Effluent Dominated Rivers

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ACRONYMS

C2000 Conservation 2000
CABB Center for Applied Bioassessment and Biocriteria
CCC Criterion Continuous Concentration
cfs Cubic foot per second
CMC Criterion Maximum Concentration
ComEd Commonwealth Edison Company
CSO Combined Sewage Overflow
CSSC Chicago Sanitary and Ship Canal
CTAP Critical Trends Assessment Program
DO Dissolved Oxygen
EMPACT Environmental Monitoring for Public Access Community Tracking
EPA Environmental Protection Agency of the United States
FC Fecal Coliform
HSPF Hydrologic Simulation Program-Fortran
IBI Indices of Biotic Integrity
ICI Invertebrate Community Index
IDNR Illinois Department of Natural Resources
IEPA Illinois Environmental Protection Agency
IPCB Illinois Pollution Control Board
IRWA Ipswich River Watershed Association
LID Low-Impact Development
MADEP Massachusetts Department of Environmental Protection
MADEM Massachusetts Department of Environmental Management
MBI Macroinvertebrate Biotic Index
MBL Marine Biology Laboratory
MGD Million gallons per day
MWRDGC Metropolitan Water Reclamation District of Greater Chicago
NAWQA National Water Quality Assessment Program by the USGS
NPDES National Pollutant Discharge Elimination System
RM River Mile
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>STP</td>
<td>Sewage Treatment Plant</td>
</tr>
<tr>
<td>SVOC</td>
<td>Semi-volatile organic compound</td>
</tr>
<tr>
<td>TARP</td>
<td>Tunnel and Reservoir Plan</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td>TP</td>
<td>Total Phosphorus</td>
</tr>
<tr>
<td>TN</td>
<td>Total Nitrogen</td>
</tr>
<tr>
<td>TRA</td>
<td>Trinity River Authority</td>
</tr>
<tr>
<td>UAA</td>
<td>Use Attainability Analysis</td>
</tr>
<tr>
<td>UIW</td>
<td>Upper Illinois Waterway</td>
</tr>
<tr>
<td>USACE</td>
<td>US Army Corps of Engineer</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile Organic Compound</td>
</tr>
<tr>
<td>WRP</td>
<td>Water Reclamation Plant</td>
</tr>
<tr>
<td>WER</td>
<td>Water Effect Ratio</td>
</tr>
<tr>
<td>WMWD</td>
<td>Western Municipal Water District</td>
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</table>
1 Introduction

1.1 What is an effluent dominated river

Effluent dominated rivers are defined as surface waters that consist primarily of discharged treated wastewater and runoff from urban and agricultural areas. Effluent dominated rivers have many different properties than natural water bodies, as most characteristics of them are dependent on human activities. Without the human generated flow, some effluent dominated rivers would be ephemeral, such as the Trinity River and the South Platte. This does not mean that they are all naturally ephemeral, however. Human activities can also influence whether a river is ephemeral or not based on the uses the river is subjected to. In the case of the Ipswich River, the main problem is associated with excessive withdrawal for public water supply of communities outside the watershed, which causes low flow condition, and therefore in some are treated effluent is the major component in the flow.

Urbanization is the driving force behind this change in river hydrology. All the rivers described are located in large metropolitan areas: the Ipswich in the Boston area, the Des Plaines in the Chicago area, the South Platte in Denver, the Santa Anna River in Los Angeles, and the Trinity River in Dallas. Urbanization leads to heavy water use, increased runoff flow, and higher base flows due to treated effluent. Flows in effluent dominated rivers are now more of a function of a communities water use than they are of natural hydrology. During dry weather flow rises and falls in these rivers due to a diurnal cycle of water uses, with heavier flows during the morning and evening when more people are using water.

Also water in effluent dominated rivers sometimes comes far from the river basin. In the case of the South Platte, water is imported for use from the other side of the continental divide by tunnel, and is subsequently discharged as effluent. Similarly, the Santa Ana River Basin imports a large portion of it’s water supply from outside of its watershed, but treated effluent is discharged into the Santa Ana River.

Recently in the last 20 years, these rivers have received an enormous increase in public interest and awareness. Millions of people live in close proximity to these urban water bodies and they are being realized for their recreational potential in terms of
fishing, parks, and bike trails along them. These rivers are an important part of each metropolitan area’s revitalization. Millions of dollars have been spent on improvements. While they will never be returned to their natural state, proper management will be required in the future as more and more of the area around them becomes more heavily urbanized.

1.2 Major issues associated with effluent dominated rivers

Effluent dominated rivers have unique characteristics and problems associated with them that are not the same as naturally occurring water bodies. However, not all effluent dominated rivers are similar – large differences can exist between the characteristics of different effluent dominated rivers. The two major characteristics in effluent dominated streams are an increase in pollution and an increase in dry weather base flow. All effluent dominated streams described in this document are in heavily urbanized areas. The construction of large sewer systems and centralized wastewater treatment plants has increased the dry weather base flow of each of these rivers. This treated effluent is typically high in nutrients, ammonia, and BOD. These conditions lead to low dissolved oxygen concentrations in the rivers, which threatens warm water fish species. Biodiversity of fish species is affected, and species that can withstand low dissolved oxygen conditions tend to dominate in these rivers.

The impervious surfaces surrounding these effluent dominated rivers also increase the speed and amount of runoff that occurs during wet weather. Every time it rains, pollution covering the impervious areas many miles away is flushed quickly to the river. These pollutants range from pesticides to heavy metals. Higher concentrations of pollutants are typically found in effluent dominated rivers.

Another issue with all of these rivers is legacy pollution in the sediments. Historically, many industries sprung up along the rivers, and discharged pollution directly into the waters to be carried away. While this practice has been discontinued, these rivers all have large amounts of legacy pollutants in their sediments. While this does not adversely affect river water quality usually, stirring up the sediments can cause the release of pollutants and affects contact recreation as well as fishing.
All of these rivers have experienced major changes, and they can never be fully restored to their pre-development status. That is not to say without proper management and they cannot be important regional assets and resources. Smart development, sustainable water use, and decentralized sewerage facilities all can help increase water quality in these rivers. The benefits are both measurable in increased tourism, and recreation revenue, and immeasurable, in terms of increased public enjoyment and civic pride.

1.3 General statements on types of studies, agencies involved

Most of the information contained herein has been obtained from reports and studies on each body of water. The majority of the studies referenced here are from the United States Geological Survey, National Water Quality Assessment Program, local state and government authorities, municipal wastewater authorities, and public river groups.

There are many different groups with many different stakes in these rivers. While the local wastewater authority might argue that the higher nutrients are a resource for downstream agriculture, a public fishing group would argue that these nutrients are damaging the fish populations.

Each agency, group, and government has a different viewpoint, and this can be seen in the different studies that are commissioned. In general however, the Clean Water Act is the determining factor in the management of these rivers.
2 Case study: Ipswich River, MA

2.1 Introduction

The Ipswich River drains a 155-square-mile watershed on the coastal plain of northeastern Massachusetts. The spring-fed river winds more than 40 miles through maple forests, swamps, and rapidly urbanizing areas from its headwaters to the Atlantic Ocean.

Captain John Smith, an early explorer, praised the Ipswich River for its abundant runs of smelt, herring, shad, Atlantic salmon, and other species. Those fisheries were largely decimated by dam construction in the 1800s. In more recent years, excessive municipal water withdrawals and excessive pumping of nearby groundwater regularly leave portions of the river dry, resulting in fish kills and other ecological damage (www.americanrivers.org/mostendangered/ipswich2003.htm). The Ipswich River is widely regarded as the most flow-stressed river in the northeastern part of the United States and in 2003 was designated by the national environmental organization, American Rivers, as one of the 20 most endangered rivers in the entire United States.

Moreover, land-consumptive development has been increasing areas of impervious surface, which in turn increase overland flow and associated flooding and erosion, degrade water quality, and prevent natural recharge to the aquifers within the watershed. The river and several of its tributaries are listed under section 303(d) of the Federal Clean Water Act as “impaired waters” by the Massachusetts Department of Environmental Protection (MADEP), which cites low flows, area of nutrient enrichment and counts of disease causing bacteria (MADEP, 1999).

More than 330,000 residents and thousands of businesses withdraw up to 35 million gallons per day from the Ipswich River. Because two thirds of these consumers live outside of the Ipswich River Basin, between 20 and 25 million gallons never return to the Ipswich River watershed, producing a major water deficit.

2.2 Physical setting

The Ipswich River Basin includes a 155-square-mile area in the Atlantic coastal plain in northeastern Massachusetts, about 20 miles north of Boston. The Ipswich River begins
in the northern town of Burlington in the Mill Brook tributary, and it empties into the Atlantic Ocean near the southern tip of Plum Island. The basin is generally 5 to 10 miles wide in the north-south direction, and it can be divided into three subsections: the upper (which drains to South Middleton), middle and lower watersheds. Below the Ipswich Dam the river becomes tidally-influenced (Figure 1).

The Ipswich River has approximately 20 tributaries. The larger tributaries, in the upper watershed include Maple Meadow Brook, Lubbers Brook and Martins Brook. In the middle watershed, tributaries include Norris, Emerson, Boston, Fish and Howlett Brooks and in the lower watershed, the Miles River is the largest tributary.

Several large and moderate size reservoirs were built for water-supply storage, for providing power to former mills, or for recreation. During high flow periods these impoundments store water and increase the potential of water loss through evaporation.

2.2.1 Climate

The climate in the basin is humid with an average annual air temperature of 49°F for the period 1961–95. Monthly mean temperatures during this period ranged from 25°F in January to 71°F in July.

Precipitation in the Ipswich River Basin is 43.5 in/yr, distributed fairly evenly throughout the year, with average monthly precipitation ranging from 3.2 inches in July to 4.8 inches in November. Annual snowfall during 1989-93 averaged 37 inches, and ranged from 22 inches in 1991 to 83 inches in 1993 (Zarriello and Ries, 2000).

2.2.2 Land use and towns

Land use in the basin is shown in Figure 2. Residential areas comprise about 29 percent of the total area, but it constitutes about 38 percent of the area above the South Middleton station. Commercial areas comprise about 3.6 percent of the basin area. Forests and open space comprise 35.5 percent of the basin area. Open water is about 2.8 percent of the total area. Agriculture land amounts to about 7.3 percent of the total basin.

Wetlands cover about 20 percent of the Ipswich Basin, of which 6 percent is no forested and 15 percent is forested. The largest of the wetlands is Wenham Swamp, which occupies an area of about 3 square-miles along the Ipswich River near the border of Hamilton and Wenham.
The graph on the left shows how the land use has changed over the last century in the watershed. “Sprawl” developments, together with the roads and infrastructure they require, segment and eliminate wildlife habitat, increase stormwater and pollutant runoff, replace diverse ecosystems with built structures and mono-cultures such as lawns. Most important to the Ipswich River, increasing urban development has required additional water for domestic, commercial, industrial, and landscape uses.

Wetlands in the Ipswich Basin are typically densely vegetated with a water table within a few feet of the land surface; these factors maximize the potential for evapotranspiration.

The Ipswich River Basin includes all or parts of 22 municipalities (Figure 1). Of these, only three (Middleton, North Reading, and Topsfield) are entirely within the basin. Boxford, Hamilton, Ipswich, Lynnfield, North Andover, Wenham, and Wilmington are mostly within the basin. About half or less than half of Andover, Beverly, Burlington, Danvers, Peabody, and Reading are in the basin, and less than 1 square-mile of Billerica, Essex, Georgetown, Rowley, Tewksbury, and Woburn are in the basin. These municipalities obtain water supplies from various sources both inside and outside of the basin.

2.2.3 Location of gauging stations

The USGS has operated two stream gauging stations in the basin since the 1930’s (Figure 1). The upstream station at South Middleton (station no. 01101500), operated since 1938, is a few hundred feet below the South Middleton Dam and has a contributing drainage area of 44.5 mi². Average river slope above this station is about 6.0 ft/mi. Mean annual stream flow at South Middleton for the period of record (1939-2003) is 63.88 ft³/s.

The downstream station at Ipswich (station no. 01102000), operated since 1930, is a few hundred feet below Willowdale Dam and has a contributing drainage area of 125 square-miles. A small area (about 0.6 square-miles) drains directly to a supply reservoir that exports water from the basin. The average river slope between stations is about 1.5
ft/mi and the mean annual stream flow at this gauge station for the period of record (1931-2003) is 188.5 ft$^3$/s.

The drainage between the Ipswich station and the Sylvania Dam (25 square-miles) is ungaged. Contributing drainage to Sylvania Dam is 150 square-miles, and includes inflows from Miles River. Average river slope below the Ipswich station is 2.8 ft/mi.

2.2.4 Topography
The Atlantic coastal plain is characterized by low relief. The Ipswich River elevation drops from about 110 ft at its headwaters to sea level at its mouth, and has an average slope of 3.1 ft/mi. Stream gradients are influenced by numerous wetlands and three low-profile dams that create flat-water conditions in many reaches along the river’s 36-mile length. Wetlands and dams also affect tributary stream gradients. Upland areas of the basin are generally low-rounded hills with a maximum elevation of 420 ft, but most hills are less than 300 ft (Zarriello and Ries, 2000).

2.2.5 Surficial geology
Glacial till covers about 54 percent of the basin, stratified sand and gravel deposits cover about 43 percent of the basin, and alluvial deposits cover about 3 percent of the basin (Zarriello and Ries, 2000).

Upland areas of the basin are mostly underlain by till; tills are highly variable in their material content and compactness and, as a result, the permeability will vary as well.

Lowland areas of the basin are generally underlain by stratified drift, which consists of well-sorted fluvial sands and gravels deposited from glacial meltwater streams. The permeability of stratified drift typically is larger than that of till.
Figure 1. The Ipswich River watershed. Source USGS - Zarriello, 2002.
Figure 2. Land use in the Ipswich River watershed. Source USGS - Zarriello and Ries, 2000.
2.3 Data & analysis

2.3.1 Previous studies

Numerous reports have been written on the water resources of the Ipswich River Basin by State environmental agencies, nongovernmental environmental organizations, regional-planning agencies, and the USGS.

Reports by state agencies include those by the MADEM (1987a, 1987b, and 1989), which produced a three-volume management plan for the Ipswich River Basin in the late 1980s.

The Ipswich River Watershed Association has released several reports on water-resources conditions in the basin. The Association releases an annual report on activities of the River Watch volunteer monitoring program, which monitors flow and water quality at about 29 locations (IRWA, 2001).

The USGS began a study in 1995 to determine the spatial distribution and correlation among parameters related to aquatic habitats and flow conditions of Massachusetts streams. The study evaluated the applicability of median daily mean flow for August (Ries, 1997) to determine streamflow requirements for Massachusetts streams.

The most recent report attempting to describe the stream habitat and fish communities of the Ipswich River, and to determine relations between flow quantity and habitat, and determine adequate streamflow requirements to maintain quality aquatic habitat in the Ipswich River was done by the USGS (Armstrong et al., 2001).

To simulate the hydrology and complex water-use patterns in the Ipswich River Basin, the USGS developed a basin-scale precipitation-runoff model with the Hydrologic Simulation Program-Fortran (HSPF) (Zarriello and Ries, 2000). The model is being used by MADEP and MADEM to calculate the effects of withdrawals on streamflow. Four critical riffle sites identified by this habitat study were included as HSPF model nodes in the hydrologic modeling study.

In Zarriello 2002, the effects of 11 hypothetical water-management alternatives on streamflow in the Ipswich River Basin, are evaluated. Water-management alternatives include altering water-withdrawal rates, returning wastewater to the basin, stopping septic-effluent inflows, and combining withdrawal and wastewater management alternatives.
A more recent USGS report (Zarriello, 2003) describes changes made to the existing HSPF model and presents simulation results that describe the effects of the 2003 withdrawal permits and management alternatives including the effect of adding low-capacity pumps to each system, the effects of alternative streamflow thresholds on firm yield, and the determination of yields and storage characteristics at successive failures.

The Ipswich River Watershed Management Plan, prepared for the IRWA (Ipswich River Watershed Association) focuses on “balancing the water budget” to help repair the current imbalance and to prevent future worsened conditions. It includes ideas from a broad group of “stakeholders” who have worked together over the past several years (Horsley & Witten, Inc., 2003).

2.3.2 Hydrological data

The major problem of the Ipswich River is the low flow condition, and the cause of this problem is the excessive withdrawal for public supply.

Municipal withdrawals in the basin dewater the river in two ways: by intercepting groundwater that would otherwise flow into the river, and by withdrawing water out of the river directly. This causes the river to actually flow backwards in some locations (e.g. Maple Meadow Brook), as water is pulled upstream. Water levels throughout the basin are perpetually low in the summer, and some stretches of the river run dry every single year, resulting in fish kills and other ecological damage. In Figure 3, which reports the daily mean stream flow in ft$^3$/s at the two gauging stations for the years 1999-2004, the extent of the low flow problem is evident. The Ipswich River’s all-time low-flow record of 0.1 ft$^3$/s, set in 1957, was tied or broken on 18 days in 1997, with a new low of 0.05 ft$^3$/s being set in September of 1997. That record was broken in 2002, with a new extreme of 0.04 ft$^3$/s. Also in 1999 very low flow was registered with a minimum value of 0.09 ft$^3$/s.

Currently all wastewater treatment plants serving communities within the Ipswich River Watershed are located outside the watershed, thereby transporting collected wastewater out of the watershed – causing more water losses. The exception is the Town of Ipswich wastewater treatment plant, which discharges treated wastewater to a sensitive estuary. The Ipswich sewer collection system has for years experienced problems
resulting in repeated discharges of raw sewage into the Ipswich River at the Ipswich town landing. This problem continues to result in serious pollution incidents.

![Graph showing daily mean streamflow](image)

**Figure 3. Daily mean stream flow in ft³/s at the two gauging stations in the period 1999-2004.** Created using data from USGS.

Table 1 and Figure 4 show the water withdrawals, inter-basin transfers in the Ipswich Watershed and the WW system of the towns, which receive all, or part of, their water supply from the basin. The average total withdrawal in 1999 was 30.28 MGD, with an average groundwater withdrawal of 9.08 MGD, and a average transfer outside the watershed of 23.54 MGD (Horsley & Witten, Inc., 2003). The groundwater withdrawals for water supplies determine the reduction of baseflow, which is the most significant cause of the extreme low-flow/no-flow problems.
Watershed Management
Effluent dominated streams in the US

Figure 4. Water exported from the Ipswich river watershed, for different usages.
Table 1. Water Withdrawals and Interbasin Transfers in the Ipswich Watershed. Source: Horsley & Witten, Inc., 2003

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<tbody>
<tr>
<td>Salem-Beverly Water Supply Board</td>
<td>100%</td>
<td>Surface water (Ipswich River &amp; reservoirs)</td>
<td>10.13</td>
<td>10.02</td>
<td>Sewered discharge to Salem Sound</td>
</tr>
<tr>
<td>Danvers/Middleton</td>
<td>100% (3.2% from wells)</td>
<td>Surface water; supplemented by groundwater wells</td>
<td>3.42 (0.11 from wells)</td>
<td>3.39 (0.11 from wells)</td>
<td>Danvers sewered, discharges to Salem Sound. Middleton on-site septic systems</td>
</tr>
<tr>
<td>Wilmington</td>
<td>100%</td>
<td>Groundwater wells</td>
<td>2.53</td>
<td>3.07</td>
<td>Partially sewered to MWRA/Boston Harbor</td>
</tr>
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<td>Reading</td>
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<td>Groundwater wells</td>
<td>2.36</td>
<td>2.05</td>
<td>Sewered discharge to MRWA/Boston Harbor</td>
</tr>
<tr>
<td>Lynn</td>
<td>16%</td>
<td>Surface water diverted from Ipswich and Saugus Rivers</td>
<td>1.75 (average 1989 and 1993 data)</td>
<td>1.68 (total pumping was 10.17)</td>
<td>Lynn Sewer/ Wastewater System/ discharge to ocean</td>
</tr>
<tr>
<td>North Reading</td>
<td>100%</td>
<td>Groundwater wells; supplemented by surface water from Merrimack basin</td>
<td>0.86</td>
<td>1.19 includes water from Merrimack river</td>
<td>One industrial area is sewered to MWRA/ Boston Harbor; the rest of town is on-site septic systems</td>
</tr>
<tr>
<td>Hamilton</td>
<td>100%</td>
<td>Groundwater wells</td>
<td>0.70</td>
<td>0.66</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Lynnfield</td>
<td>100%</td>
<td>Groundwater wells; deep bedrock well</td>
<td>0.31 (not including 4 new wells built in 1997)</td>
<td>0.71</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Topsfield</td>
<td>100%</td>
<td>Groundwater wells</td>
<td>0.49</td>
<td>0.53</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Wenham</td>
<td>100%</td>
<td>Groundwater wells</td>
<td>0.32</td>
<td>0.39</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Peabody</td>
<td>90%</td>
<td>2 wells and surface water diversion from Ipswich</td>
<td>3.7 (total pumping was 6.28; 0.07 from wells)</td>
<td>0.08 (total pumping was 5.31)</td>
<td></td>
</tr>
<tr>
<td>Ipswich</td>
<td>17%</td>
<td>Surface water (Parker basin) plus groundwater wells (Ipswich &amp; Parker)</td>
<td>0.21 (Ipswich wells)</td>
<td>0.21 (Ipswich wells)</td>
<td>Partial sewer discharge to Ipswich River estuary; remainder on-site septic systems</td>
</tr>
<tr>
<td>Sagamore Spring Golf Course in Lynnfield</td>
<td>100%</td>
<td>Groundwater and Surface water</td>
<td>0.006 from groundwater, 0.053 from surface water</td>
<td>N/A</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Thompson Country Club in North Reading</td>
<td>100%</td>
<td>Deep bedrock well</td>
<td>0.023 (April-Nov)</td>
<td>N/A</td>
<td>On-site septic system</td>
</tr>
<tr>
<td>Boxford</td>
<td>N/A</td>
<td>Private and small public groundwater wells</td>
<td>N/A</td>
<td>N/A</td>
<td>On-site septic systems</td>
</tr>
<tr>
<td>Andover, Billerica, North Andover, Tewksbury</td>
<td>N/A</td>
<td>Outside basin sources (some private wells in North Andover are in Ipswich Basin)</td>
<td>N/A</td>
<td>N/A</td>
<td>Partial sewer; remainder on-site septic systems</td>
</tr>
</tbody>
</table>
The amount of water that can be withdrawn, by each of the three supply systems of the Ipswich River (Lynn, Peabody and Salem-Beverly), is regulated by the MDEP. In an attempt to balance public-water-supply needs and environmental interests, in May 2003, the MDEP issued modified withdrawal permits to suppliers obtaining water from the Ipswich River Basin. The MDEP currently allows withdrawal of water from the Ipswich River only if a minimum threshold flow is present and can be maintained.

Annual withdrawal limits were registered under the Water Management Act Program with a small additional amount authorized under the withdrawal permits. The MDEP permit restrictions are summarized in Table 2.

