Local Impacts Complete Report

Many communities are trying to assess the impacts climate change will have or is currently having at a local level. Several coastal communities have performed in depth studies of population displacement and infrastructure losses due to sea level rise. Other communities have focused on public health issues. In some cases climate change impacts have already been observed and are being measured. Commonly, predicted impacts must be estimated from the analyses of available standard climatological data in conjunction with well established relationships between the local climate and various impact sectors.

3.1 Louisville Metro's Climate History and Predicted Changes

The full report linked at the end of Climate History section.

3.2 Sector Impacts and Recommendations

3.2. 1 Public Health

There is widespread scientific consensus that over the next century increasing global temperatures will result in greater variation in weather related events such as increased heavy precipitation, flooding, droughts, and increased frequencies of heat waves. While the impact of these events will vary in intensity across different geographic regions each has the potential to negatively impact human health in Louisville. The types of health impacts include not only disease and injury, but also impacts implicit in the World Health Organization (WHO) definition of health: 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'.

Health impacts associated with climate change can be either direct or indirect. Direct impacts are those related to local climate changes, such as increased mortality associated with heat waves. Indirect impacts result from events occurring remotely but which may have a local impact, such as crop failures from droughts impacting the availability of food locally.

Projected Impacts Related to Climate Change Include:

1. Injuries and fatalities related to heat waves;
2. Allergic illnesses related to increased allergen production;
3. Respiratory and cardiovascular disease related to worsening air pollution;
4. Injuries and fatalities related to extreme weather events; and
5. Infectious diseases related to changes in pathogen and vector distribution;

Injuries and Fatalities Related to Heat Waves:

Climate related increases in temperature are likely to cause increases in the frequency of heat waves. Health effects associated with heat waves will occur primarily in the summer, but with increasing temperatures may extend later into the fall or occur earlier in the spring. Because of the heat island effect, the impacts will likely be greater in urban areas than in surrounding suburban and rural areas. Most of the excess mortality (death) and morbidity (disease) associated with heat waves will be related to cardiovascular, cerebrovascular, and respiratory disease outcomes and will be concentrated in the elderly, the poor, and other vulnerable populations. In addition to health impacts, increased frequency and intensity of heat related events can affect worker productivity which may impact the population's social well being. Preparedness planning can be used to develop and implement adaptive strategies, which at a minimum would include a heat stress action plan that includes targeted interventions for high risk groups.

Recommendation 1:

> *Collaborate on preparedness planning used to develop and implement adaptive strategies, which at a minimum would include a heat stress action plan that includes targeted interventions for high risk groups.*

Allergic Illnesses Related to Increased Allergen Production:

Increased temperatures may increase the incidence of respiratory illness related to airborne allergens. Increased levels airborne allergens are likely to result from changes in the length of the growing season and from changes in types of plants that grow in region. Health impacts associated with increased levels of airborne allergens include both the development of new cases of allergic illnesses (asthma) as well as the exacerbation of existing cases of allergic illnesses with the largest impact during the spring, summer, and fall growing seasons. To address these impacts, asthma action plans that monitor changes in asthma incidence, utilize strategies to enhance adaptation to changes in airborne allergen levels, and provide educational messages for both susceptible persons and professional health care providers will be needed.

Recommendation 2:

> *Collaborate on asthma action plans that monitor changes in asthma incidence, utilize strategies to enhance adaptation to changes in airborne allergen levels, and provide educational messages for both susceptible persons and professional health care providers*

Respiratory and Cardiovascular Disease Related to Worsening Air Pollution:

Levels of specific air pollutants such as ground-level ozone and fine particulates may also increase during heat waves. While these pollutants can affect the general population, sensitive groups such as the elderly, the young, and those with pre-existing disease will be disproportionally affected and suffer the most severe health effects. Maintenance of existing strategies for managing air pollution and implementation of new control strategies as they become available will be needed to mitigate the health impacts of increases in air pollution. Additionally, adaptation strategies that ensure that persons at risk are identified and that effective intervention programs are available will be needed to reduce the impacts of air pollution on vulnerable populations.

Recommendation 3:

Support the maintenance of existing strategies for managing air pollution and the implementation of new control strategies as they become available.

Recommendation 4:

Develop adaptation strategies that ensure persons at risk are identified and that effective intervention programs are available to populations vulnerable to poor air quality.

Injuries and Illnesses Related to Severe Weather Events:

Severe weather events can results in a variety of adverse health impacts, ranging from immediate effects including physical injury (i.e. accidents) to increases in disease morbidity (e.g. respiratory disease associated with mold contamination). In addition to these effects there is the potential that such severe weather events can have effects on mental health that translate into poor health outcomes. While severe weather events have the potential to impact all persons, sensitive groups and those of lower socio-economic status are likely to be more vulnerable due to differences in their ability to adapt. Maintenance and adaptation of the existing preparedness infrastructure offers the best strategy of managing severe weather related health impacts.

Recommendation 5:

Support the maintenance and adaptation of the existing preparedness infrastructure. This offers the best strategy of managing severe weather related health impacts.

Infectious Diseases Related to Changes in Disease Vector Distribution:

Climate change will affect the geographic distribution disease agents and vectors and affect the potential incidence of waterborne, food borne, and vector borne diseases. Even small increases in distributions of vectors and associated disease agents may mean that the newly exposed populations lack acquired immunity, which can result in more serious clinical disease. The transmission of such diseases is also affected by socioeconomic conditions and will have a disproportionate impact on vulnerable populations. The impact of changes in vector distribution and the introduction of new pest agents can be limited through the effective maintenance and minor modification of robust public health programs. Such programs, which include existing disease surveillance and vector control programs, may need modification to assure that emergence of new diseases or vectors can be detected and appropriate programs implemented.

Recommendation 6:

Limit the impact of changes in vector distribution and the introduction of new pest agents through the effective maintenance and minor modification of robust public health programs. Such programs, which include existing disease surveillance and vector control programs, may need modification to assure that emergence of new diseases or vectors can be detected and appropriate programs implemented.

Indirect Health Impacts:

Data to support projections of indirect health impacts are less available and uncertainties are greater. The following lists several possible impacts of climate change that have indirect impacts on health.

- Changes in the distribution and abundance of plant and livestock pests and diseases, affecting agricultural production;
- Increased probability of crop failure through prolonged dry weather and famine;
- Increased population displacement due to natural disasters, crop failure, water shortages; and,
- Destruction of health infrastructure from natural disasters.

