

# WHITE PAPER ON WATER LEVEL CONTROL AND TIDAL FLOWS

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## ABSTRACT

Historic and current reduction of tidal flows to Lake Merritt is correlated to reduced water quality and diminished aquatic habitat. Periods when water levels are held constant have been linked to low oxygen levels and hold the potential for preventing successful establishment of proposed wetland areas. Although conditions have improved in the last decade, there is room for further improvement by operational and structural changes at the flood control structure. Operational changes could include daily (every 12 hours) decisions regarding tide gate closure, and making personnel should be available 7 days a week to fine tune the balance between flood control and the health of the lake. A newly designed facility could withdraw water from the bottom of the Lake (thus improving water quality) allow tidal action to the entire channel and could provide increased flood protection.

## BACKGROUND

Lake Merritt has been a salt water lagoon with natural tidal flows since the ice ages. During the last century however, the Lake's water level has been controlled. Tidal flow has been restricted, kept out, kept in, and everything else in between. This manipulation has been accomplished in the name of many good causes, but the results have often been unforeseen. Early controls were structural, including a dam across the inlet, and filling the channel between Lake Merritt and the Oakland Inner Harbor.

**The Dam:** Control began when the 12th Street dam was completed in 1869. What had been a 600 foot wide opening to the Bay was restricted to the area of a drawbridge, thus reducing tidal flow. A wooden floodgate was installed to maintain a the Lake at a higher level, thus eliminating many of the mud flats and marshes. The volume of water entering and leaving the Lake was greatly restricted.

**The Channel:** The restriction of water flow continued as the channel to the Bay (once a quarter mile wide in places) was filled and narrowed (Oakland Museum Watershed Map, 1993). Tidal flows that had once been adequate for three masted schooners to enter the Lake were diminished. Now, while San Francisco Bay rises and falls six feet daily, Lake Merritt is restricted to 1 - 2 feet of tidal influence. Its like trying to fill a bathtub with a straw; the channel is simply too small to carry more water. With the dam and narrow channel in place, tidal flows to the Lake are a fraction of their former volume.

**The Watershed:** Lake Merritt has a watershed of 7 square miles. This means that about 4,670 acres drain into a 140 acre Lake, a ratio of 33:1 (Abbe and Haltiner, 1992). Highly urbanized, this area sheds water rapidly during rainstorms, creating the potential for downstream flooding. If tidal flows and rainwater enter the Lake at the same time, water levels can rise quickly and floods can occur. Since runoff is not controlled upstream, floods are prevented by restricting the incoming high tides.

**Water Quality:** Tidal flows are an important influence on water quality in Lake Merritt. As has been documented in the past and continues to be documented today, the Lake is

dependent upon flushing from the Bay to minimize water quality problems. Restricted tidal flows to and from the Bay can create low oxygen levels, increased temperature extremes, abnormal salinity levels and other problems.

**Flood Control:** Preventing floods is the reason for most water level control activities at Lake Merritt. Without this control, the surrounding lowlands would be subject to occasional inundation. For example in 1962, 4.47 inches of rain fell in 24 hours and the Lake rose to 7.3 feet (the highest level ever recorded). This is four feet higher than normal and surrounding streets were flooded. Note that in this document all Lake levels are given with respect to the National Geodetic Vertical Datum. To minimize such flooding when there is a chance of rain, tidal flow into the Lake is sometimes limited or even eliminated.

### **1869 TO 1970 - A CENTURY OF LIMITED TIDAL FLOW CONTRIBUTES TO PROBLEMS**

Prior to the 1920's, there is little information regarding operation of the original tide gates (Travis, 1995). But in 1926 new tide gates were installed at 8th Street and tidal action (already drastically diminished) was essentially eliminated. Lake levels were kept low in the rainy season to limit floods, the gates being opened only to allow water to drain out. During the summer, levels were kept high, the tide gates being opened only a few days per month to allow flushing (Marchette, 1953).

**Effect of Control on Lake Merritt:** This artificial regime continued through the 1950's, the Lake receiving only periodic salt water inflow (CA DFG, 1957). Despite the Lake's status as a state wildlife refuge, its health as a natural system was given scant attention except when fish kills occurred. In the winter the Lake became virtually a fresh water pond; in summer the salinity of the water approached that of sea water. Without daily tidal flows, summer temperatures reached 81° F. Pollutants were concentrated. Oxygen levels often dropped. The loss of tidal flushing probably contributed to the apparent decline in Lake Merritt's water quality between the 1930's and early 1960's (Travis, 1995).

**Fish Kills:** In 1939, hundreds of dead striped bass and smelt were found in the Lake, and more frequent flushing by opening the tide gates was suggested by a pollution control official for the state Game and Fish Commission (Oakland Tribune June, 1939).

