Analyzing San Diego's Watersheds Using GIS

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This paper discusses how GIS is used at San Diego Coastkeeper to generate information packed maps and interpretations of the water quality monitoring data collected from 10(out of 11) watersheds of San Diego hydrologic region. The various steps involved in the collection, processing and analysis of data are explained with focus on the spatial and temporal data analysis and correlations. Our Water Quality Monitoring program is completely fueled by volunteer effort. Usage of GIS enables us to generate informative and appealing maps which greatly enhance comprehension of our monitoring and sampling results. This data is published on a community resource portal, our wiki site, at www.sdwatersheds.org

1. Introduction

1.1 About San Diego Coastkeeper

San Diego Coastkeeper is a grassroots environmental 501(c)(3) non-profit organization that advocates and promotes stewardship of clean water and a healthy coastal ecosystem using community outreach, education, and advocacy. San Diego Coastkeeper aims to protect the region's bays, beaches, watersheds and ocean for the people and wildlife that depend on them. It is San Diego's local affiliate of the international Waterkeeper Alliance.

One of San Diego Coastkeeper's most successful program areas is the Water Quality Monitoring Program. The program works with a wide variety of regulatory agencies, academic institutions, businesses and non-profit organizations along with dedicated members of the community to supplement the limited data resources available, protect sensitive ecosystems, identify and abate pollution sources, track the effectiveness of pollution prevention plans, and prevent further degradation of our precious water resources.

The hallmark of our monitoring program is that it is completely fueled by community participation. More than 3,000 volunteers have helped gather data on the health of local waterways to date. We engage 400 members each year in

our monthly water monitoring events alone; and in 2008 engaged over 1,600 K-12 student water monitors in our World Water Monitoring Month & Day events, which are held annually every fall.

Also, the San Diego Regional Water Quality Control Board, the California State Water Resources Control Board, and the U.S. Environmental Protection Agency have all approved our Quality Assurance Project Plan, and our on-site Water Quality Laboratory is scheduled to go through the California State Water Ambient Monitoring Program (SWAMP) certification process in 2009, following the receipt of secured state bond funds.

2. Data Sources

2.1 Water Quality Data

Since 2006, Coastkeeper volunteers have generated high-quality watershed data. Following an intensive hands-on training session, community monitors travel to one of the watersheds, collecting samples and field screening data from our established monitoring sites along local rivers, lakes, streams, lagoons and estuaries. Each group visits 3 to 9 sites depending on the watershed and level of engagement in the program. Currently we monitor water quality and watershed health at 45 locations and intend to expand to 60 sites in the future. The monitoring and training is conducted following an approved QAPP (Quality Assurance Project Plan) and Monitoring Plan. In addition to trash assessment, physical habitat and beneficial use observations, the following water quality data is collected from field observations and laboratory analysis of water samples.

(i) Dissolved oxygen
(ii) pH
(iii) Water temperature
(iv) Air temperature
(v) Electro conductivity
(vi) Turbidity
(vii) Nitrates
(viii) Phosphates
(ix) Escherichia Coli bacteria
(x) Enterococci bacteria
(xi) Total Coliform bacteria

This data is collected on the 3rd Saturday of every month. This data is SWAMP comparable and uploaded on a quarterly basis onto CEDEN network.

The California Environmental Data Exchange Network (CEDEN) is a growing statewide cooperative effort of various groups involved in the water and environmental resources of the State of California. This network is open to federal, state, county and private organizations interested in sharing data throughout the state. The purpose of the CEDEN network is to allow the exchange of water and environmental data between groups and to provide access to the public.

2.2 GIS Spatial Data

The digital boundary files and layers used for creating the maps and GIS framework have been downloaded from the GIS database of San Diego Association of Governments (SANDAG). The projection/co-ordinate system used is the GRS80 Spheroid, California State Plane Coordinate System (feet), Zone VI, North American Datum 83 (NAD 83).

