City and County of San Francisco
2030 Sewer System Master Plan

TASK 500
TECHNICAL MEMORANDUM NO. 512
DESIGN TIDE

FINAL DRAFT
August 2009
CITY AND COUNTY OF SAN FRANCISCO
2030 SEWER SYSTEM MASTER PLAN

TASK 500

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Please note this technical memorandum (TM) is a combination of TMs created in January, August, and October of 2007 that have not been updated since. It was determined by the SFPUC and the consultants that it was important to capture the information at the time of development so the reviewers could see the progression of information and decisions made at the time of the TM development. Please also note that the word 'alternative' was used instead of 'configurations' for the TMs reflecting the existing wording at the time it was written. In the Summary Report, the term was updated to 'configuration' so as not to confuse the CEQA review process. The configurations mentioned herein may have changed or been eliminated and are not considered full CEQA alternatives.

1.0 INTRODUCTION

The purpose of this TM is to report the results of a historic tide data analysis, the findings of an extensive literature review of the effects of global warming on future climate changes (more specifically the subsequent rise in sea level), and the estimated costs to retrofit the combined sewer system discharges with Tideflex® duckbill valves to prevent backflow into the system due to high tide levels. This information will be used in the consideration of alternatives currently being developed for master planning improvements to the wastewater collection and treatment facilities in San Francisco, California.

2.0 HISTORIC TIDE DATA ANALYSIS

This section summarizes the analysis of historic tide data to develop design tide conditions for the City of San Francisco.

2.1 San Francisco Tide Gage

The National Oceanic and Atmospheric Administration (NOAA) tide gage in San Francisco near Golden Gate Bridge is the oldest continuous running tide gage in the U.S. (NOAA, 2004). Installed in 1854, this tide gage has been recording tide levels in San Francisco for more than 150 years. While the location of the gage has moved four times in its history, it has remained near the Golden Gate Bridge (NOAA, 2002). The gage was moved to its current location at the Presidio in 1927. Figure 1 shows the current location of the tide gage.

2.2 Estimating Current Day Tide Levels

Verified hourly tide data from the San Francisco tide gage is available and was obtained from NOAA’s Tides and Currents website. To minimize effects of the San Francisco earthquake in 1906, data after April 1906 are used. Daily minimum and maximum tide levels were determined and are shown in Figure 2.
Figure 1  Location of the San Francisco Tide Gage

Figure 2  Daily Minimum and Maximum Tide Levels at the San Francisco Tide Gage
This study, as well as multiple others recently completed (NOAA, 2002; Cayan et al, 2006), shows that mean sea level (MSL) at the San Francisco tide gage is already rising and has steadily risen over the past century. Change in sea level is due to a number of factors. These factors are described in Section 3.0 (Climate Change and Sea Level Rise). In addition to the steadily rising MSL, daily high tides are increasing at a faster rate (~0.8 ft/century) compared to daily minimum tides (~0.6 ft/century).

The minimum and maximum tide levels were adjusted to reflect “current day” values. This was accomplished by multiplying the time that had passed since the measurement was recorded by the rate of increase observed at the gage, then adding that value to the tide level. For example, the high tide on June 30, 1957 was 3.3 feet above MSL. This was 50 years prior to the last measurement used in this analysis (June 30, 2007). Therefore, 0.4 foot (i.e., 0.8 foot increase per century) was added to the high tide value to bring the number to current day conditions. Minimum and maximum tide levels were adjusted for each ordinate in the time series for the purpose of normalizing the data to accommodate the extreme value analysis. Figure 3 is a graph showing daily minimum and maximum tide levels adjusted for current day conditions.

Figure 3 Daily Minimum and Maximum Tide Levels Adjusted for Current Day

A partial duration annual maximum time series was developed in order to perform an extreme value analysis on available tide data. Assuming a Type I (Gumbel) distribution, the high and low tide levels for various return periods were estimated. These tide levels are summarized in Table 1.
### Table 1
Summary of Current Day Design Tide Levels (Relative to City Datum)
2030 Sewer System Master Plan
City and County of San Francisco

<table>
<thead>
<tr>
<th>Return Period</th>
<th>High Tide</th>
<th>Low Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Year</td>
<td>-4.13</td>
<td>-13.50</td>
</tr>
<tr>
<td>5 Year</td>
<td>-3.81</td>
<td>-13.73</td>
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<tr>
<td>10 Year</td>
<td>-3.60</td>
<td>-13.88</td>
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<tr>
<td>25 Year</td>
<td>-3.33</td>
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<tr>
<td>50 Year</td>
<td>-3.14</td>
<td>-14.21</td>
</tr>
<tr>
<td>100 Year</td>
<td>-2.94</td>
<td>-14.35</td>
</tr>
</tbody>
</table>

### 3.0 CLIMATE CHANGE AND SEA LEVEL RISE

#### 3.1 Background

The earth’s climate is expected to change due to anthropogenic emissions altering the chemical composition of the atmosphere. Atmospheric greenhouse gases (GHG) (water vapor, carbon dioxide, and other gases) trap heat in the atmosphere and create a natural greenhouse effect. Without these gases in the atmosphere, the earth’s average temperature would be much lower and life could not sustain itself. Since the onset of the industrial revolution, however, human-generated emissions (e.g., carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and other gases) have been accumulating in the atmosphere at a much faster rate and are intensifying the earth’s natural greenhouse effect.