While these types of impacts may have local health consequences, their greater local health impact may be mental health consequences from regional, national, and global effects from population dislocation and civil conflict.

References:

1. Paul R. Epstein, Climate Change and Public Health: Emerging; Infectious Diseases Encyclopedia of Energy, 2004: (1)381-392.
2. Haines, A. and J. Patz, Health Effects of Climate Change, JAMA, January 7, 2004, 291(1): 99-103.
3. A Haines, R S Kovats, D Campbell-Lendrum, C Corvalan; Climate Change and Human Health: Impacts, Vulnerability, and Mitigation, Lancet 2006; 367: 2101–09.
4. H Frumkin, J Hess, G Luber, J Malilay, and M McGeehin; Climate Change: The Public Health Response, Am J Public Health. 2008; 98:435–445.

3.2.2 Impacts on Biodiversity

The effects of temperature and precipitation are key elements in determining the species present in any ecosystem. All organisms, including micro-organisms, plants and animals, have both temperature and moisture thresholds that limit the environment that they can survive in. Over long, geologic timescales, some species are capable of adapting to changes in the environment. The current trends of climate change (lower minimum temperature, higher average temperature, and more extreme rainfall events) show strong increases over the last 50 years that have implications for species unable to adapt to this comparatively rapid environmental change.

Biodiversity in general is being affected in the following ways:

- Life cycle timing
- Migration/hibernation timing and patterns
- Frequency and intensity of pest outbreaks
- Geographic range of location
- Increased susceptibility to invasive/exotic species

Many species of both plants and animals control their life cycles with responses to temperature and moisture. Thus, when temperatures reach a certain point, reproduction may begin or larval stages may metamorphose into adult stages. These key cycles respond directly to changes in temperature and moisture as these cues have been closely associated with season and food availability for many species.

The timing of migration of many species is also based on temperature changes. The alteration of temperature regime (higher minimum temperature, higher average temperature) in the Louisville metro area may impact species that require significant periods of time to reach feeding, mating, and/or overwintering grounds. Species that may enter a resting phase over the winter may have the timing of their patterns interrupted by changes in temperature regime.

Directly related to this is the potential for increased pest outbreaks as a result of lower minimum temperatures in the winter and shorter overall winter season. Usually pest insects such as mosquitoes are unable to survive over the cold winter season. However, with higher minimum temperatures, such pests may be able to survive over the winter and affect humans for a longer period each year. With a longer active season, these pests may also respond to warming with higher populations. Significant resources are already allocated to battling mosquito outbreaks in Louisville Metro. Such resources may have to be increased if these outbreaks become more frequent or more populous.

As temperatures increase (both lower minimum and higher average), many species that cannot tolerate higher temperatures will be forced to migrate northward to higher latitudes where temperatures are higher or become lost from the local region. Just as species with lower temperature thresholds will be forced northward, so tropical species with higher temperature thresholds (that were previously excluded from the Metro region by temperature) will now be able to survive and reproduce here. This situation creates greater susceptibility to invasive species (species from other regions that, once present, outcompete and exclude native species). When these temperature regime changes are considered in conjunction with habitat destruction and pollution (which typically impact native species more severely), it makes the potential for more exotic species to invade and become invasive. Work in Louisville Metro Parks has been focused on removing several invasive species, including the shrub Amur honeysuckle. This species leafs early and precludes many of the native spring wildflowers of the region. (Levine 2008)

Losses to biodiversity through any of the above mechanisms tend toward fewer species, even if overall number of individuals present remains the same. However, many of the species in a diverse community provide significant ecosystem services such as carbon sequestration and flood mitigation. As ecosystems become less diverse, these services are often lost.

Trade Rules and Policies:

Many invasive species that threaten biodiversity are brought in unintentionally with ornamental plants. Consider the regulation of the importation of exotic plants to the Metro region. These exotics are known to “escape” from the lawns where they are planted and due to the altered environment discussed above, take over natural areas such as our local parks where native plants are encouraged. In addition, the city’s use of non-natives species (such as Bradford pears that line streets) should be re-considered in favor of more robust native species that will encourage biodiversity of not only plants species but also animal species that rely on these natives for food and shelter, particularly birds.

Recommendation 7:

Promote trade rules and practices that foster sustainable biodiversity.

Public Education:

Educating the public about the effects of individual choices on biodiversity will do much to relieve the stress on natives. By providing information about native choices in plant species that encourage other native species, landowners can impact their local environment and even improve the health of the city's parks.

Recommendation 8:

Improve education and public awareness about the value of biodiversity.

Existing Initiatives:

The Olmstead Park Conservancy and Louisville Metro Parks have programs in place to involve the community in making our parks refuges for native plants and animals. Programs such as these are key to ensuring that native species have both habitat and food. In addition, they habitat patches provide sanctuary for migratory species that add to our regions biodiversity.

Recommendation 9:

Improve park initiatives to encourage native species.

References

Trammell, Tara (2008) Dissertation research, University of Louisville, Biology Department.
Levine, Eli (2008) Dissertation research, University of Louisville, Biology Department.

3.2.3 Impacts to Aquatic Ecosystems

Temperature is one of the main determinants of the composition of species that will be present in an aquatic ecosystem. Aquatic species have specific temperature tolerances as well as optimum temperatures at which they experience maximum growth and reproduction. As temperatures increase in Kentucky and the Louisville Metro area the range of species that require more moderate temperatures will be pushed northward, where temperatures are cooler. If a northward shift is not possible due to migration barriers, the species will be lost. These trends have been observed in other regions of the United States. For example, the Natural Resource Defense Council found that fish species such as trout and salmon were disappearing from the Interior west due temperatures increasing beyond their tolerance range (NRDC 2002). This northward shift of species ranges also allows for tropical species to invade higher latitudes where temperature previously excluded them. Their ability to tolerate higher temperatures allows them to potentially displace native species. Examples include the zooplankton species *Daphnia lumholtzi* (Jack & Thorp 1995) and the zebra mussel *Polymorpha dressiena*.

Changes in temperatures affect the timing of food availability for many species. Zooplankton abundance peaks often coincide with peaks in algal abundance as this is their primary food source. Lower minimum temperatures can alter the timing of algal blooms. Zooplankton, however, are slower to respond to increasing temperatures. If adequate food is not available for zooplankton, the peak abundances will be lower, thus impacting higher levels of the food web that rely on zooplankton for food, such as many fish species and macroinvertebrates.