In 1949, 104 striped bass from 12 - 15 pounds and hundreds of smelt were found dead, and the City decided to let sea water into the Lake for several days (Oakland Tribune April, 1949). Also in that year, the Oakland Park Board said that the Lake had become so polluted that the health of its waterfowl was in jeopardy.

In 1951, thousands of smelt died in May and William Penn Mott Jr. cited oxygen depletion as the cause. He said workers would drain the Lake as low as possible using the tide gates. But in July of that year, "tens of thousands" of smelt died due to lack of oxygen (Oakland Tribune May and July, 1951).

**Summary:** Although sewer leaks, sewage overflows and storm drain flows were also causes of poor water quality, it is clear that restricted tidal flows were a significant factor in damaging the health of the Lake Merritt. Studies in 1929 and 1953 found only a handful of San Francisco Bay's plankton and invertebrate species in the Lake (Travis, 1995). Numerous fish kills led to numerous recommendations that tidal circulation be increased. Cut off from the ocean and bay, the Lake often became stagnant as nutrients and pollutants from storm drains became trapped until the occasional few days a month in the summer when the gates were opened. In the winter, clean water from the bay was typically kept out, limiting water exchange and intensifying pollution problems.

## **1970 - 2002: ERA OF THE NEW FLOOD CONTROL STRUCTURE**

**New Tide Gates and Pumps:** In response to the flood of 1962, the County of Alameda built a then state-of-the-art flood control structure complete with automated tide gates and diesel pumps that can even reverse tidal flows. Located under the bridge that now combines 7th and 8th streets, this facility was designed to prevent flooding from rainfall events up to the 25 year storm (one that, statistically, occurs once in 25 years). Larger storms, such as a 50 or 100 year storm, will still cause flooding. The station operates mainly by opening and closing tide gates to restrict flow into or out of the Lake. The facility also includes four diesel powered pumps that can move water to or from the Lake, thus providing further control over Lake level. Use of the pumps is minimal and logs show they have been used only about 1% of the time. These devices can be controlled automatically by computer, which can be set to one of four modes of Lake level control.

**Natural Flushing Still Restricted:** Despite the enhanced ability to control Lake level and a century of evidence that reduced tidal flows exacerbate water quality problems, a 1975 report noted an "absence of natural flushing" (Travis, 1995). Data from the Alameda County Flood Control District showed that between 1972 and 1973 exchange with the Oakland Inner Harbor occurred on an average of only 8 days per month. Often the gates would remain closed for several days to a week or more at a time (CA RWQCB, 1975). Articles in the press indicated that only during times of a crisis such as a fish kill would the gates be open on a daily basis (Oakland Tribune July, 1974 and May, 1976).

**Improvements:** The 1975 study suggested flushing as the most practical water quality management program, and by the late 70's the Lake was receiving more regular tidal inflow. A 1979 study commissioned by the City listed flushing of the Lake using the pump station as a high priority recommendation (Pitt and Bozeman, 1979) and tests were conducted (ACFC&WCD and CH2M-Hill, 1982). During these experiments larger than normal volumes of water were pumped into the Lake. It was determined however that dredging the entire Lake was a better long term solution to the Lake's problems, and artificial flushing was not adopted.

In the 1980's the County allowed more frequent natural tidal flows but maintained a flood control policy which kept the gates closed during high tides for any ten day period during which rain was forecast. The result was that the Lake level was kept low (around 1 foot above mean sea level) and inflow from high tides was kept out for much of the winter (Travis, 1995). Combined with improvements in water quality from sewer repairs, this policy has led to the elimination of fish kills, the last of which occurred in 1981 (Gray, 1990).

**Current Operation of the Flood Control Structure:** In the 90's, the County adopted a policy of leaving the tide gates open to natural flow more often, and this

resulted in an improvement in water quality. With both gates open at the flood control structure, the Lake water has an average residence time of about four days (Abbe and Haltiner, 1992). "The return of regular tidal flushing undoubtedly was a major factor in improving the Lake's ecological health" (Travis, 1995).

Under current policy, natural flows are allowed except for the following:

- **Flood control** Tidal flows into the Lake are limited and the Lake is kept at about 1.0 feet when rain is in the forecast based on twice weekly weather forecasts. This is effective in reducing floods, but may result in restricted tidal flows for extended periods of time; e.g. several days or weeks. If the weather forecast changes, it may be several days before the incoming tides are allowed into the Lake.