Figure 4 shows the longest continuous record (1958 to present day) of atmospheric carbon dioxide (CO$_2$) concentrations available in the world measured at the Mauna Loa Observatory in Hawaii. The monthly average atmospheric CO$_2$ concentration is shown in parts per million (ppm). The Mauna Loa record is considered to be precise and a reliable indicator of the regional trend since the observatory has one of the most favorable locations for measuring undisturbed air. Local influences of vegetation or human activities on atmospheric CO$_2$ concentrations are minimal and any influences from volcanic vents may be excluded from the records. In addition, the methods and equipment used to obtain these measurements have remained essentially the same during the 47-year monitoring program (Keeling and Whorf, 2005).

The Mauna Loa record shows a 19.4% increase in the mean annual concentration, from 315.98 parts per million by volume (ppmv) of dry air in 1959 to 377.38 ppmv in 2004. The 1997 to 1998 increase in the annual growth rate of 2.87 ppmv represents the largest single yearly jump since the Mauna Loa record began in 1958. This represents an average annual increase of 1.4 ppmv per year. This is smaller than the average annual increase at other stations because of the longer record and inclusion of earlier (smaller) annual increases (Keeling and Whorf, 2005).
The Intergovernmental Panel for Climate Change (IPCC) of 2001 projects that a doubling in CO₂ levels (from the pre-industrial level of 280 ppm) could increase global mean surface temperatures by between 1.4 to 5.8 degrees C (2.5 to 10.4 degrees F). Although there is uncertainty about future emissions of GHG and how and when the earth’s climate will respond to the enhanced concentrations of GHG, various studies report that detectable changes are already under way. The most likely are increases in temperature and changes in precipitation, soil moisture, and sea level, which could have adverse effects on many ecological systems, as well as on human health, infrastructure, and the economy (U.S. EPA, 1997). This section summarizes the findings on sea level, relevant for the City of San Francisco’s long-term planning of the sewer system.

3.2 Sea level rise and coastal implications

Based on geological data, global average sea level has risen at an average rate of about 0.05 meters (2 inches) per century over the last 6,000 years, and at an average rate of 0.01-0.02 meters (0.4-0.8 inches) per century over the last 3,000 years (Church et al, 2001). Global climate change is already occurring, and there are likely to be significant impacts on sea levels and coastal resources. According to a study by the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA GISS) examining temperatures around the world, 2005 was either the warmest year or tied for the
warmest in more than a century. According to the GISS team, the earth has warmed 0.6 degrees C (about 1 degrees F) over the past 30 years, and 0.8 degrees C (about 1.4 degrees F) over the past 100 years (Gutro, 2006).

In 2004, the IPCC concluded that improved modeling studies were converging on a global mean surface temperature increase of 3 degrees C (5.4 degrees F) by 2100 for a doubling of CO₂ with significant regional variation and that humans were responsible for the majority of the observed changes (Kerr, 2004). Based on projections given by the IPCC and the United Kingdom Hadley Centre’s climate model (HadCM2), by 2100 temperatures in California could increase by 2.8 degrees C (5 degrees F) (with a full range of 1.1 to 5 degrees C [2 to 9 degrees F]) in the winter and summer and slightly less in the spring and fall (U.S. EPA, 1997). Consequences of such a temperature increase include increased intensity, duration, and frequency of storm events, and dramatic changes to mountainous snowfall and snowmelt dynamics. The temperature increase is also expected to cause increased melting of land ice (specifically in Greenland and Antarctica) and thermal expansion of the marine mixed layer of the ocean, both of which contribute to sea level rise.

Independent of climate change, vertical land movements also contribute to relative sea level change and astronomical tides can cause changes in water level along the California coast of about 3 meters (10 feet) (Cayan et al, 2006). Since the processes contributing to sea level changes all have significant spatial variability, it has been suggested that there will be considerable geographic variability in changes in the rate of relative sea level rise (Walsh et al, 2005). The contributions of each factor to sea level rise are discussed below.

3.2.1 Land Ice

It is projected that climate change will reduce the amount of water frozen in glaciers and ice caps, specifically in Greenland and Antarctica. As this water moves from the land to the oceans, total ocean volume, and hence sea level, will increase. Observational and modeling studies of glaciers and ice caps concluded a contribution to sea level rise of 0.2 to 0.4 millimeters per year (mm/yr) (0.01 to 0.016 inches per year [in/yr]) averaged over the 20th century (Walsh et al, 2005). The IPCC projected that by 2100 the increase in ocean volume due to the contribution of land ice will be between -0.20 and 0.34 meters (-8 and 13 inches) (IPCC, 2001).

Over a much longer period of time, more extreme increases are expected: The IPCC Third Assessment Report suggested that continuing GHG emissions could trigger polar ice cap melting beyond 2100, resulting in a sea level rise greater than 5 meters (16 feet) within the next millennium (Church et al, 2001). Studies show that both the Greenland Ice Sheet and portions of the Antarctic Ice Sheet are experiencing rapid increases in near-coastal discharge over the past few years due to climate warming and ice dynamics (Rignot and Kanagaratnam, 2006; Velicogna and Wahr, 2006).
The total loss of ice from the Greenland Ice Sheet increased from the 1996-estimated rate of 91 (±31) cubic kilometers per year to the 2005-estimated rate of 224 (±41) cubic kilometers per year. Greenland’s ice mass loss has more than doubled over the last decade and its contribution to sea level rise increased from 0.23 (±0.08) millimeters (0.009 [±0.003] inches) per year in 1996 to 0.57 (±0.1) millimeters (0.022 [±0.004] inches) per year in 2005. Unfortunately, current models projecting the Greenland Ice Sheet contribution to sea level change do not include ice dynamics and, therefore, provide only lower limits (Rignot and Kanagaratnam, 2006). Measurements obtained from the Gravity Recovery and Climate Experiment satellites during 2002-2005 show the Antarctic Ice Sheet is losing ice mass at a rate of 152 (±80) cubic kilometers per year, which is equivalent to 0.4 (±0.2) millimeters (0.02 [±0.01] inches) in global sea level rise per year (Velicogna and Wahr, 2006). Based on these estimates, the current rate of global sea level rise due to loss of ice mass from the Greenland and Antarctic Ice Sheets is 0.97 (±0.3) millimeters (0.04 [±0.01] inches) per year.