Temperature also plays a role in the physical appearance of many species. For example, in order to reduce predation some zooplankton grow appendages that make consumption by their predators more difficult. However, temperature is often an indirect cue for when the predators will be present. If an increase in temperature is not accompanied by the presence of predators, species may develop these costly defense mechanisms without the resulting benefit of reduced predation to the detriment of the overall population (Kappes & Sinsch 2002).

The timing of species' life cycle stages are often a response to temperature. Thus, species time the laying of eggs, the development of larvae, or other life cycle stages by temperature. Particularly at lower levels of the food web (zooplankton, macroinvertebrates), the effects are felt by higher levels that depend on these for food.
Aquatic ecosystems also provide inputs to the surrounding terrestrial systems. Many terrestrial insects rely on aquatic food sources, as do many migratory birds.

Changes in temperature can impact algal blooms as mentioned above. This has direct effects on Louisville's drinking water supply and water recreation opportunities. As temperatures increase, we can expect changes in the timing and species composition of algal blooms which must be taken into consideration in the water treatment process. These blooms can also impact recreational use of the Ohio River and the area's lakes. Large algal blooms can interfere with fishing, boating and are generally considered unpleasant aesthetically by the public.

While the potential effects of more extreme precipitation events is more thoroughly covered in the Hydrology section of this report, there are some possible effects on aquatic species that must be considered. Extreme precipitation events effectively scour waterways, particularly streams. This removes important debris and leaf litter inputs that are the basis of the aquatic ecosystem. This debris provides not only energy but also habitat for small organisms. Without these microhabitats, energy inputs to the stream decrease thus limiting the species that can survive in the system.

Mitigation and prevention strategies to cope with the potential changes to aquatic ecosystems do exist. Many communities have had success at managing their aquatic systems at the watershed level. This entails managing the land use that drains into the aquatic system of concern, such as the Ohio River and its tributaries. By encouraging best management practices for agricultural areas within the watershed and requiring development standards to minimize urban runoff and habitat loss, factors that compound climate change can be mitigated.

The protection of wetlands serves a dual purpose. These are areas typically in the flood plain where excess water is held. Wetlands not only help mitigate flood effects but also act as a carbon sink. Thus, the have short- and long-term benefits. The US Department of Agriculture currently has programs in both the Farm Bill and the Environmental Quality Incentives Program that encourage the protection of wetlands by helping to alleviate the cost associated with the stewardship of wetlands (US Farm Bill 2002).

Education of the community about the importance of aquatic ecosystems can also help prevent continued deterioration of these systems. Outreach programs to schools and community groups can help inform people about how the choices they make impact our waterways. Community groups such as Riverwatch have proven invaluable in protecting aquatic systems in many regions.

Addressing issues such as urban runoff can also help alleviate the effects of climate change on aquatic systems. Heat island effects from cities only compound the increasing temperatures associated with climate change in our region. Alternatives to impervious surfaces in Louisville can help to mitigate the effects of urban runoff. Programs such as the protected water areas, where sidewalk drains are marked to indicate that inputs will feed directly into protected waters, can also help prevent additional unwanted inputs.

Recommendation 10:

Work to protect the remaining wetlands in Jefferson County.

Recommendation 11:

Promote agricultural best management practices that reduce pollution and sediment runoff into aquatic ecosystems.

References

Kappes, Heike, and Sinsch, Ulrich. (2002) Temperature- and predator-induced phenotypic plasticity in Bosmina cornuta and B. pellucida (Crustaceea: Cladocera). Freshwater Biology 47: 1944-1955.

Jack, JD & Thorpe, J. (1995) Kentucky Academy of Sciences

Winder, M. & Schindler, D.E. (2004) Climatic effects on the phenology of lake processes. Global Change Biology 10: 1844-1856.

USDA Farm Bill (2002)

National Resource Defense Council (2002) Effects of Global Warming on Trout and Salmon in US Streams

3.2.4 Horticultural-Agricultural Sector

Louisvillians annually consume an estimated $137 million in fresh produce and $234 million in meat at home, food that is purchased at supermarkets, groceries, 20 farmers’ markets and via 8 community-supported agriculture (CSA) cooperatives. Beyond home-cooked food, many of their meals are consumed in approximately 440 restaurants and at school. With three-quarters of the community’s students in attendance, JCPS serves 58,000 lunches and 24,000 breakfasts each school day of the school year (plus 10,000 to 12,000 meals on summer days). A dozen on-campus establishments offer food to UofL students, faculty and staff.[1]

Though the 23-county metropolitan area includes 20,000 farms and the local food manufacturing sector has annual sales of $1.3 billion, most food consumed there is produced and processed at far more distant locations. The typical American meal is said to travel 1,500 miles from farm to table. With few exceptions, its transportation runs on fossil fuels. Further, most fertilizers—and some pesticides—used in mainstream agriculture are made from fossil fuels. As fuel cost increases are passed to consumers, the dependency on fossil fuels precipitated big jumps in food costs.

Besides food production, the local horticultural sector includes several hundred sod farms, greenhouses and nurseries that produce a wide range of landscaping materials, and is currently very dependent upon fossil fuels for its fertilizers, pesticides and transportation, as well as for heating its greenhouses.

This sector's vulnerability necessitates that it focus not only on lessening its emissions of climate-warming gases, but also on mitigating the still worsening impacts on its day-to-day operations and long-range planning.

Climate change has begun to impact the agricultural and horticultural sectors—and will continue to do so. In 2006, the US Department of Agriculture re-designated the Louisville area from its plant hardiness Zone 6 to its Zone 7, meaning some plants that historically would have not weathered our winters now can be expected to do so. See hardiness zone maps below in Figure 5.

Evidence shows that warmer temperatures are accelerating the spread of exotic, invasive plant species (particularly from Asia) to the detriment of native species and biodiversity. For example, because fewer seeds die in warmer winters, exotic plant species, especially invasive weeds, propagate faster.

The stress of climate change renders plants more vulnerable to diseases and pests. Warmer winter temperatures allow indigenous diseases and pests to avoid previously higher winter die-off rates, and new diseases and new pests, such as bark beetles and fall armyworm[2], to invade. Fighting these diseases and pests requires additional and new pesticides and treatments.

The proper formation of fruit buds requires time within certain temperature ranges at certain times of the crop's seasonal development. When temperatures are too warm and/or erratically warm and cool, fruit production, including apples, peaches and plums, is diminished.

