HOUSTON
SUSTAINABLE DEVELOPMENT *INDICATORS*:
A Comprehensive Development Review for Citizens, Analysts and Decision Makers

ENVIRONMENTAL DEVELOPMENT
PILLAR OF SUSTAINABILITY

LESTER KING


RICE UNIVERSITY
Shell Center for
Sustainability


RICE
Unconventional Wisdom

Houston Sustainable Development Indicators:

A Comprehensive Development Review for Citizens, Analysts and Decision Makers

by

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Environmental Development Pillar of Sustainability


RICE
Unconventional Wisdom

Theme - Atmosphere
Sub Theme - Air Quality

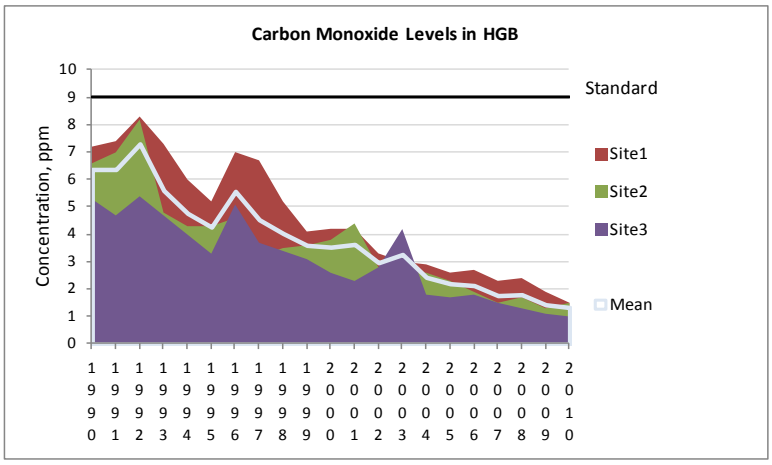
Indicator - Ambient concentrations of air pollutants

Is it possible to have clean air in Houston given the existence of major chemical processing industries adjacent to the city and the reliance on private cars for transportation? The Houston area has high ambient concentrations of ozone and has traditionally been in violation of one-hour and eight-hour ozone standards (Maret, King, Sexton, & Arscott, 2004). This study does not include air toxics, but Benzene is an issue with recorded levels that commonly exceed 2ppb (Blackburn, 2011).

Sustainability Benefit: The Houston Region is in attainment for some of the regulated National Ambient Air Quality Standards (NAAQS).

Sustainability Issue: Houston is situated next to petrochemical plants, refineries and one of the largest industrial ports in the country. Additionally, Houstonians drive long distances because the City of Houston is large and homes are separated from jobs, services, and daily needs.

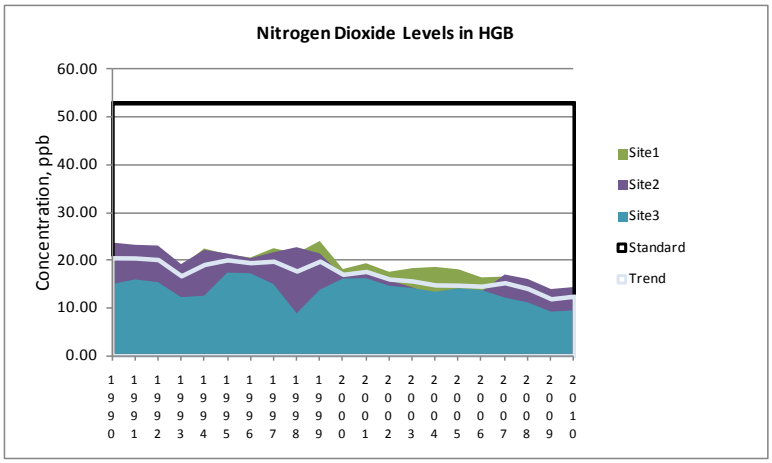
The following metrics are used to measure the indicator *Ambient Concentration of Air Pollutants:*



Source: US EPA

Figure 39: Carbon Monoxide Levels in HGB

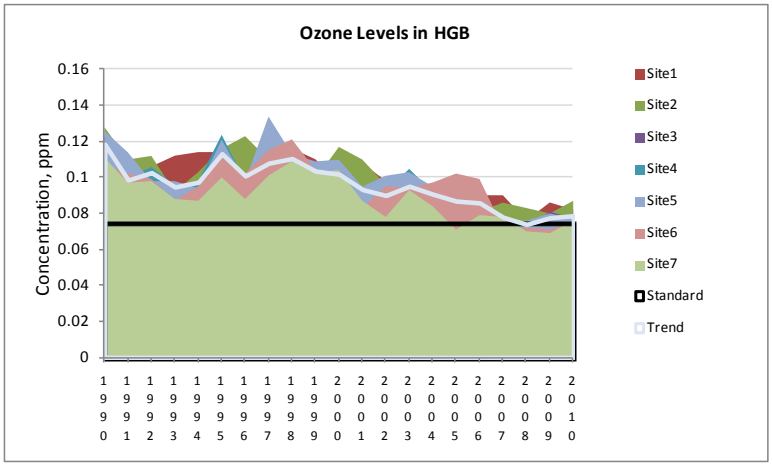
- Carbon Monoxide levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 9ppm.
- Carbon monoxide levels are decreasing steadily over time.
- The mean level for carbon monoxide in HGB was 1.3 ppm in 2010.



Source: US EPA

Figure 40: Nitrogen Dioxide Levels in HGB

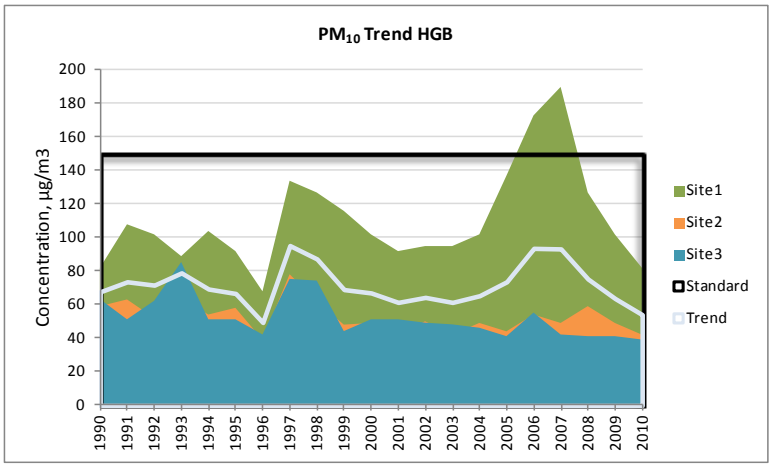
- Nitrogen Dioxide levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 53ppb.
- Nitrogen dioxide levels are decreasing at all three of the monitors used in this analysis.
- The mean level for nitrogen dioxide in HGB was 12.42ppb in 2010.



Source: US EPA

Figure 41: Ozone Levels in HGB

- Although ozone levels have been generally decreasing over time, the HGB region continues to exceed the national ambient standard of 0.075ppm.
- In 2010 Houston recorded a mean ozone level of 0.079ppm; which was the annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years.

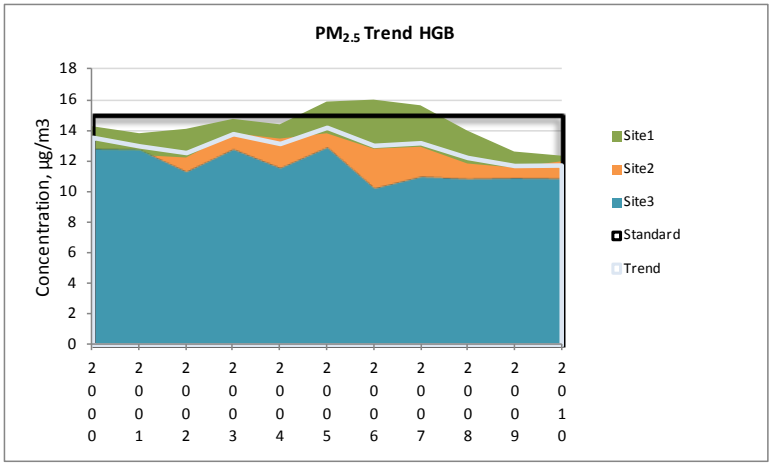


Source: US EPA

Figure 42: PM 10 Levels in HGB

- Particulate Matter (PM_{10}) levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 150 $\mu g/m^3$ (PM10 standard).