Arc Map 9.3 with Spatial Analyst extension is used at San Diego Coastkeeper. This software has been provided to us by ESRI as a part of the Conservation grant awarded to us in 2008. Arcview 9.1 was awarded to us in 2006.

2.3 GPS Co-ordinates Data

The field data of latitude-longitude co-ordinates of monitoring sites along with relevant information such as elevation, waypoint code etc. is captured using eTrex H GPS receiver which is WAAS-enabled and IPX7 waterproof. The waypoint data is captured on the GPS device and also on paper. Data is collected in accordance to a monitoring plan that establishes specific site locations, and GPS is used to guarantee that volunteers collect data from these predetermined locations.

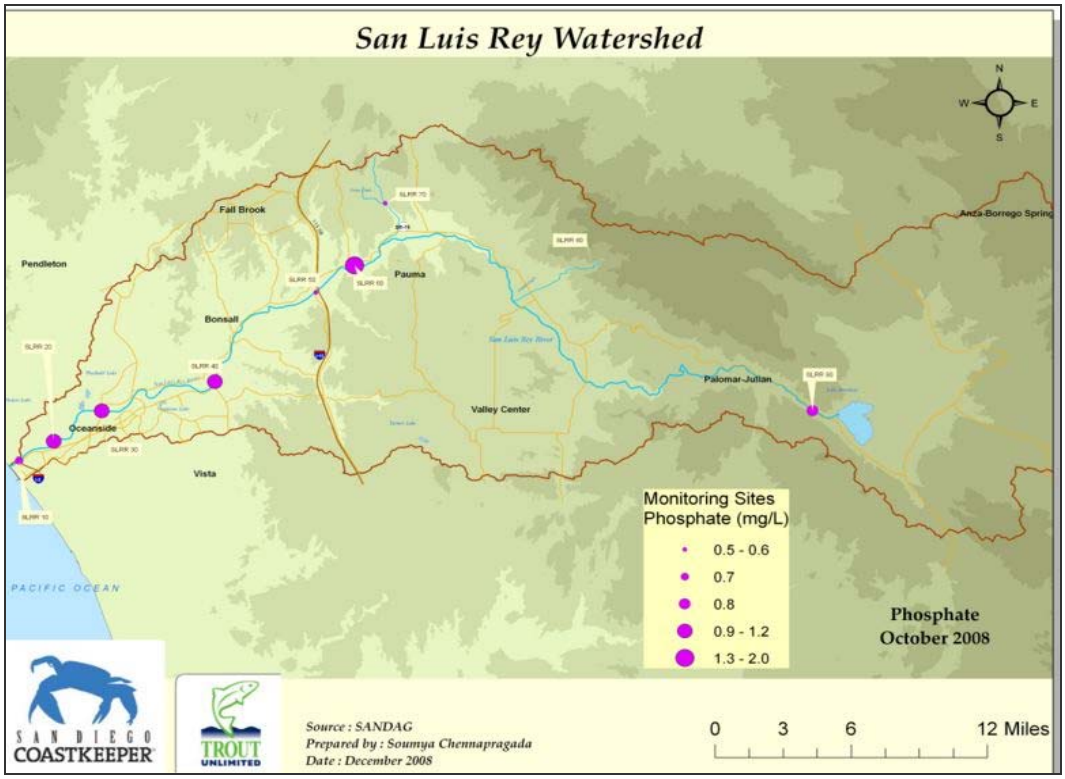
3. Maps and Data Interpretations

The data collected through our Water Quality Monitoring program is converted into information using GIS. The information is disseminated using our wiki site which is a collaborative resource and a transparent online tool. This platform enables the transformation of numeric results into actionable data. This information can be used to make responsible land use and infrastructure decisions as well as policy recommendations to uphold the Clean Water Act.

The following categories of maps are generated at San Diego Coastkeeper and are published on our wiki site.

3.1 Monthly Snapshots

As the name suggests, the monthly snapshot maps give a snapshot of the water quality parameters in a watershed. The maps are self-explanatory and comprehensive.