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[1] Market Ventures, Inc., *Building Louisville's Local Food Economy: Strategies for increasing Kentucky farm income through expanded food sales in Louisville*, 2008, accessed on 21 October 08 at http://www.louisvilleky.gov/NR/rdonlyres/4957B564-EABF-4609-BB08-A295B7EAB321/0/FarmersMarketStudyExecSummary.pdf

[2] James Bruggers, "Kentuckiana begins to feel the heat of climate changes," *The Courier-Journal*, 18 June 06

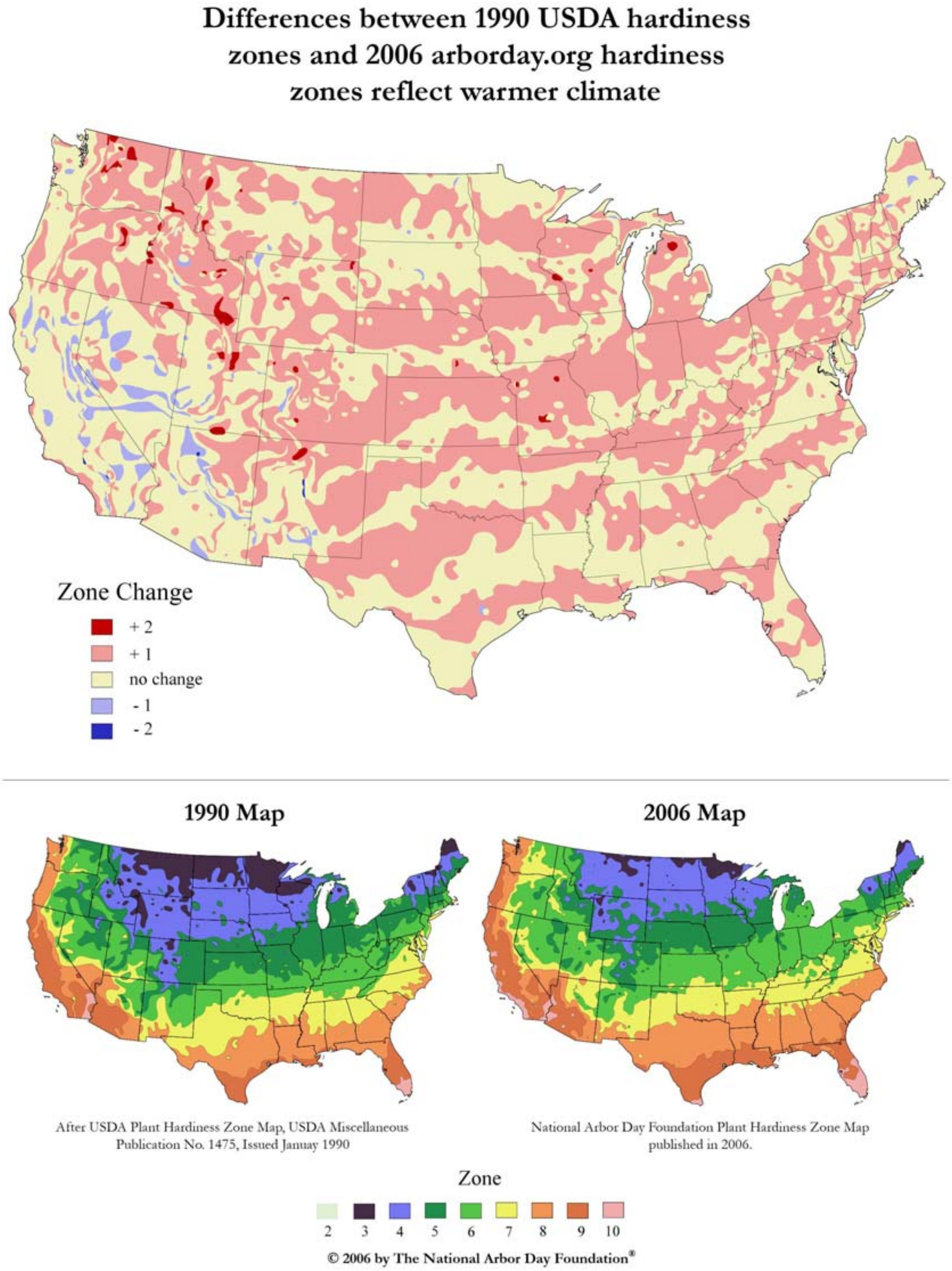


Figure 5 shows the 1990 and 2005 USDA hardiness zone maps. Hardiness zones outline the geographic range boundaries of various plants. Temperature is one on the main factors that determines plant ranges. The 2006 map was updated to show northward sifts in hardiness zones due to increased temperatures. Most of Kentucky has already shifted to from zone 6 to zone 7.

A longer growing season is often assumed to be a benefit to this sector, however such thinking overlooks two important realities: Regardless of temperatures in the fall, solar insolation steadily declines. Plants cannot flower without adequate sunlight. (Botanically speaking, flowers include heads of broccoli, ears of corn, etc.)

Changes in precipitation patterns pose particularly make-or-break risks to this sector, especially producers without auxiliary sources of water to replace precipitation during droughts. Inadequate water wreaks havoc not just on crop production, but also on animal herds general welfare, especially milk production. Even farmers with the option to truck in water, may not have the financial ability to do so. Conversely, working wet soil causes long-term damage to its structure and permeability. If rain patterns shift to disproportionately heavy in late-winter and early-spring, farmers will have to choose between plowing and sowing when the soil it too wet versus after the growing season has become shorter.

Scientists cannot yet explain the sudden accelerated disappearance of North American worker bees beginning in 2006, often referred to as pollinator Colony Collapse Disorder (CCD). Pollinators are critical to the production of about one-third of US crop species, such as soybeans, almonds and fruits (including apples, peaches and strawberries). Scientists are studying a range of possible causes, which may or not be proven, independently or synergistically, including insect pests, diseases, pesticides, genetically modified (GMO) crops, climate change and the use of large-scale, itinerant apiaries.

The above impacts, should they occur, could have less impact on smaller-scale regional farmers producing more diverse ranges of crops with fewer food miles to market than the larger mono-cultural, industrialized agribusinesses.

Recommendation 12:

Adopt a reduced food miles traveled purchasing policy.

Recommendation 13:

Support the educational programs of the Cooperative Extension Service, which uses its research to facilitate the sustainability of the horticultural and agricultural sector.

Recommendation 14:

Avoid using pesticides known to kill pollinators.

Recommendation 15:

Avoid using pesticides known to kill exotic, invasive species.

Recommendation 16:

Promote water conservation practices such as drip irrigation.