Since the 1960s, glaciologist John Mercer has been warning the scientific community about the instability of the West Antarctic Ice Sheet. Though it is smaller in mass relative to the entire Antarctic Ice Sheet, Mercer argues that it is held back in a delicate balance by the floating ice sheets (or ice shelves) at its rim and a slight warming could disintegrate the ice shelves causing a sea level rise of up to 6 meters (20 feet) (Church et al, 2001; Weart, 2005). The probability or timing of this kind of catastrophic event is highly uncertain.

### 3.2.2 Thermal Expansion

The ocean volume changes whenever a change in the heat content of ocean water takes place. Global ocean water volume is increased by decreasing the density of the existing water mass through warming of the marine mixed layer. Atmosphere-Ocean General Circulation Model (AOGCM) simulations averaged over the 20th century concluded thermal expansion rates have been between 0.3 to 0.7 millimeters (0.01 to 0.03 inches) per year (Walsh et al, 2005). It is projected that by 2100 the increase in ocean volume due to thermal expansion will be between 0.11 and 0.43 meters (4 and 17 inches) (IPCC, 2001).

### 3.2.3 Vertical Land Movement

Vertical land movements are still occurring today, some as a result of the large transfers of mass from the ice sheets to the ocean from the end of the last ice age (Church et al, 2001), and will continue to contribute to sea level change relative to the land at an unpredictable rate. Vertical land movements are caused by tectonic activity, glacial isostatic rebound, local sediment loading, or underground fluid injection or removal. San Francisco has been relatively stable with minimal vertical land movement (i.e., minimal subsidence or uplift) in the past century (NOAA, 2005; Stoltz and Gill, 2005).

### 3.2.4 Storm Events

Changes in wave or storm patterns may occur under climate change (Schubert et al, 1998). The frequency, direction, magnitude, and duration of winds are important variables which,
when combined with water depth and coastal morphology, determine wave and storm-surge forcing at the coast (IPCC, 2001). Changes in meteorological forcing have been suggested as a process contributing to increases in mean water level along the coast, independent of eustatic (changes resulting from an increase in the mass of water) and isostatic (processes that cause an increase in ocean volume without a change in mass, e.g. thermal expansion) contributions to relative sea level. Locally, the levels of the surface of the oceans are perturbed by wind-driven waves and tides. Changes in large-scale ocean-atmospheric circulation and climate regimes such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation also have implications for coastal beach and barrier stability (IPCC, 2001).

### 3.2.5 Extreme High Tides

Extreme high tides are a result of the combined effects of the lunar cycle, winds, barometric pressure, ocean temperatures, and freshwater runoff. In California, the highest astronomical tides occur in the summer and winter, and, therefore, extreme high tides occur during these times (Lamphier-Gregory et al, 2006).

Mean Higher-High Water (MHHW) is a tidal datum that is defined as the average of the higher of two daily high water levels over a long period of time. Over the last century in San Francisco, tidal records show the rate of increase in the monthly MHHW level has been approximately 19 percent faster than the rate of Mean Sea Level (MSL) rise (Flick et al, 2003). Figures 5 and 6 show the historical and projected monthly MHHW levels with respect to the San Francisco City Datum (assuming the distribution of monthly MHHW levels remains the same), in addition to the range of levels at which a portion of the City’s combined sewer overflow weirs exist (between 1.8 and 4 feet below the City Datum). The solid lines represent the mean MHHW levels (blue - historical, red - projected). The dotted lines represent two standard deviations from the mean. Figure 5 shows the high estimated projections for MHHW levels using IPCC sea level rise projections for 2050 and 2100 (IPCC, 2001) and does not include the impacts of changes in the frequency and intensity of future storm events. Figure 6 shows the low estimated projections for MHHW levels using IPCC sea level rise projections for 2050 and 2100 (IPCC, 2001) and also does not include the impacts of changes in the frequency and intensity of future storm events. Note that the historical rate of increase already appears to exceed the IPCC low estimated projection.

Clearly, long before the IPCC high projections exceed the levels of the weirs, flooding will occur. If the trend of historical MHHW levels continues, the plus-two standard deviation line shows that the MHHW will regularly overflow the lowest combined sewer overflow weirs by 2030. The figures also show the monthly MHHW approaching the lowest weirs around the year 2100, resulting in floods about 50 percent of the time. However, if the MHHW levels follow the IPCC high estimated projections, then the MHHW will begin to frequently overflow into the lowest combined sewer overflow weirs over the next 20 years.
The U.S. Army Corps of Engineers (1984b) has developed Figure 7 based on the 129-year record of average daily high tide for the San Francisco Bay Area. Figure 7 shows the effect sea level rise has on the recurrence of the present 100-year highest estimated tide (HET) elevation. A sea level rise of 0.15 meters (5.9 inches) causes the frequency of the current 100-year HET in San Francisco to increase to a one-in-ten year event (Gleick and Maurer, 1990) and increases the frequency of extreme high water levels.
Figure 7 Effect of sea level rise on recurrence of present 100-year HET elevation (based on tide and storm-surge data presented by U.S. Army Corps of Engineers, 1984b).