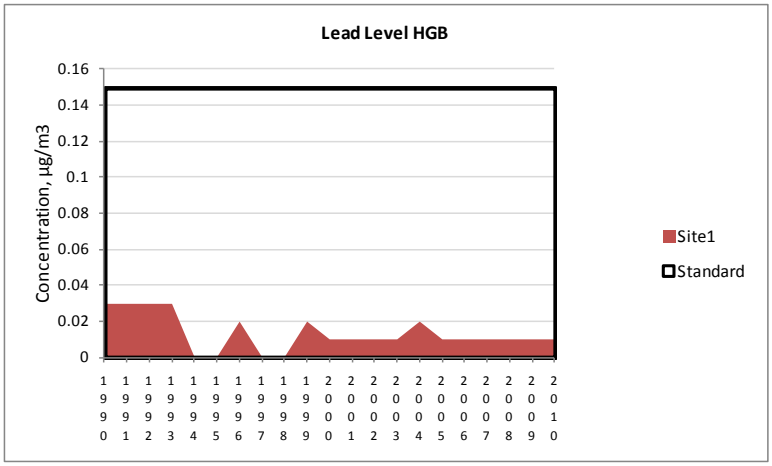
- PM_{10} levels are fluctuating at all three of the monitors used in this analysis.
- The mean level for PM_{10} in HGB was 54µg/m^3in 2010.



Source: US EPA

Figure 43: PM 2.5 Levels in HGB

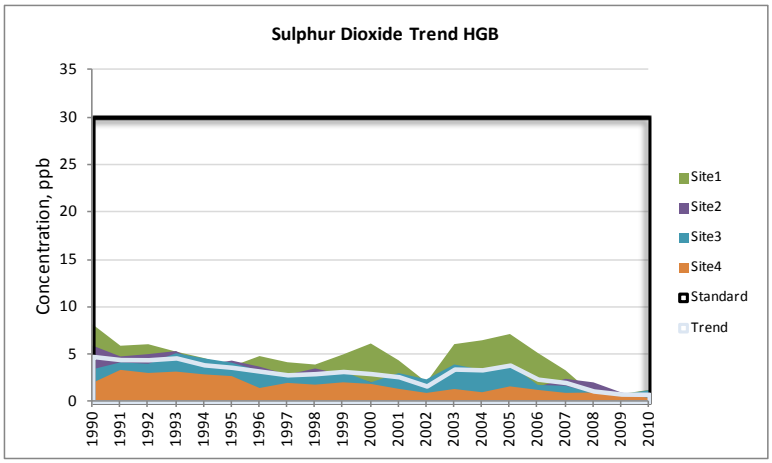
- Particulate Matter ($PM_{2.5}$) levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 15 µg/m^3.
- Particulate matter ($PM_{2.5}$) levels are decreasing at all three of the monitors used in this analysis.
- The mean level for particulate matter ($PM_{2.5}$) in HGB was 11.7 µg/m^3 in 2010.



Source: US EPA

Figure 44: Lead Levels in HGB

- Lead levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 0.15 µg/m^3.
- Lead levels are fluctuating at the one monitor used in this analysis.
- The mean level for Lead in HGB was 0.01 µg/m^3 in 2010.



Source: US EPA

Figure 45: Sulphur Dioxide Levels in HGB

- Sulphur Dioxide levels in the Houston-Galveston-Brazoria (HGB) region are below the national ambient air quality standard of 75ppb.
- Sulphur dioxide levels are gradually decreasing at all four of the monitors used in this analysis.
- The mean level for sulphur dioxide in HGB was 0.8ppb in 2010.

Theme - Atmosphere
Sub Theme - Climate Change

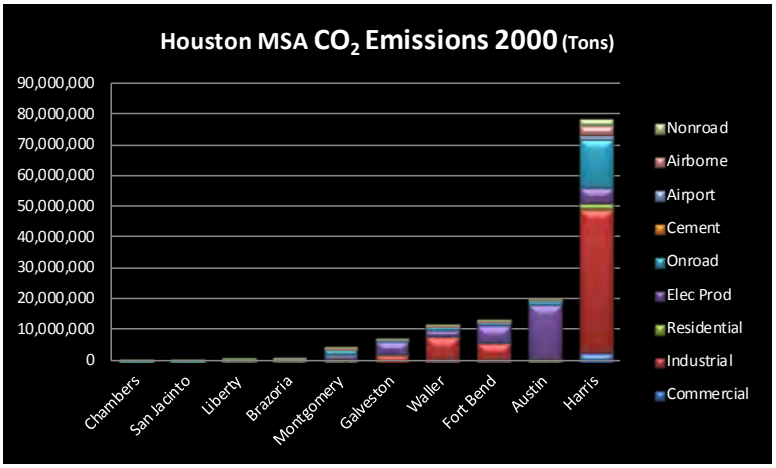
Indicator - Greenhouse Gas Emissions

City of Houston municipal operations including water treatment and street lighting generates approximately 2% of the GHG emissions in Harris County with 888,310 tons of emissions, compared with 44,531,660 tons for the county (Environmental Protection Agency, 2011; Gurney et.al., 2009). Using analyses of per unit of land area, cities generate a large amount of greenhouse gas emissions. However, on a per capita basis people who live in the city generate less CO_2 than those outside of the city (Farr, 2008; Glaeser, 2011; Glaeser, 2011). How do we balance the need to fund and build new roads, and support policies for population growth with the need to reduce GHG emissions? One of the most challenging sustainability issues for Houston will be the reduction of CO_2 emissions (Blackburn, 2011).

Sustainability Benefit: There have been major reductions in CO_2 emissions in the Industrial sector between 2000 and 2008 in Harris County.

Sustainability Issue: Electricity Production and On-road sources of emissions are increasingly a challenge for CO_2 reductions in Harris County and the Houston metropolitan area.

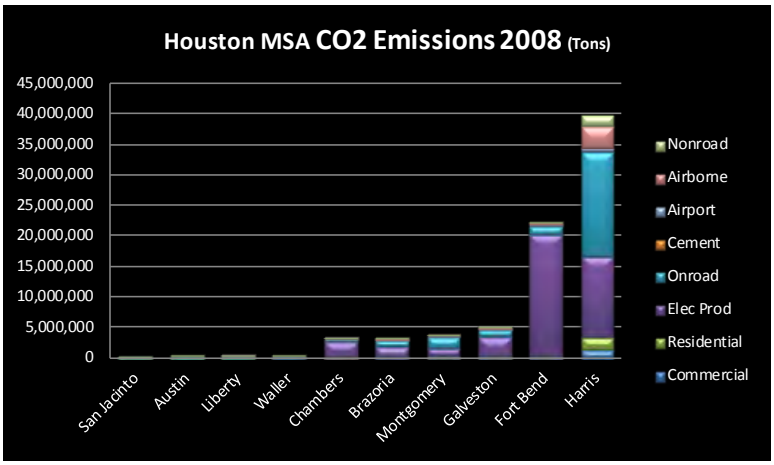
The following metrics were chosen to measure the indicator *Greenhouse Gas Emissions:*
Figure 46: Houston MSA CO2 Emissions 2000
Figure 47: Houston MSA CO_2 Emissions 2008
Figure 48: Harris County CO2 Emissions '00-'08



Source Gurney et.al (2009)

Figure 46: Houston MSA CO_2 Emissions 2000

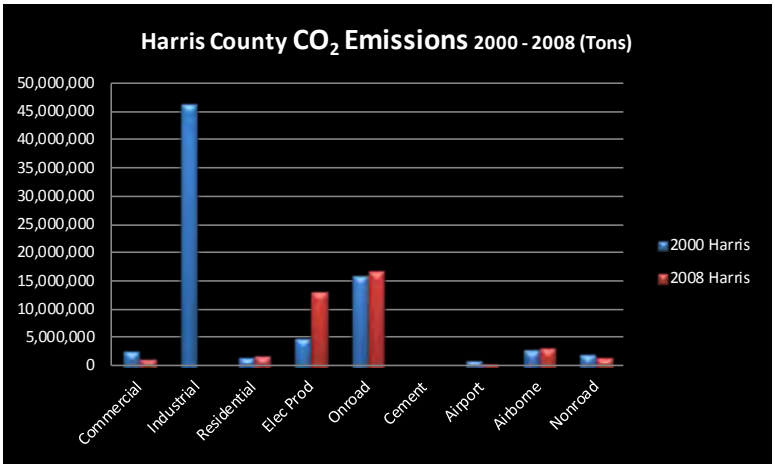
- In 2000, the total amount of CO_2 emissions produced in Harris County was 78,619,538 tons.
- Harris County led in terms of CO_2 production by about 4 times the next highest CO_2 producing county.
- In order of descending levels the top CO_2 producing counties following Harris County were; Austin, Fort Bend, Waller, Galveston, Montgomery, Brazoria, Liberty, San Jacinto and Chambers.
- In 2000, the industrial sector emitted more CO_2 than any other sector. On-road mobile sources in Harris County emitted the next highest amount of CO_2.
- Harris County industrial CO_2 emissions were more than the total emissions in every other county in the Houston MSA.