Recommendation 17:

Encourage food producers and gardeners to select plant and livestock species that are more resistant to diseases, pests and climatic variances, including droughts and excessively wet periods.

Recommendation 18:

Encourage participation with the USDA and other programs that assist farmers in improving the energy efficiency of their operations.

Recommendation 19:

Promote programs to the general public that connect people with locally produced products.

3.2.5 Infrastructure, Hydrology, and Water Resources

3.2.5.1 Infrastructure

Based on IPCC Technical Paper IV, Climate Change and Water, flooding is very likely to increase during the 21st century due to more extreme precipitation. Statistically significant increases in the occurrence of heavy precipitation have been observed across Europe and North America (Klein Tank and Konnen, 2003; Kunkel et al., 2003; Groisman et al., 2004; Haylock and Goodess, 2004). Based on this increase in heavy precipitation, there are several ways in which the infrastructure system in Louisville Metro may be affected, including a need to upgrade flood control and erosion control structures, increased demands on the stormwater, wastewater, and combined sewer systems, and more frequent landslides and road washouts.

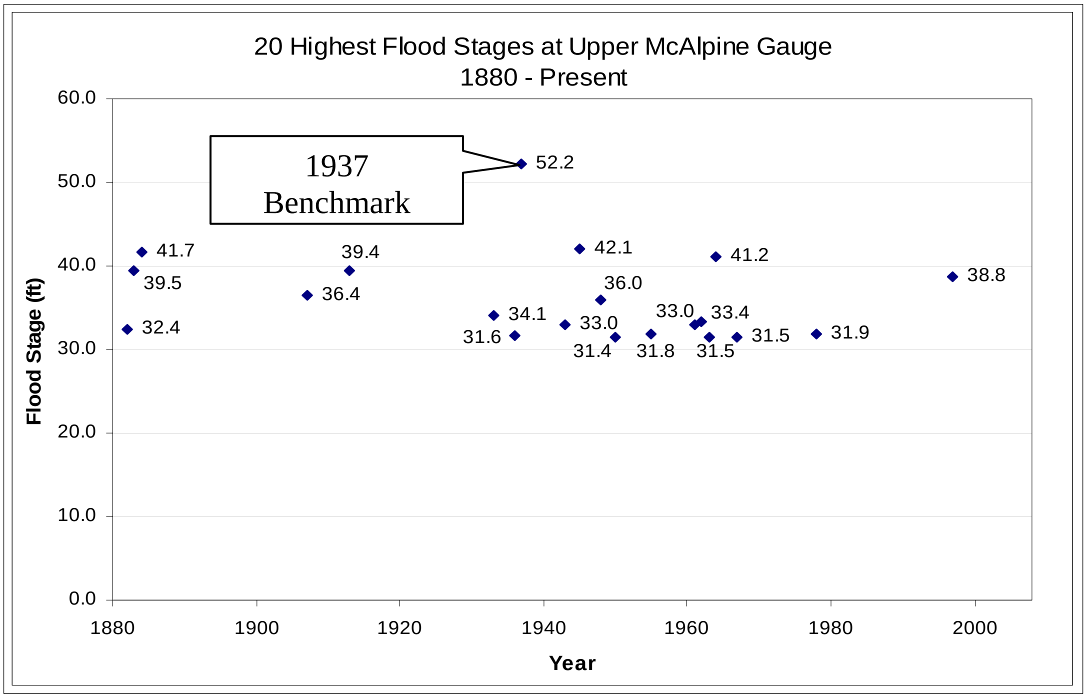
Need for New or Upgraded Flood Control and Erosion Control Structures:

Louisville Metro is located along the Ohio River. The Ohio River basin includes 14 states and 204,000 square miles, therefore extreme weather events locally and events upstream of Louisville can both cause flooding in the Louisville area.

Floodwall at 11th Street

In order to protect Louisville from flooding from the Ohio River, the Army Corps of Engineers built a floodwall and levee system beginning in 1948 and completed it in the late 1980's. The floodwall and levee system is 29.9 miles long and includes 16 flood pumping stations. It is built three feet higher than the 1937 flood stage, which is considered the benchmark flood in Louisville. If flooding was extremely severe, the floodwall or levee could overtop or flood pumping stations may become overwhelmed, which could cause flooding in the Louisville Metro area. However, as shown in Table 5, the 1937 flood stage was more than 10 feet higher than any other recorded flood since 1880. Therefore, it is unlikely the floodwall would need to be raised to a higher elevation. It is important, however, to continue to maintain the floodwall and levees and to maintain and replace the flood pumping stations throughout the system as needed.

Table 5



Sediment can be a major pollutant during construction. Onsite sediment loss can reduce or eliminate the remaining soil's ability to provide nutrients, regulate water flow, and protect plants. Offsite, water quality is impacted by unwanted biological growth due to excess nitrogen and phosphorus and increased turbidity. Sediment can also build up in streams, reducing the low flow capacity of the channel and thereby increasing flooding. (National Management Measures to Control Nonpoint Source Pollution from Urban Areas) Erosion control structures are currently regulated at a 10-yr storm event for construction sites. If intense storms are expected to increase in frequency due to climate change, the definition of the 10-yr storm event would need to be revised to a higher rainfall total. This would mean erosion control structures should be designed for a larger rainfall to minimize effects of erosion.

Increased Demands on Stormwater Management Systems:

Public stormwater conveyance systems, such as pipes, culverts, and ditches, are currently designed to convey the 100-yr storm within the drainage easement and detention basins are designed to detain the 100-yr storm. If the intensity, duration, and number of severe storms increase, the definition of the 100-yr storm will change. Therefore, basin and stormwater conveyance systems would need to be designed for larger rainfalls.

As stated in section 4.2.7, the IPCC paper, Climate Change and Water, states that flooding is very likely to increase during the 21st century. Louisville area stormwater management systems may be overwhelmed if more frequent heavy rainfalls occur, which would cause more flooding problems. Combined and sanitary sewer overflows would likely increase as well. Flooding and overflows would cause health concerns since flood waters are generally contaminated and can be very dangerous. Flooding also creates economic hardships, displaces people from their homes and businesses, impacts travel and commerce, and degrades water quality. Since Louisville Metro currently has problems in many areas with overwhelmed stormwater systems and combined and sanitary sewer overflows, increased extreme weather would amplify these problems.

