Adapting to Rising Tides GIS Exposure Analysis

The aim of this appendix is to familiarize the reader with the data and methodology that was used to conduct an analysis of shoreline and community asset exposure to sea level rise and storm events for the ART project. This analysis was conducted using a Geographic Information System (GIS). GIS is an ideal tool to support sea level rise adaptation planning because it can both perform spatial analyses and produce maps to visualize results. In particular, GIS-based spatial analysis was useful in characterizing the economic, social, and environmental setting of the project area, and in identifying the degree to which assets were exposed to sea level rise and storm events.

Sea Level Rise Inundation Data

To inform an understanding of exposure in the ART project area, a coastal engineering team developed sea level rise inundation maps for six future climate scenarios (AECOM 2011). ART project staff used the resulting maps and underlying data to examine the vulnerability and risk of various assets given the following six scenarios:
- 16" sea level rise + daily high tide (mean high higher water, MHHW)
- 16" sea level rise + 100-year storm (100-year stillwater level)
- 55" sea level rise + 100-year storm with wind waves
- 55" sea level rise + daily high tide (mean high higher water, MHHW)
- 55" sea level rise + 100-year storm (100-year stillwater level)
- 55" sea level rise + 100-year storm with wind waves

The extent and depth of inundation was provided for all the daily high tide and the 100-year storm scenarios. Only the extent of inundation was provided for the 100-year storm with wind waves scenarios because overland wave propagation dissipation processes, which could have a significant effect on inundation depth, were not evaluated. In addition, "disconnected low-lying areas" were identified as areas below the inundated water surface elevation, but not hydraulically connected to the inundated areas due to protection by levees or other topographic features. While these areas would not be flooded, it is important to map them separately because their vulnerability and risk are so closely linked to the condition of the adjacent topographic protection.

Shoreline and Community Asset Data

ART project staff evaluated exposure to sea level rise and storm events for nine of the twelve asset categories (see Table 1). Natural shorelines were evaluated in collaboration with PRBO Conservation Science using their San Francisco Bay Sea-Level Rise Website - Online Decision Support Tool for Tidal Marsh Conservation Planning (http://data.prbo.org/apps/sfbslr/). ART project staff did not evaluate the following categories:
- Community land use: A report on the data and methods used to determine the exposure of the population and household demographics, social vulnerability, jobs, property values, and community services and facilities to sea level rise and storm events is provided as a separate appendix (Heberger and Moore, 2012).
- Seaport: Exposure was not analyzed in GIS, rather a visual assessment of the terminals and rail yards was conducted.
- Structural shorelines: The coastal engineering team performed overtopping potential analysis to assess exposure (AECOM 2011, and see Chapter 2 of this report).

Table 1. Asset categories, data format and sources used in the ART GIS exposure analysis.

Assets Category	Data description	Source	Format	Notes
Airport	Oakland International Airport (runways, terminals and maintenance facilities)			Polygons depicting facility footprints digitized using ESRI World Imagery (2012) and Alameda County Parcel Data
Contaminated Lands	Superfund sites, landfills, leaking underground storage tank sites	US EPA Envirofacts, State Water Resources Control Board Geotracker	Points	
Energy, Pipelines and Telecom	Power plants and substations	California Energy Commission	Points, converted to polygons	Polygons depicting facility footprints digitized using point data, ESRI World Imagery (2012) and Alameda County Parcel Data
	Fuel transmission lines	California Energy Commission	Points, Lines	
Ground Transportation	Railroad alignment	Metropolitan Transportation Commission 2011TeleAtlas	Lines	
	Roadways	Metropolitan Transportation Commission 2011TeleAtlas	Lines	
	BART alignment and stations	Bay Area Rapid Transit	Points, Lines	
	Bus routes	Metropolitan Transportation Commission	Lines	
Hazardous Materials	Hazardous material facilities	US EPA Envirofacts	Points	
Natural Shorelines	Tidal and managed marshes	San Francisco Estuary Institute EcoAtlas	Polygons	Polygons depicting marsh footprints digitized using SFEI EcoAtlas, ESRI World Imagery (2012) and Alameda County Parcel Data
Stormwater Infrastructure	Alameda County flood zones	Alameda County Water Conservation and Flood Control District	Polygons	
	Stormwater pump stations	Alameda County Water Conservation and Flood Control District	Points	
Parks and Recreation	Parks and recreation areas	California Protected Areas Database	Polygons	Polygons depicting the land only portion of park footprints digitized using CPAD and ESRI World Imagery (2012)
Wastewater Facilities	Treatment plants, pump stations, wet weather facilities, dechlorination and discharge facilities, overflow structures, ancillary facilities	East Bay Discharge Authority, East Bay Municipal Utility District, Oro Loma Sanitary District, City of San Leandro	Points, converted to polygons	Polygons depicting facilities were digitized using points data, ESRI World Imagery (2012) and Alameda County Assessor Parcel Data