Table 2. MDEP permit restrictions. Source - USGS -Report 2004-5122.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Permitted withdrawal period</th>
<th>Streamflow threshold</th>
<th>Reference station</th>
<th>Annual volume (Mgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ft³/s/mi²</td>
<td>ft³/s</td>
<td>Mgal/d</td>
</tr>
<tr>
<td>Lynn</td>
<td>November 1-May 31</td>
<td>1</td>
<td>44.5</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>June 1- October 31</td>
<td>3.17</td>
<td>141</td>
<td>91.1</td>
</tr>
<tr>
<td>Peabody</td>
<td>November 1-May 31</td>
<td>1</td>
<td>44.5</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>June 1- October 31</td>
<td>3.17</td>
<td>141</td>
<td>91.1</td>
</tr>
<tr>
<td>Salem-Beverly</td>
<td>November 1-May 31</td>
<td>1</td>
<td>125</td>
<td>80.8</td>
</tr>
<tr>
<td></td>
<td>June 1- October 31</td>
<td>3.05</td>
<td>381</td>
<td>246</td>
</tr>
</tbody>
</table>

Besides the excess water withdrawal, another problem in the basin is the presence of constructions that have modified the hydrology of the river. There are three impoundments on the river: one in Middleton and two in Ipswich (Willowdale and Silvana Dam). These impoundments block the natural flow of water and block fish passage (Figure 5).

Figure 5. Bostik-Findley Dam (Middleton), on the left and Willowdale Dam (Ipswich), on the right. http://www.ipswichriver.org.
Most of the tributaries to the Ipswich also have one or more impoundments that were built for water supply, or to store water to power former gristmills and saw mills. The impoundments behind these dams modify the river by creating long reaches of moderately deep, slow moving water with characteristics that are more pond-like than riverine. These dams restrict the downstream movement and restrict or preclude the upstream movement of fish between reaches of the Ipswich River, and between the mainstream Ipswich and its tributaries. In addition the creation of standing open surface water increases losses to evaporation.

2.3.3 Point and non point sources of pollution

Non-point sources

Specific concerns regarding road runoff (salt, sediment and other pollutants) along major interstate and secondary routes in the basin, agricultural runoff (specifically runoff associated with improper manure management associated with livestock), stormwater runoff from commercial/industrial parks and improperly fertilized lawns, malfunctioning wastewater pump stations (e.g., Town wharf pump station in Ipswich), improperly functioning septic systems, and other contaminated stormwater runoff in the Ipswich area were of concern to stakeholders in the Ipswich River Watershed. The impact of these non-point sources of pollution and their contribution to the bacteria problems that resulted in shellfish bed closures were identified as problems (MADEP, 2004).

Point sources of pollution

Although the number of permitted NPDES discharges (major and minor) is not large in comparison to other basins of similar drainage area the cumulative impact of these discharges may be magnified by the low flow problems experienced in the Ipswich River. Specific concerns exist about the Ipswich Waste Water Treatment Facility that has historically had problems meeting effluent limits.

2.3.4 Water quality data

Besides the low flow problem, another serious issue surrounding the Ipswich River is the low dissolved oxygen level, especially during the summer months, this, together with fecal coliform contamination, impairs the river’s suitability for fisheries and other habitat.
The freshwater section of the Ipswich River is classified by the DEP as a Class B waterbody, whereas the tidal section of the river, (downstream of the Sylvania Dam), is classified as a SA waterbody. The water quality goal for Class B waters is to be fishable and swimmable throughout the year, while Class SA waterbodies are tidal waters intended to be safe for shellfishing. The water quality standards associated with the classification are the goal, not always the actuality.

Water quality data for the Ipswich River are available through the IRWA RiverWatch Volunteer Monitoring Program (IRWA, 1999, 2000, and 2001). The program, started in 1988 and funded by the Environmental Protection Agency's EMPACT (Environmental Monitoring for Public Access and Community Tracking) Program, produce a yearly report, which presents data of air temperature, water temperature, color, odor, depth, velocity, cross sections, dissolved oxygen, pH, fecal coliform and nutrients (in collaboration with The Marine Biological Laboratory at Woods Hole), for 29 monitoring sites in the Ipswich river basin (Figure 6).

![Figure 6. Monitoring sites of the RiverWatch program](http://www.ipswatch.sr.unh.edu.html).

USGS also conducted a study during the period 1999-2001, on nutrient and mercury contamination of water, sediments and fish tissue in New England Rivers,
including the Ipswich, as part as the National Water Quality Assessment Program (NAWQA).

**Dissolved Oxygen**

Dissolved Oxygen was the most significant water quality issue in the RiverWatch samplings. Extremely low DO samples were recorded in the Upper Basin of the watershed during the summer and fall months of 1998. Habitat effects of this low DO were noted by monitors (IRWA, 1999). In 1999 DO was still very low in some instances, but it did not reach the same extreme low levels for the extended length of time that it did in 1998 (IRWA, 2000). Figure 7 shows the percentage of samples with DO lower than 5mg/l, which represents the Class B standard, during the years 1998-2000, the numbers in the graph are referred to the year 2000.

![Figure 7. Dissolved oxygen in the Ipswich River monitoring stations](Source IRWA, 2001).

The problem of low DO is prevalent in the upper watershed; the lowest values of DO in 2000 were registered in June (Figure 8).

While monitoring of dissolved oxygen levels within the river and its tributaries has been ongoing for sometime, no study of the causes of low dissolved oxygen in the Ipswich River has been conducted.

However, a number of factors are known to affect oxygen levels, and are likely to play a role in the low dissolved oxygen trends seen in the Ipswich River watershed.
Those factors include: 1) In general, biological processes in wetlands utilize and decrease DO; the wetlands adjacent to and in the river may be decreasing the oxygen supply; 2) reduction of flow due to water withdrawals decreases the air / water interface; 3) temperature rises in ponded, unshaded areas of the river, resulting in less DO that can be present in the water (IRWA, 2001); 4) nutrient pollution from septic systems and sewage resulting in biochemical oxygen demand.

**Figure 8. DO and % saturation for the month of June 2000** (Source IRWA, 2001).

**Pathogens**

Fecal coliform contamination was the cause of the historical closure of all of the shellfishing areas in the Ipswich River estuary. Pathogen impairment has been documented at numerous locations throughout the Ipswich River watershed, there are at the moment 9 river segments, for a total length of 22.2 miles (about 22 percent of the total river miles) and 0.5 square-mile of estuary (100 percent) which are considered impaired relatively to this parameter.

Most of the bacteria sources are believed to be storm water related. Possible sources include failing septic systems, sanitary sewer overflows (SSO), sewer pipes connected to storm drains, certain recreational activities, wildlife including birds along with domestic pets and animals and direct overland storm water runoff.
Data on fecal coliform are available through the MADEP, 2004 WQA and the IRWA 2000 reports. Figure 9 shows the results for fecal coliform analysis for the year 1999 conducted by the IRWA.

The results from 1999 are very similar to the results seen in of 1997 and 1998 fecal studies. The Upper Basin, site IP08 in Middleton and the Ipswich area all show higher fecal coliform counts than the rest of the watershed. However, no fecal coliform sample collected in 1999 exceeded the single sample swimming standard of 400 colonies of fecal coliform /100 mL of water. Higher values were found in samples collected in 1995 by the MADEP.

![Fecal Coliform Results, 1999](image)

Figure 9. Fecal coliform in the river monitoring stations for the year 1999 (source IRWA, 2000).

A Draft Pathogen TMDL for the Ipswich River Watershed has been prepared by the MADEP and USEPA in 2005, of particular sensitivity is the lower portion of the Ipswich River, for its substantial shellfish resource.

**Nutrients**

Based on the results of the NAWQA program (Robinson *et al.*, 2004) for the period 1999-2001, the flow-weighted mean concentrations of total nitrogen and total phosphorus were less than 1 mg/l and less than 0.008 mg/L, respectively.

Ecosystems Center scientists at MBL analyzed Ipswich River samples collected by the IRWA in the year 2000 for ammonium, nitrate and total dissolved nitrogen (TDN), and phosphate and total dissolved phosphorus (TDP), respectively. Nitrate concentrations
ranged from 0 to 380 µM (over 98 percent of the samples collected had concentrations below 60 µM) and, generally, ammonium and phosphate concentrations were < 20 µM (over 98% were below 8 µM) and < 2 µM, respectively. Sampling indicated that peak concentrations of nitrate most commonly occur during winter months with a general increase from river km 51 (IP-00) to the mid-reach of the river (km 25 to 30), and a subsequent decrease to the Sylvania Dam. The largest sources of nitrate to the Ipswich River are from urban areas, likely due to the constant application of fertilizers and the influence of septic leachates. Concentrations of inorganic nitrogen tend to increase in headwaters during low flow periods, such as in the summer months of 1999.

Results of the IRWA nutrient summary indicate that water quality of the Ipswich River during the period of sampling (March 1999 to July 2001) was quite good. No sites above the Sylvania dam have chronic water quality problems associated with exceedingly the state standards for nutrient concentrations in drinking water. For instance, the maximum contamination level for nitrate is 10 mg/L (159 µM as NO₃⁻), and the mean concentration of Ipswich River water over the period of sampling was about 17 µM. (IRWA, 2001).

**Mercury**

The results of the NAWQA study on the New England coastal basin showed the highest concentration of total mercury in fish-fillet tissue among all sites sampled was within the Ipswich River. However, while the total mercury concentrations were found to be 0.40 µg/g none of the fish-fillet samples exceeded the U.S. Food and Drug Administration human consumption action level of 1 µg/g.

The total concentration of mercury in the sediment was found to be between 0.1 to 0.5 µg/g (Figure 10).
2.3.5 Biota data

In 1998 and 1999, the USGS and Massachusetts Division of Fisheries and Wildlife, in cooperation with the Massachusetts DEP and DEM, examined the existing fish species community and habitats, and the relationship of flow to aquatic habitat within the Ipswich River. The key findings of this and other research were:

- Dominant fish species were redfin pickerel (*Esox americanus*), American eel (*Anguilla rostrata*), and pumpkinseed (*Lepomis gibbosus*), which together represented 41, 22, and 10 percent, respectively, of 4,745 fish sampled; these are warm-water fishes that are tolerant of extended periods of low flow or impoundment.

- River-dependent species are being eliminated from the Ipswich River system, and currently comprise less than 9 percent of the species found in the watershed;

- Year-classes of fish are missing, possibly due to the frequency of low-flow/no-flow episodes and resulting fish kills.

- Photographs and anecdotal evidence of fish kills in 1995, 1997, 1999, and 2002 show that average fish size and age is dropping radically, indicating that the
frequency of massive kills may be preventing most fish from reaching reproductive age.

- Out of 8 sites monitored by IRWA since 1997, macroinvertebrate monitoring results have shown 6 of those sites to have moderate or severe impairment every year they were monitored.

- The river’s once-productive anadromous fisheries have been extirpated by dams and low-flow conditions; while restoration efforts for blueback herring have been underway for several years, the success of this effort is not yet demonstrated.

- Dams on tributaries block fish movement into the tributaries, some of which could provide refuge habitat during low-flow periods.

- Habitat quality does not appear to be a limiting factor in the Ipswich River if adequate streamflows are maintained.

- Fish sampled during late summer of 1998 included some stocked trout, which indicate that the Ipswich River potentially could support cold-water fish, but extreme low flows and warmer temperatures may limit their survival.

- The minimum streamflow values for the summer needed to preserve habitat sufficient to support a healthy fish population ranged from 0.44 cubic feet per second per square mile (cfs/mi²) to 0.65 cfs/mi².

Table 3 summarize the targets and deficits streamflows by watershed, obtained applying the fisheries threshold guidance of 0.49 cfs/mi² for the summer period.

Table 3. Streamflow Targets and Deficits by Watershed (Horsley & Witten, Inc., 2003).

<table>
<thead>
<tr>
<th></th>
<th>Headwaters</th>
<th>Upper Watershed</th>
<th>Entire Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy summer streamflows: Summer fisheries in Mgd</td>
<td>5.69</td>
<td>13.9</td>
<td>39.5</td>
</tr>
<tr>
<td>Avg. summer monthly medians (Mgd) July-Sept</td>
<td>N/A</td>
<td>4.9</td>
<td>25.1</td>
</tr>
<tr>
<td>Estimated deficit (Mgd) July-Sept</td>
<td>5</td>
<td>9</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Based on the results of recent reports, the task group for the development of the watershed management plan, identified a target fish community; Figure 11 shows the
existing Ipswich river fish community and the target fish community suggested (Horsley & Witten, Inc., 2003).

![Pie chart showing fish communities in Ipswich River](chart.png)

**Figure 11. Existing river fish community and the target fish community in the Ipswich River** (Source Horsley & Witten, Inc., 2003).

### 2.4 Solutions / ways for improvement

The Ipswich, as already highlighted, has been the focus of scientific research, extensive monitoring and assessment, and intensive modeling efforts, particularly by USGS.

These studies led to a comprehensive Watershed Action Plan, developed collaboratively between state and federal agencies, municipal government, local citizens and businesses, and scientists, under the organizing guidance of the Ipswich River Watershed Association.

The long-term goals of the plan are:

- balance the water budget;
- restore water quality, biodiversity, and habitat within the watershed;
- improve access and balanced use of the river for human uses;
- promote a shared responsibility among the watershed’s stakeholders to protect water quality and sufficient flows throughout the watershed.

The short-term goals address restoration through the development of alternative water supplies, localized wastewater management, enhanced stormwater infiltration, demand reduction, and improved land use practices (flow restoration).
The last three goals are the focus of the Ipswich River Restoration Project, which was awarded an EPA grant of over $1 million in Targeted Watershed Initiative. This grant will be used to demonstrate an integrated approach encompassing two strategies:

- Low-Impact Development (LID) – landscaping and design techniques that capture stormwater and recharge it to the groundwater.
- Water Conservation – education strategies and technologies that reduce demand on water supplies, and associated groundwater pumping.

A total of nine demonstration projects are at the moment conducted in eight different locations within the Ipswich River watershed. The results of these studies will be used by the USGS in a watershed computer model that will simulate the effect on river flows if these techniques were to be applied throughout the watershed.

The four projects, related to the low-impact development approach, are:

1. Low-impact development subdivision;
2. Green roof;
3. Use of permeable paving materials in a parking lot;
4. Lake water quality improvement using LID retrofits to replace conventional stormwater discharge.

The first project is still at an initial state; a new housing subdivision within the Ipswich River watershed will incorporate LID principles. Concepts and techniques will include compact site design, with housing units clustered on a portion of the parcel; reduced pavement area; permeable pavers for walkways; bioretention areas and water quality swales; reduced lawn areas and use of native, drought-resistant vegetation for landscaping; a constructed wetland for filtration of runoff; and rainwater harvesting systems.

The green roof is currently being designed, construction, including all plantings, is expected to be completed by September 2006. The location of this demonstration project is the building of the former Whipple School Annex in Ipswich, MA.

The third and forth projects are located near the Silver Lake, an important recreational resource that supports swimming, fishing, wildlife viewing, and boating. The lake is degraded from nutrients, sediment, and bacteria from the surrounding conventional stormwater system and non-point source runoff. Beach closures due to high bacteria
counts are a repeated occurrence. The projects include the construction of the beach parking lot using permeable paving materials, in order to reduce the quantity of stormwater runoff and non-point source pollution to Silver Lake and maximize infiltration to groundwater, and the replacement of the conventional stormwater collection system in two streets draining to the lake, by directing stormwater to rain gardens and porous pavers. USGS has been conducting preconstruction monitoring of groundwater since the summer of 2005 and water quality sampling will continue for at least one year after construction is completed.

The five projects, related to the water conservation approach, are:

1. Rainwater harvesting (Town of Wilmington);
2. Soil and turf amendments at municipal athletic fields (North Reading);
3. Water conservation retrofits and appliance rebates (Town of Reading);
4. Weather-based irrigation controllers (Towns of Hamilton, Middleton, North Reading, and Reading and the city of Peabody);
5. Water meter replacements and monthly water billing.

The work of IRWA related to physical habitat restoration has focus on: a) feasibility studies for fish passage on main stem dams and b) Stream continuity surveys of dams and culverts.

Another area in which the IRWA has been very active is educating the people that live and use the water from the Ipswich River; a variety of outreach materials have been developed, or are in progress. The Ipswich River Restoration Conference was held in November 2005. The Ipswich River Watershed Association has produced a River Restoration Handbook, which will be distributed to watershed communities in spring 2006.

A consistent amount of water leaves the watershed as wastewater; in order to maintain flow in the river, it would be preferable to recycle the wastewater, recharged back into the ground and consequently supplying the river with needed flow. One of the benefits of using treated wastewater to recharge groundwater is that it provides a reliable, daily source of water, independent of the weather.

To guarantee the use of the recycle wastewater as drinking water supply tertiary treatment will be needed. Furthermore a way to recycle water to the aquifer is by
injecting the treated wastewater and allowing it to infiltrate into the ground. This practice will increase the treatment and further eliminates biological and mineral contaminants in the water as it travels through the unsaturated soil.

The City of Sierra Vista, Arizona has undertaken a $7.5 million wastewater system that is designed to restore flow in the San Pedro River, which, similar to the Ipswich, has seen habitat destroyed as a result of low-flow occurrences. Recycled water, under proper treatment, has been used successfully to help restore groundwater levels and consequently drinking water supplies. Other examples of wastewater reuse for groundwater recharge are in Orange County and other arid regions in California.
2.5 References


Ipswich River Basin, Volume I: Inventory and analysis of current and projected water use: Boston, Mass. MADEM, publication 14892-156-500-6-87-C.R.


Massachusetts Department of Environmental Protection, (1999). *Final Massachusetts section 303(d) list of waters*. Executive Office of Environmental Affairs, DEP, Division of Watershed Management.


**Websites consulted**

Ipswich River Watershed Association (IRWA): http://www.ipswichriver.org

Ipswich-Parker Suburban WATershed Channel: http://www.ipswatch.sr.unh.edu/

USGS: http://www.usgs.gov/
3  Case study: Lower Des Plaines River, IL

3.1  Introduction

The Des Plaines River rises in southern Wisconsin just west of Kenosha and flows southward primarily through marshland as it crosses into Illinois. The river turns to the west and flows through woodland forest preserve districts in Lake County and Cook County. Eventually, the river turns to the southwest and joins with the Sanitary and Ship Canal in Lockport before flowing through the city of Joliet. In the heavily industrialized area around Joliet, dams control the river. Just west of Joliet, the Des Plaines River converges with the Kankakee River to form the Illinois River (Figure 12).

Parts of the Des Plaines River preserved in a mostly natural state are used for conservation and recreation, while substantially altered sections serve as an important industrial waterway and drainage channel.

According to Chicago Wilderness Magazine, as the Des Plaines River runs 95 miles through four Illinois counties, it "changes from prairie creek to a suburban stream, to a large urbanized river, to a major industrial waterway."

The portion of the Des Plaines River below its confluence with the Chicago Sanitary and Ship Canal (CSSC) historically has had very poor water quality as a result of various wastewater dischargers and channel modifications, and has been classified as “Secondary Contact and Indigenous Aquatic Life”. The Lower Des Plaines River is the largest effluent dominated stream in the world, carrying treated effluents and urban runoff from most of the Metropolitan Chicago area.

The great improvement in water quality that has occurred in the last three decades makes it possible now to consider upgrading the designation of the Lower Des Plaines to “General Use”. A use attainability analysis (UAA) has been performed on the Des Plaines River to determine whether the current classification (lower than fishable and swimmable use) should be upgraded due to the increased value placed on the water body in recent years.
### Des Plaines Watershed

![Des Plaines Watershed Map](image)

**Figure 12. The Des Plaines River watershed.**

#### 3.2 Physical setting

The watershed area of the Des Plaines River, excluding the CSSC, is 13,371 square-miles and the CSSC drainage area is 740 square-miles. The total main stem length of the river in Illinois from the state border to the confluence with the Kankakee River is 110.7 miles. The mean annual flow of the Des Plaines River just above its confluence with the Kankakee River is approximately 6080 ft³/s; seasonal flows parallel those of the Illinois River (USGS 1999, 2000b). The Des Plaines River is the primary drainage system for the greater Chicago/Cook County area (USGS 1999).

The Lower Des Plaines watershed extends from north central Cook County down through eastern DuPage County and western Cook County in-to northern Will County. Major waterways include the Lower Des Plaines River (from the point where the Salt Creek joins it near the Brookfield Zoo), Salt Creek, and portions of the Chicago Sanitary and Ship Canal and the Calumet-Sag Channel. Smaller drainages include Addison Creek, Flag Creek, Sawmill Creek, and Long Run Creek.
This 357-square-mile area unites some of Illinois' most affluent suburbs and historically important industrial towns. Twenty-eight Super-fund sites, one of them on the National Priority List, are reminders of the area's heavily industrial past.

In its lower basin the Des Plaines River flows in a channelized course parallel to the Sanitary and Ship Canal. North of Lockport, the river's channel is flanked by 80-100 foot natural bluffs within 2,500 feet of each bank of the river.

Before urbanization, low-lands remained largely wetlands, and before it was channelized the Des Plaines behaved like a meandering "prairie river," splitting and flowing toward both Lake Michigan and the Illinois River during flood events.

Below its confluence with the CSSC, there are three dams and locks, operated by the US Army Corps of Engineers to provide conditions for navigation, these dams create three pools: the Lockport Pool, the Brandon Pool and the Dresden Pool (Figure 13).

Figure 13. The three pools in the Lower Des Plaines River.
The Brandon pool is essentially a man-made channel that is bordered by side masonry, concrete or sheet pile embankments, whereas the Dresden Pool has “natural” shoreline areas and a number of natural tributaries.

### 3.2.1 Climate

The climate in the basin is classified as humid continental with an average annual air temperature of 59.6°F for the period 1971–2000. Monthly mean temperatures during this period ranged from 21.7°F in January to 73.7°F in July.

Precipitation in the Lower Des Plaines River basin were for the same period of record 36.9 in/yr, with average monthly precipitations ranging from a maximum of 4.38 inches in July, to a low of 1.58 inches in January. Annual snowfall during 1971-2000 averaged 10.3 inches, with a record high of 18.3 inch for the month of January 1967.

### 3.2.2 Surficial Geology, Topography and Land use

The landscape of the Lower Des Plaines basin was formed by the last glacial advance that ended about 13,000 years ago.

The region includes some outstanding scenery and geological features such as seeps, ponds and hills formed by glaciers, and dolomite cliffs and canyons eroded into ancient Silurian dolomite more than 400 million years old.

The eastern part of the lower Des Plaines region includes part of the flat basin of ancient Lake Chicago and, to the west of that, closely grouped moraines. In the western portion, the moraines were dissected by the rivers of water overflowing from lakes formed by melting glaciers. The northern third of the basin features broader upland areas, level between tributaries and somewhat poorly drained.

The clay-rich local soils tend to absorb water relatively slowly and flooding has been a concern since early settlement. In the last century much of the land has been paved over, therefore the problem of flooding has been exacerbated (Conservation, 2000).

A relatively large portion of the area has very thin soils. Romeoville Prairie and Lockport Prairie Nature Preserves show the distinctive meld of wetland communities that thrive in these shallow-soil areas. Approximately 10,633 acres of wetlands remain in the area, about 21 percent of the pre-settlement amount.
Unlike prairies, forests today cover more of the land than they did at the time of settlement. Approximately 16.5 percent of the area was once forested; now about 19.4 percent (44,430 acres) is forested, but only about 432 acres are high-quality and not degraded. About 94 percent of the forest is upland forest.