Source Gurney et.al (2009)

Figure 47: Houston MSA CO_2 Emissions 2008

- The above figure excludes industrial CO_2 emissions Harris County due to data inconsistencies from the source.
- With industrial CO_2 emissions removed, Harris County still led all the regions in the Houston metropolitan area.



Source Gurney et.al (2009)

Figure 48: Harris County CO2 Emissions '00-'08

- Industrial emission for Harris County far exceeds other emission sources.
- Commercial, airport, and non-road mobile sources (eg. Trains, barge traffic etc.) had reductions in CO2 emissions between 2000 and 2008.
- Electricity production had the highest increase in CO2 emissions, with a change from 5,047,991 tons to 13,283,754 tons between 2000 and 2008 respectively.

Theme - Freshwater
Sub Theme - Water Quality

Indicator - Water Pollution

There have been many improvements in the clean-up of **water pollution** and the safety of drinking water via sewage treatment plants and water purification. The primary focus has shifted from municipal and industrial dischargers to nonpoint source pollution. Approximately 60% to 70% of the water bodies in the country are impaired because of nonpoint sources (Randolph, 2004). Most streams and bayous in Houston violate the standard for bacteria possibly due to the large number of wastewater treatment plants that discharge into waterways (Blackburn, 2011).

Research shows that several types of pollutants are not removed with traditional biological treatment technology. These include anti-depressants, estrogen-containing compounds, and sophisticated chemicals used in soaps.

Sustainability Benefit: The City of Houston is in attainment for all known federal standards for drinking water quality.

Sustainability Issue: The process of using exposed surface water and treating it to drinking quality standards increases the likelihood that users may become exposed to contaminants due to system errors. Source protection of reservoirs should be priority. Houston's drinking water was reported to contain and was treated for 46 chemical contaminants between 2004-2008, including Benzene, Atrazine, Acetone and Dibromochloromethane (Environmental Working Group, 2009). There are no federal standards for emerging contaminants from pharmaceuticals, pesticides, waterborne pathogens or biological toxins.

The following metrics were chosen to measure the indicator *Water Pollution:*
Figure 49: COH Drinking Water Quality 2000-2010

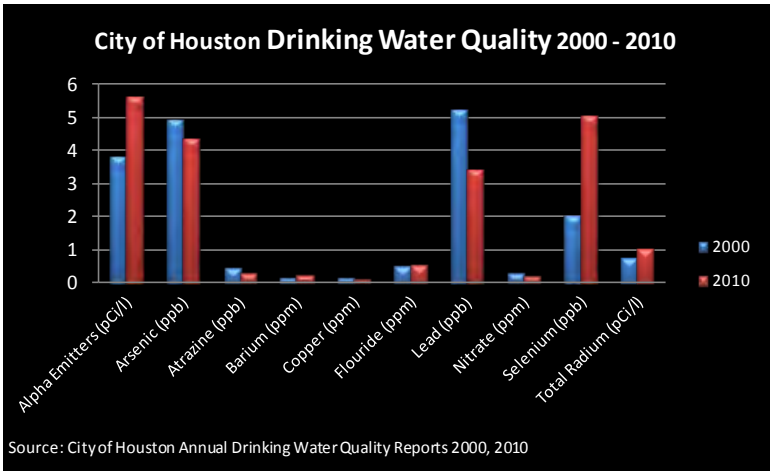


Figure 49: COH Drinking Water Quality 2000-2010

- This figure shows that levels of contaminants generally decreased between 2000 and 2010, with the exception of Alpha Emitters, Barium, Flouride, Selenium, and Radium.
- All chemicals reported were below the Maximum Contaminant Level (MCL) set by the EPA.

Theme - Freshwater

Sub Theme - Water Demand

Indicator - Water Use

In 2000 and 2006 the City of Houston Municipal **water use** was 347,947 and 346,393 acre-feet respectively. Harris County excluding Houston uses approximately 250,000 acre-feet per year for municipal purposes. Dow Chemical Company and Reliant Energy Company hold fresh water permits in the region in the amounts of 321,856 and 166, 238 acre-feet per year respectively. Four industrial companies, including Dow and Reliant, which hold manufacturing water rights, are dedicated almost 670,000 acre-feet per year of the region's water supply. This is in addition to another 580,000 acre-feet sold to other manufacturing companies in 2006. The total municipal water demand for of Region H was 865,966 acre-feet in 2006 (Region H Water Planning Group, 2010). These three users constitute three of the largest municipal and industrial users in the region. The region consists of all or part of 15 counties: Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Leon, Liberty, Madison, Montgomery, Polk, San Jacinto, Trinity, Walker and Waller.

Sustainability Benefit: Water use per capita has decreased over time.

Sustainability Issue: Large quantities of water, treated to drinking standards, is used for lawn irrigation in Houston.

The following metrics were chosen to measure the indicator *Water Use*:

Figure 50: Water Use per Capita

Figure 51: Harris County Water Demand

Figure 52: Harris County and Houston Municipal Water Demand

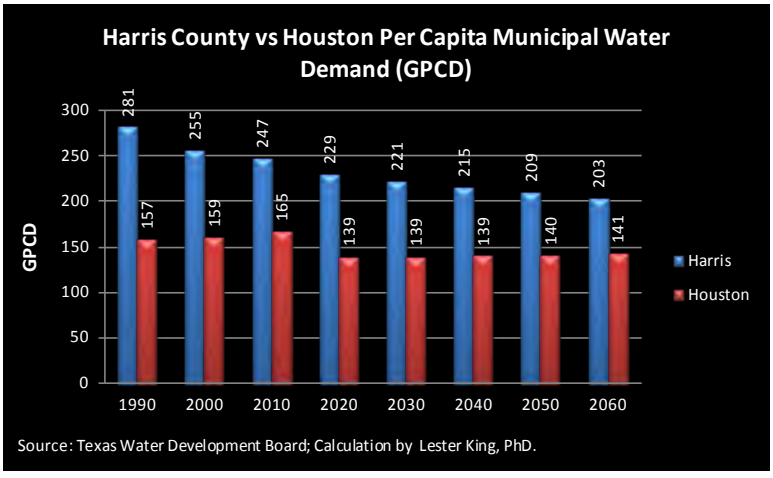


Figure 50: Water Use per Capita

- In 1990 the total amount of municipal water used was 286,550 acre feet of water (157 gallons per capita per day (GPCD)) in the City of Houston. In 2000 347,947 acre feet of water (159 GPCD). In 2010 389,082 acre feet (165 GPCD).
- The projections for 2020 to 2060 estimate water demand will be reduced to 139 GPCD for 2020 – 2040, and then increase by one GPCD between 2050 and 2060.
- The projected water demand in acre feet was extracted from the 2011 Regional Water Plan. The population projection used in that analysis was a linear projection based on 1990 – 2010 census data. This projection is not consistent with intercensal data and may need to be addressed by the Region H Water planning group.