MSD's Project WIN (Waterway Improvements Now) is currently working towards reducing combined and sanitary sewer overflows in order to comply with a federal consent decree. If rainfall intensities become higher due to climate change, design standards could be revised to plan for more extreme weather. MSD is planning to spend $800 million to reduce the overflows through various projects. Individual property owners are also encouraged to take a part in reducing overflows by disconnecting downspouts and sump pumps, redirecting downspouts to encourage infiltration into yards or gardens, and to have house sewer laterals inspected and repaired if damage is found.

Figure 6. 2008 Flooding along River Road

More Frequent Landslides and Road Washouts:

Louisville Metro has soils designated as severely erodible throughout the county. More frequent, heavy rainfall caused by climate change could potentially cause more frequent landslides and road washouts. Landslides can damage homes and businesses and are generally not covered by standard insurance policies. Landslides and road washouts can also cause difficulties with travel and delivery of goods and services, or even injuries or death. Replacing or repairing the roads would have an economic impact on the agency that has jurisdiction over those roads.

In an effort to mitigate landslide problems, the Kenwood Hills area, near Iroquois Park, was down-zoned in 2007 to limit development. The area was considered to be at a high risk for landslides due to fragile terrain, steep slopes, and unstable soils. The Louisville Metro Planning Commission endorsed zoning changes to limit future development on Kenwood Hill and the area around the bottom of the hill. Similar efforts could be undertaken in other areas of Louisville Metro if landslides are a concern. MSD and Louisville Metro can also help property owners use safe engineering practices when building on steep slopes, such as using retaining walls, minimizing runoff, and keeping good groundcover on hillsides to minimize erosion. Louisville Metro can inspect roads and hillsides near roads for erosion problems and fix problems before roads washout or landslides occur.

Reference:
National Management Measures to Control Nonpoint Source Pollution from Urban Areas (November 2005, EPA-841-B-05-004)

3.2.5.2 Hydrology and Water Resources

Hydrology and water resources in Louisville Metro are likely to be affected by climate change, especially due to likely increases in extreme weather events such as more frequent intense rainfalls and more frequent droughts. Wetlands and water quality in streams, lakes, and rivers are also likely to be affected.

Increased Risk of Flooding:

Based on IPCC Technical Paper IV, Climate Change and Water, flooding is very likely to increase during the 21st century, due to more extreme precipitation. Statistically significant increases in the occurrence of heavy precipitation have been observed across Europe and North America (Klein Tank and Konnen, 2003; Kunkel et al., 2003; Groisman et al., 2004; Haylock and Goodess, 2004).

Figure 7. 6th Street during 1997 flood

Louisville Metro is a river city and is located along the Ohio River. There are also approximately 400 miles of mapped streams within the metro area and approximately 15% of Louisville Metro is designated as floodplain. The mapped floodplain includes over 8,000 residential and commercial properties. Increased flooding could affect thousands of people, causing more frequent flooding and expanding the area that floods. Between 1989 and 2007, there were 62 flood related deaths in Kentucky. The 1997 flood, which was the largest flood in recent history, was estimated to include up to $200 million in public and private damage. In addition, flooding can cause Ohio River commerce to potentially slow and river-front recreation and tourism to be reduced. Property owners are sometimes unable to access their properties or become trapped in their properties. Sewer backups are another common problem. Water quality could be diminished, especially due to combined and separate sanitary sewer overflows. Flooding could also impact local travel and commerce as roadway flooding occurs and local infrastructure, such as storm sewers and bridges, exceeds design capacity. Because flood waters are often contaminated, health-related impacts are also associated with flooding.

Through the capital improvements program, Project DRI, and Project WIN, MSD is working to improve drainage and relieve flooding. Projects have included building regional basins, upgrading stormwater systems, and improving drainage channels. EMA and MSD have also bought-out homes in areas that repeatedly flood and returned those areas to open space. If rainfall intensities become higher due to climate change, design standards could be revised to plan for more extreme weather in the future.

Increased Risk of Drought:

IPCC Technical Paper IV, Climate Change and Water, states that although rain storms are expected to be more intense, there are likely to be fewer rain storms total; therefore, there will be more drying in the summer, which will increase the risk of droughts. Potential impacts of droughts on Louisville might include increased costs associated with agricultural products and reduced water quality, which may require more water treatment. Upstream water withdrawals, in response to a very severe drought, might reduce the surplus water supplies currently available from the Ohio River. Reduced groundwater recharge could impact the availability of geothermal cooling and heating resources. River traffic may also be affected.

Water availability will largely result from distribution of precipitation and not rely as heavily on direct temperature effects (although temperature will obviously have an effect). For example, studies have shown that transpiration rates will slow in relation to increased atmospheric CO_2 thus reducing the net effect of the associated global warming on direct streamflow and the overall water budget. However, changes in the distribution of rainfall throughout the year (driven by climate change) could change streamflow in terms of response to soil-moisture conditions and other driving factors; these conditions are much harder to predict and, therefore, makes the forecast of future flooding, droughts, and competition for water resources much more difficult. In effect, the CO_2-induced climate change required to impact streamflow (in Kentucky, not snow-melt dominated regions) would likely occur so slowly that determining any specific statistically-significant trend could take as long as 50 to 100-years. (Ayers, Mark A.; Wolock, David M.; McCabe, Gregory J.; Hay, Lauren E.; Tasker, Gary D.; 1994; Sensitivity of water resources in the Delaware River basin to climate variability and change; USGS Water Supply Paper 2422, 42p.)

Louisville Metro can plan for severe drought; however, beyond a certain point resources could become surpassed by demand. Louisville Metro could encourage water conservation and also increase the use of cisterns and groundwater reuse for non-potable water uses to minimize demand.

Increased Competition for Water:

If droughts increase, there will likely be an increase in competition for water. Potential impacts on Louisville would include increased competition for ground-water resources currently used for geothermal cooling and heating and a decrease in water supplies available from the Ohio River due to greater upstream demand. This impact is not necessarily linked entirely to climate change since urban development is already adding increased pressure to ground-water and surface water resources.

Water supplies from the Ohio River might become a more valuable commodity; therefore there is a potential economic benefit to this scenario if water were sold to nearby communities that did not have sufficient local resources. In order to mitigate impacts of the increased competition, procedures could be put in place by Louisville Metro to more closely monitor existing resources and water use resulting in more efficient management and distribution of the resource should supplies become diminished. Water conservation programs and methods to increase stormwater reuse for non-potable uses, such as rain barrels and cisterns, could be used to limit treated water usage throughout the community.