Between 1970 and 1990, population in northeastern Illinois grew by about 4 percent, yet acres of developed land increased by about 50 percent and now cover 66 percent (Figure 14). The basin's one million residents comprise 9 percent of the state's population.

Figure 14. Land Cover Lower Des Plaines River watershed. (Source Conservation 2000)
3.2.3 Location of gauging stations

Within the entire Des Plaines Basin the USGS has operated more than 50 stations. The Riverside gauging station (station no. 0553 2500) has a long-term average discharge of 350 cfs, and it can be used as reference for the part of the river above the confluence with the CSSC; in the Lower des Plaines the gauging station situated at Route 53 at Joliet (station no. 05537980), started to operate just recently and has a drainage area of 1,502 square-miles (see Figure 15 for location of the stations).

3.3 Data & analysis

3.3.1 Previous studies

The Upper Illinois Waterway (UIW) study, sponsored by the Commonwealth Edison Company, was conducted from 1991 to 1995, covering 55 miles of the waterway from the South Branch of the Chicago River down to the Dresden Island Lock and Dam. The comprehensive study included all aspects of the waterway physical, chemical and biological, and the monitoring efforts and studies has been designed and reviewed by a task force composed of representatives from IEPA, USEPA, IDNR, MWRDGC and the Sierra Club, as well as subject matter experts from leading universities and academic groups. Other studies have been commissioned by the Midwest Generation, LLC, in order to determine the environmental impact of the multiple power plants located adjacent to the Des Plaines River.

Between 1986 and 1997 a pilot study was conducted, with the NAWQA study starting in 1997 for the Upper Illinois River. Since then several reports have been published, which present data for the Des Plaines River. These studies include the collection of physical, chemical, and biological data, the description of spatial and temporal distribution of different parameters, description of the natural factors and human activities affecting the spatial patterns in concentrations and loads, describe long-term trends (or lack of trends) in water quality. These reports are available at http://il.water.usgs.gov/nawqa/uirb/aboutuirb.html.

Effects of urbanization on geomorphic, habitat, and hydrologic characteristics and fish biotic integrity of 45 streams in the Chicago area, including the Des Plaines River,
were examined by the U.S. Geological Survey from 2000 to 2001 (Fitzpatrick et al., 2005).

The Lower Des Plaines River Basin: An Inventory of the Region's Resources is a product of the Critical Trends Assessment Program (CTAP) and the Ecosystems Program of the Illinois Department of Natural Resources (IDNR). Both are funded largely through Conservation 2000, a six-year State of Illinois initiative to enhance nature protection and outdoor recreation by reversing the decline of the state's ecosystems (C2000).

The Critical Trends report analyzed existing environmental, ecological, and economic data to establish baseline conditions from which future changes might be measured. The report concluded that:

- the emission and discharge of regulated pollutants over the past 20 years has declined in Illinois, in some cases dramatically;
- existing data suggest that the condition of natural systems in Illinois is rapidly declining as a result of fragmentation and continued stress;
- data designed to monitor compliance with environmental regulations or the status of individual species are not sufficient to assess ecological health statewide.

Numerous studies have also been conducted in the Upper Lower Des Plaines River, which however does not present the character of being effluent dominated.

A use attainability analysis (UAA) has been concluded in 2003 by AquaNova International and Hey Associates on the Lower Des Plaines River; the area of study includes the reaches between the confluence of the Des Plaines with the CSSC and the Dresden Lock and Dam. The study was commissioned by the Illinois EPA to determine whether the current classification of the river (lower than fishable and swimmable use) should be upgraded due to the increased value placed on the water body in recent years.

### 3.3.2 Hydrological data

The flow in the lower segment of the Des Plaines River, after its confluence with the CSSC, is dominated by the presence of effluents from numerous wastewater treatment plants and small industries. A comparison between the flowstreams in the river before and after the confluence with the CSSC can be done looking at the data from the two USGS gauging stations located at Riverside and at Joliet, respectively. Figure 15 shows
together with a map with the location of the two stations, the daily discharge at the two stations for the same period of time. The average discharge at Riverside is about 1000 cfs, whereas at Joliet the average flow is about 3000 cfs.

The difference in flow is due to the effluents that are discharged into the Des Plaines River; for a complete quantification of these discharges refer to the pollution sources section of this report.

The mean annual flow of the Des Plaines River at Riverside is 751 ft³/s (period of record 1990-2004), whereas just above its confluence with the Kankakee River it is approximately 6080 ft³/s. Flows tend to be highest in spring (March, April, and May) and lowest during late summer and early fall (August, September, and October).

![Graph and map showing discharges at two stream gauging stations in the Lower Des Plaines River.](image)

Figure 15. Discharges at the two stream gauging station in the Lower Des Plaines River.

### 3.3.3 Point and non point sources of pollution

Over-enrichment from treated and untreated sewage is a major threat to the Lower Des Plaines River, which since the turn of the 20th century has been a conduit for most of Chicago's (usually treated) wastewater, and it has received overflow from combined sewers.
The pollution population equivalent of effluent discharge carried by the canal to the Des Plaines River is about 9.5 million. The TARP project today has significantly reduced the number (frequency) of CSOs overflows per year. With the full implementation of the reservoir portion of TARP, the frequency of overflows will be further reduced. Combined sewer overflows reaching the river via the Chicago Sanitary and Ship Canal are a source of a mixture of untreated sewage and urban runoff from Chicago and Cook County.

Table 4 lists large and medium size (more than 0.5 cfs) public sewage treatment plants (STP) and industrial discharges located on the Des Plaines River, and its tributaries upstream of the Dresden pool, while Figure 16 shows the locations of the major STP.

As already noted above, effluent discharges, which are typically about 1900 cfs, constitute a major part of the flow in the Lower Des Plaines River. This effluent flow constitutes more than 90 percent of low flow in the Lower Des Plaines River and during winter, almost the entire low flow is made of effluent discharges.

Figure 16. Location of major wastewater treatment plants discharging in the Des Plaines River and in its tributaries (source AquaNova International/ Hey Associates, 2003).
Midwest Generation operates several thermal power plants, Will County and Joliet #9 and #29 (Figure 17), which use water from the CSSC and the Lower Des Plaines River for cooling. The water use of these facilities is comparable with the low flow of the CSSC and the Des Plaines River.

Figure 17. Will County and Joliet power plants.
Table 4. Industrial facilities and public sewage treatment plants (STP) and their effluent flow on the Des Plaines River and Tributaries (average effluent flow greater than 0.5 cfs).

<table>
<thead>
<tr>
<th>River</th>
<th>Facility</th>
<th>Average effluent flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Plaines River</td>
<td>Lindenhurst STP</td>
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</tr>
<tr>
<td></td>
<td>NSSD Waukegan STP</td>
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<tr>
<td></td>
<td>NSSD Gurnee STP</td>
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<tr>
<td></td>
<td>Foulds Inc</td>
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</tr>
<tr>
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<td>Mundelein STP</td>
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<td></td>
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<td>Aptakisic Sand Corp.</td>
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</tr>
<tr>
<td></td>
<td>Lake County Public Works, Des Plaines STP</td>
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</tr>
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<td>Buffalo Creek</td>
<td>Buffalo Grove S.T.P</td>
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</tr>
<tr>
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<td>MWRDGC Kirie STP</td>
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<td>MWRDGC Eagan STP</td>
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<td>Itasca STP</td>
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<tr>
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<td>Addison North STP</td>
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</tr>
<tr>
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<td>Addison South STP</td>
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<td>Salt Creek Sanitary District STP</td>
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<td>Elmhurst STP</td>
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<td></td>
<td>Addison STP</td>
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</tr>
<tr>
<td>Des Plaines River</td>
<td>Reynolds Metals</td>
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</tr>
<tr>
<td>Sawmill Creek</td>
<td>Argonne National Lab(^1)</td>
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<tr>
<td>Des Plaines River</td>
<td>Romeoville STP</td>
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<tr>
<td><strong>TOTAL FROM DES PLAINES RIVER</strong></td>
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</tr>
<tr>
<td>Little Calumet River</td>
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<td>Thorn Creek Sanitary District STP</td>
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<td></td>
<td>MWRDGC Northside Chicago STP</td>
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<td>Chicago River</td>
<td>NSSD Clavey STP</td>
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<td>Chicago San. Ship</td>
<td>MWRDGC Stickney STP</td>
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<td>Canal</td>
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<td></td>
<td>Lockport STP</td>
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<td><strong>TOTAL FROM CSSC</strong></td>
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<tr>
<td><strong>TOTAL TO BRANDON POOL</strong></td>
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<td>From Brandon Pool</td>
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<td>Frankfort South and North STPs</td>
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<td></td>
<td>Joliet STP</td>
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<td>Amoco Chemicals-Joliet</td>
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<td></td>
<td>Stephan Chemical-Elwood</td>
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<tr>
<td><strong>TOTAL AT DRESDEN POOL</strong></td>
<td></td>
<td>1888.3</td>
</tr>
</tbody>
</table>

1. STP: Sewage Treatment Plant, the others are industrial discharges. 2. Discharges include mercury and radioactive elements.
3.3.4 Water quality data

For almost 100 years, the Des Plaines River has been heavily impacted by channelization, construction of locks and dams, periodic dredging, stormwater runoff from continued expansion of upstream urban areas, and its use as a conduit for sanitary and industrial discharges from metropolitan areas within the Upper Illinois River Basin. However, during the past 50 years, water quality has improved in the Basin because of advances in municipal and industrial waste treatment. Numerous ongoing research and management programs, such as the implementation of Total Maximum Daily Loads, Best Management Practices, Wetland Restoration, and Pesticide Management and Monitoring, have been initiated to address point and non-point source pollution (USGS 1998).

Up to 2004, the Illinois Environmental Protection Agency (IEPA) had assessed more than 200 river miles in the watershed and rated them as being good or fair (Figure 18). Fourteen percent were found to meet the needs of designated uses, about half were impaired to a minor degree, and 17 percent were severely impaired.

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Figure 18. Ranking of Illinois Rivers based on water quality. Source IEPA.
The designated use of part of the Lower Des Plaines River, plus other smaller streams and canals and Lake Calumet, is at the moment of Secondary Contact and Indigenous Aquatic Life (Figure 19).

Figure 19. Designated use for the Lower Des Plaines river. (Source IEPA, 2004).

The current Secondary Contact use designation is not intended for body contact recreation (swimming) or for the protection and reproduction of aquatic life species native to the area. It was designated by the Illinois Pollution Control Board (IPCB) in the early 1970s for those man-made and modified waterways in which flow is dominated by treated municipal effluents. For these reasons, Secondary Contact waters do not meet the goals of the Clean Water Act, therefore a Use Attainability Analysis (UAA) needed to be addressed.

AquaNova International and Hey Associates concluded the UAA for the Lower Des Plaines Illinois in 2003, while a UAA for the Chicago waterway system is been conducted in 2004 by CDM. Based on the assessment of water quality data, biological conditions and physical habitat, both these studies have proposed a change in the present designated use for those water bodies.
The Illinois EPA 2004 303(d) list has identified the following parameters of concern for the sections between the confluence with the CSSC and the Kankakee River: priority organics, ammonia, nutrients, pathogens, metals, siltation, habitat alterations, flow alteration and low dissolved oxygen/organic enrichment.

A good summary of all the water quality data for this portion of the Des Plaines River is available in the UAA (AquaNova International/Hey Associates, 2003), which collected data from different agencies (IEPA, USGS, MWRDGC, Commonwealth Edison Company and Midwest Generation). Figure 20 shows the location of the sampling sites used in the previously mentioned studies. The UAA provides also a statistical analysis of the data.

Water quality data for the entire Des Plaines River watershed are also available in the Upper Illinois NAWQA study. In the following section a summary of the water quality data, for the most critic parameters, is given.
**Dissolved Oxygen**

The DO levels are affected by the discharges of the biodegradable organic matter from point and non-point sources, atmospheric re-aeration, sediment oxygen demand, nitrification of ammonium and organic nitrogen, temperature and by algal photosynthesis and respiration. DO fluctuates during the day as a result of algal activity in nutrient enriched streams, exhibiting the lowest summer DO concentrations in the late night and early morning hours and potential over-saturation in late afternoon. On cloudy days, algal respiration may bring dissolved oxygen to very low levels.

Dissolved oxygen in the Brandon Pool of the Lower Des Plaines River frequently falls below the General Use Standard of 5 mg/L. The river is made of two impoundments that have a very low re-aeration capacity. The Metropolitan Water Reclamation District of Greater Chicago and Midwest Generation have DO measuring stations: one at Joliet at Jefferson Street (MWRDGC 93) and a second one at I-55.

Figure 21 shows DO concentrations in Joliet and I-55 in the summer of 2000. In this year, the I-55 site fully complied with the 5 mg/L standard. However, violations of the 4 mg/L Indigenous Life Use were measured in the Brandon Road pool by the MWRDGC Jefferson Street. The difference in average DO between the Brandon pool and I-55 was about 2 mg/L.

![Figure 21. DO concentrations in two location of the Des Plaines River](source AquaNova International/Hey Associates, 2003).
The DO level in the Des Plaines River has increased in the last 30 years (Figure 22), this is mainly due to the enhancement in the sewage treatment in the different wastewater facilities which discharge their effluents into the Des Plaines. However, the presence of nutrients that enhance algal respiration and high temperatures during the summer do not allow the general use standard to consistently satisfied. One way to increase the DO level would be to enhance aeration at the Lockport Dam.

![Figure 22. DO concentrations in two location of the Des Plaines River in 1972 and in 2000 (source AquaNova International/ Hey Associates, 2003).](image)

**Nutrients**

Nitrate concentrations within the river have been increasing in the last ten years, and are now approaching, but have not yet exceeded, the drinking water limit of 10 mg/L (Figure 23). Potable water use of the Lower Des Plaines River is not an existing use, therefore this concentration does not represent a significant problem (AquaNova International/ Hey Associates, 2003). However the presence of nutrients in the river enhances algal growth which may interfere with recreation and the aesthetic of the river, as well as determines, as already mentioned, DO fluctuation during the day, which could be problematic for biota.

In addition, phosphorus concentrations at the G-23 monitoring station have also increased over the last 10 years, reaching values over 1 mg/l.

Based on the results of the NAWQA study for the upper Illinois River, the CSSC brings to the Lower Des Plaines River almost 20,000 tons of nitrate and nitrite per year and 4,300 ton of phosphorus (Sullivan, 2000).
Watershed Management
Effluent dominated streams in the US

Figure 23. Nitrate and nitrite at G-23 (source AquaNova International/ Hey Associates, 2003).

**Ammonia**

Ammonium and Total Kjeldahl Nitrogen have been declining in the last ten years (Figure 24).

Ammonia was the subject of a statistical study by the UAA group; the results of this analysis indicate that the acute standard is attained at all sampling stations, while the chronic standard for ammonium would most likely be attained at all monitoring stations with a high margin of safety, with the exception of the station MWRDGC 95 (I-55) where a combination of higher pH caused by algal development and high temperature would result in a small margin of safety.

Figure 24. Total ammonia concentration at G-23 (source AquaNova International/ Hey Associates, 2003).
Pathogens

The Lower Des Plaines River, as already stated, is an effluent dominated stream and has in the past received large quantities of CSO. Therefore, the presence of fecal coliforms bacteria is attributed to these multiple point and nonpoint sources.

Several studies have shown that the effect of point source effluents on bacteria density diminishes with the distance of the source from the Lower Des Plaines River. Therefore, the nearest sources to the river, (i.e. the effluents from Joliet East and West plants, Figure 16), that discharge directly into the Dresden Island pool, have a larger impact than effluent discharges from more distant MWRDGC plants on the Chicago waterways.

This can be seen also from the two studies commissioned by the MWRDGC, which documented that disinfection at the MWRDGC plants would not have a significant effect on the bacterial densities in the Lower Des Plaines River.

Figure 25 and Table 5 show the average values for fecal coliforms in four different sampling sites, and the probability of excursions as determined in the UAA study.

![Average Density Fecal Coliform](image)

**Figure 25.** Average Density of fecal coliform in 4 sampling location in the Lower Des Plaines river.

The increase of the FC densities between Brandon and Dresden Island Pool is most likely attributed to the discharge of the effluent and CSOs from the Joliet
wastewater treatment plants. In both pools the maximum of 400 cfu/100 mL of 10 percent of samples is exceeded, moreover in the Dresden Pool, the densities of fecal coliforms result to be 3 to 4 times higher than the standing Illinois General Use Standard based on the geometric mean of 200 FC cfu/100 mL, therefore this use cannot be met.

Table 5. Probability of excursion of the Illinois General Use Standard of 400 cfu/100ml.

<table>
<thead>
<tr>
<th>Sampling location</th>
<th>Probability of excursion 400 cfu/100ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brandon Pool (MWRDGC 93)</td>
<td>43</td>
</tr>
<tr>
<td>Brandon Pool (G-23)</td>
<td>48</td>
</tr>
<tr>
<td>Dresden Pool (MWRDGC 94)</td>
<td>73</td>
</tr>
<tr>
<td>MGWRDGC 95</td>
<td>59</td>
</tr>
</tbody>
</table>

However, based on the statistical analysis conducted, and observation of the actual use of the different stretches of the Lower Des Plaines the UAA suggested to:

1. Adopt the federal criteria for pathogens;
2. Establish a secondary contact use for the Brandon Road pool;
3. Establish a primary higher risk recreational use for the Dresden Island pool.

**Toxic metals**

The UAA analyzed the available data for toxic metals in the water column, and found that the concentration of all metals but copper, mercury and zinc, satisfy the acute and chronic standards for the Illinois General use.

Mercury has a very low standard for total concentrations, and the Illinois standard is even lower. Most of the measurements at MWRDGC 92-95 and IEPA G-23 were below the detection limit of 0.1 µg/l. However, all MWRDGC sites have one to three measurements that exceed the standards of 0.5 µg/l.

The concentrations of zinc measured in all the stations are lower than the federal chronic criteria, which is site specific and in the Des Plaines is around 230 µg/l. However, 50 percent of the measurements are higher than the Illinois chronic criterion which is about 5 times smaller than the federal criterion.

A detailed analysis for copper concentrations was been done for the UAA, the conclusion of the study can be summarized as follow:

- The majority of data is either 10 or 5 µg/L, these values being detection limits. The only measurable concentrations were reported during the winter or late fall.
- Copper concentrations in the Lower Des Plaines River is in compliance with the CMC (acute) toxicity standard at the compliance level at or better than 99.8 %

- Analysis of the water column and sediment copper concentrations indicate a possible source of copper between the MWRDGC water quality monitoring stations 93 (Joliet, Brandon Pool) and 94 (Dresden Island Pool, Empress Casino) and between Upper Dresden Island (RM 285) and Lower Dresden Island (RM 278) Pool sediment sampling points.

- The UAA suggested a different way to determine the CCC standard, which uses the water effect ratio (WER); in this case the Lower Des Plaines will be in compliance with the standard.

**Temperature**

Temperature is a critical parameter in the Lower Des Plaines River. As previously mentioned, several power stations are located on the upstream CSSC (Will County) and on the Des Plaines itself, which discharge heated effluents which affect the temperature in the river.

In 1999-2000, Midwest Generation conducted an aquatic monitoring program, which included water temperatures measurements in the Upper Dresden pool (Figure 26). During this sampling program, water temperatures ranged from 14.1°C to 37.8°C with the warmest temperatures occurring at the discharge canal of station 29 during the summer months.

![Figure 26. Maximum monthly temperatures at the condenser outlets into the discharge canals of the Joliet power plant units and at the I-55 bridge. (source AquaNova /Hey Associates, 2003).](source)
The UAA highlighted that the existing thermal standards for the Lower Des Plaines River allow the temperatures to achieve, and be maintained for extended periods of time, levels lethal to most biota. Therefore, it was suggested that the standard be revised to a value equal or close to the statewide General Use temperature standard.

As suggested by the UAA, the U.S. EPA and the Illinois EPA have recently commissioned the Center for Applied Bioassessment and Biocriteria (CABB) to develop temperature criteria options for the Lower Des Plaines River in northeastern Illinois (CABB, 2005).

The principal objective of this project was the development of seasonal temperature criteria options that are protective of the biological assemblages that are representative of the designated use options that may be considered for the Lower Des Plaines River.

3.3.5 Sediment data

The sediment quality of the Lower Des Plaines River has been extensively analyzed by the USGS in its NAWQA study of the Upper Illinois River (Schmidt and Blanchard, 1997; Fitzpatrick et al., 1998; Sullivan et al., 1998). MWRDGC has also been conducting sediment quality monitoring since 1983. A sediment toxicity study, commissioned by the Commonwealth Edison Company, has been performed by Wright University in the period 1994-1995.

Some of the results of these studies are summarized in Figure 27, which shows the concentration of four metals in the sediments in two locations within the Lower Des Plaines river for the period 1989-2000.
The U.S. Environmental Protection Agency has conducted three detailed sediment surveys and analyses in 2001. The sampling point locations were both in the navigational channel and in the depositional areas outside of navigation traffic. The USEPA sediment surveys provide the most comprehensive and detailed information on sediment quality, location of “hot spots” of toxic contamination and pollutant levels in the sediment. Table 6 reports a summary of the findings of this study. It shows the concentration in the sediment ($C_T$) of several contaminants, the pore water concentration ($C_d$), sediment toxic level (STU) together with the acute and chronic toxicity standards CMC and CCC (source AquaNova International/ Hey Associates, 2003).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CMC µg/L</th>
<th>CCC µg/L</th>
<th>C_T µg/kg</th>
<th>C_d µg/L</th>
<th>STU</th>
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<tr>
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<td>0.0038</td>
<td>10.00</td>
<td>0.71</td>
<td>25.4</td>
</tr>
<tr>
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<tr>
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<td>-</td>
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<td>39</td>
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<td>(6,000)</td>
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</tr>
<tr>
<td>1221</td>
<td>-</td>
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<td>600</td>
<td>1.54</td>
<td>110</td>
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<td>(16,000)</td>
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<tr>
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<td>-</td>
<td>0.014</td>
<td>600</td>
<td>0.015</td>
<td>1.05</td>
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</table>

From the table above we can conclude:

- USEPA survey and the elaboration done in the UAA, identified an hot spot in the depositional zone above the Brandon Road Dam (RM 286). The sediment has high PCB, pesticide and elevated toxic metal contamination relative to benchmark and background levels.

- The Lower Des Plaines River sediments also have high concentrations of several toxics, which are byproducts of biological degradation of pesticides used years ago. These pesticide pollutants were used years ago as insecticides on agricultural fields, in homes as well as for other widespread uses.
- Toxic metals do not appear to be a toxicity problem with the exception of cadmium in the RM 286 depositional zone.

### 3.3.6 Biota data and habitat

Biota data for the Lower Des Plaines river are available for two different communities: the benthic macroinvertebrates and the fish community. The analysis of these communities able to assess the quality and the “ecological health” of a stream as macroinvertebrates are an important component of a balanced ecosystem, and fish represent the upper level of the aquatic food chain.