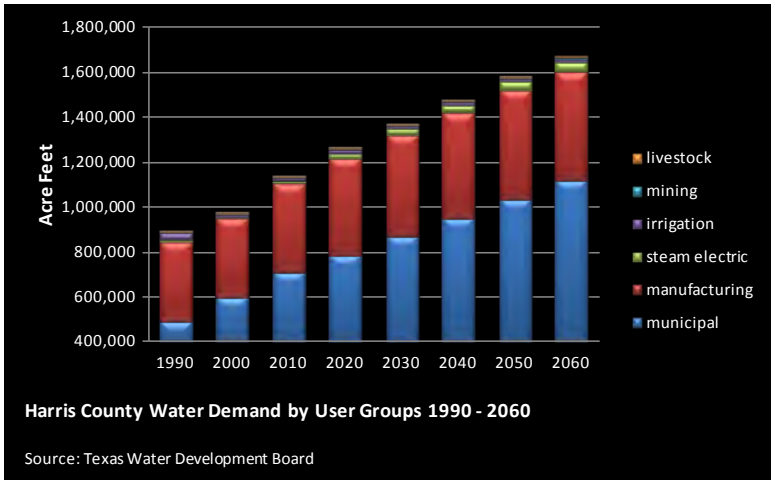


Figure 51: Harris County Water Demand

- Municipal and manufacturing users constitute the largest water user groups in Harris County. Other water user groups such as livestock, mining, irrigation for agriculture, and electricity production use less water.
- Manufacturing demand will remain roughly the same over the next few decades, municipal demand will double over 2000 levels by 2060. By 2060 the municipal water demand will be 1,119,592 acre feet per year.

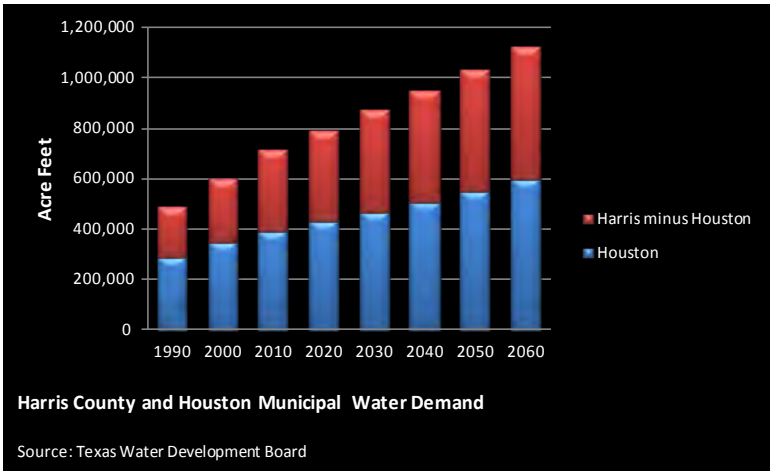


Figure 52: Harris County and Houston Municipal Water Demand

- More municipal water is used within the Houston city limits than in the rest of Harris County.
- In 2010 City of Houston municipal water demand was 389,082 acre feet and for Harris County, outside of Houston, was 320,218 acre feet.

Theme - Freshwater
Sub Theme - Water Resources

Indicator - Water Availability

Water resource planning for the City of Houston is conducted at the regional level by state mandate. Houston is in the Region H water planning group, which is one of 16 regional water planning districts in the state that develops water plans every 5 years. Region H is composed of fifteen counties in southeast Texas and includes the San Jacinto River basin, and the lower reaches of the Brazos and Trinity River basins. Region H contains two thirds of all U.S. petrochemical production and almost one third of the petrochemical industries in the country. These industries consumer large amounts of water. Population is projected to grow from 6 million in 2010 to 11.3 million in 2060. Water demand is projected to grow from 2.38 million acre-feet per year in 2010 to 3.52 million acre-feet per year by 2060. Almost half of the total water demand in the region is from Harris County. The City of Houston is the water provider for Harris County and portions of seven surrounding counties (Region H Water Planning Group, 2010).

Water availability is important for our present daily personal and economic development needs. It is also important to the natural environment, since several ecologies depend on regular stream flows. For example, stream flows into Galveston and contiguous estuaries, significantly influences these ecosystems. In 2011, the City of Houston agreed to dedicate approximately 300,000 acre feet of treated sewage return from Buffalo Bayou to Galveston Bay (Blackburn, 2011).

Sustainability Benefit: We have the financial resources necessary to invest in infrastructure to deliver water from new sources to our city. The regional water plan identifies $12 billion in capital costs for water planning strategies (Region H Water Planning Group, 2010).

Sustainability Issue: We are dependent on surface water sources since land subsidence from groundwater extraction is an issue (Hight, Anderson, Robinson, & Wallace, 2011). The City of Houston is responsible for providing water to surrounding cities. The issue here is that with the city acting both as consumer and commercial supplier, there may be the complication of reducing demand for this scarce resource and increasing sales income.

The following metrics were chosen to measure the indicator *Water Availability:*
Figure 53: Houston Region Water Supply
Figure 54: Houston Region Water Demand vs Supply

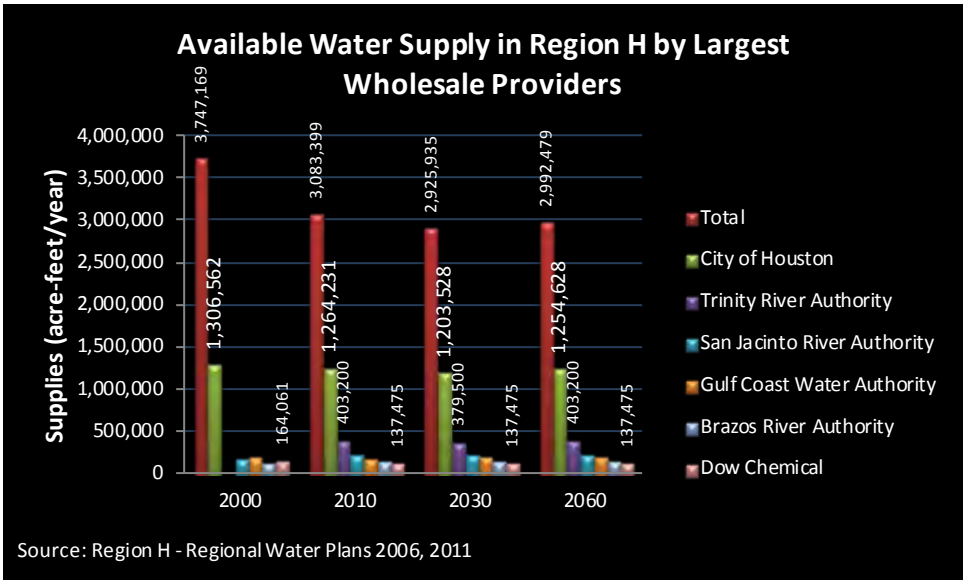


Figure 53: Houston Region Water Supply

- The City of Houston is the largest wholesale water provider in the region and has an estimated 1.8 billion gallons of water per day of availability (Chang, 2012). This is a little less than half of the total available water supplies in the region.
- There are 24 other water providers in the region who have 2,440,607 acre-feet/year of water.

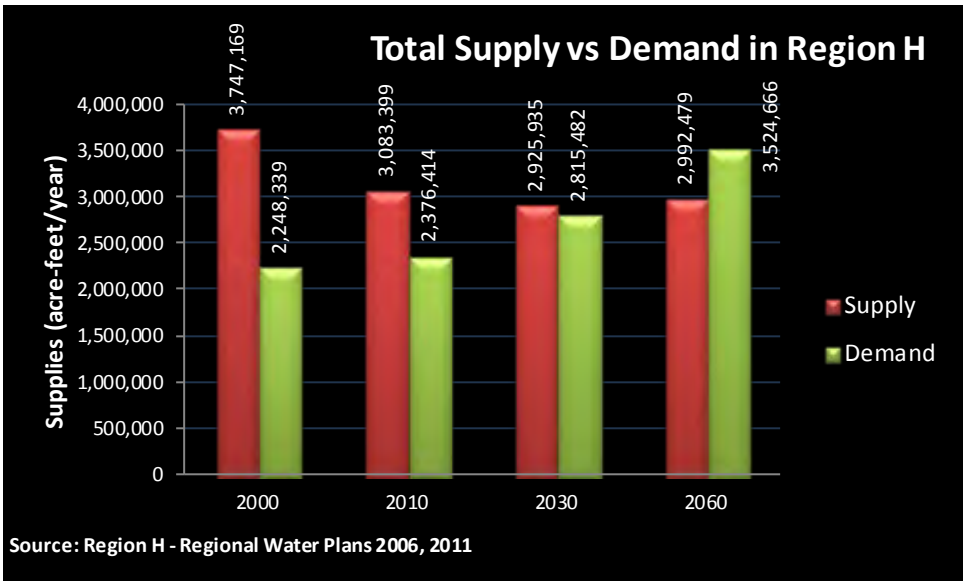


Figure 54: Houston Region Water Demand vs Supply

- The total supply of water in the Houston region was 3 million acre-feet/ year in 2010. This supply will drop slightly below 3 million acre-feet/year by 2060. At the same time the demand is expected to increase to 3.5 million acre-feet/year so there is a shortfall in the region for water availability in 2060.
- Over time water demand in the region is increasing, while water supply is decreasing. The regional water plan identifies $12 billion in capital costs for necessary water planning strategies (Region H Water Planning Group, 2010).