**Dates of Limited Tidal Circulation in 1998-99:** During the winter of 1998 - 1999, high tides were kept out of the Lake on the following dates:

November 2 - 12  
November 21 - December 6  
January 16 - 19  
February 4 - 7  
March 16 - 24  
April 5 - 7

- Keeping the Lake level high (2 feet above MSL) during boating races and special events such as Festival at the Lake
- Keeping the Lake level high or low for unusual circumstances such as dock inspections, construction, emergency spills etc. and
- Keeping the Lake high for several days per week so that the harvester boat can navigate closer to shore to pick up nuisance growths of algae and drifting pieces of widgeon grass. In 2001, the Lake was kept at about 2.0 feet for two days per week from June - August.

To implement one of the above listed scenarios, instructions are given to County staff from one or more of several City of Oakland departments, including the Boating Center, the Public Works Agency or the Parks and Recreation Department.

**The Relationship Between Tidal Restriction and Bottom Oxygen Levels:** When high tides are restricted from entering Lake Merritt, low oxygen conditions at the bottom of the Lake may be exacerbated. This occurs when the Lake is stratified, which means that fresh water from creeks and storm drains forms a separate layer above the salty sea water. The bottom layer of sea water does not mix with the upper layer, and oxygen depletion results. Several years of water quality monitoring have demonstrated that this is a common condition at Lake Merritt during the winter and spring.

During flood control, only the surface water of the Lake drains out to the Bay. This is because the outlet of the Lake at 12th Street is several feet above the bottom of the Lake.

At the bottom, oxygen is depleted by the decomposition of organic matter, and low to extremely low oxygen levels can result. Oxygen monitoring at the Lake has shown that levels of 1 - 4 parts per million (ppm) are not uncommon. Given that water quality standards call for at least 5 ppm to support aquatic life, these conditions are the reason that the US Environmental Protection Agency has listed Lake Merritt as an impaired body of water with respect to oxygen. This topic is presented in more detail by the Institute's White Paper on Oxygen, which can be found under the "Information" button at [www.lakemerrittinstitute.org](http://www.lakemerrittinstitute.org).

**Data Demonstrates That Oxygen Conditions are Worse During Restricted Tidal Flow:** Studies by the Environmental Academy of Oakland High School have demonstrated that bottom oxygen conditions are lower when Alameda county is limiting tidal flow. Using data from four stations in the Lake, it was found that oxygen levels were at or below 5 ppm 65% of the time when tidal circulation was restricted. But when the tide gates were left open, oxygen levels were at or below 5 ppm only 29% of the time. Based on these numbers, oxygen levels in bottom waters are more than twice as likely to be low when tidal flow is restricted.

At the mid-Lake sampling station, the average oxygen level for 36 days when the tide gates were left open was 7.7 ppm. However when the tide gates were shut to keep out high tides on five days, the average oxygen level was 5.0 ppm, a significant decrease. At this station, oxygen levels were less than 6 ppm 80% of the sampling days when there was limited tidal circulation, but these levels occurred only 18 % of the sampling days when there was normal tidal circulation.

At the Glen Echo Inlet station, the average oxygen level for 20 days when the tide gates were left open was 4.62 ppm. When the gates were shut during high tides, oxygen levels were only 3.2 ppm.

**The Relationship Between Tidal Restriction and Proposed Wetland Construction:** According to a professional hydrological study (Abbe and Haltiner, 1992) conducted in conjunction with the Lake Merritt Enhancement Plan "a functional marsh (emphasizing mid-and high-marsh vegetation) can be created with the existing system hydraulics. The limited tide range restricts marsh restoration, but does not prevent it; however, the extended periods during which the lake levels are kept high or low are of greater concern." This study concluded that:

"If a marsh is created, gate closures and extended periods of artificially high and low water levels should be minimized."

**Current Location and Design of Flood Control Station are Out-Dated:** Designed in the late 1960's, the County Flood Control Structure has become out of date. If redesigned and re-built at the 12th Street dam, the following benefits could occur:

- Water withdrawal from the Lake during tide gate closure could occur from the **bottom** of the Lake, thus reducing the layer of stagnant water
- Flood control could be improved to include events larger than the 25 year storm
- The channel upstream of 7th Street could be opened to natural tidal action
- Computer modeling could be used to refine decisions as to when tide gates should be closed and more accurate electronic (not paper) tide gauge charts could be used
- Movement of marine life to and from the Lake could be improved by eliminating the trash rack bars across the channel.

## **Summary**

**History of Tidal Flow Limitation:** Lake Merritt is a natural tidal estuary whose connections to the sea have been drastically limited, both structurally and operationally. In decades past, this limitation has led to water quality problems, fish kills and limits on the types of life found in the Lake. Operational limits to natural tidal flows were reduced in the 1990's after studies recommended a more natural tidal regime

Although structural limits (the dam and narrow channel) are still in place, operational limits to unrestricted tidal flows have been reduced compared to previous decades and the past century. This has led to improvements in water quality.

