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Validating Satellite Observations of Wastewater Plume Biological Impacts in Santa Monica Bay, California

 **Technical Report**

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Sea surface temperature, chlorophyll-a, ocean color, coastal ocean, algal blooms, matlab

# II. Introduction

The coastal waters of Southern California are of great ecological and economic importance; the waters are home to many marine species and serve as a valuable resource to humans in terms of sport and commercial fishing, recreation, and tourism. As a result, coastal pollution management of offshore effluent is necessary to maintain water quality, which relies heavily on the dispersal and dilution by ocean currents to reduce local concentrations (Uchiyam et al. 2014).

Located in Playa del Rey, California, the Hyperion Water Reclamation Plant (HWRP) of The City of Los Angeles-Department of Public Works, Bureau of Sanitation, is one of the largest wastewater plants on the west coast of the United States (Washburn et al. 1992). It serves two-thirds of Los Angeles County, approximately 4 million people, releasing an average of 362 million gallons per day (MGD) into coastal waters (Reifel et al. 2013). Wastewater from the HWRP undergoes two levels of treatment, removing about 85% of suspended solids before being discharged. However, the effluent, treated municipal wastewater, that is discharged into the ocean still contains oils, bacteria, particulates, metals, chlorine, nutrients, and other compounds that may have ecological implications and pose a risk to human health (Raco-Rands and Steinberger 2001). Effluent from the HWRP is primarily discharged from a 3.7 m diameter outfall pipe that terminates 5 miles (8.05 km) offshore and at a depth of 57 m, near the head of the Santa Monica Marine Canyon. Discharging effluent at depth along the continental slope allows for rapid flushing and mixing with ambient seawater which dilutes the buoyant wastewater plumes before they reach the water’s surface or coastline (Washburn et al. 1992). HWRP also has a secondary backup outfall pipe that terminates 1 mile (1.61 km) from shore at a depth of about 15 m (Reifel et al. 2013). During emergencies or scheduled maintenance, effluent is diverted from their primary 5-mile deep ocean pipe to the shallow 1-mile pipe. An inspection of the 5-mile pipe uncovered structural damage to the interior of the pipe. To perform the necessary maintenance on the 5-mile pipe, HWRP planned a 6-week outfall diversion from September 21 to November 2, 2015.

Public concern grew during this diversion event, after a large storm event on September 15, 2015 caused an unexpected amount of wastewater, medical waste, and other materials of sewage origin (MOSA) to wash ashore on the beaches adjacent to the HWRP (Rocha 2015). The beaches remained closed for several days, and the public became increasingly concerned about the water’s pollution due to media coverage of the story. This study, along with our partners’ studies, offers transparency on the environmental impacts of such diversion events to the public, the scientific community, and municipalities planning similar diversions.

Wastewater plumes are characteristically rich in suspended organic particles, giving them a unique spectral response. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Aqua satellite and the Operational Land Imager (OLI) on NASA’s Landsat 8 can detect these signatures in ocean-color images. MODIS and Landsat 8 are also able to detect the level of chlorophyll-a in phytoplankton, which may bloom in response to the high nutrient load of the effluent. Effluent will have a cold sea surface temperature (SST) signature as compared to the ambient water as the buoyant effluent plume entrains and brings colder bottom ocean water to the surface as it rises. The thermal signature can be detected by MODIS, the Thermal Infrared Sensor (TIRS) on Landsat 8, and the thermal infrared band of the Advanced Spaceborne Thermal Emission and Reflection (ASTER) instrument on Terra. Images from these satellites were processed by DEVELOP during the previous term of this project at the NASA Jet Propulsion Laboratory (JPL) (Trinh et al. 2015).