#### Benthic macroinvertebrates community

In the mid-90’s Commonwealth Edison Company collected macroinvertebrate data as part of an assessment of the Upper Illinois Waterway; the results of the study are summarized in Figure 28. The Ohio Invertebrate Community Index (ICI) ranged between 10 and 22, corresponding to poor and fair condition, respectively. The lower ICI value was registered at the river mile 286, which, as already highlighted in the previous section, has highly contaminated sediments, and this could be the cause of the low integrity.

More recent macroinvertebrate data were collected in 2000 by the Metropolitan Water Reclamation District of Greater Chicago (MWRGC) and the Illinois Environmental Protection Agency (IEPA). In this studies two collection methods were used and different metrics (e.g. total number of taxa, percent of intolerant species, etc), were used to determine the biological integrity, which was expressed using the Ohio multi-metric Invertebrate Community Index (ICI) or the single metric Illinois’ Macroinvertebrate Biotic Index (MBI).
Based on artificial substrates and use of the Illinois single matrix MBI, the Upper Dresden Pool appears to provide water quality sufficient to support a General Use Classification. The use of the Ohio multi-metric ICI indicates that the Upper Dresden Pool is not meeting its potential use as impounded water. The macroinvertebrate community in the Brandon Pool does not support a General Use Classification and both the Illinois MBI and Ohio ICI indicate a degraded macroinvertebrate community.

The causes of the poor condition are mainly lack of habitat and barge traffic, as well as the presence of toxic compounds in the sediments, where the macroinvertebrates live.

**Fish community**

A study of the fish community of the Lower Des Plaines River, commissioned by the Commonwealth Edison Company or Midwest Generation EME, LLC, has been conducted by scientists from Engineering, Science and Technology (EA). The EA sampling campaign was conducted between 1999 to 2001 using the methods prescribed by the Ohio Indices of Biotic Integrity (IBI) methodology (EA, 2001). The Lower Des Plaines River has also been sampled in the past by the Illinois Department of Natural Resources (IDNR).

The EA study area was divided into four reaches (from downstream to upstream): (1) lower Dresden Pool, from the confluence with the Kankakee River up to the I-55
Bridge; (2) upper Dresden Pool, from the I-55 Bridge upstream to the Brandon Road Lock and Dam; (3) Brandon Pool, between the Lockport and Brandon Dams, and (4) lower Lockport Pool, waters of the CSSC upstream of Lockport Dam.

The results of this study were analyzed for the UAA; Figure 29 shows the results of this analysis for the year 2001, similar results were obtained for the year 1999 and 2000. Additionally the IBI for these reaches were compared with IBI values calculated for other navigatable rivers in Illinois, characterized by different level of human-induced impacts (Figure 30).


Figure 30. Comparison between Ohio IBI calculated for sampling stations in the Lower Des Plaines River and in other Illinois boatable rivers (source AquaNova International/ Hey Associates, 2003).
Assessment of IBI scores reveals a statistically significant decrease in biotic integrity moving upstream from Lower Dresden, to Upper Dresden, and into Brandon Pool.

IBI scores for Upper and Lower Dresden are not significantly different than those for impounded reaches of the Fox River. However, free-flowing reaches of the Fox River have significantly higher IBI scores. This suggests that the presence of and proximity to dams has significant effects on the fish biotic integrity.

The Lower Dresden Pool with a IBI mean value of 23.79 is close to the Ohio IBI criteria of 24, identified for channel-modified stream. The other reaches fall below this criterion.

Part of the reason for the poor IBI values throughout the Lower Des Plaines River is lack of adequate habitat. While habitat improvement opportunities in the Brandon Road Pool are limited by the maintenance of the federal navigation channel, in the Dresden Island Pool, the improvements are limited to improvements in riparian habitats.

**Habitat**

The loss of diversity in the fish community and the low ICI for macroinvertebrates are cause by poor habitat in the Lower Des Plaines River, which is the result of a lack of riffle/run habitat, limited hard substrates (i.e. gravel/cobbles), channelization, poor riparian habitat, lack of in-stream cover, and impounded water.

The Lower Des Plaines river is used, besides as effluent conduit, for commercial barge traffic, a protected use under the Clean Water Act; as a result, the channelization of the Brandon Pool and the three locks and dams, operated by the US Army Corps of Engineers to provide conditions for navigation, which are the major causes of the degraded habitat cannot be eliminated.

Artificial placement of in-stream cover and improvements in riparian buffer areas could improve habitat quality in the Dresden Pool, and in a minor extent in the Brandon Road Pool.

### 3.4 Solutions / ways for improvement

The analysis of the present situation in Des Plaines River highlighted the increasing water quality in the river, similar studies have also reported a improvement in the
Chicago Waterways. The Use Attainability Analysis for the Lower Des Plaines, as well as the one for the Chicago area waterways, have proposed a change in the present designated use for those water bodies. However, the it is clear that the Lower Des Plaines River is a highly modified water body that does not resemble its pre-development status, and most of the physical modification and attributes are mostly irreversible, taking also in consideration that the navigation use of the river, which is one of cause of habitat loss and alteration, is a protected use by the CWA, and could not therefore be eliminated.

The UAA has also suggested several short term and long term actions: in the regulation area (i.e. apply the new defined uses for the different reaches of the river), in the monitoring of the water quality of the river (chemical as well as biotic), in the abetment of discharges (e.g. CSOs for the City of Joliet), and remediation action (e.g. address Temperature problem for Midwest Generation).

One of the first consequences of the UAA, as already pointed out, is the development of seasonal temperature criteria options that are protective of the biological groups that are representative of the designated use options that may be considered for the Lower Des Plaines River.

The most important action must be taken from the Illinois EPA and it is the change in designated use of the water body; indeed, once the new use is assigned, more actions could, and will be taken place in the restoration of the river.

According to the Illinois Natural History Survey, "with improvements in water quality, species that have been extirpated could return and natural communities could become reestablished in areas where they have been eliminated or altered." Indeed, fish communities in the Des Plaines have registered increases in tandem with water-quality improvements in recent years. Of 13 Lower Des Plaines subwatersheds prioritized by IEPA, 11 - including the Des Plaines and Salt Creek - were identified as restorable.

A few ways to further that goal include, but are not limited to:

- Discharge wastewater into treatment lagoons and wetlands before releasing it into area waterways, this not only reduce the nutrient loading into the river, but also help in the flood control;
- Use primary and secondary detention basins before releasing stormwater into the waterways;
• Remove some additional dams that degrade water quality by obstructing flow.

Several groups and agencies have been involved in the last decades in projects to restore the Illinois riverways and habitats.

Among those, OpenLand, that is one of the nation oldest urban conservation organizations. To date, OpenLands Project has taken leadership roles in securing more than 45,000 acres of land in the Chicago area for public parks, forest preserves, land and water greenway corridors, and urban gardens.

CorLands is OpenLands Project’s land acquisition affiliate. Starting in 2001, CorLands has been involved in one of the most significant and ambitious ecological restoration and acquisition initiatives in the nation. Acting in conjunction with the Chicago District of the U.S. Army Corps of Engineers and using funds generated from the resolution of wetland violations, permits and/or compliance cases, CorLands contributed to or made commitments for several land acquisitions assisted with 21 restoration projects provided funding or coordination for nine research projects (including wetland restoration projects, hydrologic study, etc). The major emphasis is on the restoration and enhancement of dolomite prairie habitats. Figure 31 shows a map with the location of the OpenLand projects, most of this projects are along the Des Plaines River, other project are along the Kankakee River and the Long Run Creek. In this last location, in particular, because of concerns about flooding and the area's natural resources, citizens and government officials began meeting in December 1998 to develop a plan for the Long Run Creek Watershed. Over the past few years the group has been actively addressing many of the concerns listed in the plan as well as educating property owners, townships, and municipalities about these concerns. For example, the Long Run Creek Watershed Committee has held workshops to teach property owners about the best management practices for creek maintenance. It has also partnered with the Village of Homer Glen to enhance and restore a wetland on the Creek, and to incorporate watershed resource concerns in the village's comprehensive plan.

Other projects related to ecosystem restoration along the Des Plaines River are been conducted through the Ecosystem Program of the IDNR.
The purpose of the Ecosystems Program is to integrate the interests and participation of local communities and private, public and corporate landowners to enhance and protect watersheds through ecosystem-based management.

Figure 31. Wetland Acquisition and Restoration/Enhancement Projects

The Ecosystems Program is funded through Conservation 2000 (C2000), a comprehensive long-term approach to protecting and managing Illinois' natural resources. The Ecosystems Program is a voluntary, broad-based incentive program, which consists of four components:

1. Assessment and Monitoring
2. Integrated Technical Assistance
3. Ecosystem Project, Planning, and Support Grants
4. Ecosystem Interpretation and Education
The “Lower Des Plaines River Basin: An Inventory of the Region’s Resources” is a product of the Critical Trends Assessment Program (CTAP) and the Ecosystems Program of the Illinois Department of Natural Resources (IDNR).

Fourteen projects have been funded by C2000 in the Lower Des Plaines River (Figure 32).

**Lower Des Plaines Ecosystem partnership**

*Projects Receiving Funding Through C2000 grants*

Among these projects, two are located around the area examined by this report:

- **Des Plaines River Diversion Channel Project (Project 2 in Figure 32):** restoration of the in-stream structure to a section of the Des Plaines River Diversion Channel, which will create a series of rock structures that will re-establish flow diversity & create habitat.

- **Enhancing the Aquatic Habitat of the Lower DesPlaines (Project 6 in Figure 32):** River Benthic mesh will be installed in an old borrow pit connected to the river in
Waterfall Glen Nature Preserve of DuPage County. Fish populations will be monitored for two years.

Even though the location is the Upper Des Plaines, a project that merit to be mentioned is the Des Plaines River Wetlands Demonstration Project. The Upper Des Plaines River faces different challenges with respect to the Lower Des Plaines, the major of which is a long history of flooding, that has caused significant economic losses. For this reason the efforts in this area have mainly been devoted to wetland restoration. The Des Plaines River Wetlands Demonstration Project, which started in 1986, has transformed a 550-acre site of abandoned farm fields and gravel quarry pits into a rehabilitated ecosystem along the upper Des Plaines River in Lake County, Illinois.

The Lower Des Plaines River, following the examples of other Rivers including the Upper Des Plaines, should establish a watershed management commission, that could include the Chicago Waterways. The commission could be responsible for the water quality monitoring, the planning of restoration actions, as well as fish management.
3.5 References


**Websites consulted**

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Midwest Regional Climate Center:

http://mrcc.sws.uiuc.edu/climate_midwest/maps/il_mapselector.htm

NAWQA Illinois River Basin (UIRB) Study:

http://il.water.usgs.gov/nawqa/uirb/aboutuirb.html


Discharges into the Des Plaines River:

http://pages.ripco.net/~jwn/sewage.html#desplaines_river

IDNR: http://www.dnr.state.il.us/orep/c2000/ecosystem/

Open land project: http://www.openlands.org/reports/OP%202000%20AR.pdf

USGS: http://www.usgs.gov/
4 Case study: South Platte River, Segment 15, CO

4.1 Introduction

The South Platte River Basin has a drainage area of about 24,300 square miles and is located in three states: Colorado, Nebraska, and Wyoming. (Dennehy et al, 1998) The South Platte originates in the Rockies and flows about 450 miles northeast across the Great Plains to its junction with the North Platte River in North Platte, Nebraska, eventually flowing into the Missouri and then Mississippi Rivers. Altitude in the drainage basin ranges from 14,286 feet at Mt. Lincoln on the continental divide to 2,750 feet at the confluence of South Platte and North Platte Rivers.

When the South Platte was first encountered by the early Anglo-explorers, the river was characterized as a dry sand bed one year, and a raging torrent the next. (Silkensen, 1992). Pioneers traveling Oregon trail used the river as a source of water, but often found it just about dry in the summer. Theodore Talbot, an early explorer, wrote in his diary of the river, “Here the buffalo come to drink and stand during the heat of the day, adding their own excrement to the already putrescent waters. This compound, warmed by the sun, makes a drink palatable to one suffering from intense thirst.” (Harris) During storms and spring snowmelt, Eisly (1989) describes the river as a “…mile wide roaring torrent of destruction…”

Even the earliest settlers recognized that the high plains could be made more habitable by irrigation. Western prior appropriation water doctrines heavily influenced the history of the South Platte and of the agriculture and industry of the region.

Today the South Platte River is a highly regulated river with flow 365 days a year. Over 65% of Colorado’s population lives along a 30-mile strip of the river. Daily river flow now is more a function of the population’s water use in the region than it is of the hydrology of the river basin. Most of the river’s flow upstream of the treatment plant is diverted for agriculture. Treatment plant effluent often accounts for 100% of the flow downstream of Denver. This effluent accounts for the primary source of nitrate, ammonia, and phosphorous in the river directly downstream of the plant. (Litke, 1996)

The 26-mile segment of river downstream of the treatment plant is known as Segment 15, which is the section of the South Platte that will be analyzed in this report.
In 1986, low dissolved oxygen (DO) and the presence of toxic ammonia, other toxics, and metals convinced the Colorado Water Quality Control Commission to identify Segment 15 of the South Platte River as water quality impaired and a high priority for TMDL development. (USGS) Ammonia was the primary concern as it combined with the amount of nutrients were contributing to very low dissolved oxygen levels that threatened aquatic life.

Segment 15 was identified on Colorado’s 1998 303(d) list as partially impaired for dissolved oxygen, and a TMDL was developed. Over the next 50 years, much of the remaining open land along segment 15 is expected to become urbanized. This land use will change the characteristics of the river and greatly affect flow, nutrient loads, and dissolved oxygen levels in the future.

4.2 Physical setting

The South Platte River Basin drains an area of about 24,300 square miles and is located in three states, Colorado, Nebraska, and Wyoming. Colorado includes 79% of the watershed, Nebraska 15% and Wyoming 6%. The South Platte River begins roughly in the center of Colorado and runs to the northeast corner of the state, Figure 33. The basin includes two physiographic provinces - the Front Range Section of the Southern Rocky Mountain Province and the Colorado Piedmont Section of the Great Plains Province. (http://co.water.usgs.gov/nawqa/splt/html/spbasininfops.html) The river originates as runoff tributaries in the Rocky Mountains. The river then descends the foothills and enters the highly urbanized Front Range urban corridor, where the mountains meet the high plains. As it flows through Denver, the river can be divided into two sections. The first section can be classified as transmontane, that is having characteristics of a mountain stream: cold water and a cobble substrate. This section of river travels through a highly industrialized area receiving flow from numerous storm water discharges and effluent from municipal wastewater facilities. Four tributaries, Bear Creek, Cherry Creek, Sand Creek and Clear creek, drain the Denver Metropolitan area and connect to the South Platte here. The second section of the South Platte possesses the characteristics of a high plains stream: meandering, reduced velocity and sandy substrate. This section of the river passes through primarily agricultural and livestock grazing lands. (CDM, 1992)
Segment 15 is a 26-mile stretch of the South Platte, beginning right after the Burlington Ditch diversion structure, located at 52\textsuperscript{nd} street, at the northern city limits, Figure 34. Two river-miles downstream is the Denver Metro Wastewater Treatment Plant in Commerce City. Segment 14, immediately upstream is intensely urbanized. North of Denver, Segment 15 undergoes a transition from urban land use to agricultural land use. Two main tributaries feed Segment 15, Sand Creek and Clear Creek. Sand Creek was once an intermittent stream, but now due to urbanization it discharges steadily. Clear Creek is mostly diverted for agriculture prior to meeting the South Platte during the agricultural months of April to September. Segment 15 ends one mile South of Fort Lupton, before the mouth of the Big Dry Creek.
Figure 34. Map of the South Platte Segment 15 showing relevant Features. Source
http://www.cdphe.state.co.us/wq/Assessment/TMDL/tmdls/COSPUS15.pdf, 2000

4.2.1 Climate

The South Platte River basin climate is modified by its topography, in which there are
large temperature ranges and irregular seasonal and annual precipitation. Mean
temperatures increase from west to east and on the plains from north to south
Areas along the Continental Divide average 30 in. or more of precipitation annually, which includes snowfall in excess of 300 in. In contrast, the annual precipitation on the plains east of Denver, Colorado, and in the South Park area in the southwest part of the basin, ranges from 7 to 15 in. Most of the precipitation on the plains occurs as rain, which typically falls between April and September, whereas most of the precipitation in the mountains occurs as snow, which typically falls between October and March. (USGS NAWQA Program). The Denver area typically receives between 12 to 16 inches of annual rainfall, and annual natural runoff in the area ranges from 0.1 to 1 inch, (higher in urbanizes areas) (USGS, 1985). During the most recent year, 2005, the Denver area precipitation average was 12.8 inches, 3.01 inches below the normal 15.81 inches for the city. Average temperature for the city was 65.7 degrees F, 1.4 degrees higher than the average temperature of 64.3 degrees. Temperatures for 2005 ranged from 105 degrees F in July all the way to –13 degrees F in December. (National Weather Service, 2005)

Figure 35. Average annual precipitation (1951-80) and location of National Atmospheric Deposition Program (NADP) sites in the South Platte River Basin. Source USGS – NAWQA Program, 2002
4.2.2 Land use and Water Use

For the first 75 years, since being settled, the primary land use along the river corridor was agricultural. During the period after World War II, manufacturing and service industries began to become the major employers in the area, as farming became more efficient and needed less workers. Also, the South Platte area was developed as a railroad hub, and many heavy industries sprung up along the river during the late 1800s. (CDM, 1992).

The river essentially cuts the City of Denver in half, and as the riverbanks became more industrialized over time, the area became a less desirable part of the city. Eventually, four major landfills were located in the area between East 22nd Street and East 27th street during the 1950’s. (CDM, 1992) During the second half of the twentieth century, people became interested in the restoration of the river for aesthetic and recreational purposes.

Today Segment 15 of the South Platte River is divided into two types of land use. Upstream of Segment 15 is heavily urbanized as it passes through downtown Denver. As Segment 15 begins on the North side of Denver, it is characterized by heavy commercial and industrial use. As segment 15 progresses, it passes several active and flooded gravel mines, pastureland, and then mostly agricultural land. Also three wastewater treatment plants discharge treated effluent in Segment 15. Natural vegetation in the riparian corridor consists mostly of short grass prairie. (Neal, 1999) Over the next 50 years, much of this pastureland and agricultural land is expected to become urbanized.

Water use of the South Platte is governed by the Prior Appropriation doctrine. This doctrine was first developed in California in 1855, and decided in the case about water rights, “first in time was the first in right.” In the years following, the prior appropriation doctrine was expanded. The Prior Appropriation doctrine does not take leaving natural flow in a river into consideration. By this doctrine, as long as water is put into beneficial use, and a user has prior water rights to it, the water can be diverted. If a user with senior water rights is not receiving the water guaranteed to them by decree, the user files a written document called a River Call to request that the Division Engineer curtail all upstream water rights that are junior to them until the senior water right is satisfied. Water not used is “abandoned” and water rights can be lost. This doctrine drives the
water usage of the South Platte. Downstream of the Metro Sewer plant on the Segment 15, there are six water rights appropriated, as follows:

<table>
<thead>
<tr>
<th></th>
<th>Amount (cfs)</th>
<th>Year Granted</th>
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<td>1865</td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>622.70 cfs</strong></td>
<td>(Table from Harris)</td>
</tr>
</tbody>
</table>

It is interesting to note that even though 622 cfs of water rights have been granted, the flow of Segment 15 is typically nowhere near 622 cfs. Most of the water above the treatment plant at the beginning of segment 15 is diverted during the agricultural irrigation season at the Burlington Canal. For most of the year, the treatment plant is discharging into a mostly dry river. The treatment plant generally discharges about 200 cfs. This effluent flow makes up about 90% of Segment 15’s flow for about 9 months of the year.
4.2.3 Location of gauging stations

The USGS currently operates four stream gauging stations in Denver area of the South Platte, Figure 36. In order of flow, they are South Platte at Englewood (station no. 6711565), South Platte at Denver (station no. 6714000), South Platte at 64th Avenue (station no. 6714215), and South Platte at Fort Lupton (station no. 6721000). Several other inactive gauging sites are along the river that were used for various USGS studies. The Colorado Division of Water Resources also has several gauging stations in the South Platte. These typically measure amounts of water flowing in or out of the river to help manage water use. These stations include the Burlington Ditch diversion structure and the Metro Sewer Effluent Outfall.

The USGS gauging station at 64th Avenue gives the best view of Segment 15 just before the treatment plant effluent outfall, Figure 37.
Pink are Active, Blue are inactive

**Figure 36. South Platte Gauging Stations.** Source USGS Website.
4.2.4 Topography

Altitude in the South Platte drainage basin ranges from 14,286 feet at Mt. Lincoln on the continental divide to 2,750 feet at the confluence of South Platte and North Platte Rivers. The river goes from a mountainous topography to one characterized by the high plains. Segment 15 has the characteristics of a high plains stream, with many meanders and a slow river velocity. The river goes from 5105 feet above sea level at 64th street station at the beginning of Segment 15 to 4860 feet at Fort Lupton at the end of segment 15. That is a total drop of about 245 feet over 26 miles.

4.2.5 Surficial geology

The current geology of the South Platte River basin was formed during the Mesozoic Era, 100 million years ago. At one time, there was a large inland sea covering a large
portion of the North American continent. The pressure exerted on the land as well as magma below created an upward force that created the Rocky Mountains. As the mountains rose, rivers drained them. At some point, all of the rivers coalesced and created one, the South Platte. (CDM)

### 4.3 Data & analysis

#### 4.3.1 Previous studies

Numerous studies and reports have been conducted and written on the water resources of the South Platte River, especially segment 15, by State environmental agencies, nongovernmental environmental organizations, regional-planning agencies, and the USGS.

Segment 15 flow has been recorded at the Henderson, CO site for the past 78 years. In 1991, the South Platte river basin was chosen as one of the 20 study units of the NAWQA program, a priority of which was to identify the source and distribution of nutrients in the river. Low dissolved oxygen due to high ammonia was identified as a major problem. In 1992, a STREAMDO model was created to study dissolved oxygen levels throughout segment 15. (CDM, 1992) From 1993 to 1995 extensive water quality measurements were taken from six sites along the South Platte. In 1995, a NAWQA fact sheet was developed, focusing on nutrients in the river. (Litke, 1995) A report by the same author investigates the sources and loads of the nutrients. (Litke, 1996) This led to the South Platte being listed on the Colorado’s 1998 303(d) list, triggering a TMDL to be developed.

In 2000, a TMDL for dissolved oxygen was created for Segment 15, for the protection of aquatic life. This TMDL focused on ammonia levels from point sources to control the instream conversion of ammonia to nitrate, reducing dissolved oxygen levels. (USGS, 2000) A TMDL assessment for nitrate was also done in parallel. In the future, TMDL assessments will be done for copper and cadmium.

Since then, the dissolved oxygen problem has been continuously studied and several re-aeration structures have been put in place in conjunction with the Metro Wastewater Reclamation District (CDM).
4.3.2 Hydrological data

During dry weather, the flow of the South Platte in segment 15 is highly regulated. The flow of the river is more of a function of regional water use than it is of natural hydrology. Most of the natural flow is diverted upstream of segment 15 for agriculture. The major diversion in at the beginning of Segment 15 is the Burlington Ditch Canal. Flows diverted here can typically range over 100 cfs, Figure 38.