At present, natural tidal flows are allowed except that incoming high tides are prevented from entering the Lake when rain is forecast in order to provide flood control. This can occur for several days to several weeks at a time. Tidal flows are also restricted to keep the Lake at a high level for seaweed harvesting, for boat races and during unusual circumstances.

## **Impact of Limited Tidal Flow on Oxygen Levels and Proposed Wetlands:**

Although Lake stratification and low bottom oxygen levels can occur during both limited and normal tidal exchange, existing data clarify that restricting tidal flow for flood control purposes can significantly lower oxygen levels in Lake Merritt. In addition, restrictions on natural tidal flows should be minimized in order to insure the survival of any wetlands that may be established at the Lake.

## **2002: Options for Control of Tidal Flow and Lake Level**

We have learned much from our efforts to control the level of Lake Merritt. As the 21st century begins there are opportunities (such as described in the Channel Study and Master Plan) to re-evaluate current operational limits to tidal flows and to redesign and re-locate the flood control structure.

The Channel Study: Alternatives 1 - 4 of the Channel Study (Port of Oakland, 2002) include several modifications that would greatly improve tidal flow to Lake Merritt. These include:

- Replacement of the "bottleneck" culverts at 10th Street with a bridge
- Dredging the channel from the Lake to the Bart tunnel, lowering the outlet by 1.88 feet

- Replacing the flood control structure with a new facility at 12th Street
- Improving other road and utility crossings over the channel.

**The Master Plan:** The Lake Merritt Master Plan (City of Oakland, 2002) also includes proposals that would improve water quality. In addition to the installation of storm White Paper on Tidal Flows October, 2002 Page 9 drain filters, the plan recommends:

Replacement of the narrow culverts at 12th Street with a bridge.

**Operational Changes:** Improvements could be made by changing operational patterns at the flood control structure, e.g. providing more manpower to fine tune gate closures and Lake levels. At present this multi-million dollar facility is being operated largely to provide flood control at minimal labor costs. If additional manpower were assigned to this county facility during the times when gate closures are implemented (typically only several weeks per year) it would be possible to significantly reduce the time when tidal flows are restricted.

**Recommendations:** To improve water quality by providing better tidal flushing, promote the health of wetlands that are expected to be built in 2003, minimize low oxygen conditions and increase opportunities for the passage of migratory fish, the following are recommended:

- Restrictive tidal structures at 12th and 10th Streets should be replaced with bridges
- The flood control facility at 7th-8th Streets should be re-designed and moved to 12th Street
- Decisions on tide gate closure should be made daily every 12 hours, and should be based on computer modeling (using a program such as the Corps of Engineers, Hydrologic Engineering Center's RAS model). Gates should not be kept closed for longer than 12 hours unless current conditions indicate a flood is possible if high tides are allowed to enter the Lake.
- Tide gate closure should be avoided except during imminent flood threat, 12 hour periods for seaweed harvesting and for occasional 12 hour boating events or maintenance efforts.
- Alameda county should make personnel available on an as-needed basis, 7 days a week, to modify tide gate operation. For example, if a boat race ends on Saturday or Sunday afternoon, the gates should be opened that night, not Monday morning. In like manner, when rain is not expected within 12 hours, the gates should remain open. A 12 hour window should be adequate to drain the Lake on a low tide and close the gates to keep out a high tide.
- Optimal operation of this very expensive capital improvement should not be hampered by the cost of labor needed to run it. The damage to Lake Merritt marine life, future wetlands and to oxygen levels from keeping tide gates closed more than absolutely necessary far outweighs the cost of overtime for 1-2 employees several weeks per year.

**Consideration of Flood Control:** These recommendations are not in any way meant to compromise flood control. Floods can cause serious property damage, cost millions of

dollars, and may even be life threatening. The judgement of a professional operator is needed to determine when such factors as ground water saturation, runoff, weather, wind and tidal conditions warrant more severe controls on Lake level and tidal restriction. Under severe circumstances where floods are likely, flood control must be the higher priority.

**Balance Between Flood Control and Lake Health:** Decisions on flood control however, should be made based on the best and latest information on a daily basis. For example, if tide tables do not indicate high tides, if rain has not occurred in several weeks, soils are dry, and there is a low percentage chance of rain, flooding is unlikely and natural tidal flows could be maintained. But if the forecast changes and significant rain is likely, gates could then be closed to keep out high tides. In this way flood control can be better balanced with the health of the Lake.

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