4.0 SAN FRANCISCO AND SEA LEVEL RISE

The results of the extensive literature review conducted to determine the ranges of sea level rise predicted for the globe and San Francisco are presented in Table 2. As shown in Table 2 and Figure 8, the consensus findings from this review are that the rate of sea level rise at San Francisco over the past century has an average 2.13 mm/yr (0.08 in/yr), while the rate for the globe has a range of 1.0 to 2.5 mm/yr (0.04 to 0.1 in/yr).

The rate of sea level rise at San Francisco for the past decade has been 3.2 mm/yr (0.13 in/yr), while the rate for the globe has an estimated range of 1.8 to 2.8 mm/yr (0.07 to 0.11 in/yr). A recent (2005) study published argues that there are no significant differences in the rates of coastal and global averaged sea level rise between 1950 and 2000 as predicted by 20th century climate model simulations, and that the best estimate of global and coastal average sea level rise is 1.8 mm/yr (0.07 in/yr) (White et al, 2005). However, altimetry data obtained from the Topography Experiment (TOPEX)/Poseidon and Jason satellites between 1993 and 2003 show non-uniform geographical distribution of sea level change, with some regions exhibiting trends about 10 times the global mean. It appears that local thermal expansion contributes to the regional variability (Cazenave and Nerem, 2004).
Future rates of sea level rise, however, are likely to accelerate. As shown in Table 2, the estimated sea level rise by the year 2100 ranges between 0.3 and 3 meters (12 to 120 inches). However, most publications made within the last decade show that San Francisco can expect a sea level rise between 0.3 and 0.88 meters (12 to 35 inches) by the year 2100 as a result of the factors described above. Figure 9 shows the monthly mean sea level at San Francisco from 1855 to 2005, as well as the range of sea level rise projections determined by the IPCC to the year 2100. Some uncertainty exists, due to uncertainty about the emissions of greenhouse gases, population growth rates, government policies to address emissions, and the actual dynamics of the oceans and ice sheets.

Some studies show a small probability, but extremely high consequences of more rapid and severe sea level rise, resulting from accelerated melting on Greenland and the West Antarctic Ice Sheet. Glaciologist, John Mercer, argues that the ice shelves supporting the West Antarctic Ice Sheet have the potential to disintegrate within the next 40 years and result in a 6-meter (20 feet) rise in sea level (Weart, 2005). Much of the world’s population lives near the shore, and a sea level rise of this magnitude could displace up to 2 billion people and result in the abandonment of many cities. We do not address this scenario here.
Figure 9  San Francisco Monthly Mean Sea Level (Relative to the City Datum) Measured at the San Francisco Tide Gage Between January 1855 and December 2005, as Well as IPCC Projections in Sea Level Rise to the Year 2100.

In addition to developing Figures 5 thru 9, the tide levels presented in Table 1 (Section 2) were adjusted upwards to account for the predicted rise in sea level as summarized in Table 2. It is projected that MSL would rise between 12 and 35 inches and MHHW will increase between 14 and 41 inches in the next 100 years. Table 3 shows adjusted design tide levels for 30 and 100 years out assuming these rates of increase. Due to the large range of future projected tide levels, some engineering judgment may be required when adjusting tides for future levels.

5.0 RECOMMENDATIONS

The master planning alternatives being developed for the San Francisco Public Utilities Commission (SFPUC) 30-year Sewer System Master Plan (and beyond to the year 2100) should, at a minimum, consider designing infrastructure to account for the potential impact of the following:

- Increase in MSL by ~0.04 to 0.24 meters (1.4 to 9.5 inches) by year 2035.
- Increase in MSL by 0.3 to 0.88 meters (12 to 35 inches) by year 2100.
- Increase in Mean Tide Level (MTL) by 0.3 to 0.88 meters (12 to 35 inches) due to rise in MSL by year 2100.
Table 2  Summary of Literature Review Findings (1)
2030 Sewer System Master Plan
San Francisco Public Utilities Commission

