plume are presently impossible to quantify. However, as mentioned previously, the slight decrease in thickness of the freshwater lens appears to be a relatively small reduction in estuarine habitat. Three native ‘o’opu species were present in low numbers during surveys conducted in this section Waikele Stream. It is important to point out that introduced fish species dominated this section of Waikele Stream, as well as areas above the USGS Gaging Station weir. Lower Waikele/Kipapa Stream is highly biologically degraded, and native stream fish (excluding ‘ama’ama and aholehole in estuarine regions) appear to be quite uncommon (Englund 1993, Englund 1997).

Although low numbers of native fish are found in the lower reaches of Waikele Stream, a significant population of large, mature ‘o’opu nakea was found in the upper reaches of the Waikele Stream watershed (Englund 1993). During withdrawals conducted at ‘normal’ stream flows (> 80% of the time) the current freshwater signature in Pearl Harbor at the mouth of Waikele Stream would be slightly reduced. Again, the thickness of the freshwater lens at the Waikele Stream mouth would be reduced by 0.08 ft.

At flows less than the ‘normal’ (80% of the time) there would be a greater effect on the freshwater plume at the Waikele Stream mouth. A worst case scenario, or the lowest flow day from 1989 to 1997, was also analyzed in Tables 11 and 12 by Nance (1998). These tables show that a 4.6 MGD diversion during a nine-year low-flow of 7.1 MGD would decrease the fresh water layer from 0.13 ft to 0.05 ft. in the Waikele Stream mouth area (Site 7 in Nance 1998). A decrease of 0.08 ft. in the freshwater lens at the Waikele Stream mouth appears to be a small reduction in habitat. The hydrological analysis also determined that overall salinity levels in the West Loch of Pearl Harbor would only be minimally changed by a maximum of 0.9 ppt due to the proposed 4.6 MGD diversion. There is currently no way to quantitatively assess (unless a long-term study was conducted) if the native ‘o’opu nakea population in the upper reaches of Waikele/Kipapa Stream would be adversely impacted by the proposed 4.6 MGD diversion. On the other hand, impacts to salinity levels and the size of the freshwater lens even in a worst case scenario have been shown by Nance (1998) to be minimal under the proposed 4.6 MGD diversion. Impacts to ‘o’opu nakea would be far less than the former sugarcane diversions that regularly exceeded 4.6 MGD, and often were substantially greater than 10 MGD.

Kapakahi Stream

No adverse impacts are anticipated to occur to native Hawaiian stream biota in Kapakahi Stream resulting from the proposed channel dredging in the area of the Chevron petroleum pipeline. This is due to the small scale and temporary nature of impacts channel dredging that is required to install a pipeline under the stream channel. Additionally, with the exception of one native ‘o’opu species that was uncommon, Kapakahi Stream contains almost no native aquatic stream biota, and must be considered one of the most biologically degraded Oahu streams. Even if Kapakahi Stream was in a better condition, dredging a small section of stream channel would likely lead to no serious short-term or long-term impacts. Impacts would probably be no worse than sediment input from a large rainstorm. However, best management practices should be employed during construction to minimize soil erosion into downstream and nearshore ocean areas. This project is not proposing to divert water from Kapakahi Stream, thus no impacts due to water diversion from this project are possible.

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APPENDIX I - ENGLUND (1993) SURVEY RESULTS

Distribution of native and introduced aquatic biota collected in 1993 in Waikele/Kipapa Stream and estuary, Pearl Harbor (from Englund 1993).

	Elevation (ft)					
Taxon	**0 (estuary & USGS)**	**400**	**800**	**1250**	**1600**	**Geographic Status**
Amphibians						
Giant marine toad (*Bufo marinus*)	X	X	X	X	X	Introduced
Bullfrog (*Rana catesbeiana*)	X	X	X	X	X	Introduced
Wrinkled frog (*Rana rugosa*)					X	Introduced
Turtles (red-eared slider)						
Chrysemys scripta elegans	X					Introduced
Fish						
Eleotris sandwicensis	X					Endemic
Stenogobius hawaiiensis	X					Endemic
Awaous guamensis	X	X	X	X		Endemic
Mugilogobius cavifrons	X					Introduced
Mugil cephalus	X					Indigenous
Kuhlia sandvicensis	X					Endemic
Ancistris sp.	X	X				Introduced
Poecilia sphenops (currently mexicana)	X	X	X	X		Introduced
Poecilia reticulata	X	X	X	X		Introduced
Xiphophorus helleri	X	X	X			Introduced
Tilapia (Sarotherodon) melanotheron	X					Introduced
Clarias fuscus			X			Introduced
Misgurnus anguillicaudatus			X	X		Introduced
Crustaceans						
Macrobrachium grandimanus	X					Native
Macrobrachium lar	X	X	X			Introduced
Procambarus clarkii	X	X				Introduced
Mollusks						
Lymnaea reticulata?	X	X				status uncertain
Thiaria tuberculata	X	X				Introduced
Corbicula fluminea	X					Introduced
Insects						
Damselflies and dragonflies (Odonata)						
Dragonfly (*Anax junius*)	X					Indigenous
Dragonfly (*Anax strenuus*)				X	X	Endemic
Dragonfly (*Pantala flavescens*)	X					Indigenous
Dragonfly (*Orthemis ferruginea*)	X					Introduced
Fragile forktail (*Ischnura posita*)				X		Introduced
Rambur's forktail (*Ischnura ramburi*)	X					Introduced
True flies (Diptera)						
Chironomidae						
Cricotopus bicinctus				X		Introduced

Table 1 (cont.). Distribution of native and introduced aquatic biota collected in 1993 in Waikele/Kipapa Stream and estuary, Pearl Harbor (Englund 1993).

	Elevation (ft)					
Taxon	**0 (estuary & USGS gage)**	**400**	**800**	**1250**	**160 0**	**Geographic Status**
Dolichopodidae						
Campsicnemus miritibialis				X	X	Endemic
Chrysotus paliidipalpus				X		Endemic
Ephydridae						
Neoscatella hawaiiensis				X	X	Endemic
N. warreni				X		Endemic
Tipulidae						
Limonia jacoba					X	Endemic
Limonia stygipennis					X	Endemic
True bugs (Heteroptera)						
Mesoveliidae						
Mesovelia amoena				X		Introduced
Saldidae						
Saldula exulans				X	X	Endemic
Veliidae						
Microvelia vagans				X	X	Endemic
Caddisflies (Trichoptera)						
Cheumatopsyche pettiti	X			X		Introduced