Theme - Land

Sub Theme - Flooding

Indicator – Flood Plain Expansion

Flooding is a major issue in the city and the floodplain is increasing as a result of increased development. In Harris county, the floodplain increased by 65 square miles between 1996 and 2007 (Blackburn, 2011). According to the Harris County Flood Control District (HCFCD), 65% of the area in Harris County that flooded during Tropical Storm Allison was outside of the mapped regulatory floodplain (Harris County Flood Control District, 2004).

Sustainability Benefit: The delineation of the 100-year floodplain is a good estimate to identify areas at risk of flooding.

Sustainability Issue: Increasing the amount of impervious paving in the city also increases the amount of stormwater runoff and hence exacerbates flooding.

The following metrics are used to measure the indicator *Flood Plain Expansion*:
Houston floodplain expansion

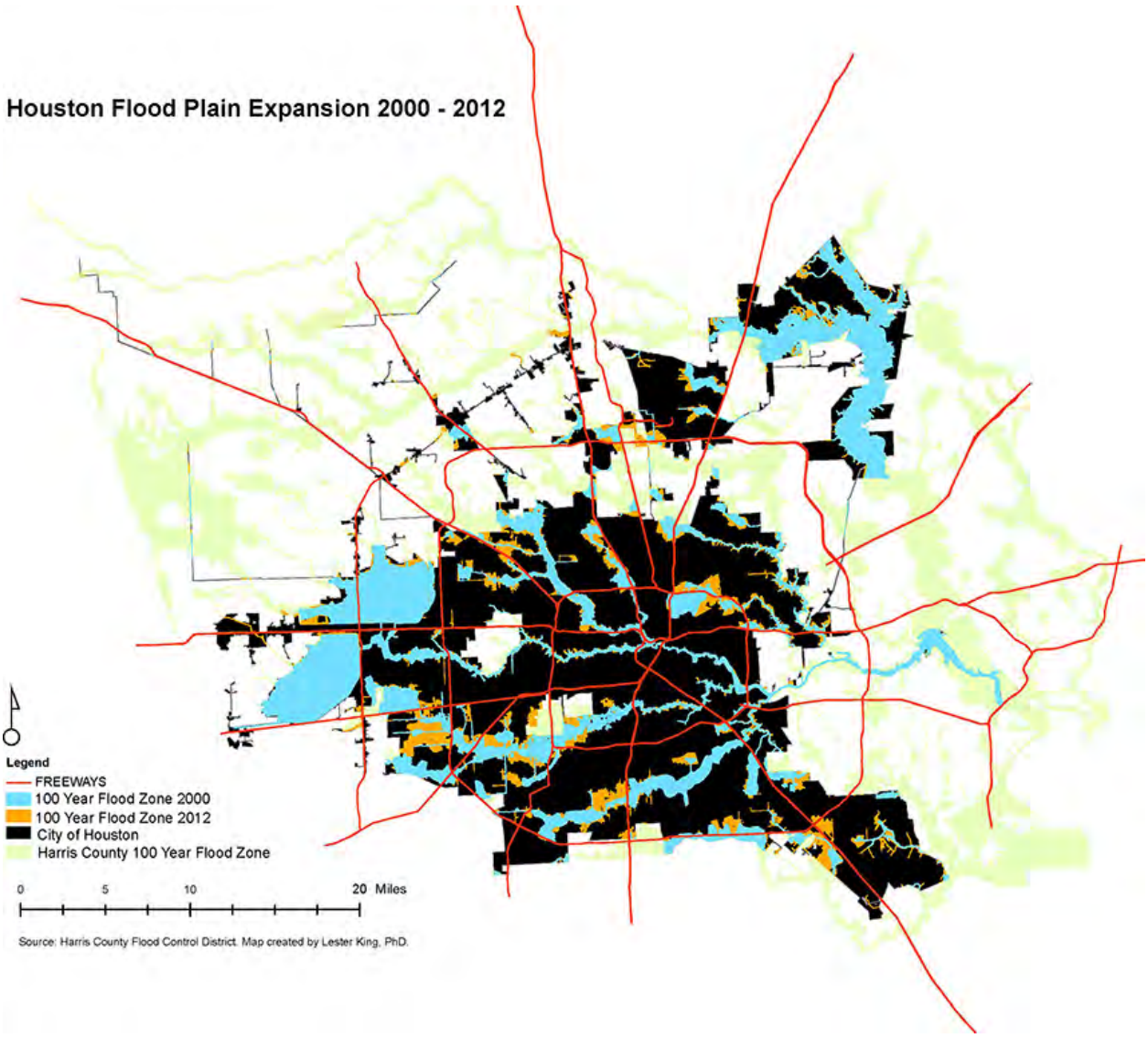


Figure 55: Houston floodplain expansion

- The 100 year floodplain expanded from 24% to 25.5% of the City of Houston, between 2000 and 2012.
- The 100 year floodplain expanded by 11,375 acres (18 sq mi) between 2000 and 2012.
- An estimated 17% (364,497) of Houstonians live within 25 feet of the 100 year floodplain.
- An estimated 148,853 housing units are within 25 feet of the 100 year floodplain. Using the Census 2010 median housing value estimate of $124,700 in Houston, this gives the estimated value of $18.5 billion for housing units within 25 feet of the 100 year floodplain.