Warmer Water Temperatures in Lakes, Rivers, and Ground Water:

Links of climate change to local temperature increases are fairly well documented; however, there is also substantial information to suggest urban development (urban heat islands) will increase water temperatures independently of climate change. Warmer water temperatures could have a direct impact on Louisville as aquatic communities would potentially shift in response to increased temperatures and water quality could degrade (algae, taste, odor issues, etc).

Figure 7. Pervious Concrete at the Girl Scout Program and Learning Center on Lexington Road

Currently Louisville Metro and MSD are encouraging green methods that might improve this potential situation. These methods include use of pervious pavement, green roofs, rain gardens, rain barrels, infiltration basins, and other means to increase infiltration of water. The Land Development Code requires stream buffers along protected waterways within Louisville Metro, which also encourages infiltration and lower water temperatures. Intermittent streams currently have no stream buffer requirements. Including buffers for intermittent streams in the Land Development Code could also help reduce water temperatures in those streams.

Changes in Water Quality:

Potential impacts of changes in water quality in Louisville would likely include increased water-treatment costs. Currently, most water companies deal with elevated contaminants during flooding events and prolonged droughts; however, changes in the frequency and timing of these events might pose an economic, environmental, and health risk. Recreational uses of local streams and aquatic ecosystems are also impacted with decreased water quality.

Figure 8. Rain garden planted by MSD on Havard Street

The impact is not necessarily linked entirely to climate change as natural climate variability can mask or exceed the effect of climate change. Upstream development, withdrawals, and discharges could play equal, or greater, roles in reducing water quality. There is substantial information to suggest urban development will alter water quality (in some cases actually showing improvement as agricultural and suburban chemicals are reduced); however, there is currently insufficient data to support climate change as the cause of this projection.

Metro Louisville and MSD are encouraging green methods aimed to increase water quality. These methods include use of pervious pavement, green roofs, rain gardens, rain barrels, infiltration basins, and other means to increase infiltration of water and improve water quality. Stream buffers are also required along protected waterways in the Land Development Code. MSD’s Project WIN is also working to reduce combined and separate sewer overflows, which should improve water quality and MSD’s future stormwater permit will likely include new water quality requirements also.

Reduction or Increase in the Size of Wetlands:

Potential impacts on Louisville from a reduction in upstream wetlands would likely be the loss of natural water treatment and the loss of natural attenuation of overbank flows (floods). These would include environmental, economic, and health issues.

The impact is not necessarily linked entirely to climate change as natural climate variability can mask or exceed the effect of climate change. There is some documentation indicating that biologic communities will shift in response to climate change, however, the change would happen generally over a time span that makes accurate prediction of statistical trends difficult. Changes in wetland and biologic communities may also be attributed to factors such as adjacent land use and so forth; therefore, the connection between loss of upland wetland areas and climate change may be less direct.

Metro Louisville, JCPS, and U of L could actively work to reduce this impact through the study of wetland function and restoration and protection efforts.

Recommendation 20:

> *Design standards for stormwater conveyance systems and erosion control structures should be updated.*

Recommendation 21:

> *Continue to encourage property owners to reduce sewer overflows by disconnecting downspouts and sump pumps, redirecting downspouts to encourage infiltration into yards or gardens, and to have private plumbing inspected and repaired if damage is found.*

Recommendation 22:

> *Encourage water conservation programs and stormwater reuse, such as cisterns and rain barrels, to minimize water demand.*

Recommendation 23:

> *Continue to encourage "green" construction methods to encourage infiltration and thereby reducing water temperatures and increasing water quality.*

Recommendation 24:

Expand existing blue line stream buffer to include intermittent blue line streams.

Recommendation 24:

Evaluate wetland function, restoration, and protection efforts.

Recommendation 25:

Adopt a post construction erosion control ordinance.

3.3 ADAPTIVE CAPACITY

ICELI defines adaptive capacity as “the ability of built, natural, and human systems to accommodate changes in climate (including climate variability and climate extremes) with minimal potential damage or cost.” Louisville Metro already has several systems in place that can mitigate and adapt to impacts of climate change. These following are a few examples of the city’s adaptive capacity.

3.3.1 Natural Hazards Mitigation

In 2005, Louisville Metro adopted its Natural Hazards Mitigation plan to comply with federal regulations in the Disaster Mitigation Act of 2000. The plan’s development was coordinated though the Louisville Metro Emergency Management Agency (LM EMA). The team responsible for developing the plan is an extensive partnership of local agencies, businesses, and the public.

The following goals are identified in the Natural Hazards Plan:

1. Minimize the loss of life and injuries that could be caused by natural hazards.
2. Facilitate a sustainable economy by protecting agriculture, business, and other economic activities from natural hazards.
3. Facilitate the strengthening of public emergency services, its infrastructure, facilities, equipment, and personnel to natural hazards.
4. Develop a community-wide mitigation effort by building stronger public partnerships between government, business, and the general public.
5. Increase public and private understanding of natural hazard mitigation through the promotion of mitigation education and awareness of natural hazards.
6. Develop a strategy for working with the print, electronic and broadcast media to disseminate mitigation education and outreach material.
7. Enhance existing technical and GIS data and capabilities that will reduce the effects of natural hazards.

To meet these goals, the natural hazards planning team performed a risk analysis on the potential threats to the community. The analysis identified hazards, profiled hazard events, identified assets, estimated potential losses, and analyzed development trends. The result was the creation of a hierarchical ranking of Louisville Metro’s 12 identified hazards.

Ranking of Louisville Metro's 12 Natural Hazards

- Severe Risk Hazards – Flooding, Severe Thunderstorm
- High Risk Hazards – Hailstorm, Tornado
- Moderate Risk Hazards – Earthquake, Severe Winter Storms
- Limited Risk Hazards – Dam Failure, Extreme Heat, Karst Sinkhole, Landslides, Wildfire
- Low Risk Hazards – Drought

The natural hazards planning team continues to meet quarterly. It discusses ongoing mitigation initiatives, reviews new data, and learns about various response capabilities. Mitigation efforts are ongoing and can be reviewed in annual progress reports.

Climate change due to anthropogenic warming was not taken into considered when the plan was developed. However, the majority of potential hazards identified in the plan are directly influenced by climate. If climate change begins to alter the frequency or intensity of natural hazards, the corresponding data will be reviewed by the natural hazards planning team. The team can then discuss mitigation strategies and make recommendations to the proper agencies.

