2010 Mass Envirothon Current Issue

Questions and Resources for Team Preparation

Protection of Groundwater through Urban and Environmental Planning

This year's Envirothon current issue focuses on learning the fundamentals of groundwater hydrology and how the use of this knowledge is critical to land development and water use decision making from the perspective groundwater protection.

The 2010 Current Issue problem asks teams to understand the importance of urban and environmental planning from the perspective of protecting groundwater as a sustainable resource for its quantity and quality - as a source that sustains man and the environment. It will be your job to research the groundwater resource in the watershed where you live and to identify those plans and actions that have been adopted and implemented by your community and those sharing the watershed but also to identify some opportunities for its protection that you may want to pursue. A brief primer on groundwater protection is provided to acquaint you with this year's topic and to help you identify, prepare and carry out a specific plan of inquiry for a better understanding of the issues for a watershed-based approach for protecting groundwater. As you will discover the tools municipalities use for protecting groundwater are similar, yet vary in their application and use for a number of reasons.

This primer consists of the following components:

1. Understanding Groundwater Protection
2. Protecting Groundwater: Questions and Strategies for Watershed-Based Community Investigations and Resources For Community Investigation
3. Sources of Information
4. Selected Reading

This guide was prepared by Dr. George Zoto, Massachusetts Department of Environmental Protection. Your questions are welcome, as are your suggestions for the inclusion of other resources that will benefit all Massachusetts Envirothon teams. Contact George at 508-771-6034 or george.zoto@state.ma.us . The views expressed do not necessarily reflect those of MassDEP and should not be interpreted as conveying, official MassDEP approval, endorsement, or recommendation.

1. UNDERSTANDING GROUNDWATER PROTECTION

Get started by viewing this introductory video on groundwater hydrology by Annenberg Median: http://www.learner.org/resources/series78.html?pop=yes&pid=332# Topics presented include aquifers, rock porosity and permeability, artesian wells, the water table, cave formation, sinkholes, and how groundwater may become contaminated.

What do we mean by "watershed" and what is its connection to groundwater?

The land area that defines a watershed is characterized by its topographic features, where its highest elevations are interconnected – similar to the rim of a bowl. Some watersheds are small and others are quite large, consisting of several watersheds; otherwise known as a basin. Topographically, the rim of this "bowl" defines the boundary of the watershed drainage area (http://www.stormwatercenter.net/Slideshows/delineating_boundaries_files/frame.htm) and any rain water that falls within this rim is caught and through the pull of gravity coalesces with other rain drops as it infiltrates into the aquifer or zone of saturation where it becomes groundwater.

The capacity of a watershed to absorb and retain rain water through groundwater infiltration (http://ga.water.usgs.gov/edu/watercycleinfiltration.html) (or groundwater recharge) is defined by the makeup of its soils; both on the surface and below the ground by its porosity to transmit and store water within the pore spaces within the aquifer. When these spaces are fully saturated it becomes groundwater. The capacity of an aquifer to absorb and store water will also vary and is dependent on the aerial extent and depth of its pore spaces and other openings. For example, the storage capacity of a valley aquifer, where many well fields are located in Massachusetts, are defined by the area and depth of its sand and gravel deposits that were deposited by the glaciers as they retreated many millions of years ago. This is in contrast to the vast sand and gravel aquifers on Cape Cod and southern Plymouth where these deposits extend the length and breadth of these regions.

Ultimately, this rain drop will become part of a regional "down hill" groundwater flow pattern that discharges to a lake, pond, stream, estuary or ocean. The time required to discharge to a surface water body may be anywhere from a few days to hundreds or even thousands of years – depending on its proximity to the surface water, and the porosity/permeability of the aquifer (sand/gravel vs. clays and silts) and or bedrock (with or without fissures) where it is stored or confined. What is important to know is the connection between groundwater and surface water. These water resources are interconnected and continuous and any factor that affects groundwater quantity/quality, with time, will with some limitations, affect surface water (http://upload.wikimedia.org/wikipedia/en/3/32/Groundwater_flow_times_usgs_cir1139.png).