Theme - Land
Sub Theme - Land Cover

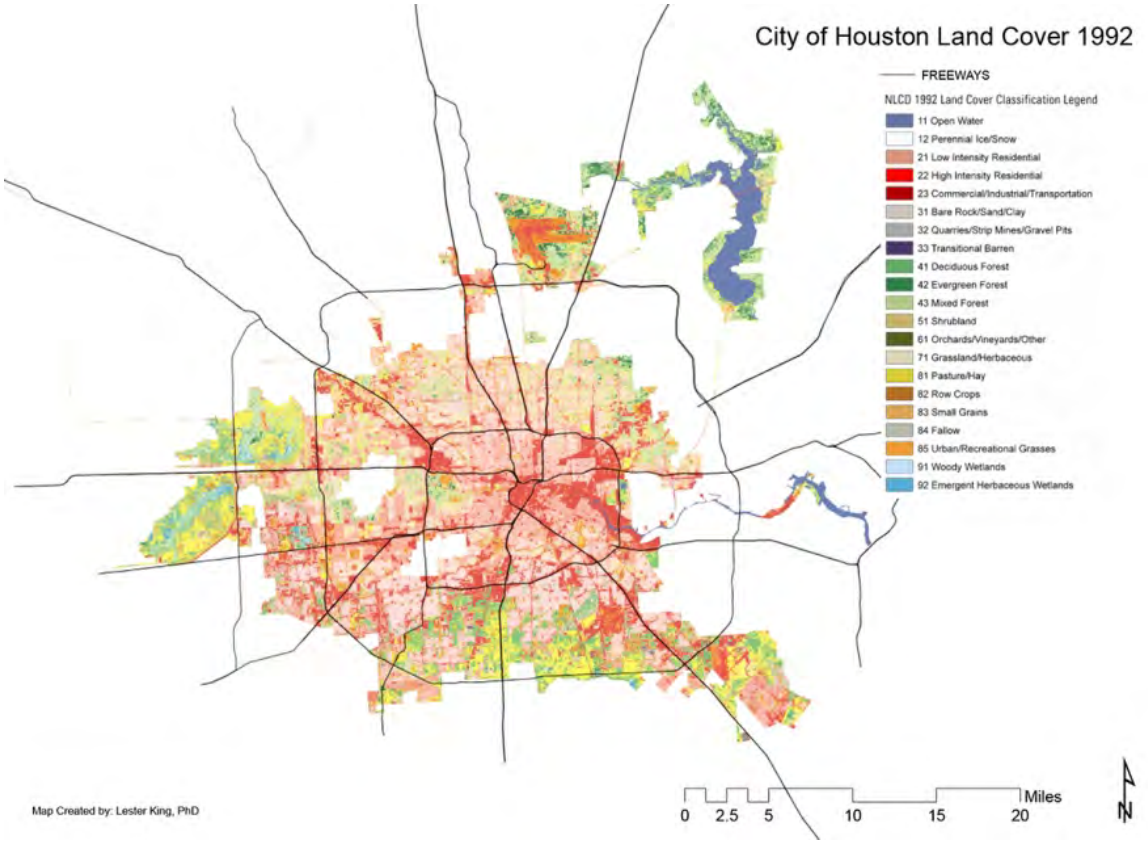
Indicator - Land Cover Change

During the period 2000 to 2025, if development practices remain the same, the United States is expected to lose 7 million acres of farmland and 7 million acres of fragile lands to real estate development (Burchell, Downs, McCann, & Mukherji, 2005). **Land cover** is constantly changing in the city and surrounding region. Despite the traditional definition of Houston as a sprawling city because of its large land area, Houston has more recently been described as an 'Opportunity City' because it has an openness to outsiders; a diverse and entrepreneurial economy; a friendly business climate; commitment to transportation infrastructure; and a positive attitude towards growth (Kotkin, 2007). The Houston transportation region is composed of 13 counties. In a 2005 analysis of ecosystems in the 8 most central counties, there has been a loss of up to 40% of some ecosystems to development. The analysis shows there has been a loss of 25% of Big Thicket, 14% of Coastal Marshes, 21% of Columbia Bottomlands, 31% of Piney Woods, 16% of Post Oak Savannah, 40% of Coastal Prairie, and 11% of Trinity Bottomlands ecosystems (Blackburn, 2011).

Sustainability Benefit: Houston is a large city capable of absorbing a lot of growth and development.

Sustainability Issue: Growth and development does not maximize land utility since most development in the city has single story buildings. As a result more open space and natural areas are developed and commuting distances increased.

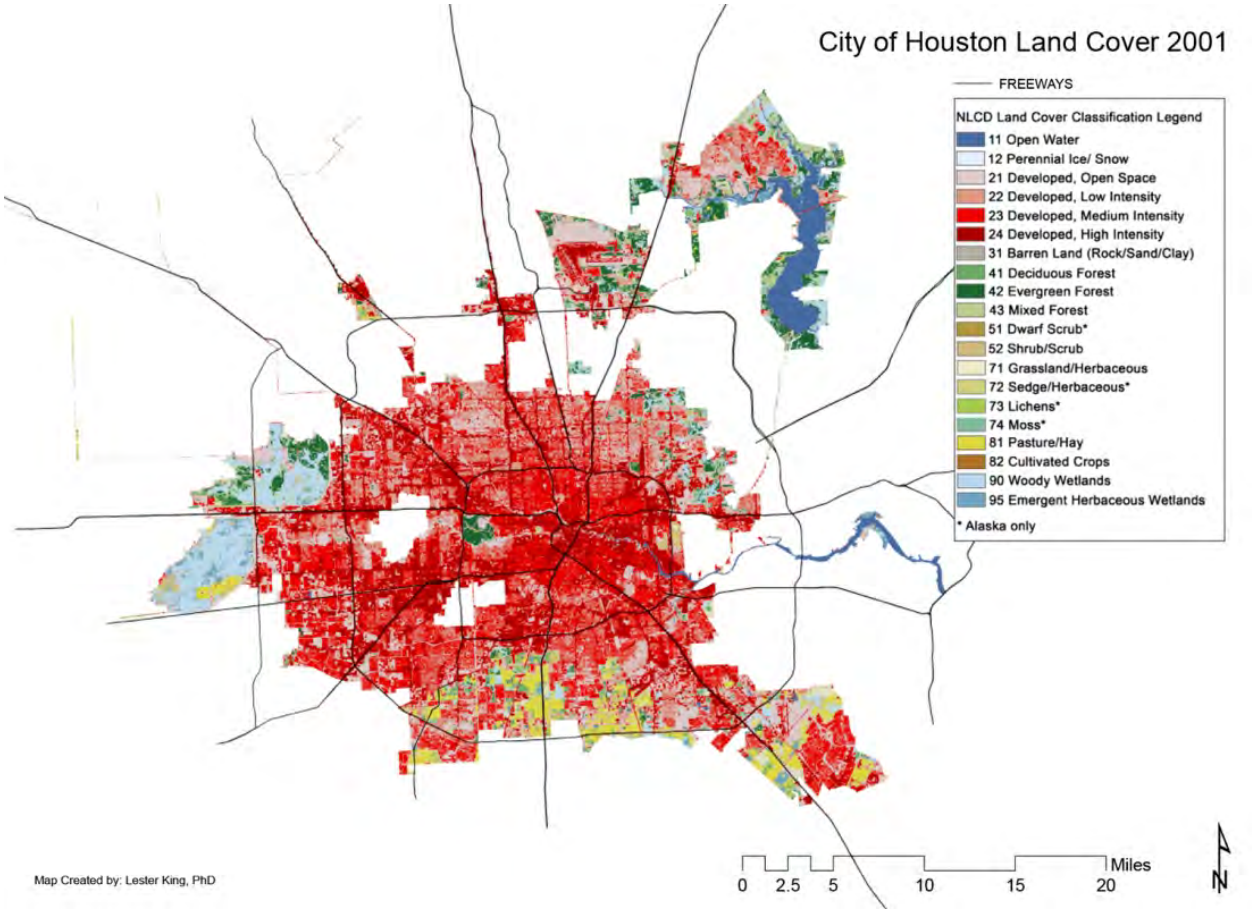
The following metrics were used to measure Land Cover Change:



Source: US Department of the Interior – USGS

Figure 56: City of Houston Land Cover 1992

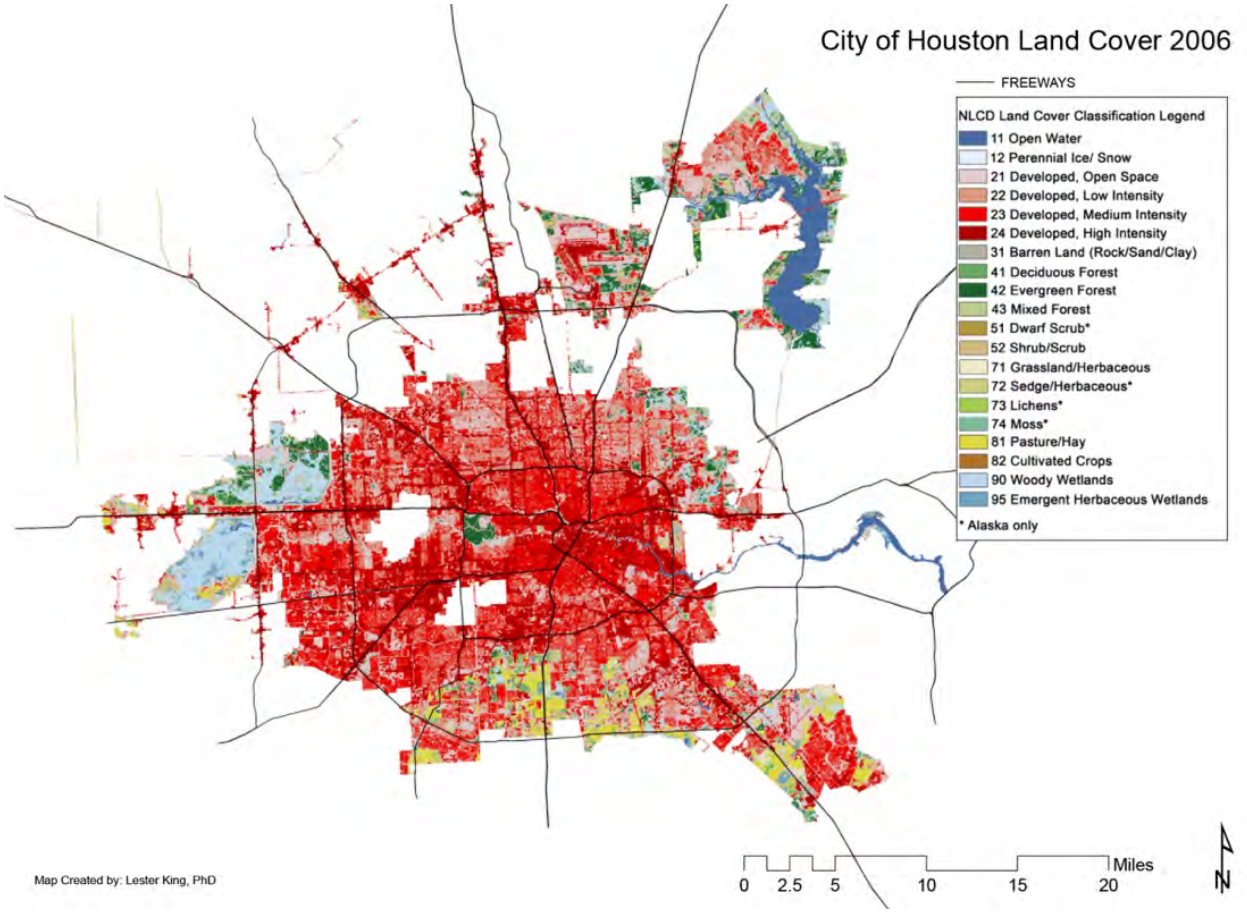
- The map shows land cover complexity in Houston.
- There are several areas to the south, north-east and west of the city with undeveloped land but most of the City is covered by low-intensity residential uses.