<table>
<thead>
<tr>
<th>Resource</th>
<th>Temperature Rise by 2100 degrees C (F)</th>
<th>SLR - Last 100 years, mm/yr (in/yr)</th>
<th>SLR - Last 10 years, mm/yr (in/yr)</th>
<th>SLR - Projection, mm/yr (in/yr)</th>
<th>Future SLR m (in) (2)</th>
<th>Rise in MTL, mm/yr (in/yr)</th>
<th>Rise in MHW, mm/yr (in/yr)</th>
<th>Rise in MHHW, mm/yr (in/yr)</th>
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<tr>
<td>IPCC: Physical Science Basis Report, 2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.18-0.59 (7 - 24)</td>
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<tr>
<td>(global)</td>
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<tr>
<td>ACIA (Walsh et al), 2005 (global)</td>
<td>1 - 2 (0.04 - 0.08)</td>
<td>2 (0.08)</td>
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<td>0.09 - 0.88 (3.5 - 35)</td>
<td></td>
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<tr>
<td>ASCE (Walsh et al), 2005 (global)</td>
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<td></td>
<td></td>
<td></td>
<td>“Some” change expected</td>
<td></td>
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<tr>
<td>CSIRO (White et al), 2005 (global)</td>
<td>1.8 (0.07)</td>
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<tr>
<td>Cazenave &amp; Nerem, 2004 (global)</td>
<td>2.8 (0.11)</td>
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<tr>
<td>IPCC Workshop, 2004 (global)</td>
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<tr>
<td>IPCC: Impacts, Adaptation, &amp; Vulnerability, 2001 (global)</td>
<td>1.4 - 5.8 (2.5 - 10.4)</td>
<td>0.11 - 0.77 m (since LIG) (3)</td>
<td>0.05-0.32 (2.0 - 13)</td>
<td>0.09 - 0.88 (3.5 - 35)</td>
<td></td>
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<tr>
<td>NASA/GISS (Russell et al), 2000 (global)</td>
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<td></td>
<td></td>
<td></td>
<td>0.45 (18)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>U.S. EPA, 1997 (global)</td>
<td>0.9 - 3.5 (1.6 - 6.3)</td>
<td>1.0 - 2.5 (0.04 - 0.1)</td>
<td></td>
<td></td>
<td>0.15 - 0.97 (6 - 38)</td>
<td></td>
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<tr>
<td>NOAA NWLP/NWLon, 2005 (SF)</td>
<td>2.13 (0.084)</td>
<td>3.2 (0.13)</td>
<td></td>
<td></td>
<td>3.2 (0.13) (4)</td>
<td>7.6 (0.3)</td>
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<td>Stoltz &amp; Gill, 2005 (SF)</td>
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<td></td>
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<tr>
<td>Flick et al, 2003 (SF)</td>
<td>2.17 (0.085)</td>
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<td>Rodriguez et al, 2002 (SF)</td>
<td>1.2 (0.047)</td>
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<td></td>
<td>0.11 (4.3)</td>
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<tr>
<td>U.S. EPA, 1997 (SF)</td>
<td>1.1 - 5.0 (2 - 9)</td>
<td>1.3 (0.05)</td>
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<td>0.33 - 0.48 (13 - 19)</td>
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<tr>
<td>Gleick and Maurer, 1990 (SF)</td>
<td>1.0 - 1.5 (0.04 - 0.06)</td>
<td>7 - 50 (0.3 - 2)</td>
<td></td>
<td></td>
<td>0.5 - 3 (20 - 120)</td>
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</tr>
</tbody>
</table>

Notes:
(1) Projected/Future sea level rise (SLR) values in this table do not include the modified rates of land ice contribution, 0.97 (±0.3) millimeters (0.04 [±0.01] inches) per year, determined by altimetry data for 1993-2003 (Cazenave and Nerem, 2004).
(2) This analysis uses the IPCC 2001 projections for sea level rise. The IPCC 2007 projections were released in February 2007 and are noted here.
(3) IPCC reported an estimated global sea level rise of 0.11-0.77 meter since the Last Glacial Maximum (approximately 21 thousand years ago).
(4) The average tide level rose about 2.5 inches over the last 20 years.
Table 3: Design Tide Elevation Adjusted for Future Sea Level Rise
2030 Sewer System Master Plan
San Francisco Public Utilities Commission

**Low Tide Levels (Relative to City Datum)**

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Today</th>
<th>In 30 Years</th>
<th></th>
<th>In 100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>12&quot;/100 years</td>
<td>35&quot;/100 years</td>
<td>Average</td>
</tr>
<tr>
<td>2 Year</td>
<td>-13.50</td>
<td>-13.20</td>
<td>-12.62</td>
<td>-12.91</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Today</th>
<th>In 30 Years</th>
<th></th>
<th>In 100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>14&quot;/100 years</td>
<td>41&quot;/100 years</td>
<td>Average</td>
</tr>
<tr>
<td>2 Year</td>
<td>-4.13</td>
<td>-3.78</td>
<td>-3.10</td>
<td>-3.44</td>
</tr>
<tr>
<td>5 Year</td>
<td>-3.81</td>
<td>-3.46</td>
<td>-2.78</td>
<td>-3.12</td>
</tr>
<tr>
<td>10 Year</td>
<td>-3.60</td>
<td>-3.25</td>
<td>-2.57</td>
<td>-2.91</td>
</tr>
<tr>
<td>25 Year</td>
<td>-3.33</td>
<td>-2.98</td>
<td>-2.31</td>
<td>-2.64</td>
</tr>
<tr>
<td>50 Year</td>
<td>-3.14</td>
<td>-2.79</td>
<td>-2.11</td>
<td>-2.45</td>
</tr>
<tr>
<td>100 Year</td>
<td>-2.94</td>
<td>-2.59</td>
<td>-1.91</td>
<td>-2.25</td>
</tr>
</tbody>
</table>

- Increase in MHHW level by 0.05 to 0.29 meter (1.7 to 11 inches) due to sea level rise by year 2035. This is equivalent to MHHW levels ranging between 5.3 to 4.5 feet below the City Datum.

- Increase in MHHW level by 0.36 to 1.05 meter (14 to 41 inches) due to sea level rise by year 2100. This is equivalent to MHHW levels ranging between 4.3 to 2.0 feet below the City Datum.