![BURCANTO Discharge Graph (Hourly Average)](image)

Figure 38. Hourly mean flow in ft³/s at the Burlington Canal Diversion Structure gauging station for the period 4/7/2006-4/17/2006. Taken from Colorado Division of Water Resources.

The bulk of the flow then is effluent from wastewater treatment plants. This is primarily from the largest plant on the segment, the Metro Wastewater Reclamation Central Treatment Plant, Figure 39. Further downstream, the South Adams County Water and Sanitary District and City of Brighton also discharge treated effluent to the river.
During wet weather, the flow in segment 15 can increase dramatically, particularly during spring snowmelt conditions. Figure 40 shows the average daily flow at the Denver and Henderson, Colorado gauging stations for a ten-year time period. The Denver gauging station is upstream of the Metro Wastewater Central Plant, and Henderson is downstream. The difference in flows shown on the chart between these two gauging sites is mainly the treatment plant’s effluent. The large spikes in flow are from snowmelt periods and storms. The base flow during dry weather at the two stations varies by about 150-200 cfs, which is almost exactly the average amount of effluent discharged by the treatment plant.
Figure 40. Daily mean stream flow in ft³/s at the Henderson gauging stations in the period 1995-2005. Created using data from USGS.

Two main tributaries feed Segment 15, Sand Creek and Clear Creek. Sand Creek was once an intermittent stream, but now due to urbanization it discharges steadily. Clear Creek is mostly diverted for agriculture prior to meeting the South Platte during the agricultural months of April to September.
4.3.3 Point and non point sources of pollution

Figure 41. Sources of Nutrients to the South Platte River Basin (Litke, 1995)

Nonpoint source

The South Platte River basin is largely an agricultural region, with the large amount of pollution related to agricultural activities. In the entire river basin, fertilizer and manure is by far the largest contributor to non-point nutrient pollution, Figure 41. Much of these nutrients stay in the soil and are taken up by plants, however during rain many of these nutrients are washed into the ground and as surface runoff. Point source pollution is the major contributor to nutrient pollution in segment 15. (Litke, 1995)

Point sources of pollution

The major source of nutrients in segment 15 is the Metro Wastewater Central Treatment Plant. This point source discharges approximately 200 million gallons per day of effluent. This effluent contains approximately 7000 tons of nitrogen and 860 tons of phosphorous every year, discharged directly into the steam. (Litke, 1995)

4.3.4 Water quality data

The main problem affecting the South Platte segment 15 is low dissolved oxygen levels. (Figure 43). Segment 15 is classified as a warm water class II aquatic life, class II recreation, drinking water, and agricultural water body. In 1991, the South Platte river basin was chosen as one of the 20 study units of the National Water Quality
Assessment Program (NAWQA), a priority of which was to identify the source and distribution of nutrients in the river. Six sites were monitored along the river for various water quality measurements from 1993 to 1995.

**Dissolved Oxygen**

Dissolved Oxygen was the most significant water quality issue in the NAWQA study. Dissolved Oxygen levels were field measured and calculated using STREAMDO IV models. The models and field measurements showed that DO levels would go below standards for warm water aquatic life. While the average daily dissolved oxygen levels met the criteria, Figure 42, the modeled data showed and individual samples showed that at certain times of the day, instantaneous dissolved oxygen levels were below the criteria. Also, values as low as 1.0 mg/L have been measured at some locations during the nighttime in warm weather and low flow conditions. (Thornton et al) Dissolved oxygen levels change throughout the day and seasons, with minimums typically occurring at night when plant photosynthesis is at a minimum.

![Average Daily Dissolved Oxygen at Henderson, CO - 4/1993 - 9/1995](image)

**Figure 42.** Average Daily DO Measurements at Henderson, CO from April 1993 to September 1995. Created from NAWQA data.
In 2000, site-specific dissolved oxygen limits were developed for Segment 15. An acute, 1-day limit of 3.0 mg/L and 5.0 mg/L 7-day average was set for the early life protection period (April 1 through July 31). An acute 1-day limit of 2.0 mg/L and 4.5 mg/L 30 day average was developed for the remainder of the year.

Low dissolved oxygen measured in the segment have been attributed, in part, to the instream conversion of ammonia to nitrate. The point source of this ammonia is the Metro Wastewater Central Treatment plant effluent. Other causes of low dissolved oxygen include oxygen demands from the respiration of aquatic plants, decomposition of detritus in the river, and nutrients entering the river from groundwater, overland flow, and discharges from other smaller municipal wastewater treatment plants. (Thornton et al)

**Ammonia**

Ammonia is a contributor to low DO levels that threaten warm water life in segment 15. In stream conversion of ammonia to nitrate reduces dissolved oxygen. This was identified as a problem and the Metro Wastewater Central Treatment Plant and in 1990, the Metro District installed nitrification facilities for the plant’s 70 MGD North Complex, which significantly improved Segment 15 water quality. (Neal et al, 1999) The South Complex of the plant still has no nitrification facilities and effluent is still a large contributor of ammonia to the river. Figure 43 shows the daily average ammonia level measured at the Henderson water quality site during the NAWQA study. Levels of ammonia are site specific and are related to temperature and pH of the water at the time of measurement. The pH and temperature determine how much of the ammonia is ionized or de-ionized. Non ionized ammonia is toxic to fish, while non-ionized ammonia is a nutrient to algae and aquatic plants and also exerts dissolved oxygen demand. (Novotny, 2003)

In Figure 44, the south Platte pH during the time shows that the average daily pH is 7.8. This means that portions of the ammonia will be both ionized and de-ionized.
Figure 43. Average Daily Ammonia Measurements at Henderson, CO from January 1993 to September 1995. Created from NAWQA data.
Figure 44. Average Daily pH Measurements at Henderson, CO from January 1993 to September 1995. Created from NAWQA data.

4.3.5 Biota data

Historically, the South Platte river had an intermittent flow, however it had supported species of fish. In 1982, it was concluded that 29 native fish species and 12 non-native fish species have inhabited Segment 15. (Propst, 1982) Most of the non-native fish that were introduced over the years were game fish to support recreational fishing. The Colorado Division of Wildlife still stocks the river today. (CDM) Carp also were introduced at some point to the river.

Twenty-six species of fish were identified in Segment 15 to be protected by the site specific low oxygen criteria in Segment 15. Laboratory tests were conducted on six fish species representative of these 26 species. It was determined that there were no significant effects on these species as long as minimum dissolved oxygen concentrations were greater or equal than 1.9 mg/L for OLS and 2.6 mg/L for ELS. (Thornton et al
4.4 Solutions / ways for improvement

The major water quality issue affecting the South Platte is low dissolved oxygen levels. This is mainly due to nutrients and ammonia being released by the treatment plant in this effluent dominated river.

One option is to install nitrification facilities on the Metro District’s Central Plant’s South Complex. In 1989, a study was done to evaluate the costs and feasibility of adding this equipment. Construction costs alone were estimated to be $112 million, not including increase Operations and Maintenance costs. This was deemed too much of a financial hardship.

The focus then went to providing better aerations for the river by installing drop structures. Several drop structures have been designed and installed. These have increased the dissolved oxygen in problem areas.

The Metro District is also considering equalizing discharge flow, to improve water levels for fish. (Harris)

Finally, the Metro District has argued that the South Platte segment 15’s nutrient rich waters are a resource for agriculture downstream of the plant. It is argued that almost all of the stream’s flow is captured for agriculture downstream of the plant and the nutrient rich water is a benefit to the farms. (Harris)
4.5 References


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http://www.cdphe.state.co.us/wq/Assessment/TMDL/tmdls/COSPUS15.pdf
5 Case study: Santa Ana River, Orange County, California

5.1 Introduction

The Santa Ana River in Orange County, California is the last segment of the Santa Ana River, southern California’s largest stream system, before discharging into the Pacific Ocean. The hydrologic cycle of the entire Santa Ana River Basin has been substantially altered by human activity. Urbanization throughout much of the Santa Ana Basin has resulted in major alteration of stream channels, as well as of the sources from which water reaching those channels is collected from. Treated wastewater effluent is the primary source of base flow in most sections of the Santa Ana River, including in many of its tributaries. Other, secondary, sources of water include runoff from mountain within the basin and urban areas as well as inflow from groundwater. During storms, base flow in the Santa Ana River is increased from urban runoff and to a lesser extent from runoff from undeveloped and agricultural areas. Groundwater has also been severely impacted by human activity by groundwater extraction and artificial groundwater recharge (Belitz et al., 2004).

In general, the quality of surface and groundwater in the Santa Ana Basin becomes progressively poorer as water travels through the basin (SAWPA, 2005). The highest quality water is typically associated with tributaries flowing from surrounding mountains and groundwater recharged by these streams. However this water is mostly collected and used either for water supply or for groundwater recharge. Water quality is altered by a number of factors including consumptive use, importation of water high in dissolved solids, run-off from urban and agricultural areas, and the recycling of water within the basin (http://www.sawpa.org/about/watershed.htm#Surface%20Water).

5.2 Physical setting

The Santa Ana River is the largest stream system in southern California, located to the south and east of Los Angeles. The entire Santa Ana River has a catchment area of approximately 2,700 square miles, and is located in parts of Orange County (18%), San Bernardino County (36%), Riverside County (44%), and Los Angeles County (2%). The source of the Santa Ana River is in the San Bernardino Mountains, which reach altitudes
exceeding 10,000 feet. From the mountainous headwaters, the Santa Ana River flows in a westerly direction more than 100 miles to the Pacific Ocean, and has over 600 miles of major tributaries. To the south of the Santa Ana River basin is the Santa Margarita watershed, to the east is the Salton Sea and Southern Mojave watersheds, and to the northwest is the Mojave and San Gabriel watersheds (http://www.sawpa.org/about/watershed.htm#Location).

The Santa Ana River Basin is commonly separated into three sub-basins. The Inland Basin is located to the north and includes most of the high elevation tributaries for the Santa Ana Basin, as well as large areas of high yielding groundwater alluvium filled areas, primarily in the river and stream valleys. The Inland Basin is also the largest of the three sub-basins in terms of land area. The Inland Basin has the highest percentage of undeveloped land in the Santa Ana River Basin, as well as the lowest population density. The San Jacinto Basin is located in the south-eastern part of the basin and also includes high elevation tributaries. Only during periods of extreme precipitation does the San Jacinto contribute substantial flow to the Santa Ana River. Base flows as well as normal wet weather are typically used entirely for groundwater recharge. The Coastal Basin, where the Santa Ana River discharges into the Pacific Ocean, is located in the southwestern part of the basin and includes most of Orange County. The Coastal Basin is by far the most urbanized portion of the entire Santa Ana River basin. Like the Inland Basin, the Coastal Basin also has large alluvium filled areas which have high hydraulic conductivity.

The entire Santa Ana River basin is highly urbanized, which has resulted in substantial modification of the Santa Ana River and its tributary streams. Approximately 20% of the overall Santa Ana River is concrete lined, and many of the Santa Ana River tributaries are also concrete lined (SAWPA, 2005). The majority of tributary mountain streamflow is diverted for water supply or ground-water recharge before reaching the Santa Ana River. Streamflow in most portions of the Santa Ana River itself consists primarily of discharge from wastewater treatment plants, urban runoff, and groundwater inflow (Belitz et al, 2004, http://www.sawpa.org/about/summary_facts.htm). Under natural conditions, much of the Santa Ana River would be intermittent with little or no flow in the summer months (Hamlin et al, 1999).
Within the Coastal Basin / Orange County, there are four distinct reaches of the Santa Ana River. The first section begins just below Prado Dam and then passes through the Chino Hills. In this region the Santa Ana River is unlined, has many deep channels and pools, with a rock and gravel substrate and multiple rapid sections. The channel follows the natural stream course in this section. Approximately 11 miles downstream below Prado Dam, the Santa Ana River passes under the Imperial Highway (I-90) bridge, where diversion facilities send essentially all dry weather flows into groundwater recharge ponds operated by the Orange County Water District. These groundwater recharging ponds are located within and adjacent to the Santa Ana River channel, and extend for several miles along the Santa Ana River. Downstream of the groundwater recharge, the Santa Ana River is typically dry during most of the year and is used primarily as a means to divert flood waters during times of precipitation. In this section the channel is concrete lined for approximately 11 miles and then enters the final 5 miles, which is unlined but is contained within a highly modified channel (Watershed and Coastal Resources Division of Orange County, 1995). Refer to Figure 45 for a map of the Santa Ana River Basin.

Within the entire Santa Ana River basin, there are five major tributaries. The larger tributaries upstream of Orange County are Chino Creek, Cucamonga Creek, San Timoteo Creek, San Jacinto Creek. Within Orange County, Santiago Creek is the largest tributary to the Santa Ana River. Eleven lakes, reservoirs or large percolating basins are located throughout the Santa Ana River Basin, with the largest being the 11 sq-mi Prado Flood Control Reservoir. Others large water bodies include Lake Elsinore, Hole Lake, Ely Percolation Basins, Carbon Canyon Flood Control Reservoir, Villa Park Flood Control Reservoir, Santiago Reservoir, Big Bear Lake, Seven Oaks Flood Control Reservoir, Lake Hemet, and Railroad Canyon Reservoir.

Prado Dam is located immediately upstream from the Orange County line and separates the upper and lower portions of the Santa Ana River basin. Operation of Prado Dam has a significant affect on not only the quantity of flow but also the quality of water in the Santa Ana River in Orange County. The dam was built in 1940 and continues to be operated by the U.S. Army Corps of Engineers. The original purpose of the dam was to assist with flood control in Orange County. However, in addition to its original purpose, Prado Dam is currently operated to ensure minimum downstream flows during dry
periods, typically between 0 – 600 cfs. These flows are required as a result of a lengthy litigation process between water users upstream and downstream of Prado Dam which resulted in a 1969 court decision which provided a clear declaration of rights of entities in the lower area of the Santa Ana River Basin downstream of the Prado Dam (WMWD, 2005)

The original construction of Prado Dam included a groundwater cutoff wall and consequently almost all groundwater and uncontrolled drainage areas upstream of the dam must pass through the dam gates or over its spillway. For most of the year most of the reservoir is maintained at a low level to assist with operation of constructed wetlands used for denitrification. Under current hydrological conditions, Prado Dam can provide downstream protection for a 70-year flood. Modifications are currently underway by the U.S. Army Corps of Engineers to provide protection against a 190 year flood. Modifications to the Santa Ana River channel downstream of Prado Dam to accommodate higher flows are also being made (SAWPA, 2002; USGS, 2004; USACE, 2003).
5.2.1 Climate

The climate of the entire Santa Ana River basin is “Mediterranean” with hot, dry summers and cool, wet winters. Average annual precipitation ranges from 10-24 inches per year in the Coastal Basin to 24 to 48 inches in the upper, more mountainous reaches of the watershed. Most precipitation occurs between the months of November and March, primarily in the form of rain with snow in the higher elevations. High surface water flows occur during spring and early summer, with periods of flooding during both
winter and spring during years with more than normal precipitation. Low flows are experienced throughout the watershed during the summer months, with severe flooding in smaller tributaries occurring during occasional summer storms (Belitz et al., 2004, SAWPA, 2005).

5.2.2 Land use and towns
The Santa Ana River drains a watershed with highly heterogeneous land use. Mountainous areas within the watershed are generally steep and are not developed. The coastal plain and the flatter mountain valley areas are primarily used for urban and agricultural purposes. Overall land use in the basin is approximately 35 percent urban, 10 percent agricultural, and 55 percent undeveloped (Belitz et al., 2004, SAWPA, 2005). Land use in the Santa Ana River basin is shown in and Figure 46.

![Figure 46. Land Use in the Santa Ana Basin](Source USGS, Belitz et al., 2004)

In 2005, the population within the Santa Ana River watershed was estimated to be 5.5 million, with over 40% of the population living in Orange County (http://www.ocsd.com/about/service_area.asp, access 4 mar). Population has increased over 10% in the past 5 years (http://www.sawpa.org/about/watershed_city_population_estima.htm). By 2025 the population is expected to reach 7 million, and 10 million by 2050 (SAWPA, 2002). Population density for the entire Santa Ana River watershed in 2004 was 1,500 people per square mile, and approximately 5,000 per square mile for
Orange County. However, if land which is too steep for development is excluded from the population density calculation, the density within the Santa Ana River basin increases to about 3,000 per square mile. The most densely populated part of the watershed is within the city of Santa Ana, Orange County, where the population density is as high as 20,000 per square mile (Belitz et al., 2004). The Santa Ana River watershed includes all or portions of 59 cities.

### 5.2.3 Location of gauging stations

The USGS maintains and operates over fifty stream gauging stations throughout the Santa Ana River Basin, including four stations within Orange County (Figure 47). The Santa Ana River station at Santa Ana (station number 11078000) is the only permanent gaging station located directly on the Santa Ana River in Orange County and has been in operation since 1923. Two other gaging stations are located in Orange County which have been operated for several decades, one on Santiago Creek (station number 11077500) and Carbon Creek (station number 11075720). Several miles upstream from the point where the Santa Ana River enters Orange County is the Prado Dam. Immediately downstream of Prado Dam is a stream gauging station which has been in operation since 1940 (station number 11074000). USGS gaging stations in Orange County, plus the Prado Dam station are summarized in Table 7.
<table>
<thead>
<tr>
<th>Station Name</th>
<th>Santa Ana River - Below Prado Dam</th>
<th>Santa Ana River - Santa Ana, CA</th>
<th>Santiago Creek - Santa Ana, CA</th>
<th>Carbon Creek - Below Carbon Canyon Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>USGS Reference</td>
<td>11074000</td>
<td>11078000</td>
<td>11077500</td>
<td>11075720</td>
</tr>
<tr>
<td>Drainage Area (mi²)</td>
<td>1490</td>
<td>1700</td>
<td>98.6</td>
<td>19.5</td>
</tr>
<tr>
<td>Gage Datum</td>
<td>449</td>
<td>61.01</td>
<td>110</td>
<td>n/a</td>
</tr>
<tr>
<td>Peak Streamflow Begin Date</td>
<td>2-Mar-38</td>
<td>31-Jan-23</td>
<td>1929</td>
<td>13-Feb-62</td>
</tr>
<tr>
<td>End Date</td>
<td>15-Jan-05</td>
<td>11-Jan-05</td>
<td>20-Oct-04</td>
<td>26-Feb-04</td>
</tr>
<tr>
<td>Daily Streamflow Begin Date</td>
<td>1-Oct-40</td>
<td>1-Feb-23</td>
<td>1-Oct-28</td>
<td>1-Oct-61</td>
</tr>
<tr>
<td>End Date</td>
<td>30-Sep-04</td>
<td>30-Sep-04</td>
<td>30-Sep-04</td>
<td>30-Sep-04</td>
</tr>
<tr>
<td>Count</td>
<td>23376</td>
<td>29463</td>
<td>27680</td>
<td>15706</td>
</tr>
<tr>
<td>Water Quality Samples Begin Date</td>
<td>11-Oct-66</td>
<td>19-Nov-67</td>
<td>4-Jan-74</td>
<td>n/a</td>
</tr>
<tr>
<td>End Date</td>
<td>17-Sep-04</td>
<td>6-May-03</td>
<td>17-Jul-78</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Table 7. Summary of selected USGS gaging stations. (Source USGS website, www.usgs.gov, compiled by R.Peary)
Figure 47. Schematic diagram of the Santa Ana River basin, with gaging station locations and diversions (Source Agajanian et al, 2004)
5.2.4 Surficial geology

In the northern portion of Orange County, areas immediately adjacent to the Santa Ana River are characterized by deep layers of unconsolidated sands and gravels which can be up to 4,000 feet thick, with occasional lenses of clay and silt. This area is referred to as the “forebay” and covers approximately 50 sq-km and is the location of numerous groundwater recharge facilities. The lenses of clay and silt do not hinder flow of groundwater in any substantial way. The southern part of Orange County has similar deposits as in the northern portion, but are generally thinner (typically 200 to 1,000 feet deep) and substantially finer grained (Hamlin et al, 2002).

The Inland Basin, located upstream of Orange County is filled with alluvial deposits eroded from the surrounding mountains which range in thickness from less than 200 to more than 1,000 ft. Within the Inland Basin are several active faults, including the San Andreas Fault, which lies along the base of the San Bernardino Mountains, and other faults, which lie along the base of the San Gabriel Mountains and Chino Hills. These faults locally restrict ground-water flow and control the location of ground-water discharge. The Irvine Basin, also located upstream of Orange County, has similar deposits as in the Coastal basin but are relatively thin (Hamlin et al, 2002).

5.3 Data & analysis

5.3.1 Previous studies

Reflecting the overall importance of the Santa Ana River and the Santa Ana River Basin, as well as the complexity of the water issues involved, there are numerous state, federal, county and city agencies, stakeholder associations, regulatory offices, and other involved parties with the study and management of water resources within the Santa Ana River watershed, including many specific to Orange County.