Source: US Department of the Interior – USGS

Figure 57: City of Houston Land Cover 2001

- This map shows that most of the City of Houston is covered with low and medium intensity development. Low intensity areas are described as areas with a mixture of constructed materials and vegetation and with impervious surfaces covering 20 – 49% of total land cover. Medium intensity areas have 50 – 79% impervious surface cover.
- Single family housing units are allocated to either the low-intensity or the medium-intensity areas.



Source: US Department of the Interior – USGS

Figure 58: City of Houston Land Cover 2006

- The 2006 land cover map is almost identical to the 2001 land cover map except it shows the newly annexed areas to the north-west and west of the city as being areas of predominately high to medium intensity development.

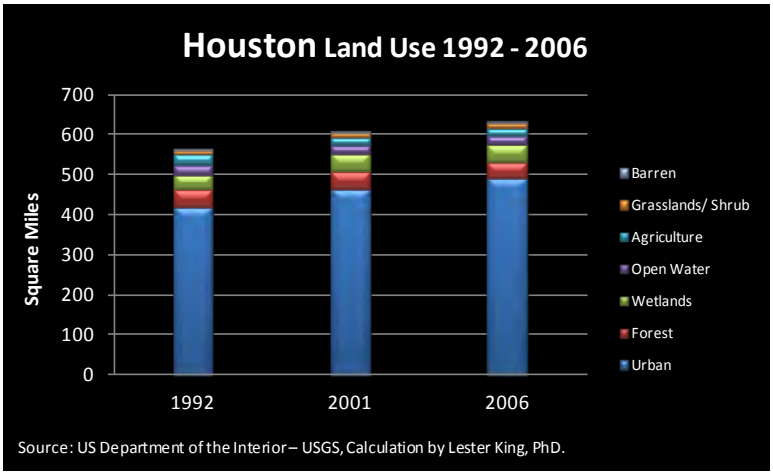


Figure 59: Houston Land Cover 1992 – 2006

- Data classification of the land cover in Houston shows the degree of land cover change between 1992 and 2006. All land uses remains virtually the same over time except for urban land use. Urban is here defined as all developed areas with constructed materials.
- Wetlands and forests actually constitute the next largest land coverage types in the City of Houston.
- 78% of Houston was urbanized in 2010 (491 acres).

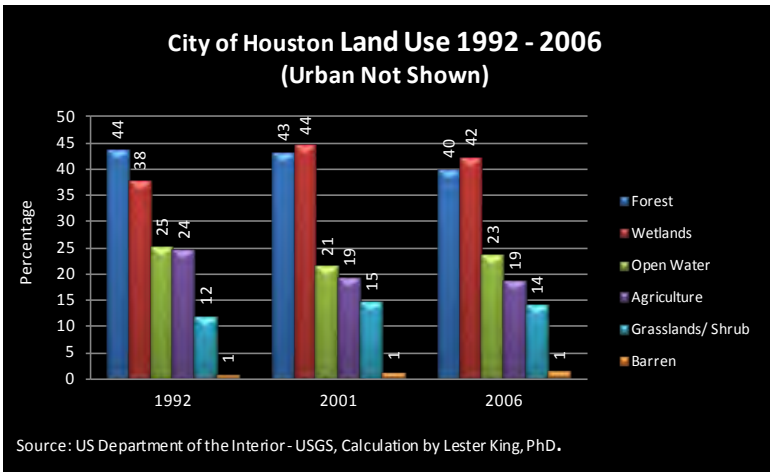


Figure 60: Houston Land Cover 1992 - 2006 (Urban Not Shown)

- The above map shows a comparison of smaller land coverage types in Houston excluding urban land use.

- This figure shows that Forests were the dominant type in 1992. This land use then gave way to Wetlands which increased by 2001 to be the second most common type of land with urban land being dominant.
- Agricultural land is decreasing in the City of Houston. It has decreased at a very slow rate through, between 2001 and 2006.

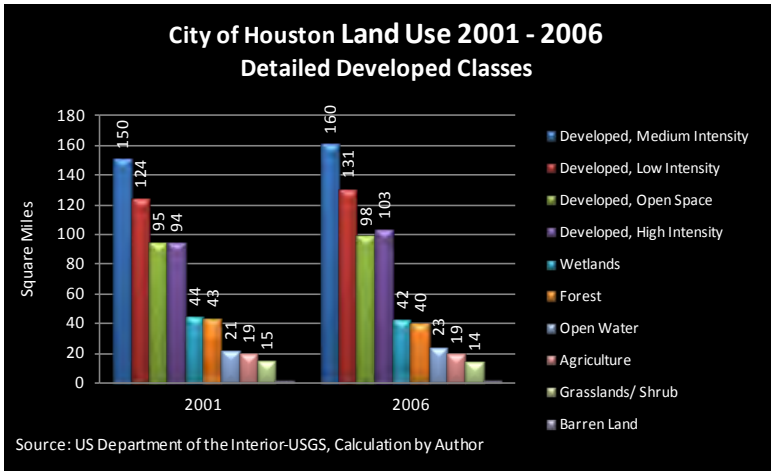


Figure 61: Houston Land Cover 2001 – 2006

- Between 2001 and 2006, medium Intensity development was the highest form of land coverage. Medium Intensity development increased from 150 square miles to 160 square miles.
- High intensity development and developed open space changed little between 2001 and 2006.
- 291 acres was medium to low intensity development in 2006 (46%).
- High intensity development was 16% of the urbanized area in 2006 (103 acres).

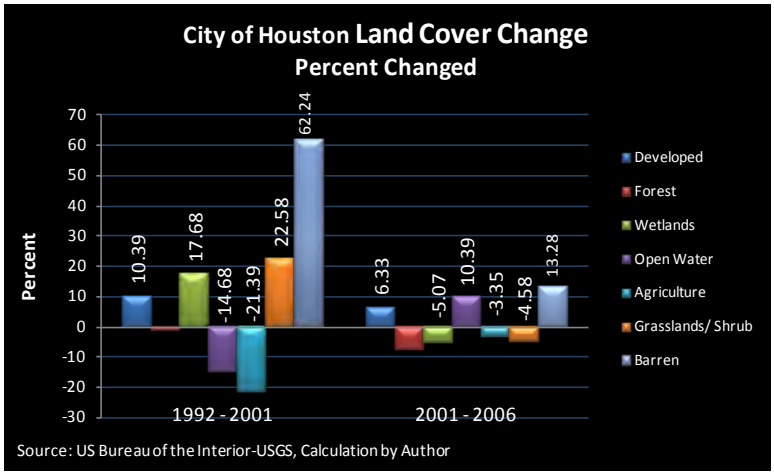


Figure 62: Houston Land Cover Change 2001 - 2006 Percent Change

- Between 1992 and 2001 there was greater change in land cover than between 2001 and 2006.
- The largest changes between 1992 and 2001 were: a 62% increase in barren land cover; a 22% increase in grasslands; and a 21% decrease in agricultural land. Developed land increased by 10%
- The largest change between 2001 and 2006 was a 13% increase in barren land and a 3% decrease in agricultural land.