- Increase in recurrence of present 100-year HET elevation with increase in MSL. A sea level rise of 0.15 meters (5.9 inches) would cause the frequency of the current 100-year HET in San Francisco to increase to a one-in-ten year event (Gleick and Maurer, 1990).

In conclusion, extreme water levels are the cause of flooding and should be considered in the design of coastal structures. Most of the potential damage will occur when high water stands due to tides, weather, and climate anomalies are made more frequent by the gradual rising of MSL (Cayan et al, 2006). The information gleaned from the historic tide analysis and literature review and application of the sea level rise projections is important to the Master Planning process as it relates to:

- Building development policy
• Flood insurance

• Design elevation of overflows

• Pumping head requirements

In addition, it is vital to evaluate and compare the cost of designing for a higher sea level in advance (see the Appendix for estimated costs to retrofit the combined sewer system discharges with Tideflex® duckbill valves as a short term solution), compared to the cost of having to retrofit facilities in the future.


Workshop on Climate Sensitivity of the Intergovernmental Panel on Climate Change Working Group I, 26-29 July 2004, Paris, France.
PURPOSE

The purpose of this analysis is to estimate costs to retrofit the combined sewer system discharges with Tideflex® duckbill valves. This information will be used in the consideration of alternatives currently being developed for master planning improvements to the wastewater collection and treatment facilities in San Francisco, California.

BACKGROUND

A portion of San Francisco’s combined sewer discharge (CSD) structures on the bayside of the City are at risk of being inundated at least 50 percent of the time should the sea level rise by 2 feet above existing average conditions (Task 500 TM 509).

Currently, the sewer system consists of large below ground storage/transport structures throughout the city where both sewage and storm water are collected. The sewage is then pumped to the wastewater treatment facilities for treatment and eventual discharge to the Bay and the Ocean. During rainfall events, storm water is diverted to and collected in the storage/transport structures. In the event that the structures reach their capacity, the combined sewage discharges into the Bay or Ocean by gravity.

As sea levels rise, seawater will backflow into the CSD gravity overflow structures, which will result in problems for the wastewater treatment plant processes.

RECOMMENDED SOLUTION

As a short-term solution, San Francisco is considering retrofitting all active CSD structures (Table 1) with Tideflex® duckbill valves (Figure 1) for backflow prevention. The "duckbill" design of the valve eliminates hinges, springs, levers, and counterweights. With no moving parts to lubricate or replace, the Tideflex® is considered to require little, if any, maintenance. The Tideflex® also has no seats that can become clogged, and the rubber construction of its check sleeve allows it to seal around entrapped debris.

ESTIMATED COSTS

In response to global climate change and the resulting sea level rise, the combined sewer system discharges must be modified to prevent bay water intrusion into the system during high tides. As a short-term solution, San Francisco is considering retrofitting all active CSD structures with Tideflex® duckbill valves for backflow prevention. In the long-term, the structures will need to be permanently sealed.
### Table 1  Active CSD Structures