Analysis Methods

Inundation raster files from AECOM (2011) were used to analyze the exposure of selected assets represented as vectors in point, line, or polygon format (see Table 1) to sea level rise and storm events using ESRI's ArcMap Version 10.0 with the Spatial Analyst extension.

The goal of the analysis was to identify assets that were either totally or partially within inundated areas and to determine the depth of inundation where appropriate. In certain instances this required converting the raster data into polygons using the ArcToolbox Conversion Tool (From Raster to Polygon). Below is an overview of the three data formats and how the data was configured.

Point – A 25-meter (82-feet) buffer using the **AcrToolbox Buffer** tool was created around the point location to approximate the footprint of the asset and to account for any potential spatial error in its exact location. Asset categories with point data included hazardous materials, contaminated lands, and wastewater for example. Using **ArcToolbox Zonal Statistics as Table** tool (Figure 1), assets exposed to each of the inundation scenarios were determined and average depth of inundation computed within the buffered point. Where inundation depth was not determined, i.e., for the storm event with wind wave scenarios and within the low-lying disconnected areas, the Intersect tool was used to determine if assets were exposed.

Line – A 5-meter (16-feet) buffer was created to more accurately depict the footprint of linear assets including the roadways and rail lines. The analysis was conducted in two phases because in creating the buffer the data was converted to a polygon, and it was not possible to calculate the length of the resulting polygon using the **Calculate Geometry** function. Therefore, the initial analysis used **ArcToolbox Intersect** tool (Figure 2) to analyze the overlay between the buffered line data and the inundation data. This analysis determined if the asset was exposed or not as well as the length of asset exposed (e.g., road miles exposed). Where inundation depth was not determined, for example for the storm event with wind wave scenarios and within the low-lying disconnected areas, the Intersect tool was used to determine if assets were exposed.

Polygon – Polygons were used to depicted assets with larger footprints such as parks, wastewater facilities, and tidal marshes. **ArcToolbox Zonal Statistics as Table** tool (Figure 1) was used to determine if the asset footprint was exposed, the portion of the asset footprint exposed, and the average depth of inundation. Where inundation depth was not determined, for example for the storm event with wind wave scenarios and within the low-lying disconnected areas, the Intersect tool was used to determine if assets were exposed.

Recommendations and Considerations

When conducting a multi-sector GIS-based exposure analysis there are a few issues to consider. These include:
- Acquiring, creating and managing geospatial data is time consuming. Allow adequate time to acquire, create and manage GIS data.
- Test a few analytical approaches to find one that is appropriate for the data and is consistent with the project goals. Reach out to peers and GIS experts to troubleshoot problems.
- Structure the data and data output so it can easily be exported into other formats include spreadsheets or databases for use in assessing vulnerability.