Map-1: Monthly Snapshot Map of San Luis Rey Watershed showing Phosphate Values in October 2008

3.2 Beneficial Uses Maps

Beneficial Uses (BU) designated under the Clean Water Act are defined as the uses of water necessary for the survival of or well being of man, plants and wildlife. Examples of BU include the use and value of water for public water supplies, protection and propagation of fish, shellfish and wildlife, recreation in and on the water, agricultural, industrial and other purposes including navigation. Currently, there are 23 beneficial uses defined statewide and designated within the San Diego region.

1	AGR	Agricultural supply
2	AQUA	Aquaculture
3	BIOL	Preservation of biological habitats of special significance
4	COLD	Cold freshwater habitat
5	COMM	Commercial and sport fishing

6	EST	Estuarine habitat
7	FRSH	Freshwater replenishment
8	GWR	Ground water recharge
9	IND	Industrial service supply
10	MAR	Marine habitat
11	MIGR	Migration of aquatic organisms
12	MUN	Municipal and domestic supply
13	NAV	Navigation
14	POW	Hydropower generation
15	PROC	Industrial process supply
16	RARE	Rare, threatened, or endangered species
17	REC-1	Contact water recreation
18	REC-2	Non-contact water recreation
19	SAL	Inland saline water habitat
20	SHELL	Shellfish harvesting
21	SPWN	Spawning
22	WARM	Warm freshwater habitat
23	WILD	Wildlife habitat

Table -1 : List of Beneficial Uses with codes (Basin Plan, 2007. Chapter-2)

The process of developing the beneficial use maps for inland surface waters consisted of the following:

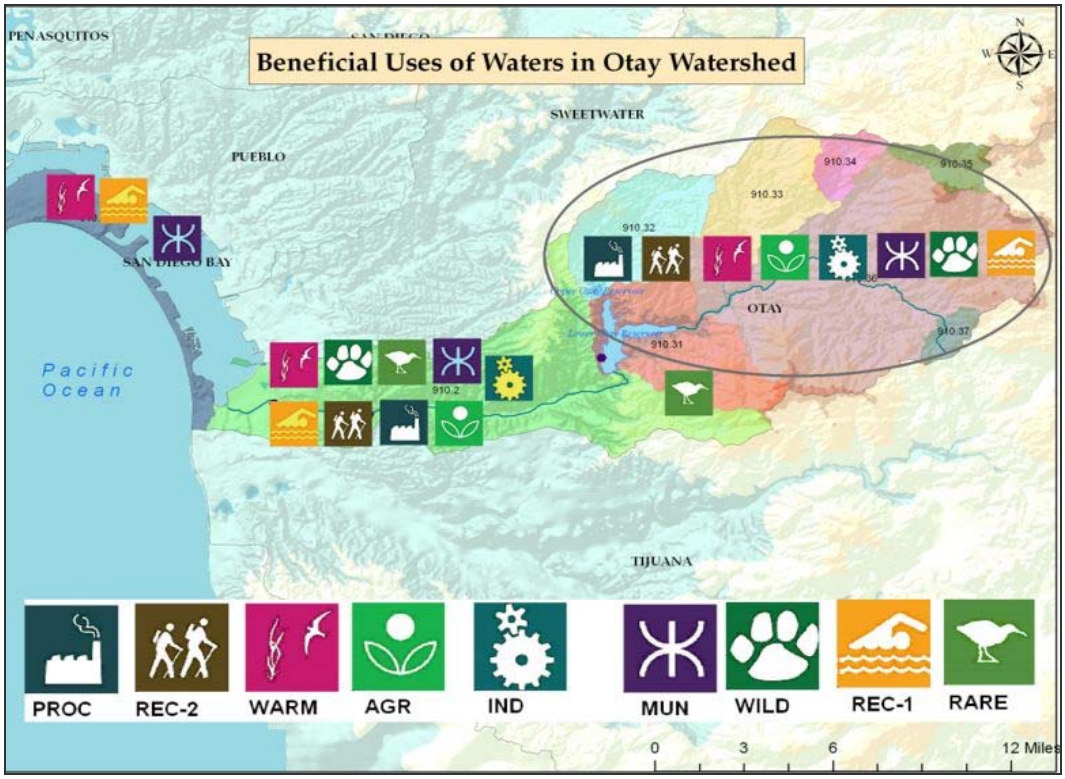
1. Delineation of data from the Basin Plan on a watershed basis
2. Building attribute tables
3. Linking the BU attribute tables to the watershed layers based on the Hydrologic Unit Basin Number (HBNUM)
4. Developing logos for each BU in 3 categories (Existing, Exempt and Potential)
5. Integrating all the components to create an effective beneficial use maps for each of the watersheds.