Theme - Land
Sub Theme - Classification

Indicator - Jobs/ Housing Balance

Sprawl can be described as the separated spread-out development practice that has dominated suburban development over the last 60 years. The **Jobs/ Housing balance** is a focus on the supply of housing in proximity to jobs. The ideal Jobs/Housing balance is one that offers access to various types of housing such as single family, duplexes, and multifamily housing in walking distance to jobs. The Jobs/Housing balance alludes to the importance of mixed-use developments where access to schools, services, entertainment, jobs and housing is made possible (Burchell, Downs, McCann, & Mukherji, 2005). For sustainable development, should companies be encouraged to locate in existing business centers or should we let the market decide? In a survey of Harris County residents in 2010, 80% called for redevelopment of older urban areas for mixed use development (Klineberg, 2010). However in a 2005 survey, Anglos preferred neighborhoods that do not have high percentages of African American or Hispanic people (Klineberg, 2005) This complicates the location theory of maximizing income to find housing close to jobs and factors most important in individuals choice of housing location. It also explains why some inner city neighborhoods such as the Houston Third Ward and parts of the Fifth Ward still have large supplies of vacant and underused property, despite their close proximity to the central business district.

Sustainability Benefit: Houston has a very efficient freeway system which connects most areas of the city to employment centers very efficiently.

Sustainability Issue: Less than 25% of Houstonians live within a quarter mile of high density business centers.

The following metric were used to measure *Job / Housing Balance:*

Figure 63: Houston Business Centers
Figure 64: Houston Jobs/ Housing Balance

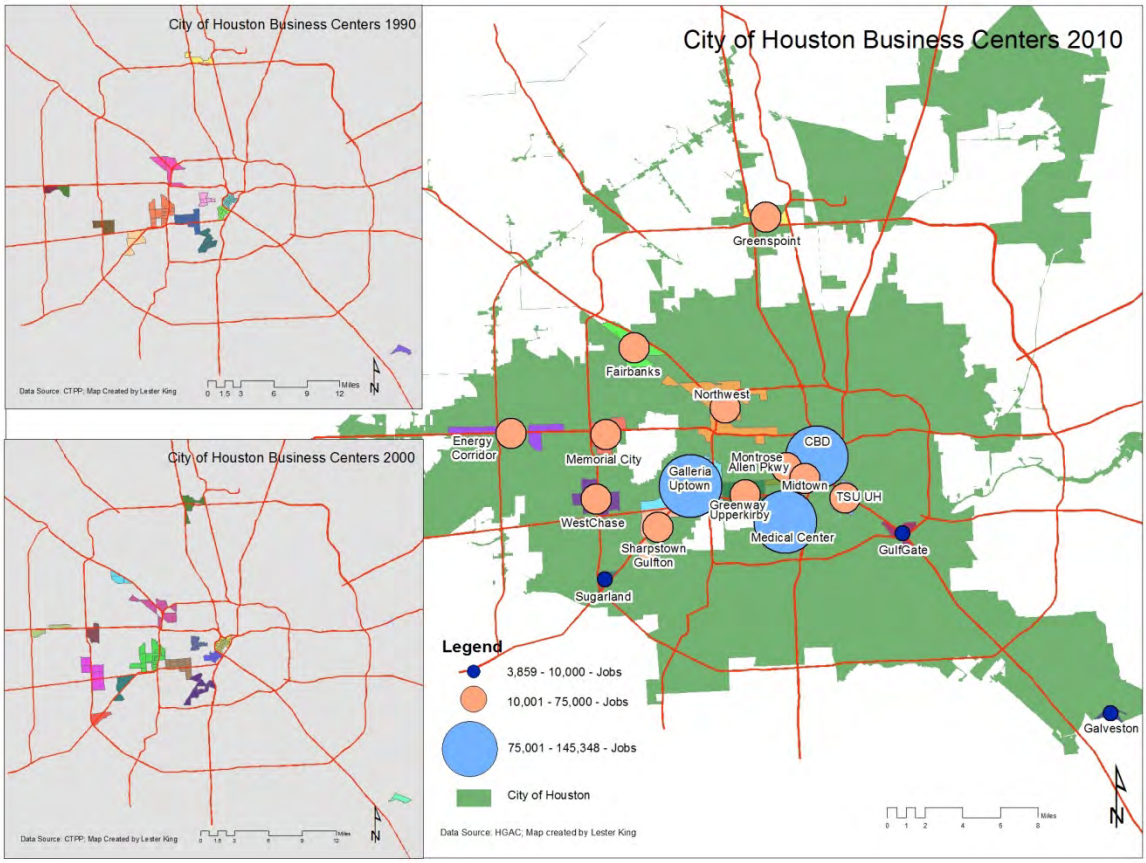


Figure 63: Houston Business Centers

- This map shows the location of business centers in Houston from 1990 – 2000. These business centers are defined primarily as places with a high density of jobs (Greater than 10 per acre within transit analysis zones (TAZs) and clusters of such high density TAZs with more than 10,000 jobs). In most cases the actual boundaries of the business center will be larger than depicted and contain more jobs than reported. This analysis only reports jobs in the high density areas.
- In 1990 there were 12 business centers; in 2000 there were 15 business centers; in 2010 there were 17 business centers (Due to reclassification of TAZs by HGAC and based on their 2010 job projection numbers, Sugarland, Gulfgate, and Galveston show less than 10,000 jobs in the areas selected).
- Downtown, the Galleria, and the Medical Center show the highest concentration of jobs in the City of Houston with more than 75,000 jobs.

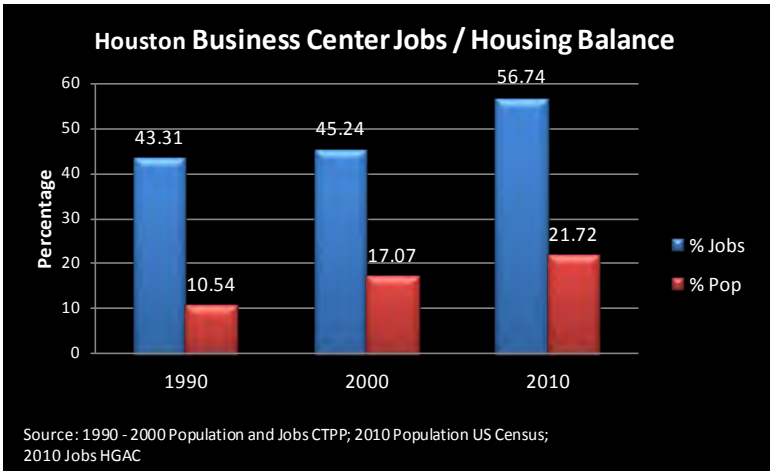


Figure 64: Houston Jobs/ Housing Balance

- The percentage of persons and jobs located close to high density business centers in Houston is increasing.
- Between 1990 and 2010, the percentage of jobs located in high density business centers increased by 13%.
- From 1990 to 2010 the percentage of persons that reside within a quarter mile of high density business centers more than doubled from 10% to 22%.
- Less than 25% of Houstonians live within a quarter mile of high density business centers.

Environmental Development Policy Recommendations

THEME – Atmosphere

Sub Theme – Air Quality: Indicator – Ambient Pollutants

- **Expand the air quality monitoring network**.
- **A Gulf Coast Mobility Plan is needed** for coastal cities along the gulf since the efficient delivery of logistics reduces air pollution generated from this sector.

Sub Theme – Climate Change: Indicator – Greenhouse Gas Emissions

- **A Climate Vulnerability Assessment and Adaptation plan is needed** for the entire city and not just city operations.

THEME – Fresh Water

Sub Theme – Water Quality: Indicator – Water Pollution

- **Expanded monitoring and enforcement of the waste water treatment plants.** Present monitoring of the discharges into surface streams is unsatisfactory.
- The City of Houston meets all known federal standards for drinking water treatment. However **emerging and unregulated contaminants are not addressed under federal standards** and as we continue to rely more heavily on surface water risks of exposure are increasing.

Sub Theme – Water Demand: Indicator – Water Use

- A strong **Drought Contingency Plan** is needed and **public education campaign.**
- Need **better assessment of end user water demand** such as landscape irrigation.
- Need to establish a city **Water Vulnerability Tax**.

Sub Theme – Water Resources: Indicator – Water Availability

- Our dependency on surface water increases our vulnerability to drought.

THEME – Land

Sub Theme – Flooding: Indicator – Floodplain Expansion

- Need to accelerate **conversion of property in floodplains to open space**.
- **Eliminate development in the floodplain.**

Sub Theme – Land Cover: Indicator – Land Cover Change

- **Stronger policies for green space acquisition are needed.**

Sub Theme – Land Classification: Indicator – Jobs/Housing Balance

- **Development codes are not robust enough to increase livability** in the city.
- The development codes should include elimination of minimum lot sizes or setbacks; complete streets; encouraging housing closer to job centers etc.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