<table>
<thead>
<tr>
<th>No.</th>
<th>Discharge Name</th>
<th>CSO size: Dia. or W x H</th>
<th>Elevation (1)</th>
<th>Discharge Location</th>
<th>Overflows per year</th>
<th>Control Program</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lake Merced</td>
<td>10' x 11'3&quot;</td>
<td>+6.5</td>
<td>Ocean Beach</td>
<td>8</td>
<td>LMT</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Vicente St.</td>
<td>5' dia. (2)</td>
<td>+6.0</td>
<td>Ocean Beach</td>
<td>8</td>
<td>WST</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lincoln Way</td>
<td>6' x 6&quot; (3)</td>
<td>+6.0</td>
<td>Ocean Beach</td>
<td>8</td>
<td>WST</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mile Rock</td>
<td>9' x 11'</td>
<td>+39.14</td>
<td>Mile Rock</td>
<td>8</td>
<td>RTS</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sea Cliff I PS</td>
<td>18&quot; dia.</td>
<td>+55.04</td>
<td>China Beach</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sea Cliff</td>
<td>6' dia.</td>
<td>+54.78</td>
<td>China Beach</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sea Cliff II PS</td>
<td>12&quot; dia.</td>
<td>+34.50</td>
<td>Baker Beach</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>22nd St.</td>
<td>9'</td>
<td>-20.0</td>
<td>Marina</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Baker St.</td>
<td>7'</td>
<td>-6.63</td>
<td>Marina</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Laguna St.</td>
<td>6'</td>
<td>-1.0</td>
<td>Marina</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Beach St.</td>
<td>7' x 6&quot;</td>
<td>-5.0</td>
<td>Pier 31</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Sansome St.</td>
<td>5'6&quot; x 6'6&quot; (2)</td>
<td>NA</td>
<td>Pier 31</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Jackson St.</td>
<td>8' x 9'6&quot;</td>
<td>-3.5</td>
<td>Pier 3</td>
<td>4</td>
<td>NSOC (3)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Howard St.</td>
<td>7'6&quot;</td>
<td>-4.92</td>
<td>Pier 14</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Brannan St.</td>
<td>7'6&quot; x 6&quot;</td>
<td>-5.97</td>
<td>Pier 32</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Third St.</td>
<td>2'6&quot; x 3'9&quot;</td>
<td>-7.25</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Fourth St.</td>
<td>6'6&quot;</td>
<td>-4.0</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Fifth St.</td>
<td>9' x 7&quot;</td>
<td>-5.0</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Sixth St./N</td>
<td>10' x 7', 6&quot;</td>
<td>-5.5</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Division St.</td>
<td>9'6&quot; x 8'3&quot; (4)</td>
<td>+0.75</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Sixth St./S</td>
<td>3'6&quot; x 5'3&quot; (3)</td>
<td>-2.25</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Fourth St/S</td>
<td>2'6&quot; x 3'9&quot;</td>
<td>-7.25</td>
<td>Mission Creek</td>
<td>10</td>
<td>COC</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Mariposa St.</td>
<td>6'</td>
<td>-4.4</td>
<td>Central Basin</td>
<td>10</td>
<td>— (5)</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Twentieth St.</td>
<td>3'6&quot;</td>
<td>-9.0</td>
<td>Central Basin</td>
<td>10</td>
<td>— (5)</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>3rd St./N</td>
<td>3'6&quot; x 5'3&quot;</td>
<td>-6.25</td>
<td>Isla Creek</td>
<td>10</td>
<td>ICTS (6)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Islais Creek /N</td>
<td>600' weir</td>
<td>-3.0</td>
<td>Isla Creek</td>
<td>10</td>
<td>ICTS (6)</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Marin St.</td>
<td>10' x 8'</td>
<td>-4.0</td>
<td>Isla Creek</td>
<td>10</td>
<td>ICTS (6)</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Selby St.</td>
<td>10' x 7'6&quot; (3)</td>
<td>-2.5</td>
<td>Isla Creek</td>
<td>10</td>
<td>ICTS (6)</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>3rd St./S</td>
<td>4'6&quot;</td>
<td>-7.7</td>
<td>Isla Creek</td>
<td>10</td>
<td>ICTS (6)</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Evans Ave.</td>
<td>6'</td>
<td>+0.27</td>
<td>India Basin</td>
<td>1</td>
<td>— (8)</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Hudson St.</td>
<td>2'</td>
<td>+1.0</td>
<td>India Basin</td>
<td>1</td>
<td>— (8)</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Griffith /S</td>
<td>5'6&quot;</td>
<td>-4.45</td>
<td>South Basin</td>
<td>1</td>
<td>— (9)</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Yosemite Ave.</td>
<td>146' weir</td>
<td>NA</td>
<td>South Basin</td>
<td>1</td>
<td>— (10)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Fitch St.</td>
<td>6'9&quot;</td>
<td>-4.35</td>
<td>South Basin</td>
<td>1</td>
<td>— (10)</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Sunnydale Ave</td>
<td>158' weir</td>
<td>NA</td>
<td>Cndlsth Cove</td>
<td>1</td>
<td>— (11)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1) Elevation based on City datum - crown of outfall at shoreline.
2) Elevation based on City datum - weir height where overflow occurs from collection system.
3) NSOC - North Shore Outfalls Consolidation.
4) COC - Channel Outfalls Consolidation.
5) Mariposa Transport/Storage.
6) Islais Creek Transport/Storage.
7) ICOC - Islais Creek Outfalls Consolidation (See 14).
8) Hunters' Point Transport/Storage.
9) Griffith Pump Station.
10) Yosemite-Fitch Outfall.
11) Sunnydale Transport/Storage.
12) Outfall Nos. 1-8 are governed by NPDES Permit No. CA0037681.
13) Outfall Nos. 8, 12, 14, 16, 20, 21, 34, 36 and 39 have been abandoned.
14) Air release only, does not overflow.

WPCD Engineering - 2003
The estimated planning-level project costs (in December 2007 San Francisco dollars) to retrofit all active CSD structures are provided in Table 2. The cost estimate for the valves includes $1.2 million for the 600-foot weir along Islais Creek and $1.5 million for all remaining CSD structures (Table 3) excluding the weirs located at Yosemite Avenue and Sunnydale Avenue. The “guesstimates” for the cost of the Yosemite Avenue and Sunnydale Avenue weir valves are $0.3 million for each weir (based on the prorated cost of the Islais Creek weir valves).

<table>
<thead>
<tr>
<th></th>
<th>Estimated Project Costs to Retrofit all Active CSD Structures with Tideflex® Duckbill Valves ($ in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tideflex® valves (not including the Yosemite &amp; Sunnydale weir valves)</td>
<td>$2.7</td>
</tr>
<tr>
<td>“Guesstimate” - Yosemite &amp; Sunnydale weir valves</td>
<td>$0.6</td>
</tr>
<tr>
<td>Valve Subtotal</td>
<td>$3.3</td>
</tr>
<tr>
<td>Installation</td>
<td>$9.3</td>
</tr>
<tr>
<td>Estimating Contingency (15%)</td>
<td>$1.9</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$14.5</td>
</tr>
<tr>
<td>Engineering, legal, administrative, and construction management (25%)</td>
<td>$3.6</td>
</tr>
<tr>
<td>Total Project Cost</td>
<td>$18.1</td>
</tr>
</tbody>
</table>
Table 3. Estimated Costs to Retrofit all Active CSD Structures with Tideflex® Duckbill Valves