The U.S Geological Survey (USGS) has collected and analyzed water resource data from within the Santa Ana River watershed for almost a century. In 1997 the entire Santa Ana River Basin became part of the USGS’s NAWQA project. Study planning and analysis of existing data was done from 1997 to 1999. Between 1998-2001 surface water, ground water, and biological data were intensively collected intensively. In 2002 a
six year reduced intensity phase commenced, during which water quality has been, and will be until 2007, monitored at only a few selected sites and areas that were sampled during the 1998-2001 high-intensity phase. Data collection for the NAWQA project was separated into three components

- Stream chemistry
- Stream ecology, streambed sediment and fish tissue
- Groundwater quality

Table 8 summarizes data collection in the Santa Ana River Basin from 1998 to 2001
### Watershed Management

**Effluent dominated streams in the US**

<table>
<thead>
<tr>
<th>Study component</th>
<th>What data were collected and why</th>
<th>Types and number of sites sampled</th>
<th>Sampling frequency and period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Streams and rivers</strong></td>
<td>Streamflow, dissolved oxygen, pH, alkalinity, specific conductance, temperature, nutrients, major ions, organic carbon, and suspended sediment; to determine concentration and variability of a constituent over seasons or time.</td>
<td>4 sites—Santa Ana River (SAR) at Mentone (reference); Cucamonga Creek (urban, treated wastewater); SAR at MWD Crossing and SAR below Prado Dam (mixed urban, predominantly treated wastewater).</td>
<td>Monthly plus 6 storms, October 1998–September 2001.</td>
</tr>
<tr>
<td><strong>Organic compounds in streams and rivers</strong></td>
<td>Same as streams and rivers plus pesticides and volatile organic compounds (VOCs); to determine the occurrence, concentration over time, and seasonality of organic compounds. VOCs collected in air.</td>
<td>2 sites—Warm Creek (urban, ground water); and SAR below Imperial Highway (mixed urban, predominantly treated wastewater) discontinued, April 2001. (Prado added July 2000, Mentone added February 2001)</td>
<td>Semimonthly to monthly plus 6 storms, October 1998–September 2001.</td>
</tr>
<tr>
<td><strong>Mountain streams</strong></td>
<td>Same as streams and rivers; to determine if SAR at Mentone is representative of mountain runoff.</td>
<td>5 sites located at the base of the mountains and 1 alpine site.</td>
<td>Quarterly, January 2000–July 2001</td>
</tr>
<tr>
<td><strong>Drinking-water reservoirs</strong></td>
<td>Pesticides; to assess pesticide occurrence from drinking-water reservoirs before and after treatment as part of a nationwide study.</td>
<td>2 sites—at a drinking-water treatment plant located near Canyon Reservoir, one site before treatment and one site after.</td>
<td>16 samples, July–December 1999</td>
</tr>
<tr>
<td><strong>Tracer study</strong></td>
<td>Same as stream and rivers plus bromide, isopropyl, and rhodamine dye; to assess how much of the base flow is from treated wastewater and how much is from other sources.</td>
<td>9 sites on the Santa Ana River from the Rapid Infiltration/Extraction treatment facility to the wetlands behind Prado Dam, and 7 sites on other water sources to the river.</td>
<td>Hydrograph sampling in May 2001</td>
</tr>
</tbody>
</table>

#### Stream ecology, streamed sediment and fish tissue, and reservoir sediment

<table>
<thead>
<tr>
<th>Study component</th>
<th>What data were collected and why</th>
<th>Types and number of sites sampled</th>
<th>Sampling frequency and period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecology in streams and rivers</strong></td>
<td>Invertebrate, algae, and fish communities and stream habitat conditions; to assess the temporal variability in contrasting stream environments.</td>
<td>4 sites—2 collocated with the 2 mixed urban river sites, 1 site located upstream from dam construction and 1 site located in the mountains.</td>
<td>Annually, single reach, 1999–2006; 3 reaches, 2001</td>
</tr>
<tr>
<td><strong>Urban land-use study</strong></td>
<td>Same as ecology and streams and rivers, but used artificial substrates for algal and invertebrate communities; to assess water source and channel type as factors affecting biological communities.</td>
<td>19 sites—3 reference, 16 urban, representing 4 sources of water and 3 channel types. Sites were collocated with stream and river sites or bed-sediment sites when possible.</td>
<td>July—September 2001</td>
</tr>
<tr>
<td><strong>Cucamonga Creek study</strong></td>
<td>Streamflow, nutrients, organic carbon, pH, temperature, dissolved oxygen, specific conductance, alkalinity, carbon dioxide, bicarbonate and carbonate; to assess nitrate uptake by algae.</td>
<td>2 sites in the concrete-lined Cucamonga Creek located below treated-wastewater outfall.</td>
<td>25 samples in a diel study, August 2001</td>
</tr>
<tr>
<td><strong>Streambed sediment and fish tissue</strong></td>
<td>Organochlorine compounds, semivolatile-organic compounds and trace elements in sediment and fish tissue to determine occurrence and distribution and to compare urban and undeveloped land use.</td>
<td>12 sediment and 10 fish tissue sites—8 urban sites located on the basin floor and 4 undeveloped sites.</td>
<td>Once, September 1998</td>
</tr>
<tr>
<td><strong>Reservoir-sediment coring sites</strong></td>
<td>Same as for streambed sediment but at multiple depths in sediment cores to evaluate changes in concentration in relation to time and historical land- and chemical-use patterns.</td>
<td>3 reservoirs representing 3 types of land use; undeveloped, actively urbanizing, and a well-established urban area.</td>
<td>Once, November 1998</td>
</tr>
<tr>
<td><strong>National mercury study</strong></td>
<td>Mercury, methylmercury, and acid-volatile sulfides in bed sediment and fish fillets; to evaluate factors for mercury occurrence and methylation potential.</td>
<td>4 urban and 1 undeveloped sites as part of a larger national mercury study.</td>
<td>Once, September 1998</td>
</tr>
</tbody>
</table>

#### Ground-water quality

<table>
<thead>
<tr>
<th>Study component</th>
<th>What data were collected and why</th>
<th>Types and number of sites sampled</th>
<th>Sampling frequency and period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major aquifer survey</strong></td>
<td>Major ions, nutrients, pesticides, volatile organic compounds, trace elements, stable isotopes, tritium, and radon analyzed to assess occurrence in the Coastal, Inland, and San Jacinto Basins.</td>
<td>Spatially distributed randomized deep public supply, irrigation, and domestic wells in the Coastal (20 wells), Inland (29 wells), and San Jacinto (23 wells) ground-water basins.</td>
<td>Coastal—spring 1999 Inland—Summer 2000 San Jacinto—winter 2001</td>
</tr>
<tr>
<td><strong>Urban land-use study</strong></td>
<td>Same constituents as above, to assess shallow ground-water quality in the Coastal Basin.</td>
<td>Monitoring wells installed at 30 randomly chosen sites in commercial and residential areas.</td>
<td>Summer 2000</td>
</tr>
<tr>
<td><strong>Flow-path study</strong></td>
<td>Same constituents as for the major aquifer survey, to assess replacement of ground water by engineered recharge.</td>
<td>23 deep production wells. 20 deep monitoring wells and 1 production well.</td>
<td>Summer 2000</td>
</tr>
</tbody>
</table>

Table 8. Data collection in the Santa Ana River Basin for NAWQA, 1998-2001 (Belitz et al, 2005)
There are five regional water districts, each with an individual public agency, located within the Santa Ana River basin:

- OCWD – Orange County Water District
- IEUA – Inland Empire Utilities Agency (previously named the Chino Basin Municipal Water District)
- SBVMWD – San Bernardino Valley Municipal Water District
- WMWD – Western Municipal Water District
- EMWD - Eastern Municipal Water District

The specific mission for each of the five water district agencies varies slightly in the exact operations they undertake. However, in general, each water district agency is responsible for managing most aspects of water resources in the communities they serve. Responsibilities include importing water from outside the district, water treatment, distribution of water (including potable, fire and irrigation), water treatment, storm water management, and management of groundwater resources (including extraction and recharge). Each of the regional water district agencies prepares and implements water management plans for each specific district.

Multiple state and federal regulatory agencies are also involved in management of water resources with the Santa Ana River basin. The main agencies are:

- U.S. Environmental Protection Agency (EPA)
- State of California State Water Resources Control Board
- State of California Region 8 Regional Water Quality Control Board
- California Department of Water Resources

In addition to the organizations and agencies involved in the study and management of water resources within the Santa Ana River basin listed above, there are dozens of other organizations that operate on local, state, and national levels involved with the study and management of water resources. Among these are:

- Individual city governments
- Several dozen non-government organizations (NGOs) and stakeholder interest groups
- The United States Army Corps of Engineers
- The U.S. Bureau of Reclamation
- Approximately 100 local water providers and wastewater agencies
5.3.2 Hydrological data

The hydrology of the Santa Ana River within Orange County is closely intertwined with the entire basin, as upstream use has a significant and direct impact on the quantity and quality of water in the Orange County portion of the Santa Ana River. Prior to entering Orange County the Santa Ana River passes through the Chino Hills and discharges into the Pacific Ocean approximately 30 miles later. Within Orange County the Santa Ana River has two main tributaries, Carbon Creek (approximately 11 miles upstream from the Pacific) and Santiago Creek (approximately 16 miles upstream from the Pacific Ocean). A hydrograph for the Santa Ana River below Prado Dam (immediately upstream from the Orange County border) is presented in Figure 48. Hydrographs for the Santa Ana River below the junction with Carbon and Santiago Creeks in Orange County for the period of September 1998 to September 2004 are presented in Figure 49, Figure 50, and Figure 51.
Figure 48. Daily mean streamflow in ft³/s at USGS Station 11074000. Source: USGS

Figure 49. Daily mean streamflow in ft³/s at USGS station 11078000. Source: USGS

Figure 50. Daily mean streamflow in ft³/s at USGS station 11075720. Source: USGS

Figure 51. Daily mean streamflow in ft³/s at USGS station 11077500. Source: USGS
Annual mean flows in the Santa Ana River throughout much of the entire basin have been steadily increasing since the 1940s. During the 1940’s the mean annual flow below Prado Dam (just upstream of Orange County) was approximately 130 cfs. For the decade 1994 to 2003 the mean annual flow was 350 cfs, an increase of 270%. Similarly, mean annual flow in the Santa River near Santa Ana went from approximately 20 cfs in the 1940s to over 110 cfs in the period of 1994 to 2003, an increase of 550%. Mean annual discharge in Canyon creek increased from 0.65 cfs during the 1950s to 1.75 cfs in the period of 1994 to 2003, an increase of 270%. Annual discharge in Santiago Creek has remained relatively consistent since the 1940s (http://nwis.waterdata.usgs.gov/nwis/nwisman).

Annual peak flows have been increasing throughout the entire basin since the 1940s. During the 1940’s average annual peak flow recorded below Prado dam was 1,200 cfs while during the 1950’s and 1960’s annual peak flow was recorded to be less than 700 cfs. This contrasts with peak flow an average recorded annual peak flow of 2,900 cfs during the 1980s and over 5,000 cfs during the 1990s. A similar trend has been observed at the USGS station on the Santa Ana River in Santa Ana, Orange County. Average annual peak flows between 2,000 and 1,500 cfs were recorded during the 1940s and 1950s, respectively, while during the 1980s and 1990s average annual peak flows increased to over 10,000 cfs.

The increase in mean annual flows and annual peak flows reflect increasing anthropogenic activities within the overall basin, and also highlights the hydrological impact that imported water has on the basin.

Artificial groundwater recharge, groundwater extraction and discharge of treated effluent plays a major role in the hydrological cycle of the Santa Ana River throughout most of the year. Many of the Santa Ana River tributaries are diverted to groundwater recharge facilities, with water being subsequently pumped from the ground and used as the primary source of water in the basin. These activities substantially reduce flow throughout the Santa Ana River. However, after groundwater is extracted and used, it is treated at one of the 35 treatment facilities located throughout the basin, and then discharged. Most treatment plants located in the Inland and San Jacinto Basins discharge effluent directly into the Santa Ana River and its tributaries while wastewater treatment
plants within Orange County discharge directly into the Pacific Ocean or use the effluent to recharge groundwater supplies. Effluent that is not suitable for discharge into the Santa Ana River, typically due to high concentrations of sodium chloride, are collected by the “Santa Ana Regional Interceptor” and discharged directly to the Pacific Ocean. The location of major treatment plants located in the Santa Ana River basin, as well as primary recharge facilities are shown in Figure 52.

![Figure 52. Wastewater treatment and groundwater recharge facilities. Source: Belitz et al, 2004](image)

During dry periods of the year most of the flow within the Santa Ana River entering Orange County is diverted to spreading ponds adjacent to the river channel, or impounded within the Santa Ana River Channel through small weirs, near the city of Anaheim (Figure 53). River water enters the ponds and subsequently infiltrates into the ground, thereby significantly increasing quantities of groundwater while reducing the flow of the Santa Ana River. As seen in Figure 49, flow in the Santa Ana River downstream of the Anaheim recharge facilities is close to non-existent during much of the year.
A substantial percentage of the Santa Ana River flowing into Orange County is treated effluent discharged from wastewater treatment plants in the Inland Basin, upstream of Orange County. During dry periods of the year, discharge of the Santa Ana River below the Prado Dam is approximately the same as the total effluent discharge from wastewater-treatment facilities upstream (Hamlin, et al., 1999). A Lagrangian discharge study, using rhodamine dye as a tracer was conducted on a portion of the Santa Ana River immediately above the Prado Dam to determine what portion of the base flow is from treated wastewater, as compared with other sources. The study demonstrated that Santa Ana River flow entering the Prado reservoir is 77% wastewater (Mendez, 2002). In addition to the Santa Ana River, both Chino Creek and Cucamonga Creek also flow into the Prado Reservoir. Consequently, the Mendez study may not accurately represent the proportion of effluent contained in discharge from Prado Dam, and then entering Orange County. However, both of these tributaries have multiple wastewater treatment plants discharging effluent into them, similar to the where the study was conducted on the Santa Ana River. All flow discharge from Prado Reservoir subsequently enters Orange County. Published data regarding specific flows discharged from each of the wastewater treatment plants above Prado Reservoir is not available.

Water demand in the entire Santa Ana River basin for the year 2000 was approximately 1.4 million acre-feet and is expected to increase to 1.7 million acre-feet by
the year 2010, and to 2.2 million acre-feet by 2050 (SAWPA, 2002). Current and projected sources of water are presented in Table 9. Imported sources noted in the table are primarily from northern California and Colorado. Groundwater is extracted throughout the Santa Ana River basin by use of an estimated 10,000 municipal and domestic groundwater wells, with most wells located in the Inland and Coastal Basins.

<table>
<thead>
<tr>
<th>Source</th>
<th>Percent &amp; Equivalent daily flow</th>
<th>Year 2000</th>
<th>Year 2010</th>
<th>Year 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td></td>
<td>68%</td>
<td>62%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>875 MGD</td>
<td>924 MGD</td>
<td>1,220 MGD</td>
</tr>
<tr>
<td>Imported</td>
<td></td>
<td>23%</td>
<td>24%</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>296 MGD</td>
<td>358 MGD</td>
<td>507 MGD</td>
</tr>
<tr>
<td>Surface sources</td>
<td></td>
<td>5%</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 MGD</td>
<td>89 MGD</td>
<td>86 MGD</td>
</tr>
<tr>
<td>Others, including recycled sources</td>
<td></td>
<td>4%</td>
<td>8%</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52 MGD</td>
<td>119 MGD</td>
<td>212 MGD</td>
</tr>
</tbody>
</table>

Table 9. Sources of water for the Santa Ana River Basin (Source: SAWPA, 2002)

Water use within the Santa Ana River basin is approximately 75% for urban use and 25% for agricultural irrigation (Belitz et al., 2004). Urban water use includes landscape irrigation and for indoor purposes. Wastewater collected by sanitary sewers is routed to wastewater-treatment facilities and then discharged, primarily to surface-water bodies. In the San Jacinto Basin wastewater is diverted to constructed ponds for groundwater recharge. In the Inland Basin treated effluent is discharged to the Santa Ana River and its tributaries, as well as ponds used for groundwater recharge. In the Coastal Basin treated effluent is either discharged to the Pacific Ocean or is injected into aquifers along the coast to assist in preventing saltwater intrusion (http://www.sawpa.org/about/summary_facts.htm).

### 5.3.3 Water Quality Issues, Point and Non-Point Sources of Pollution

In 2005 there were twenty-three water bodies within the Santa Ana River Basin categorized as being impaired, primarily due to unacceptable concentrations of metals, nutrients or suspended solids. None of these included portions of the Santa Ana River within Orange County. In general, the water quality issues in the upper Santa Ana River
basin mainly relate to high levels of bacterial indicators. In the mid portion of the Santa Ana River basin, water quality is affected by urban and agricultural runoff (which consequently increases bacterial indicators), and is also characterized by elevated levels of nutrients, suspended solids, and high salinity. The coastal portion of the Santa Ana River basin is affected by pollutants that include metals from urban runoff, pathogens from urban runoff and storm sewers, nutrients from agriculture and urban runoff, pesticides from agriculture, contaminated sediments and other unknown non-point sources (SAWPA, 2005).

As part of the NAWQA project, the USGS conducted several detailed water quality studies throughout the Santa Ana Basin, including at points on the Santa Ana River in Orange County. These studies were designed to assess the effects of urbanization. Sampling sites were established on streams with a variety of channel characteristics as well which receive a variety of water sources. Sources included mountain runoff, urban runoff, ground water, and treated wastewater (Belitz et al, 2004).

**Non-Point Sources of Pollution**

Major non-point sources of pollution associated with water quality deterioration in the Santa Ana River Basin include atmospheric deposition of contaminants to the soil and water bodies, land application of animal waste, agricultural and residential use of fertilizers, agricultural runoff (including irrigation return flow), as well as urban storm water runoff.

**Point Sources of Pollution**

Multiple point sources of pollution exist in the Santa Ana River Basin, including conventional wastewater treatment plant effluent discharges, industrial discharges, leaky underground storage tanks, runoff from concentrated animal operations, storm sewer outfalls, and construction sites. In 2004 there were 115 National Pollutant Discharge Elimination System (NPDES) permits issued by the EPA. Upstream of Prado Dam is the 50 sq-mi Chino Basin Dairy Preserve, an intensive dairy farming area. The Chino basin has approximately 300,000 cows concentrated contain one of the highest concentrations of dairy animals found anywhere in the world and has been estimated to generate waste
equivalent to an unsewered city of 3 million people. (http://www.wrpinfo.scc.ca.gov/watersheds/sa/sa_profile.html).

5.3.4 Water quality data

Total Dissolved Solids

In generally, median total dissolved solid (TDS) concentrations in effluent dominated base-flow from Santa Ana River sampling sites between 1998 to 2001 in Orange County ranged from 600 just below Prado Dam to 620 mg/L at the Imperial Highway crossing. These results are three times higher than median TDS concentrations observed in base-flow samples from mountain sites, and up to two times higher than at sites receiving only urban runoff. TDS concentrations in the main stem of the Santa Ana River were observed to increase, regardless of source inputs. TDS concentrations were observed to be significantly lower throughout the basin during storm flow events, including at the two sampling sites within Orange County (Kent et al., 2004)

Nitrogen

Water quality studies conducted between 1998-2001 highlighted the importance of water source on quantities of total nitrogen, as well as the speciation (total organic plus ammonia, nitrate, nitrite). Samples were collected throughout the Santa Ana River Basin, including at sites below the Prado Dam and at the Imperial Highway crossing, as well as in mountainous tributaries located in the mountains. Results from the studies indicate that at the Prado Dam and Imperial Highway sites, nitrogen concentrations and proportions of nitrogen species were similar under base-flow and storm flow conditions. This is likely due to flow regulation at Prado Dam which collects and stores flows, including treated effluent and storm flows. Mean values observed for total nitrogen at the Prado site were 6.4 mg/L during base flow conditions (e.g. primarily treated effluent) and 7.6 mg/L during storm flows. At the Imperial Highway crossing site, mean values for total nitrogen were 6.2 mg/L for base flow conditions and 6.0 mg/L for storm flows. More than 75% of the nitrogen in samples from both the Prado and Imperial Highway sites, both of which receive effluent dominated base flows, was in the form of nitrate. Nitrogen in samples collected from sites that did not receive treated effluent was
predominantly in the form of total organic nitrogen plus ammonia. The National Atmospheric Deposition Program estimated nitrate concentrations in Santa Ana Basin precipitation to be between 0.7 and 1.3 mg/L during the period of study. Therefore, it is expected that precipitation itself may contribute to increasing nitrate levels during storm flows.

**Phosphorus**

Total phosphorus was sampled between 1998-2001 throughout the Santa Ana River Basin, including at the Prado Dam and Imperial Highway crossing. Results indicate that base-flow total phosphorus concentrations in samples from sites receiving mountain runoff rarely exceeded 0.03 mg/L while total phosphorus concentrations in samples receiving effluent water, including the Prado and Imperial Highway crossing sites, typically had total phosphorus concentrations near 1 mg/L. Total phosphorus concentrations in storm flow varied between sampling locations, but were typically higher than concentrations in base flow. Throughout the entire Santa Ana River Basin the median concentration of total phosphorus in flows consisting of at least 75% storm flow was 1.0 mg/L.

Most phosphorus in base-flow samples was in the form of dissolved orthophosphate, which is the most biologically available form of phosphorus to aquatic organisms. Similar to total phosphorus, sites not receiving wastewater usually had orthophosphate concentrations less than 0.05 mg/L. For samples collected at mountain sites, dissolved orthophosphate was usually less than or equal to the laboratory reporting limit (0.01–0.02 mg/L). Fixed sites that received wastewater, such as the Prado and Imperial Highway crossing, usually had concentrations above 0.05 mg/L, and the collective median for these sites was 0.76 mg/L (Kent et al, 2004).

**Pesticides**

Between November 1998 and September 2001, 148 samples from 23 sites throughout the Santa Ana River Basin were collected and analyzed for 138 separate pesticide compounds. It is important to note that common compounds found in many of the host highly used pesticides in California were not included in the target analyte list for study.
Sixty-six different pesticides (including herbicides, insecticides, fungicides, as well as their degradates) and compounds were detected, with at least one pesticide being detected in 92% of all samples.

All pesticide concentrations were below maximum levels permitted in drinking water. However, both diazinon and diuron were detected at concentrations above nonenforceable drinking water health advisory levels in at least one stream sample. Additionally, carbaryl, chlorpyrifos, diazinon, lindane, and malathion exceeded guidelines to protect aquatic life. Twenty-two pesticide compounds were detected in at least 25 percent of the samples collected from any one fixed site and were identified as “major” pesticide compounds.

While most pesticides are likely to enter streams with urban runoff, water sources other than urban runoff may also contribute to the presence of pesticide compounds in the Santa Ana. In portions of the Santa Ana where groundwater contributes to the flow, atrazine may enter the river (or its tributaries) as a result of historical use in the basin. Lindane, commonly used to control parasites on humans and pets, were detected in over 50% of all samples collected at the Prado Dam site, and 25% of samples from Imperial Highway. Lindane was not observed at either of these sites during storm events. These observations indicate the high degree of effluent in the flows at these two sites.

At the Prado sampling site, 6 parent herbicide compounds were detected, with at least 3 separate compounds being detected in over 50% of all samples, while eight herbicide degradates were detected. Ten insecticide compounds and 8 insecticide degradates were also detected.

At the Imperial Highway site, 27 parent herbicide compounds were detected, with at least 7 separate compounds being detected in over 50% of all samples, while only one herbicide degradates was detected. Seven insecticide compounds, 1 insecticide degradates, and three fungicide compounds were also detected. (Burton et al, 2005).

Seven sets of pair samples were collected at the Prado Dam and Imperial Highway sites to observe water quality changes between the two sites. Results indicate that most detected compounds did not change much between two sites during the 11 mile reach between them. However, lindane concentrations, associated with wastewater effluent, did decrease between Prado Dam and Imperial Highway, which is to be expected since
there are no effluent discharges to the Santa Ana River between these two sites. Only one pesticide, tebuthiuron (a common non-selective herbicide used for weed control on rights of way, industrial sites and rangelands), was consistently detected at the Imperial Highway site but not at the Prado Dam site, indicating a source between the two sampling sites. (Kent, 2005)

**Others**

Caffeine was also detected in over 50% of the samples from Imperial Highway. While caffeine is not a pollutant, it is typically an indicator of wastewater, and its presence in the Imperial Highway samples is not surprising since most of the base flow in the Santa Ana River at this point is treated effluent. However, caffeine was not detected at the Prado Dam site, only 11 miles upstream. Additionally, caffeine concentrations were observed to increase during storm events, which is counter to the expectation that effluent, the probable point source of caffeine, would be diluted during storm events. Consequently, urban runoff may be a significant source of caffeine in the Santa Ana Basin, with the source being individual consumers and coffee vending cart operators dumping waste coffee directly into storm drains.