Attributes of otaybu

HUNAME	HANAME	HSANAME	HBNUM	HBNUM_1	MUN	AGR	IND	PROC	REC1	REC2	WARM	WILD	RARE
OTAY	Dulzura	Jamul	910.33	910.33	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Dulzura	Lee	910.34	910.34	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Dulzura	Lyon	910.35	910.35	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Dulzura	Hollenbeck	910.36	910.36	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Dulzura	Savage	910.31	910.31	BU	BU	BU	BU	BU	BU	BU	BU	BU
OTAY	Dulzura	Engineer Springs	910.37	910.37	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Dulzura	Proctor	910.32	910.32	BU	BU	BU	BU	BU	BU	BU	BU	
OTAY	Otay Valley	Otay River	910.2	910.2	EXEM	BU	POT		POT	BU	BU	BU	BU
OTAY	Coronado	Coastal Stream	910.1	910.1	EXEM				POT		BU		

Record: 1 Show: All Selected Records (0 out of 9 Selected) Options

Table-2: Attribute Table of Otay Watershed Beneficial Uses



Map-2: Beneficial uses map of Otay Watershed

3.3 Land Use Maps

Land use management has a very significant impact on the water quality in a watershed. The effects can be both short and long term (Burges, 1998). The objectives of creating the land-use maps on a watershed basis are:

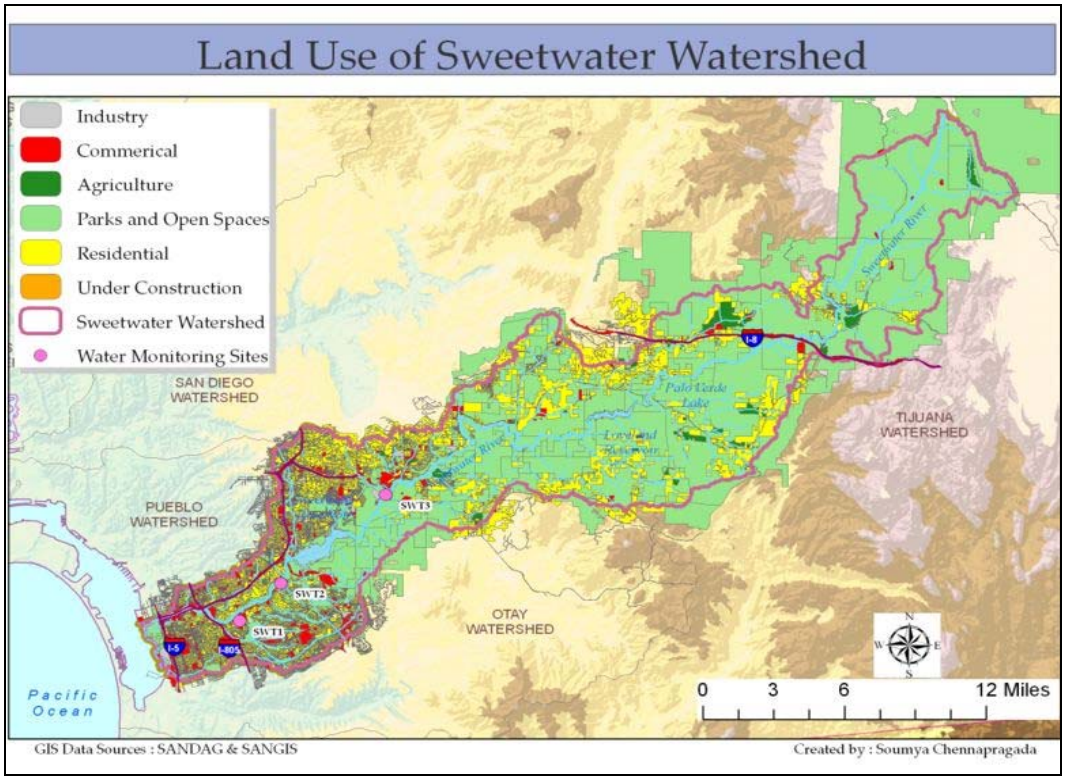
1. To better understand the correlations between land-use and water quality
2. Track land-use changes annually.