<table>
<thead>
<tr>
<th>Discharge Name</th>
<th>CSD Size</th>
<th>Location</th>
<th>Tideflex Model/Size</th>
<th>Notes</th>
<th>Mounting Plate Size</th>
<th>Mounting Style</th>
<th>Net Price Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 BAKER STREET</td>
<td>108&quot;</td>
<td>Marina</td>
<td>108&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$77,000</td>
</tr>
<tr>
<td>10 PIERCE STREET</td>
<td>84&quot;</td>
<td>Marina</td>
<td>84&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$60,000</td>
</tr>
<tr>
<td>11 LAGUNA STREET</td>
<td>72&quot;</td>
<td>Marina</td>
<td>72&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$47,000</td>
</tr>
<tr>
<td>13 BEACH STREET</td>
<td>84&quot; X 72&quot;</td>
<td>Pier 39</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 114&quot;</td>
<td>C</td>
<td>$88,000</td>
</tr>
<tr>
<td>15 SANSOME STREET</td>
<td>66&quot; X 78&quot;</td>
<td>Pier 31</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 114&quot;</td>
<td>C</td>
<td>$88,000</td>
</tr>
<tr>
<td>17 JACKSON STREET</td>
<td>96&quot; X 114&quot;</td>
<td>Pier 3</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 132&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>18 HOWARD STREET</td>
<td>90&quot;</td>
<td>Pier 14</td>
<td>90&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$65,000</td>
</tr>
<tr>
<td>19 BRANANN STREET</td>
<td>90&quot; X 72&quot;</td>
<td>Pier 32</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 114&quot;</td>
<td>C</td>
<td>$88,000</td>
</tr>
<tr>
<td>22 THIRD STREET</td>
<td>30&quot; X 45&quot;</td>
<td>Mission Creek</td>
<td>54&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>66&quot; X 66&quot;</td>
<td>A</td>
<td>$31,000</td>
</tr>
<tr>
<td>23 FOURTH STREET</td>
<td>78&quot;</td>
<td>Mission Creek</td>
<td>78&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$52,000</td>
</tr>
<tr>
<td>24 FIFTH STREET</td>
<td>84&quot; X 72&quot;</td>
<td>Mission Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 114&quot;</td>
<td>C</td>
<td>$88,000</td>
</tr>
<tr>
<td>25 SIXTH STREET/N</td>
<td>120&quot; X 90&quot;</td>
<td>Mission Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>114&quot; X 130&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>26 DIVISION STREET</td>
<td>114&quot; X 99&quot;</td>
<td>Mission Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>117&quot; X 132&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>27 SIXTH STREET/S</td>
<td>42&quot; X 63&quot;</td>
<td>Mission Creek</td>
<td>76&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>90&quot; X 90&quot;</td>
<td>A</td>
<td>$58,000</td>
</tr>
<tr>
<td>28 FOURTH STREET/S</td>
<td>30&quot; X 45&quot;</td>
<td>Mission Creek</td>
<td>54&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>66&quot; X 66&quot;</td>
<td>A</td>
<td>$31,000</td>
</tr>
<tr>
<td>29 MARIPAOSA STREET</td>
<td>72&quot;</td>
<td>Central Basin</td>
<td>72&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$47,000</td>
</tr>
<tr>
<td>30 TWENTIETH STREET</td>
<td>42&quot;</td>
<td>Central Basin</td>
<td>42&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$15,000</td>
</tr>
<tr>
<td>30A 22nd STREET</td>
<td>24&quot;</td>
<td>Central Basin</td>
<td>24&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$5,000</td>
</tr>
<tr>
<td>31 3rd STREET/N</td>
<td>42&quot; X 63&quot;</td>
<td>Islais Creek</td>
<td>76&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>90&quot; X 90&quot;</td>
<td>A</td>
<td>$58,000</td>
</tr>
<tr>
<td>31A ISLAIS CREEK/N</td>
<td>600 Ft. Weir</td>
<td>Islais Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>138&quot; X 114&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>32 MARIN STREET</td>
<td>120&quot; X 96&quot;</td>
<td>Islais Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>138&quot; X 114&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>33 SELBY STREET</td>
<td>120&quot; X 90&quot;</td>
<td>Islais Creek</td>
<td>96&quot; Series TF-1 w/Plate</td>
<td>2</td>
<td>138&quot; X 114&quot;</td>
<td>C</td>
<td>$89,000</td>
</tr>
<tr>
<td>35 3rd STREET/S</td>
<td>54&quot;</td>
<td>Islais Creek</td>
<td>54&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$24,000</td>
</tr>
<tr>
<td>37 EVANS AVENUE</td>
<td>72&quot;</td>
<td>India Basin</td>
<td>72&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$47,000</td>
</tr>
<tr>
<td>38 HUDSON STREET</td>
<td>24&quot;</td>
<td>India Basin</td>
<td>24&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$5,000</td>
</tr>
<tr>
<td>40 GRIFFITH STREET</td>
<td>66&quot;</td>
<td>South Basin</td>
<td>66&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$40,000</td>
</tr>
<tr>
<td>41 YOSEMITE AVE.</td>
<td>146 Ft. Weir</td>
<td>South Basin</td>
<td>96&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>(3)</td>
</tr>
<tr>
<td>42 FITCH STREET</td>
<td>81&quot;</td>
<td>South Basin</td>
<td>81&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>$54,000</td>
</tr>
<tr>
<td>43 SUNNYDALE AVENUE</td>
<td>158 Ft. Weir</td>
<td>Candlestick Cove</td>
<td>96&quot; Series TF-1 Slip-On</td>
<td>1</td>
<td>N/A</td>
<td>Slip-On</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Notes:

(1) Valve size assumes carbon steel pipe outer diameter.
(2) Mounting plates are epoxy-coated carbon steel and include gasket material. Mounting hardware is not included.
(3) Cost not included for the "special weir" valves.

TOTAL NET PRICE (tax and freight is not included): $2,702,000