The Natural Hazards Plan and progress reports can be viewed online at:
http://www.louisvilleky.gov/EMA/Natural+Hazards+Mitigation+Plan.htm

3.3.2 Syndromic Surveillance

As discussed in the Public Health 4.5.1 of this report, climate change associated increases in the range of disease vectors in another geographic location could increase the likelihood of imported cases of infectious disease in Louisville Metro. Moreover, population dislocation associated with climate change could lead to increases in the number of disease carrying hosts and demand on the local health care system as Louisville Metro's immigrant and refugee populations increase. Although individual weather events can not be attributed to climate change, Hurricane Gustav serves as an example of how this could happen in Louisville Metro and the adaptive capacity the city has to cope with similar situations.

In August 2008, the Federal Emergency Management Agency (FEMA) evacuated the City of New Orleans prior to the arrival of hurricane Gustav. Evacuees were dispersed around the country. In Louisville, the Department of Public Health and Wellness Office of Emergency and Public Health Preparedness (OE&PHP) worked with FEMA and local agencies to accept approximately 1,500 evacuees. More than 30 percent of the evacuees needed medical treatment while in Louisville, requiring more than 700 doctor visits over 7 days.

Current studies of rising sea levels predict significant impacts on U.S. coast lines where large concentrations of population exist. If this prediction is correct, Louisville Metro might be expected to host larger numbers of evacuees more frequently and for extended periods. This influx of evacuees could strain the local health care system and increase the likelihood of a disease outbreak.

Local public health agencies are best equipped to reduce susceptibility and build resilience to climate-related disasters, because adaptation to impacts from climate change must occur at the community level. LM EMA with support from OE&PHP coordinates programs to reduce Louisville Metro's susceptibility to disasters and other public health emergencies, including disasters that could be associated with climate change, through prevention and mitigation. OE&PHP programs also increase community resilience through health promotion, surge capacity of health care facilities, and emergency response.

One such program is syndromic surveillance, which provides OE&PHP officials early warnings of outbreaks or changes in patterns of morbidity and mortality. Syndromic surveillance is a computer program networked to local health care providers and coroners' offices. It collects, analyzes, interprets and disseminates information regarding public mortality and morbidity from one database. Key parameters of syndromic surveillance include cause of death, hospital emergency data, and ambulance dispatch data. Statistically significant increases in the number of coroner cases or people needing medical care will trigger an alarm. Health care providers would then be notified for heightened awareness and an investigation to determine the cause of the trigger will begin. This type of system may be useful for monitoring population health during and after disasters, in providing an early warning against surprise outbreaks and other changes in patterns of morbidity and mortality.

3.3.3 Monitoring and Improving Air Quality

As discussed in section 4.5.1 of this report, warm and dry conditions resulting from climate change could decrease the city's air quality and create challenges for the city to meet the National Ambient Air Quality (NAAQ) standards. Louisville Metro's Air Pollution Control District (APCD) has the technical capability to monitor the air quality of the city, inform residents of air quality concerns, and has experience working with public stakeholders to adapt to new air quality standards.

APCD has ambient air monitoring stations located throughout Louisville Metro. These stations monitor Carbon Monoxide, Sulfur Dioxide, Oxides of Nitrogen, Ozone, and Particulate Matter ($PM_{2.5}$, PM_{10}, and Speciated $PM_{2.5}$).

With the exception of Speciated $PM_{2.5}$, the data is collected by continuous samplers that report the data hourly to a central computer located at the APCD offices. Speciated $PM_{2.5}$ sampling requires the collection of a sample every six days and then shipping that sample to a laboratory for analysis. The District also operates meteorological stations to provide wind speed, wind direction, temperature, humidity, barometric pressure, solar radiation, and rainfall and this data is collected on an hourly basis.

The data is used for several purposes including determining the attainment status with EPA's National Ambient Air Quality Standards, the effectiveness of regulatory programs, measuring trends, and informing the public of air quality levels in their area.

For public notification the data is disseminated in the form of the Air Quality Index which takes the raw data and places it into Health related categories (Good, Moderate, Unhealthy for

Sensitive Groups, Unhealthy, and Very Unhealthy). A voice recording of the AQI is available by calling 574-3319 or can be accessed on the District's Website. The Index is updated hourly.

In addition, the data is automatically sent to EPA's AIRNOW site which combines local data with other data nationally. The site is similar to the Index but it also has the capability to generate pollution maps that generalize air quality over large geographic areas.

The public may view the raw data on APCD's AirNet website and may obtain summary data from the EPA AirData and AirExplorer websites.

APCD staff holds forecasting calls with meteorologists from the Indiana Department of Environmental Management several days during the week to compile forecasts. Weather, measured readings of pollutions, known events, and computer modeling are used to forecast the Air Quality Index for the next day or so. The forecasts are only made for ozone and $PM_{2.5}$. In the event levels of either of these pollutants are forecasted to reach the Unhealthy for Sensitive Groups range, an Air Quality Alert is issued. These alerts are issued to the public through the KAIRE network, to local media, and are displayed on TRIMARC signs. The Air Quality Index will also indicate an Air Quality Alert has been issued.

Air Quality Alerts may also be issued if the measured values of any of the pollutants listed above are approaching the level of a National Ambient Air Quality Standard.

Sometime in late 2008, the District will begin participating in EPA's Radiation Network (RadNet) Air Program. The plan is for approximately 160 radiation sampling stations to be deployed nationally by 2011. The stations will measure real-time gross beta and gamma radiation and collect samples that are later analyzed for Isotopic Pu and U. The data will be distributed by the EPA's National Air and Radiation Environmental Laboratory (NAREL).

As for trends, generally speaking, the levels of all the pollutants listed above are and have been on the decline. The Louisville Metro area currently does not meet the National Ambient Air Quality Standards for the 2008 ozone standard and for the daily and annual $PM_{2.5}$ standards but is very close to meeting them.

There are several reports that provide evidence of this decline; some of which can be accessed at EPA's website (http://www.epa.gov/). The Kentucky Division for Air Quality issues a report each year and includes Jefferson County's ambient air monitoring network in that report. The link is:

http://www.air.ky.gov/programs/airmonitoring/Kentucky+Ambient+Air+Quality+Annual+Report+and+Air+Quality+Surveillance+Network.htm

In addition to constantly monitoring the city's air, APCD must continue to improve the city's air quality to meet new federal regulations. APCD has developed a public stakeholder process that helps the city accomplish this with input from the public and private sectors. Stakeholder groups have reviewed air quality data, considered mitigation strategies, and have ultimately developed recommendations that help reduce criteria air pollutants. Public processes such as these could be utilized in the future for adaptation if climate change produces negative impacts on the city's air quality.