3. Select future monitoring sites based on the information from the land use maps

For convenience purposes, we clumped the various land-uses (121 categories from Source data and 125,851 records) into 6 major categories.

1. Industry
2. Commercial
3. Agriculture
4. Under Construction
5. Parks and Open Spaces
6. Residential

Standard ESRI color coding symbology has been used in the maps.



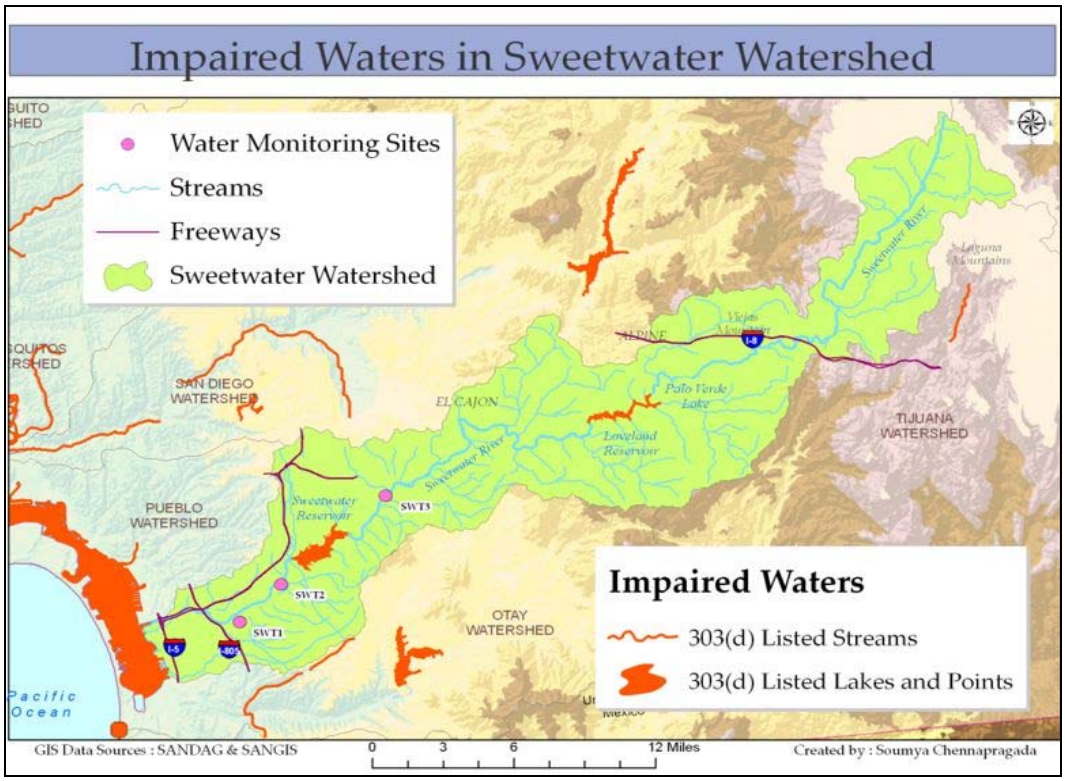
Map-3: Land Use Map of Sweetwater Watershed

3.4 Impaired Waters Maps

If water quality standard is not attained and the standards of non-attainment is due to toxicity, a pollutant, or pollutants; and remediation of the standards attainment problem requires one or more TMDLs; then the waters are included

in the Clean Water Act section 303(d) list. These waters are hence 'impaired waters'.