Figure 1. Zonal Statistics as Table
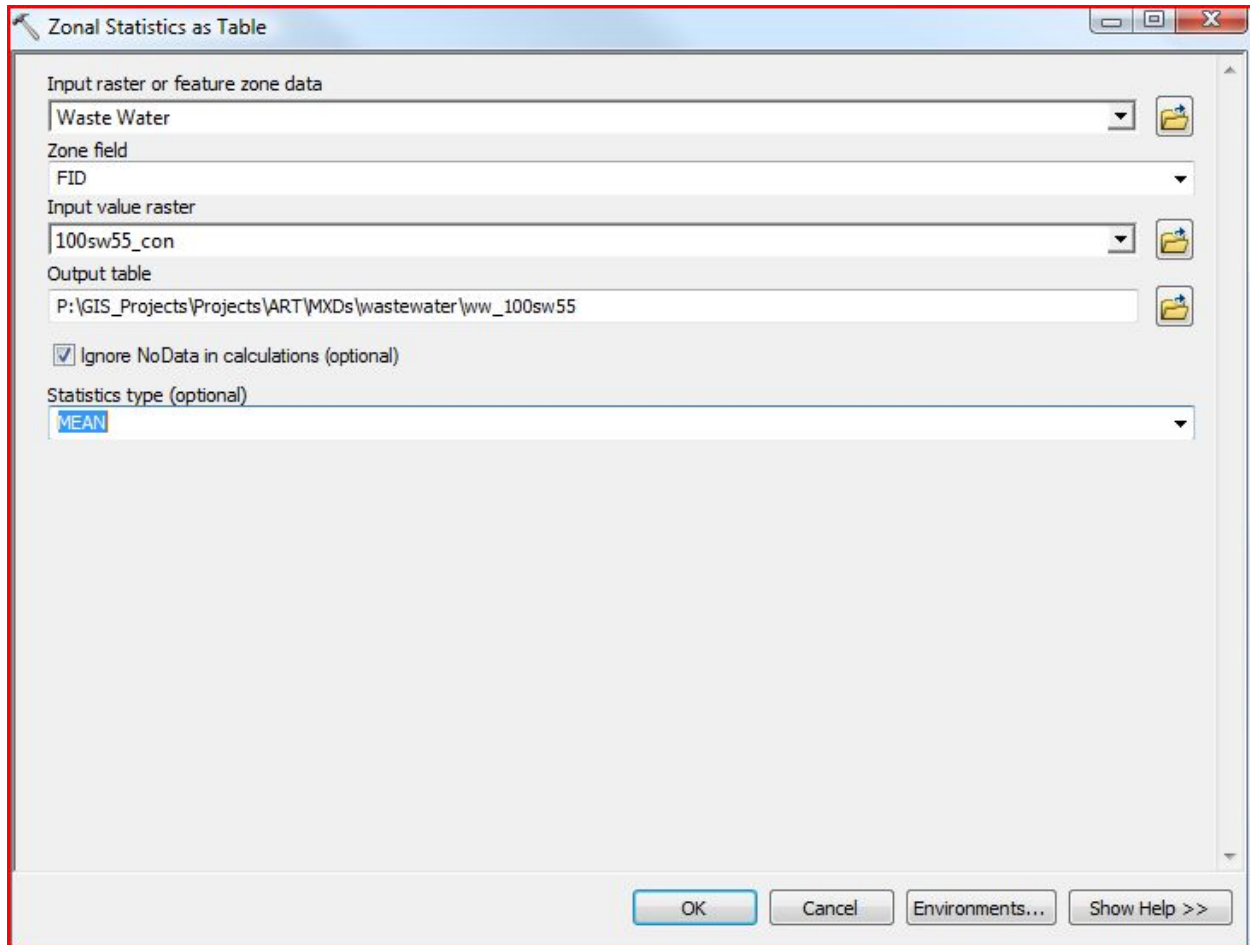
Figure 2. The Intersect Tool
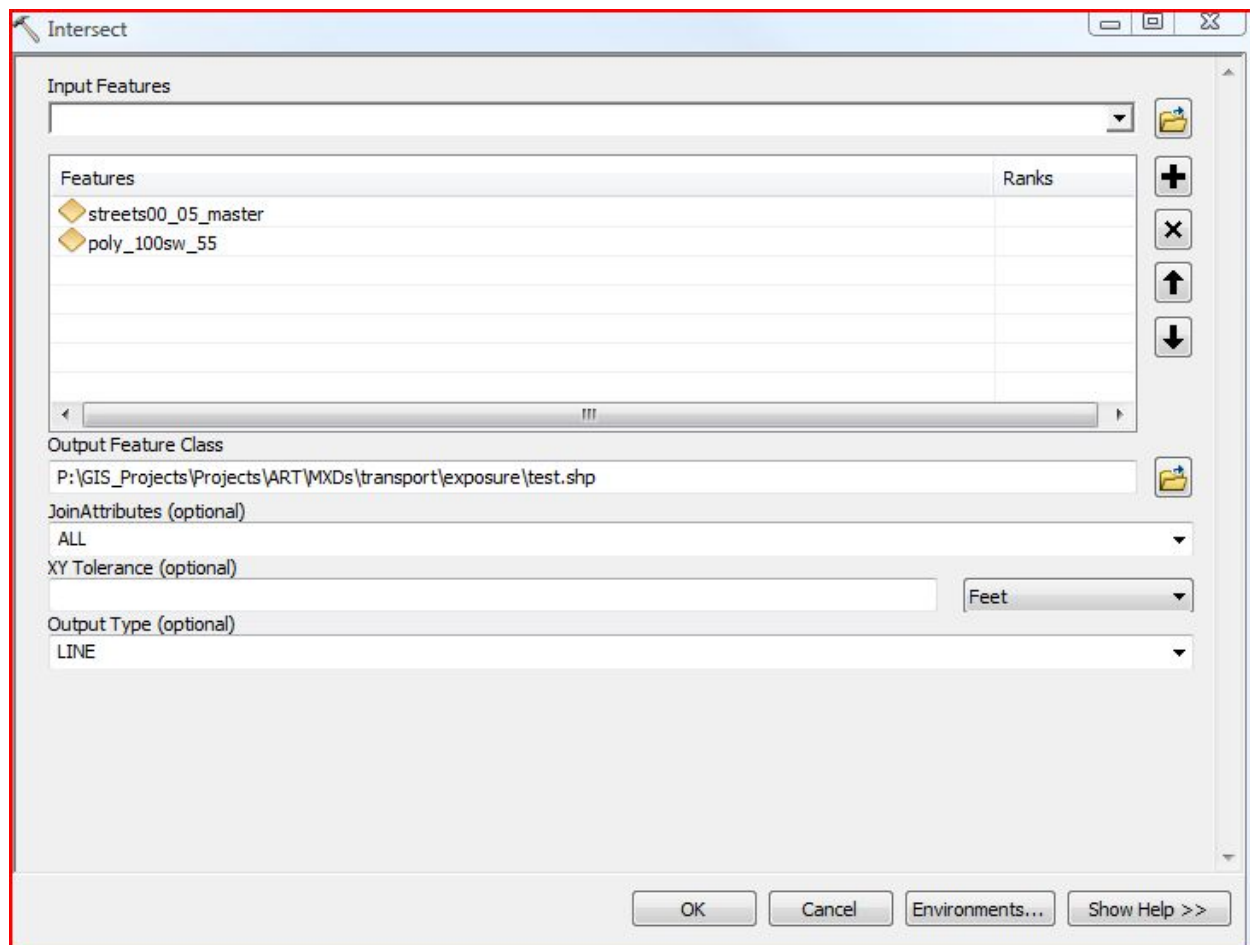
References

Adapting to Rising Tides: Vulnerability to Sea Level Rise in Select Communities in the San Francisco Bay Region. April 12, 2012. Prepared by Matthew Heberger and Eli Moore of the Pacific Institute, Oakland, California.

Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project. November 2011. Prepared by AECOM and Arcadis for the San Francisco Bay Conservation and Development Commission, Metropolitan Transportation Commission and the California Department of Transportation.