**Organochlorine compounds, SVOCs, Trace elements**

In 1998 the USGS collected streambed sediment and fish tissue samples at 12 locations as part of the three-year intensive-study phase portion of the NAWQA study, specifically to assess the status of hydrophobic contaminants in the Santa Ana River Basin. Three specific groups of compounds were analyzed; organochlorines, semi-volatile organic compounds (SVOCs), and 42 trace elements. Eight of the locations were located in the Inland Santa Ana Basin (upstream from Orange County), two in the Coastal Basin, and two in the San Jacinto Basin. One site located in the Coastal Basin was below Prado Dam, immediately upstream of Orange County. The second site in the Coastal Basin was located at the Imperial Highway (I-90) Bridge, ten miles below the Prado Dam sampling station and immediately above diversion facilities for groundwater recharge ponds. Results were published in a 2002 USGS report, “Effects of Urbanization and Long-Term Rainfall on the Occurrence of Organic Compounds and Trace Elements
in Reservoir Sediment Cores, Streambed Sediment, and Fish Tissue from the Santa Ana River Basin, California, 1998”. Key findings of this report include:

- Detection frequency and concentrations of the three groups of compounds were generally higher at urban sites than at non-urban sites. This distribution reflects the anthropogenic nature of the compounds. Most of the organochlorine compounds detected in the study had been banned for several years prior to sampling, indicating that the compounds have a strong persistence in the environment.

- At the Imperial Highway crossing sampling site, nine organochlorine compounds were detected in sediment samples (the highest number of any sampling site) and 2 in fish samples. At the sampling site immediately below Prado Dam, 4 organochlorine compounds were detected in sediment samples and 8 in fish samples (the highest number of any sampling site). Concentrations of organochlorine compounds were overall higher in the Santa Ana River than in its tributaries, indicating either direct discharging of these compounds into the Santa Ana or accumulation. The number of organochlorine compounds detected in fish and sediment samples at the tributary sites ranged from 0-3 and 0-2 for non-urban sites.

- At the Imperial Highway crossing site, 4 SVOCs were detected, while three were detected at the Prado Dam site. The number of SVOCs detected in tributaries ranged from 1-19 and at non-urban sites 1-2. In addition to a higher number of compounds detected, the concentrations were also higher at urban sites than at non-urban sites, and in tributaries than in the Santa Ana River itself. These results suggest that SVOCs are less persistent than organochlorine compounds, possibly due to volatization or degradation.

- Analysis of 42 trace elements indicated that, in general, urbanization has a slight effect on detection frequency and concentration, with some elements (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) having significantly higher concentrations in urban areas. Four of the trace elements (As, Cu, Hg, and Se) were found in fish tissue from non-urban sites at significantly higher concentrations than urban sites. Frequency and concentrations of trace
elements detected did not vary between the Santa Ana River and its tributaries.

5.3.5 **Biota Data**

The 11 mile reach of river between the Prado Dam and the groundwater recharge facilities below the Imperial Highway crossing near Anaheim has substantial flow throughout the year. Below the groundwater recharge facilities flow is generally non-existent, or less than 1 cfs, except during periods of heavy precipitation when high flows are quickly discharged to the Pacific Ocean. Consequently, biota studies have largely focused on the upper portions of the watershed above Prado Dam, as well as the first portion of the Santa Ana River in Orange County, between Prado Dam and the recharge facilities.

In 2000 a study was conducted to assess the relationship between water source and channel type on aquatic organisms, including benthic macro-invertebrates and periphyton. Periphyton are microscopic underwater plants, which includes algae and heterotrophic microbes, that are firmly attached to submerged rocks, logs, pilings or other structures, and serve as an important food source for invertebrates and some fish (www.epa.gov).

The study area included 18 sampling locations on the Santa Ana River and its tributaries above the Prado Dam. One sampling location was located immediately below Prado Dam. Channel types included in the study included natural, channelized with natural bottom, and concrete lined. Water sources identified in the study included natural, urban-impacted groundwater, urban runoff, and treated wastewater. Variables measured for all sampling sites included discharge, river bed gradient, channel width, canopy coverage, depth of water, riverbed substrate, specific conductance, water temperature, pesticides present, nitrite plus nitrate, orthophosphate, and silica. The sampling location below Prado Dam was identified in the study as being a natural channel with flow being primarily treated wastewater. Measured variables for the Prado Dam sampling location were: discharge - 190m3/s, river bed gradient - 0.013 m/km, channel width - 17.0m, canopy coverage - 61 degrees, depth of water - 0.64m, riverbed substrate - coarse gravel, specific conductance - 965us/cm, water temperature 23.5 degrees C, number of pesticides...
present - 7, nitrite plus nitrate -5.65 mg N / L , orthophosphate - 0.964 mg P /L , and silica - 21.53 mg/L.

The overall study demonstrated that considerable variation exists in macro-invertebrates and fish populations in highly urbanized streams within the Santa Ana River Basin. Results also indicate that the reliability and the quantity of flow are highly important environmental variables in the Santa Ana River system. Treated effluent is a reliable source of water in many portions of the Santa Ana River, and appears to support valuable aquatic resources, including threatened fish species (Brown et al., 2005).

Additional findings for the Prado Dam sampling location which relate to the Santa Ana River in Orange Country include:

- 32 distinct periphyton taxa were found at the Prado Dam sampling site, 30 of which were diatoms. The results from the Prado Dam sampling location were similar to other sampling sites located in urbanized portions of the Santa Ana River basin, regardless of channel type or water source. However, periphyton were found to response to changes environmental variables when including least impacted sampling sites as well as urbanized sites.
- 8 macro-invertebrate taxa were found, with a density of 39,187 organisms per square meter.
- 17 separate fish species were found throughout the Santa Ana River basin, 66% of which were non-native. For the sampling site below Prado Dam, almost all fish species were non-native. Results from sampling sites which had natural channel structures as well as natural water sources (small tributaries high in the basin) indicate a much lower presence of alien species. Sampling sites with concrete channels and which received treated effluent and or were substantially impacted by urban runoff had a higher portion of non-native fish species.
- Both benthic macro-invertebrate and fish assemblages were found to be strongly dependent on environmental variables, even when the least impacted sites were excluded from analysis, with urban sites supporting more tolerant taxa.
For the Prado Dam sampling site, as well as others receiving treated effluent, nutrient concentrations did not appear to favor the growth of particular periphyton colonies, since nitrite, nitrate, and orthophosphate was present at these sites. Availability of sunlight was similar for most sites as well. Consequently, the specific periphyton taxa colonizing at the sampling sites appeared to be random, rather than in response to environmental factors. However, separate analysis of the data collected has indicated that the observed periphyton did respond to channel type and water source, within the subset of urban sites. This may indicating that urbanized streams may create conditions suitable for certain taxa, but that the presence of specific taxa with these environmental preferences is determined by random colonization (Burton et al, 2005).

Periphyton and macro-invertebrates were favorably affected by discharge from wastewater plants in that these sites had more constant and higher flows than those sites without treated effluent.

Little information is available on other forms of biota, such as birds, amphibians, reptiles, insects or plants.

5.4 Conclusions

The Santa Ana River in Orange County, California is a heavily effluent dominated river, with effluent contributing approximately 75% of total flow during dry periods. Without the discharge of treated effluent to the Santa Ana River upstream of Orange County, periods of extreme low or no flow would most likely occur during summer months, with negative effects on fish and other forms of wildlife. Water quality in the river is generally quite good, although concentrations of nitrogen, mainly in the form of nitrate, are typically quite high. Most water in the Santa Ana River is used for groundwater recharge, consequently leaving the lower length of the river dry during summer months.

Improvements in wastewater treatment plant effluent processes upstream of Orange County could help to reduce nitrogen and other nutrient concentrations. However, other
sources of nutrients and pollutants upstream of Orange County would also need to be addressed for water quality improvements to be significant.

5.5 References


Santa Ana Watershed Project Authority, 2002a *Santa Ana Integrated Watershed Plan; Volume 1 Water Resources Component* (June 2002)


**Websites consulted:**


Santa Ana Regional Water Quality Board ([http://www.swrcb.ca.gov/%7Erwqcb8/](http://www.swrcb.ca.gov/%7Erwqcb8/))


Orange County Water District ([www.ocwd.com](http://www.ocwd.com))

Inland Empire Utilities Agency ([http://www.ieua.org](http://www.ieua.org))


Western Municipal Water District ([http://www.wmwd.com](http://www.wmwd.com))

Eastern Municipal Water District ([http://www.emwd.org](http://www.emwd.org))

Southern California Wetlands Recovery Project Information Station ([http://www.wrpinfo.scc.ca.gov/watersheds/sa/sa_profile.html](http://www.wrpinfo.scc.ca.gov/watersheds/sa/sa_profile.html))
Watershed & Coastal Resources Division of Orange County
(http://www.ocwatersheds.com/)
5.6 Additional Resources


Santa Ana Watershed Project Authority, 2002c, Santa Ana Watershed Project Authority Upper Santa Ana Regional Interceptor (SARI) Planning Study December 2002

Santa Ana Regional Water Quality Board (2002), The Watershed Management Initiative Chapter, 2002

Santa Ana Regional Water Quality Board (2004), The Watershed Management Initiative, Revised November 2004

Watershed and Coastal Resources Division of Orange County. Orange County Hydrological Report

Watershed and Coastal Resources Division of Orange County Water Quality Control Plan for Santa Ana Basin, Amendments

Watershed and Coastal Resources Division of Orange County Santa Ana Regional Water Quality Control Board Municipal NPDES Permit Order No. R8-2002-0010

6 Case study: Trinity River, Texas

6.1 Introduction

Non-native American settlement in the 18,000 square mile Trinity River Basin began in the early 1800s, with use of the Trinity River increasing as the population gradually enlarged. By the mid-1880’s many steam boats were operating in the lower reaches of the Trinity River, facilitating trade between communities along the Trinity River, as well as with other parts of North America. Movement on the Trinity River was often impeded the presence of numerous sandbars, snags or shallow water depths due to insufficient flow during dry months. Nevertheless, by 1870 steam boats were successfully navigating from the Gulf of Mexico to Trinidad, less than 40 miles downstream from preset-day Dallas. Numerous plans were considered to improve the navigability of the river, but none of any significance were implemented. During the 1870’s river traffic began to decline as cargo transport on newly constructed railroad lines became the preferred transportation route (http://www.texasoutside.com/easttexas/TrinityRiverNWR.htm).

During the past century the Trinity River Basin pollution has steadily increased as use of the river to dispose of waste increased. Sources of pollution include agricultural runoff, often containing high concentrations of pesticides and dissolved solids, as well as runoff from industrial activities, including petroleum production, and human waste. The Dallas-Fort Worth metropolitan area has the highest concentration of population in the river basin and has historically been the source of most industrial and waste pollution. As a result, the most severely affected portion of the Trinity River Basin is the 250-mile long stretch of water between the Dallas-Fort Worth area to Livingston Lake (Land, 1998). In the early 1960s the Trinity River downstream of Dallas was so polluted that it was described as “septic” by the United States Public Health Service, which was only a slight improvement over the Texas Department of Health characterization of this river segment as the “mythological river of death” in the mid 1920s (Land et al, 1998). With the passage of the Clean Waters Act in 1972 efforts began to gradually improve the health of the Trinity River. (http://www.texasoutside.com/easttexas/TrinityRiverNWR.htm)

Many smaller tributaries to the Trinity River have periods of no flow during summertime months and may be completely dry, while throughout the Trinity Basin there
are wastewater treatment plants that discharge effluent throughout the year. Consequently, during dry periods effluent can provide a substantial portion of the flow downstream of discharging treatment plants, and in some cases all of the flow. These effluent dominated waterways can be small or large tributary streams, or portions of the Trinity River itself (TRA, 2003). Immediately below Dallas, over 90% of base flow in the Trinity River during dry weather conditions originates from wastewater treatment plants in the Dallas-Fort Worth area (TRA, 2003). Such effluent dominated conditions persist not only immediately downstream of Dallas, but for a 250-mile reach extending to Livingston Lake.

Since the early 1970s the Dallas-Fort Worth metropolitan population has grown considerably, but water quality in the main stem of the Trinity River has steadily increased, largely due to reduced pollution loading being discharged in the effluent. However, over 1 million fish were killed during thirteen documented fish kills occurred in the Dallas to Livingston Reservoir portion of the Trinity River between 1970 and 1985 as flood discharges disturbed polluted sediments (Land et al, 1998). Ironically, it has been suggested that these fish kills were made possible by improvements in water quality which allowed fish to repopulate the river (Land, 1998).

In 1991 the Trinity River Basin became one of the first study units to begin full scale investigations as part of the National Water Quality Assessment Program (NAWQA), conducted by the U.S. Geological Survey (Ulery et al, 1993). During the planning phase of this study, existing information on nutrients and suspended sediment was compiled and analyzed. Subsequent activities included extensive monitoring of the entire Trinity Basin between 1992-1995.

6.2 Physical setting

The Trinity River drains an 18,000 square mile watershed in north-central and eastern Texas. Land use and vegetation cover within the watershed varies widely, from grass filled prairies, to the highly urbanized area of Dallas-Fort Worth, to the coastal marshes along the Gulf of Mexico. The Trinity River Basin has an overall length of 360 miles. The watershed is approximately 130 miles wide in the headwater region, located to the north and west of Dallas/Fort Worth metropolitan area, and tapers to approximately 30
miles at near its point of discharge in Trinity Bay, which is part of Galveston Bay, in the Gulf of Mexico. The Dallas-Fort Worth metropolitan area is located at the junction of three of the Trinity River’s four major tributaries and has a population of approximately 5.5 million (TRA, 2002). Several thousand water storage reservoirs are located throughout the Trinity River Basin, with approximately 30 being “major” (TRA, 2003). Reservoirs are used for flood control, irrigation, and municipal water supply. Many water supply reservoirs are located upstream of the Dallas-Fort Worth area which consequently reduces flow in the Trinity River.
6.2.1 Climate

The climate of the Trinity River Basin is modified marine, subtropical humid, with warm summers and a predominant onshore flow of tropical maritime air from the Gulf of Mexico (Metre, 1996). Annual rainfall varies significantly throughout the Trinity River Basin. An average of 27 inches of annual rainfall occurs in the northwestern part of the basin, with up to 52 inches in the southeastern part (Land, 1998). The wide range in precipitation values is largely attributed to changes in land elevation over the basin from east to west, and its proximity to the Gulf of Mexico and the southern Great Plains (Ulery et al., 1993). Most precipitation occurs during a few storm events, with little or no precipitation during summer months, causing a moisture deficit (as compared with potential evapo-transpiration) in summer months and a surplus in winter months (Ulery et al., 1993). These climatic conditions typically cause long periods of low flow in many parts of the Trinity River and its tributaries during the summer months (TRA, 2002). Less than 18% of total precipitation appears as flow near the Gulf of Mexico due to evaporation, seepage into underground formations, and consumptive use withdrawals (TRA, 2003).

6.2.2 Land use and towns

Total population in the Trinity River Basin in the early 1990s at start of the the NAWQA study was approximately 4.5 million, with about 3.5 million people living in the Dallas-Fort Worth metropolitan area (Van Metre, 1995). Other large urban areas include Denton, McKinney, Corsicana, Gainesville, Arlington, Irving, and Waxahachie. During the decade prior to the NAWQA study, the total population in the basin had increased by 26% (Ulery et al., 1995a). Population density at the time of the NAWQA studies was approximately 260 people per square mile.

Land use within the Trinity Basin is shown in Figure 46. Forest and wetland areas comprise about 25% of the total area, rangeland about 10%, urban areas about 5%, cropland and pasture about 57%, and about 3% is open water or barren land. Most industrial activity is located within the Dallas-Fort Worth metropolitan area and includes
a variety of manufacturing industries, such as automotive, aerospace, electronics, plastics, and oilfield equipment (http://www.texasoutside.com/easttexas/TrinityRiverNWR.htm).

As part of the NAWQA study, a classification system of “integrated land resource units” was developed to characterize physical and hydrologic features and is shown in Figure 56 and summarized in Table 10 (Ulery et al, 1993).
<table>
<thead>
<tr>
<th>Land Unit</th>
<th>Terrain</th>
<th>Vegetation</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central Prairie</td>
<td>Level to hilly</td>
<td>Natural prairie grass / brush</td>
<td>Cattle ranching, oil/gas production</td>
</tr>
<tr>
<td>Western and Eastern</td>
<td>Hilly</td>
<td>Oak trees prominent</td>
<td>Area between Fort Worth – Dallas heavily urbanized</td>
</tr>
<tr>
<td>Cross Timbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Prairie</td>
<td>Nearly level plains / rolling hills</td>
<td>Prairie grass</td>
<td>Fort Worth metropolitan area</td>
</tr>
<tr>
<td>Blackland Prairie</td>
<td>Nearly level to rolling hills</td>
<td>Prairie grass, cultivated crops</td>
<td>Cattle grazing, Dallas metropolitan area</td>
</tr>
<tr>
<td>Texas Claypan</td>
<td>Rolling hills</td>
<td>Prairie grass / oak trees</td>
<td>Cattle ranching, coal mining</td>
</tr>
<tr>
<td>Eastern Timberlands</td>
<td>Rolling plain to gently rolling hills</td>
<td>Piney woods</td>
<td>Commercial timber, oil / gas production</td>
</tr>
<tr>
<td>Coastal Prairie &amp; Marsh</td>
<td>Very flat</td>
<td>Prairie grass &amp; Forest</td>
<td>Rice / pasture</td>
</tr>
<tr>
<td>Bottomlands</td>
<td>Flat</td>
<td>Varying</td>
<td>Located along Trinity River and major tributaries</td>
</tr>
</tbody>
</table>

Table 10. **Land Resource Units of the Trinity Basin.**  (Source: Land et al, 1998)

![Figure 56. Land Resource Units of the Trinity River Basin](image)
6.2.3 Location of gauging stations

The USGS has been measuring stream flow in the Trinity River Basin since 1890 and currently maintains and operates ninety-one stations throughout the Trinity River Basin which monitor stream flow, reservoir stage, and/or water quality. Six gaging stations are located on the Trinity River between Dallas and Livingston Reservoir, the 250 mile segment which is most heavily effluent dominated (Aragon, 2005). Three of these stations are also currently used to collect water quality data, while two others were used for water quality measurements in the past. Five gauging stations, one of which is also a water quality station, are also located on tributaries discharging into the Trinity River between Dallas and Livingston Lake. Figure 57 shows the Trinity River between Dallas and Livingston Lake and indicates the location of all USGS gauging stations in the area. Table 11 summarizes relevant data for these USGS gauging stations.
Figure 57. USGS Gauging Station Locations between Dallas and Lake Livingston
Table 11. Summary of selected USGS gaging stations. (Source: Compiled with information from USGS website, www.usgs.gov)
6.2.4 Topography

Topology in the Trinity River Basin varies quite widely. Predominant features include rolling, treeless prairies, smooth to slightly rolling prairies, rolling timbered hills, and a relatively flat coastal plain. In the northwest portion of the basin the land slopes gradually from about 1,200 feet above sea level, to about 600 feet mid-basin, and on to sea level in the southeastern section of the area, at Trinity Bay. Land-surface altitude decreases at about 2.7 feet per mile over the length of the Trinity River Basin (Ulery et al, 1993). Depth to bedrock is relatively thin in the upper portions of the basin but increases as progressing downstream to the Gulf of Mexico.

6.3 Data & analysis

6.3.1 Previous studies

The U.S. Geological Survey (USGS) has collected and analyzed water resource data from within the Trinity River watershed for over a century. However, until the 1960s much of this data has largely been related to quantification of stream flow. The first long term water quality station became operation in 1959, approximately 10 miles below Dallas.

In 1991 the entire Trinity River Basin became one of the first study units to begin full scale investigations as part of the USGS’s NAWQA project, conducted by the USGS (Ulery, et al, 1993). Study planning and analysis of existing data was done from 1991 to 1992, which included collection and analysis of existing information on nutrients, suspended sediments and biota. Between 1992-1995 surface water, ground water, and biological data were intensively collected intensively. Data collection for the NAWQA project was separated into four components

- Chemistry of surface water and bed sediment
- Aquatic biology
- Chemistry of ground water
- Special studies

Table 12 summarizes data collection in the Trinity Basin from 1992 to 1995

<table>
<thead>
<tr>
<th>Study component</th>
<th>Objectives</th>
<th>Brief description and water-quality measures</th>
<th>Number of sites</th>
<th>Frequency during 1993–95</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemistry of surface water and bed sediment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water chemistry—Basic and Intensive Fixed sites</td>
<td>Describe concentrations and loads of water-quality constituents at selected stream sites.</td>
<td>Sample at or near streamflow-gaging stations. Basic sites are sampled for major ions, organic carbon, suspended sediment, and nutrients. Intensive sites are a subset of the Basic sites and include sampling for pesticides.</td>
<td>8 Basic, 2 Intensive</td>
<td>~14 per year at Basic, ~25 per year at Intensive</td>
</tr>
<tr>
<td>Water chemistry—Basinwide synoptic studies</td>
<td>Describe short-term presence and distribution of contamination over the entire basin and how well the Basic and Intensive sites represent the Trinity River Basin.</td>
<td>Sample streams during winter base-flow and spring runoff conditions for major ions, organic carbon, suspended sediment, nutrients, and pesticides.</td>
<td>43</td>
<td>2</td>
</tr>
<tr>
<td>Bed-sediment contamination—Presence and distribution survey</td>
<td>Determine presence of potentially toxic compounds attached to sediment deposited on streambeds.</td>
<td>Sample depositional zones of streams for trace elements and hydrophobic organic compounds.</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Aquatic biology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecological assessments—Basic and Intensive Fixed sites</td>
<td>Assess in detail biological communities and habitat in streams representing primary ecological and land-use regions.</td>
<td>Sample and quantify fish, macroinvertebrates, and algae in streams at stream chemistry sites and describe stream habitat. Intensive sites are a subset of the Basic sites where there is repetitive sampling over three stream reaches.</td>
<td>? Basic, 5 Intensive</td>
<td>1 at Basic; 1 per year and multiple reaches at Intensive</td>
</tr>
<tr>
<td>Aquatic-biota contamination—Presence and distribution survey</td>
<td>Determine presence of contaminants that can accumulate in tissues of aquatic biota.</td>
<td>Collect clams and fish species that are present in most streams of the Trinity River Basin. Sample composites of clams or fish for organic compounds and trace elements.</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td><strong>Chemistry of ground water</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water chemistry—Basinwide survey</td>
<td>Describe the overall water quality and natural chemical patterns of water in aquifers.</td>
<td>Sample existing supply wells in the outcrop of three major aquifers for major ions, nutrients, pesticides, trace elements, and VOCs.</td>
<td>71</td>
<td>1</td>
</tr>
<tr>
<td>Water chemistry—Land-use study</td>
<td>Determine the effects of urban land use on the quality of shallow ground water.</td>
<td>Sample shallow monitoring and supply wells where there is residential and commercial development for major ions, nutrients, pesticides, trace elements, and VOCs.</td>
<td>38</td>
<td>1</td>
</tr>
<tr>
<td>Water chemistry—Flow-path study</td>
<td>Describe changes in water quality in an urban area along flow paths from a shallow aquifer to small streams.</td>
<td>Sample clusters of wells in land-use effects survey and a nearby small stream for major ions, nutrients, pesticides, and age-dating constituents.</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Water chemistry—Use of SPMDs</td>
<td>Determine presence of organic contaminants in water and sediment by deploying caged clams and SPMDs and comparing the results of the two approaches.</td>
<td>Deploy caged native clams and SPMDs side by side for 1 month and determine the presence and concentration of PCBs and PAHs in each medium.</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Water chemistry—Comparison of urban point- and nonpoint-source contaminants</td>
<td>Compare the presence and distribution of nutrients and pesticides in small urban streams and in effluent from regional wastewater-treatment plants in the same service area.</td>
<td>Sample streams and effluent from regional wastewater-treatment plants during late winter to summer for major ions, nutrients, and pesticides.</td>
<td>6 streams: 3 wastewater-treatment plants</td>
<td>6</td>
</tr>
<tr>
<td>Water chemistry—Richland-Chambers watershed</td>
<td>Describe presence and distribution of agricultural chemicals in streams and reservoirs in a major crop-producing area.</td>
<td>Sample streams from late winter to late summer for major ions, nutrients, pesticides, and suspended sediment. Reservoirs sampled at beginning or end of study, or both.</td>
<td>5 streams: 11 reservoirs</td>
<td>7 at streams; 1 or 2 at reservoirs</td>
</tr>
<tr>
<td>Water chemistry—Coastal Prairie agricultural area</td>
<td>Describe presence and distribution of agricultural chemicals in streams in a major crop-producing area with irrigation.</td>
<td>Sample streams for 1 year for major inorganic ions, nutrients, pesticides, and suspended sediment. Sampling much more frequent during late spring and summer than full and winter.</td>
<td>3</td>
<td>~25</td>
</tr>
<tr>
<td>Water-quality trends—Reservoir sediment cores</td>
<td>Determine temporal trends of trace elements, organochlorine compounds, and PAHs in streams.</td>
<td>Collect sediment cores at Lake Livingston and White Rock Lake. Horizontal slices analyzed for age-dating elements, trace elements, organochlorine compounds, and PAHs.</td>
<td>2 reservoirs</td>
<td>1</td>
</tr>
</tbody>
</table>

Watershed Management
Effluent dominated streams in the US
The USGS has several dozen fact sheets and reports describing and summarizing results from the NAWQA project. In addition to the USGS there are multiple federal, state, regional and local agencies, organizations and stakeholder groups involved in the management of water resources in the Trinity River Basin. These agencies include the U.S. Army Corps of Engineers (primarily involved in the construction, operation and maintenance of storage reservoirs and flood protection), the U.S. Environmental Protection Agency, regional and local water utility agencies and water districts, and the Trinity River Authority. However, of these agencies, only the Trinity River Authority has produced reports relevant to the effluent dominated conditions below Dallas.