The spatial data information of the impaired waters has been downloaded from the State Waters Resources Control Board (SWRCB), clipped to the extent of the watershed layers overlaid with them to create Impaired waters maps on a watershed basis.



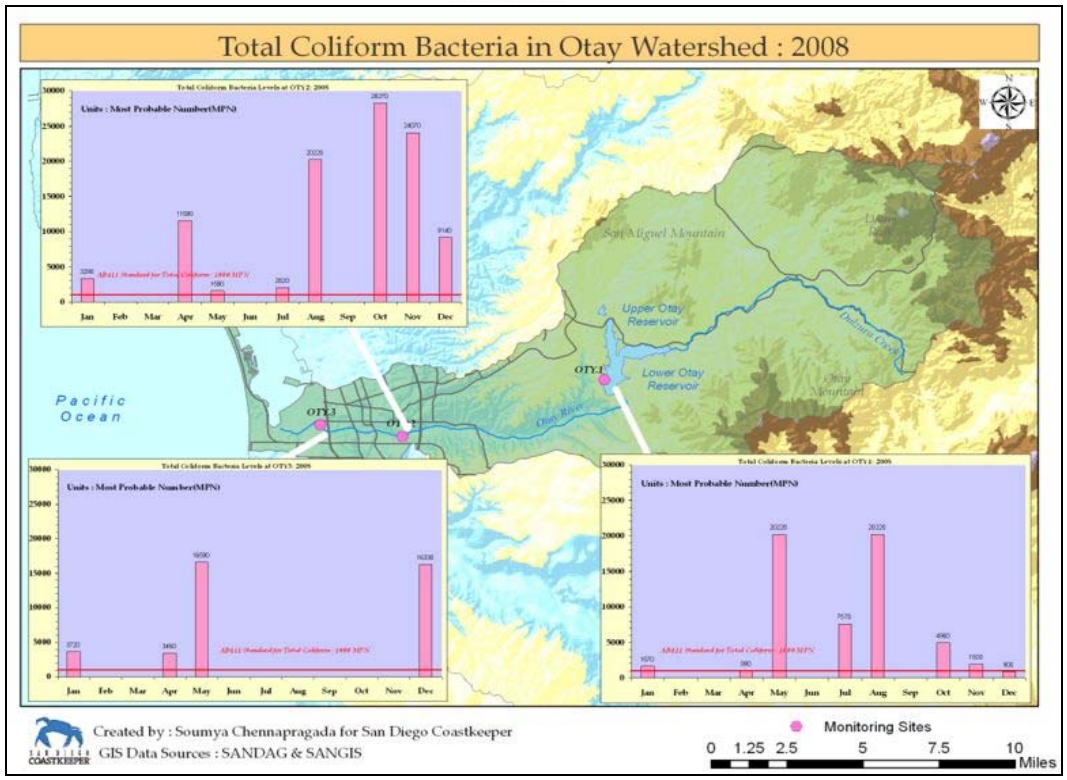
Map-4: Map of Impaired Waters in Sweetwater Watershed

These maps illustrate the spatial extent of impaired waters (coastal shoreline and surface waters of rivers, streams, lakes and reservoirs) in a watershed.