There was a massive effort taken to collaborate research results from various institutions during and after the diversion event. JPL’s profiling hyperspectral instrument measured conductivity, temperature, and depth (CTD), levels of atmospheric aerosols, chlorophyll-a (chl-a), and Colored Dissolved Organic Matter (CDOM). The scientists from HWRP, City of Los Angeles, used a CDT sensor and a Yellow Springs Instrument (YSI) to get basic water quality parameters at the surface, and at depth, at 13 points in the Santa Monica Bay. HWRP’s microbiology scientists took daily shoreline and offshore readings of fecal indicator bacteria (FIB) E.coli, fecal coliform, and enterococcus. The University of California, Santa Barbra installed Lagrangian Drifters, which tracked the plume as it moved through the localized surface currents. The University of Southern California performed phytoplankton water chemistry laboratory experiments to determine if harmful algal species were present due to the diversion. Measurements were taken at critical sampling stations within, around, and outside of the effluent plume to provide an accurate cross section of the plume signature, both temporally and spatially. Many of the instruments were used during satellite overpasses to give a direct comparison to the measurements obtained by the satellite sensors. The results of collaborator’s *in situ* measurements can be used to further verify our remote sensing data. All of the collaborators, including NASA, posted their results on a website managed by Southern California Coastal Ocean Observing System (SCCOOS).

The objectives of this current study were to: (1) coordinate with other agencies and compare our previously processed satellite imagery to measurements provided by their *in situ* data, (2) investigate potential ecosystem impacts of this diversion event, (3) provide HWRP with a comprehensive technical report of findings from satellite and *in situ* comparison analysis, and (4) write a manuscript with the intent of journal publication.

# III. Methodology

In conjunction with satellite remote sensing monitoring from the previous term, our team has compiled *in situ* data results to ground truth the satellite data and provide a more comprehensive overview on the biological impact by the effluent plume within the coastal environment. Both satellite and *­in situ* data were gathered prior to, during, and after the effluent diversion, beginning August 26, 2015 and ending November 30, 2015, to provide baseline condition data and a clear picture of the coastal waters without impacts from surfacing effluent.

**Table 1**: Satellites and sensors used to cover the 6-week effluent diversion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Satellite** | **Sensor** | **Band** | **Resolution** | **Acquisition** | **Detection** |
| Terra | ASTER | Thermal Infrared | 90 m | 16 days | Sea surface temperature |
| Aqua | MODIS | Optical | 250 m | Daily | Sea surface temperature,Chlorophyll-a,Particulate reflectance |
| Landsat 8 | TIRS | Thermal Infrared, Optical | 30 m | 16 days | Sea surface temperature,Chlorophyll-a,Particulate reflectance,Turbidity |

To make the previously processed satellite data from fall 2015 more accurate, atmospheric corrections which correspond specifically with the Santa Monica Bay study area were incorporated using SeaDAS, ENVI, ACOLITE, and Matlab.

MODIS L2 data were reprocessed using an aerosol optical thickness value (Tau-A, τ) obtained from *in situ* results measured on specific days from JPL’s "microTops" instrument. When satellites emit electromagnetic radiation waves down to the earth, some of the radiation is scattered or absorbed by microscopic aerosol particles in the atmosphere. These aerosols prevent the transmission of light waves, thus distorting the true color of the earth. τ is defined as the extinction coefficient over a vertical unit of atmosphere, and is dimensionless (NASA 2012). This newly processed image allows for a true ocean-color image, removing interference from aerosol particulates that lie between the satellite and ocean. Daily cloud cover was observed using MODIS images, and data from clear day fly-overs were reprocessed into NetCDF4-CF format to import into Matlab programming code.

Landsat-8 OLI data were atmospherically corrected by switching the default short wave infrared (SWIR) atmospheric correction to a near infrared (NIR) reflectance in the red spectral band. We used an epsilon value based on the “microTops” instrument data to determine the correct atmospheric scattering reflectance in the optical bands. **(TBD)**

ASTER atmospheric correction algorithm **(TBD)**

An algorithm will be entered into Matlab to isolate only chl-a pigments from other CDOM particles. **(TBD)**

Maps and *in situ* data were imported into Matlab using a basic mapping toolbox code called M-Map (Pawlowicz 2014). **(TBD)**

**Table 2**: *In situ* data used to validate satellite observations

|  |  |  |
| --- | --- | --- |
| **Data Provider** | **Parameter/ Sensor** | **Detection** |
| Hyperion Water Reclamation Plant | CTD | SalinityTemperatureChlorophyll-a |
| University of California, Santa Barbara | Drifters | Surface current movement |
| University of Southern California | Fluorometer | Chlorophyll-a |

# IV. Results & Discussion

# V. Conclusions

# VI. Acknowledgments

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

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# IV. Appendices

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