In 1991 the Clean Rivers Program was enacted by the Texas Legislature which aimed to improve surface water quality throughout Texas. The program for the Trinity River Basin is managed by the Trinity River Authority, under contract with the Texas Commission on Environmental Quality. The Trinity River Authority work is focused on three main areas; routine monitoring, special studies and public outreach (TRA, 2006). Specific powers provided to the authority cover almost all aspects of water resource development and management, including flood control, irrigation, water supply, transport, construction of water related civil works, recreational facilities, wildlife preservation, sewage treatment, electricity generation, and soil conservation (TRA, 2003). The Trinity River Authority has undertaken many studies related to water quality management, many of which directly concern the effluent dominated portion of the Trinity River below the Dallas-Fort Worth metropolitan area. Specific reports recently published by the TRA include:

- Water Quality Standards Evaluation Post Oak Creek Arm of Richland-Chambers Reservoir (2005)
- Investigation into the Seasonal Affects of Municipal Wastewater Treatment Plant Discharges on a Small Receiving Stream in North-Central Texas (2004)
• Algal Succession in the Trinity River Under Summer and Autumn Effluent Dominated Conditions Trinity River Authority (2003)

• Analysis of Use and Nutrient Data on Selected Reservoirs of the Trinity River Basin (2003)

6.3.2 Hydrological data

Throughout the Trinity River Basin streamflow is generally proportional to rainfall and the size of the watershed, except downstream from reservoirs and point sources, such as wastewater treatment plant effluent discharge points. Within the Trinity River Basin the natural stream network has been substantially altered by anthropogenic activities. Over 1,000 water storage reservoirs are located throughout the Trinity River Basin, most of which are used primarily for flood control with capacities of 500 to 1,000 acre-ft. There are 22 reservoirs that have a capacity of over 10,000 acre-feet, mainly located on tributaries of the Trinity River (Ulery et al., 1993). Water is also imported from outside the Trinity River Basin from 7 water supply reservoirs. The largest reservoir, 83,000 acre Livingston Lake, is located directly on the Trinity River, approximately 250 miles downstream of Dallas (TRA, 2006). Water from this reservoir is exported outside the Trinity River Basin, and is used as a water supply source for the city of Houston. Within the Trinity River Basin, surface water is used for 95% of all water supply (including municipal, mining, agricultural, and industrial uses), with the groundwater supplying the remaining 5%.

Annual mean flows in the Trinity River throughout much of the entire basin have been steadily increasing during the period the USGS has been monitoring streamflow, which in some cases begins in 1902. However, these increases in annual flows became more pronounced in the 1960s. During the 1960’s the mean annual flow below at the USGS station 0805700 located in central Dallas was 1310 cfs, while in the 1990s it increased to over 3,000 cfs, 235% of the average 1960s flow. Similarly, at stations 08062500 (approximately 10 miles downstream of Dallas) and 08065350 (close to Livingston Lake) flows increased from 3660 to 5500 cfs and 5520 to 9375 cfs, respectively representing 230% and 170% of the 1960s flows (Compiled with information from USGS website, www.usgs.gov).

While flows vary greatly from year to year, the data collected from the USGS station in Dallas indicates there are no significant trends (e.g. generally increasing or
Watershed Management
Effluent dominated streams in the US

decreasing) for annual peak flow. Similarly, other USGS stations on the Trinity River between Dallas and Livingston Lake also indicate no significant long term trends in changing annual peak flows. However, increases in annual peak flow have been observed in some tributaries to the Trinity River, which have been associated with increasing urbanization (Compiled with information from USGS website, www.usgs.gov).

Approximately 540 MGD of effluent is discharged into the entire Trinity River Basin, with over 80% of it being discharged in the Dallas-Fort Worth area (TRA, 2003). This quantity of effluent is less than the estimated 600 MGD discharged to the Trinity River in 1990, but substantially more than the 200 MGD discharged in 1970 (Ulery et al, 1993). Seven major wastewater treatment plants currently discharge treated effluent within the Dallas-Fort Worth metropolitan area (Figure 58 & Table 13). Collectively, these treatment plants have a permitted discharge limit of 721 MGD, equivalent to continuous discharge of 1,115 cfs (TRA, 2002). Actual cumulative effluent discharge into the Trinity River from the Dallas-Fort Worth area is approximately 450 MGD, equivalent to continuous discharge of 696 cfs. This effluent discharge represents 16% of the total annual flow in the Trinity River, as measured downstream of Dallas at USGS station 0806250, and often over 80% during the summer months of July and August.

Hydrographs for three gauging stations on the Trinity River are shown in Figure 59, as well as the average flow of effluent discharged from the seven major wastewater treatment plans in the Dallas-Fort Worth area. Effluent clearly contributes a considerable portion of the total flow in this portion of the Trinity River.
Watershed Management
Effluent dominated streams in the US

<table>
<thead>
<tr>
<th>Waste Water Treatment Plant</th>
<th>Permitted Discharge Limit (MGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Worth Village Creek</td>
<td>169</td>
</tr>
<tr>
<td>Trinity River Authority Central</td>
<td>162</td>
</tr>
<tr>
<td>Dallas Central</td>
<td>200</td>
</tr>
<tr>
<td>Dallas Southside</td>
<td>110</td>
</tr>
<tr>
<td>South Mesquite Creek</td>
<td>25</td>
</tr>
<tr>
<td>Duck Creek</td>
<td>30</td>
</tr>
<tr>
<td>Rowlett Creek</td>
<td>25</td>
</tr>
<tr>
<td>Total Permitted Discharge</td>
<td>721</td>
</tr>
</tbody>
</table>

Table 13. Permitted discharge limits. (Source: TRA, 2002)

Figure 58. Major Wastewater Treatment Plants in the Dallas-Fort worth Metropolitan area
6.3.3 Water Quality Issues, Point and Non-Point Sources of Pollution

A variety of water quality issues exist within the Trinity River Basin, many of them unique to specific geographic location, type of water body, and/or source of water. Low water quality is typical during periods of low flow, which is quite common in many water bodies in the Trinity River Basin, and at the beginning of increased flows. Typical water quality problems include low dissolved oxygen concentrations and high bacteria growth. Small streams which receive reservoir flow to support base flow typically do not have any severe water quality issues (TRA, 2003). Intermittent, non-urban streams generally have high suspended solid concentrations, with some streams occasionally having high dissolved solids, chlorides or fecal coliforms, mainly attributed to non-point sources. Lakes throughout the Trinity River Basin are of consistently good quality, with the exception of Lake Livingston. Effluent dominated streams exist throughout the basin, with the largest being the main stem of the Trinity River between Dallas and Lake Livingston (TRA, 2003). It is this portion of the Trinity River which is discussed in the following section.
6.3.4 Water quality data

Dissolved Oxygen

Dissolved oxygen concentrations in the Trinity River between Dallas and Lake Livingston have dramatically improved since the late 1960s, when occurrences of nearly no dissolved oxygen were commonly observed, to the present-day, when concentrations are rarely less than 5 mg/L (Lands et al., 1998). Levels of Dissolved oxygen vary considerably during the year as flow in the Trinity River fluctuates. Concentrations are typically highest between November and April. Figure 60 shows average annual dissolved oxygen concentrations at two USGS stations. Station 08062500 is located several miles downstream of both the actual Dallas-Fort Worth metropolitan area and effluent discharge points for the metropolitan areas wastewater treatment plants. Station 08065350 is located approximately 200 miles downstream of Dallas and approximately 50 miles upstream of Lake Livingston. Refer to Figure 57 for stream gauge locations.
Improvements in dissolved oxygen concentrations have largely been attributed to the improved quality of effluent being discharged from treatment plants in the Dallas-Fort Worth metropolitan area (Land et al., 1998). Between 1970s and 2003 effluent discharge increased approximately 250%, yet biochemical oxygen in 2003 was only 20% early 1970s levels (TRA, 2003). Dissolved oxygen levels generally increase between the Dallas-Fort Worth area and Lake Livingston (TRA, 2002). A study conducted by the Trinity River Authority in 2002 demonstrated that dissolved oxygen consistently increases during low flow periods from approximately 6 mg/L immediately above the first major effluent discharge point in the Dallas area, to approximately 8 mg/L approximately 150 miles downstream of Dallas (TRA, 2002).

**Total Suspended Solids**

Very limited historic data for suspended solids is available. It is unknown whether present day TSS concentrations vary significantly from past concentrations, nor is it possible to develop any statistical cause-effect relations with environmental factors such as land use, soils and geology (Ulery et al., 1995).

As the Trinity River flows from Dallas to Lake Livingston concentrations of total suspended solids increase. However, treated effluent discharged to the Trinity River does not appear to contribute to this problem. Unlike dissolved nutrients however, TSS concentrations were observed during a 2002 study to decrease with each input of treated wastewater effluent, and to slowly increase with distance from the point source. A study conducted by the Trinity River Authority in 2002 observed TSS concentrations of less than 20 mg/L immediately upstream of Dallas, to approximately 90 mg/L approximately 150 miles downstream of Dallas (TRA, 2002).

**Phosphate**

Throughout the Trinity River Basin, total phosphorus concentrations have been observed to noticeably vary during the year (Figure 61). Total phosphorus concentrations have been observed to increase from mid-winter to mid-spring and decline in the summer
months, with the trend associated with changes in streamflow rather than seasonal changes in land use or fertilizer application (Ship, 1995; Land et al, 1998). Since the early 1970s total phosphorus levels have dropped from an average concentration of approximately 5 mg/L to approximately 1 mg/L in 2004 (http://nwis.waterdata.usgs.gov/tx). However, dissolved orthophosphate, dissolved phosphorus and total phosphorus downstream of Dallas were observed to be higher than any other location in the entire Trinity River Basin during the NAWQA study from 1993-1995, and consistently exceeded EPA guidelines (Land et al, 1998). During the summer of 2002 orthophosphate and total phosphorus concentrations in the Trinity River were observed to be strongly impacted by effluent discharge from wastewater treatment plants. Collected data clearly indicates that immediately below each major treatment effluent outfall in the Dallas-Fort Worth area both total phosphorus and orthophosphate levels suddenly increase, begin to decrease, and then increase once again after the next major effluent outfall (TRA, 2002).

**Figure 61. Monthly variations in TP concentrations between 1993-1995 (Source: Land, 1998)**

**Nitrogen**

Between 1974 and 1991, a 95% reduction in ammonia and organic nitrogen concentrations was observed downstream of Dallas These changes have been attributed to the implementation of improved wastewater treatment technologies at the major treatment plants in the Dallas-Fort Worth area (Land, 1998).
Similar to total phosphorus and orthophosphate, concentrations of nitrate plus nitrite have been shown to increase dramatically after each input of wastewater effluent, and then slowly decrease before the next point source (TRA, 2002). Also similar to total phosphorus, concentrations of nitrate have been observed to increase with flow from midwinter to mid-spring, and to then decline in the summer months (Ship, 1995; Land et al, 1998).

Concentrations of nitrate and total nitrogen were observed between 1993 and 1995 to be higher downstream of Dallas-Fort Worth area than at any other area in the Trinity River Basin. Of the 440 samples from the entire Trinity River Basin and analyzed for nitrate during the NAWQA study, only two exceeded the EPA maximum contaminant limit of 10 mg/L, one of which was from a water quality monitoring station downstream of the Dallas-Fort Worth area. The NAWQA study between 1993 and 1995 also demonstrated that:

- Total nitrogen and nitrate nitrogen concentrations were between 0.25 to 2.5 in approximately 30% of all samples, and greater than 2.5 in the remaining 70%.
- Total ammonia plus organic nitrogen concentrations were consistently between 0.25 to 2.5 mg/L.
- Dissolved ammonia nitrogen concentrations were less than 0.25 mg/L in over 95% of all samples analyzed.

**Pesticides**

Pesticides, including herbicides, insecticides, and fungicides, are used for a variety of purposes and are present throughout water bodies within the entire Trinity River Basin (Ship et al, 1995b). Herbicides are more commonly detected below the Dallas-Fort Worth area and are related to land use and not to wastewater effluent discharges (Land et al, 1998). Five herbicides and two herbicides were frequently detected in samples collected from the Trinity River downstream of the Dallas-Fort Worth metropolitan area during the 1993 to 1995 sampling period for the NAWQA study. These pesticides included:

**Herbicides**
• Altrazine, used typically on fields of corn, hay, sorghum, was the most commonly detected herbicide within the entire Trinity River basin, as well as in the Trinity River below the Dallas-Fort Worth metropolitan area. All samples collected and analyzed for herbicides from this portion of the Trinity River were found to contain altrazine; 90% of the samples had concentrations between 0.1 to 1.0 ug/L and 10% had concentrations greater than 1.0 ug/L, but were less than the EPA 1996 MCL for altrazine of 3.0 ug/L.

• Metolachlor was also detected in all samples collected from the Trinity River below Dallas. Approximately 60% of all samples had concentrations less than 0.1 ug/L, with the remaining 40% having concentrations between 0.1 to 1.0 ug/L. All samples had concentrations below the 1996 EPA guidelines.

• Prometon and tebuthiuron were detected in over 90% of all samples collected, with almost all samples having concentrations of less than 0.1 ug/L, far below the 1996 EPA HA of 100 ug/L.

• Simazine was detected in all samples collected, with approximately 10% of samples having concentrations above 1.0 ug/L, 25% of samples with concentrations between 0.1 to 1.0 ug/L and the remaining 65% of samples having concentrations less than 0.1 ug/L. All samples had concentrations below the 1996 EPA guidelines.

• Insecticides

• Diazinon is used typically applied to lawns, gardens, and landscaped areas and was the most commonly detected insecticide within the entire Trinity River basin, as well as in the Trinity River below the Dallas-Fort Worth metropolitan area. Diazinon was detected in approximately 90% of all samples collected and analyzed for insecticides from this portion of the Trinity River. 80% of the samples had concentrations less than 0.1ug/L and 10% had concentrations between 0.1 to 1.0 ug/L. Some samples had concentrations that exceeded the 1996 EPA HA 0.6 ug/L.

• Carbaryl was also detected in approximately 50% of all samples, with all concentrations being less than 0.1 ug/L.
Others

As part of the NAWQA study, sediment cores were collected throughout the Trinity River Basin, including downstream of the Dallas-Fort Worth metropolitan area. Measurements made between 1993-1995 indicate that trace element concentrations and semi-volatile organic compound concentrations in Trinity River sediments downstream of Dallas are between the median and 75th percentile for all NAWQA sites studied prior to 1998. Concentrations of organochlorine pesticides and PCBs in sediments were found to be among the highest in the nation (Land et al, 1998).

6.3.5 Biota Data

In the early 1960s the Trinity River downstream of Dallas was so polluted that it was described as “septic” by the United States Public Health Service, which was only a slight improvement over the Texas Department of Health characterization of this river segment as the “mythological river of death” in the mid 1920s (Land et al, 1998). After passage of the Clean Waters Act in 1972, efforts began to improve the health of the Trinity River. These efforts resulted in a gradual, but substantial, improvement in water quality. Three fish surveys conducted downstream of Dallas between 1972 and 1974, 1987, and 1993-1995 clearly that the water quality has improved.

Prior to the early 1970s, few fish species were able to exist in the Trinity River downstream of Dallas. During a survey in the early 1970s, only four fish species were detected, and included the smallmouth buffalo, gizzard shad, common carp, and yellow bass, all of which are highly tolerant species. In 1987, eleven species of fish were collected from the same reach of the Trinity River. While the study indicated a higher number of species, the species richness was considered to be low, mainly due to effluent discharge from the Dallas-Fort Worth area which had high concentrations of ammonia nitrogen and heavy trace metals. During the 1993-1995 NAWQA study, 25 species were collected, including several game species and several indigenous species not detected in earlier surveys. Figure 62 summarizes the three surveys. Increases in dissolved oxygen and reductions in ammonia nitrogen concentrations, both discussed above, have had a direct impact on fish populations (Figure 63).
Since the early 1800s population in the Trinity River Basin has progressively increased, and until recently this increase in population was accompanied by increased levels of pollution, and subsequently a reduction in ability for people to use and enjoy Trinity River. As discussed above, the main stem of the Trinity River below the Dallas-Fort Worth metropolitan area was heavily polluted at the time the Clean Waters Act of 1972 first came into effect. Since then, the Dallas-Fort Worth metropolitan population has continued to grow considerably, but water quality in the main stem of the Trinity River has improved significantly.
River has steadily increased. Improvements have largely been due to implementation of improved wastewater treatment processes, as well as from a substantial reduction in industrial pollution sources.

Sediments contaminated with heavy metals, SVOCs, and other pollutants exist throughout much of the Trinity River downstream of Dallas. This pollution is largely a legacy of past industrial and agricultural activities upstream of Dallas. While these contaminated sediments do not present an immediate threat to the Trinity River ecosystem under normal flow conditions, they do negatively affect fishing and contact recreation activities on this part of the Trinity River. Additionally, during periods of high flow, sediments can be disturbed, resulting in re-suspension of the contaminants into the water body. While this contributes to the “natural attenuation” of the sediment contamination issue, re-suspension of sediments can cause severe impacts on water quality and consequently on biological processes that depend on the Trinity River, as well as those who use Lake Livingston as a water supply source.

Waste water effluent contributes a large portion of the Trinity River’s total flow, especially during dry periods when almost all flow is treated effluent. Consequently, nutrient loads, while substantially reduced from the levels achieved in the 1970s, are still high, and negatively influence water quality in Lake Livingston, which is also used as a water supply for the city of Houston. Further improvements in water quality of treated effluent water are possible, but may not be practical or wanted at this time. Besides effluent discharges, the Trinity River is affected by other factors, such as runoff from urban and agricultural areas. Any improvements in effluent water quality are likely to lead to more severe impacts during times of higher flows, when non-effluent related pollutants may negatively affect fish and other wildlife (TRA, 2003). Consequently, any significant further improvements will need to address not only effluent discharge quality, but also upstream pollutant sources.
6.5 References


Trinity River Authority (2004). Investigation into the Seasonal Affects Of Municipal Wastewater Treatment Plant Discharges on a Small Receiving Stream in North-Central Texas


Websites consulted:
Fort Worth Water Department   http://www.fortworthgov.org/water/
Trinity River Authority  http://www.trinityra.org
Texas Commission on Environmental Quality http://www.tceq.state.tx.us/
Texas Agricultural Extension Service  http://agextension.tamu.edu/
Texas Natural Resource Conservation Commission  http://www.tceq.state.tx.us/
Texas Water Development Board  http://www.twdb.state.tx.us/home/index.asp
Texas Water Resources Institute  http://twri.tamu.edu/
U.S. Environmental Protection Agency, Region 6  http://epa.gov/region6/index.htm
U.S. Fish and Wildlife Service http://www.fws.gov/
Trinity River Corridor Project http://www.trinityrivercorridor.org/
6.6 Additional Resources


Trinity River Authority (2005b) Water Quality Standards Evaluation Post Oak Creek Arm of Richland-Chambers Reservoir

Trinity River Authority (2005c) Trinity River Authority Investigations into The Relationship Between Water Column Algal Concentrations And User Perceptions of The Suitability Of Lake Livingston For Recreation And Aesthetic Enjoyment , Summer 2005

Trinity River Authority (2005d) Trinity River Authority Investigations Into the Occurrences of Low Dissolved Oxygen in Johnson Lake Trinity River Authority, 125 pages

Trinity River Authority (2006b)Trinity River Authority of Texas Clean Rivers Program Quality Assurance Project Plan Draft 3.


7 Conclusions

While all of the effluent dominated rivers discussed above share common characteristics and face similar problems, each river system is unique. All five of the rivers discussed above are located in heavily urbanized areas and their flows are highly managed and regulated. All locations around each river are expected to become even more heavily urbanized in the future. The many uses each river is subject to often conflict with each other. Each river can never be restored to its original natural state, but water quality can be improved through proper management, sustainable water use, and green building techniques in the watershed.

Each community must promote a shared responsibility among the watershed’s stakeholders to protect water quality and sufficient flows throughout the watershed. The river’s uses must be met, in many casing including navigation and agricultural water use, at the same time improving water quality, biodiversity, and habitat within the watershed. Satisfying all use requirements is a difficult task.

In the last 20 years, these rivers have received an enormous increase in public interest and awareness. Millions of people live in close proximity to these urban water bodies. The public is recognizing its right to clean water and there is a willingness to pay to improve the water quality.

Each river pays a large part in the revitalization of its surrounding urban area. Ideas like urban drainage systems that behave similar to the natural hydrology of the area, including pervious paved surfaces, will all play a part in improving the watersheds and the rivers themselves. Traditional land development will need to be changed to create sustainable watersheds. Water conservation will need to be practiced by populations living in these watersheds to reduce cross-basin transfers and decrease treated effluent.

All of these are long-term plans that will take many years before they are realized, and they imply not only the participation of the institutions but the education and intervention of the watershed’s population.