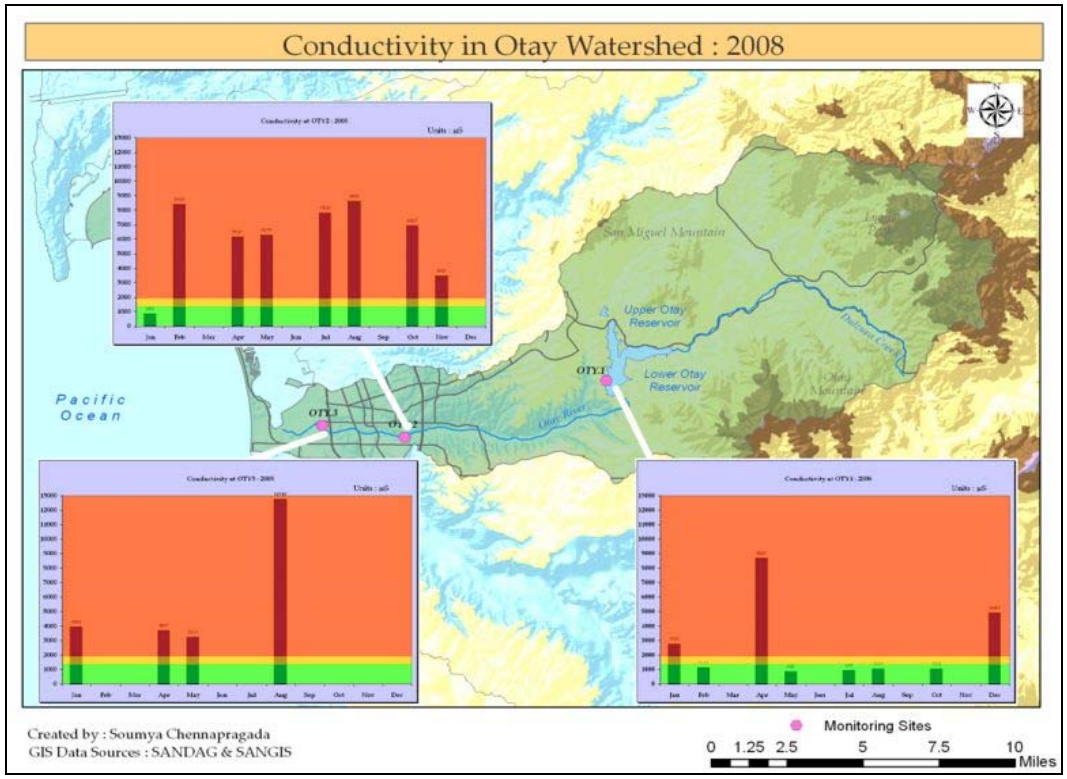
3.5 Annual Data Interpretation Maps

The annual data interpretation maps are the most effective means of displaying our water quality data by- far. The process for developing these maps consisted of:

1. Building attribute tables for each watershed with data extracted from our in-house excel database;
2. Developing baseline maps;
3. Integrating data and iterating on the best form of graphics and charts to display data effectively.



Map-5: Total Coliform Bacteria levels in Otay Watershed in year 2008



Map-6: Conductivity levels in Otay Watershed in year 2008

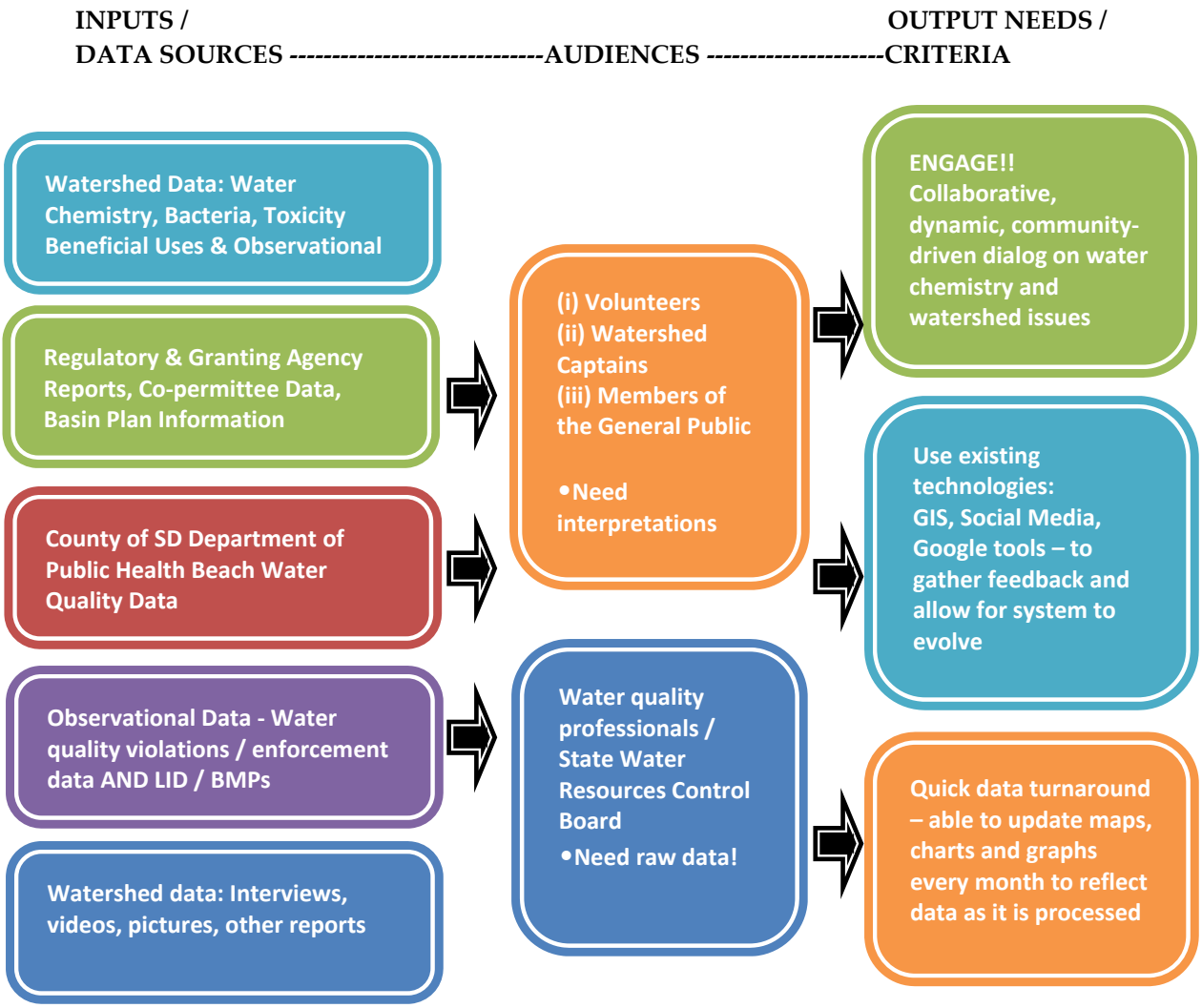
3.6 Other Maps

In addition to the maps mentioned in this paper, we at Coastkeeper have generated other maps such as (i) Hydrologic Region Maps, (ii)Reference maps for each watershed etc using Arc GIS. These maps are published online on our wiki site and also in print publications.

4. Significance of the Data

Being the only program in San Diego County conducting monthly snapshot monitoring of the health of the region's surface waters, we recognize that it is extremely important to share the data in a timely and effective manner with the members of the public and the policy makers.

The following flow-chart illustrates how the data is disseminated and the role of Arc GIS in this endeavor.



5. Future Work and Scope

The future work in this project involves generating animated graphs, interactive maps and developing a sustainable plan to automate the process of data integration and map generation. Coastkeeper is collaborating with EPA to adapt the D2M custom application generated for EPA Region 5 to San Diego watersheds. Using these maps will allow for Coastkeeper to easily generate month by month interpretations and close the time gap in regards to data turn around for the community.

References:

Burges, S. J., Wigmosta, M. S., and Meena, J. M. (1998). "Hydrological Effects of Land-Use Change in a Zero-Order Catchment." J. Hydr. Engr., ASCE, 3(2), 86-97

Water Quality Control Plan for the San Diego Basin (9), 2007. Chapter-2