Keeping this in mind is important. A sustainable supply of groundwater in balance with the hydrologic cycle and its uses (water supply, industry, agriculture, and habitat protection) as measured by its groundwater elevations and stream flow is referred to as a water budget (balance) analysis; an approach that measures the relationship between the inputs and outputs within a watershed (see: http://wi.water.usgs.gov/glpf/images/usgs-concepts-1.jpg). As you might imagine, a rural watershed that undergoes urbanization will eventually lose its capacity to replace the rainwater that would normally be absorbed through aquifer recharge from each new impervious cover and losses resulting from water withdrawals. Over time, these losses in recharge and storage will be evident as measured by a reduction in groundwater elevation and stream flow; especially at the higher elevations of a watershed where the watershed's catchment area for recharge and storage capacity is less. This reduction can be seen over a period of time when a perennial segment of a river or stream is no longer flowing year round. These changes may have been recorded historically for your watershed by US Geological Survey maps. Determine if any stream beds or perennial stream segments in your watershed were intermittent or perennial streams at one time. If changes are identified, what were the accompanying changes in landuse that occurred that affected the water budget? The historic maps for your area can be found at this University of NH website: http://docs.unh.edu/nhtopos/MassachusettsList.htm. A current map of your watershed will be provided to your team by MassGIS for use in making these comparisons.

2. PROTECTING GROUNDWATER

2a. QUESTIONS AND STRATEGIES FOR WATERSHED-BASED COMMUNITY INVESTIGATIONS

What Land Use Changes affect Groundwater Quantity and Quality? Changes in groundwater quantity/quality will occur, either alone or in combination, from the conversion of undisturbed open space to residential, urban and/or agricultural development. Impacts that can accompany these changes include, but are not limited to: a) increases in impervious surfaces (pavement of all types and roof tops, soil compaction from land grading, and soils without vegetative cover), b) water withdrawals, c) transfer of water withdrawals or wastewater out of the watershed of origin; d) stormwater collection and conveyance systems that move water away from paved surfaces and roof tops to the nearest stream or lake; e) leaky water distribution systems; f) fractured wastewater systems that collect and dewater groundwater through these openings; g) inoperative stormwater infiltration structures, and h) discharge of toxic and hazardous materials and wastes from motorized vehicles, and residential and business uses. Agricultural production practices also have groundwater impacts that can result from a) fertilizers and pesticides, b) animal confinement wastes, and c) water withdrawals.

Can landuse changes and uses affect groundwater quantity and quality?

1. Pre and Post Development of a Watershed. **A** Federal Interagency Stream Restoration Working Group (FISRWG) study (FISRWG (10/1998)) presented some useful statistics concerning groundwater infiltration and storage capacity at different levels of land development - measured as the percentage of the watershed that has been made impervious (http://www.planningwithpower.org/pubs/id-257.htm). Watersheds with natural vegetative cover with a 0 to 10 percent impervious area were found to have 10 percent runoff, 25 percent infiltration and a 40 percent evaporative/transpiration (green plant uptake and loss via transpiration) loss; in contrast to urbanized watersheds with a 75 - 100 percent impervious surface area that sheds as much as 55 percent of the rainfall as runoff, 10 percent infiltration and 30 percent evapotranspiration.

Equally effective in reducing groundwater infiltration and recharge is the degree urban and rural soils have been compacted by heavy equipment during excavation and landscaping. It should also be understood, that heavy and prolonged rainfall event in urbanized settings, with this reduced capacity to capture and store rainwater within the aquifer has a greater capacity to shed water in the form of runoff and channel this flow downstream in the form of destructive flood event. Also, these events can also occur in a natural, undeveloped watershed with soils and geologic settings that are not conducive to groundwater recharge.

2. Water Supply Withdrawals, Aging Water Supply Delivery and Waste Water/ Stormwater Conveyance Systems, and Water Conservation. Businesses and home owners can significantly reduce demand by replacing inefficient water fixtures installed prior to 1992 when there wasn't a national water conservation standard for the sale of water efficient plumbing fixtures (faucets, toilets, and shower heads). Did you know that in 1988 Massachusetts was the first state to require all new and replacement toilet fixtures to not exceed 1.6 gallons per flush? However, many older homes, especially in our older cities and town centers continue to use toilets requiring 5 to 7 gallons with every flush. EPA reported that 40% of toilets in use today are of the older, higher-water use type that use more than twice the volume of their newer counterparts and when replaced by the 1.6 gallons/flush models can save up to 10,000 gallons per year. The replacement of these older fixtures can reduce demand and help restore the water budget while at the same time save a town' water department the added energy costs for pumping but also the planning and construction expenses for the construction of a new well.

Water losses resulting from a town's aging and inefficient water supply, wastewater and stormwater conveyance system can be substantial in the impact they collectively have on a watershed's water budget. The American Water Works Association' has stated in their "Plain Talk About Drinking Water: Questions and Answers About the Water You Drink" report that public water suppliers, on average, lose 15% of their withdrawal from leaky water mains or are otherwise unaccounted for; including faulty water meters and non-metered uses by municipalities. Addressing groundwater losses resulting from inflo and infiltration (see: (http://www.kingcounty.gov/environment/wastewater/II/What.aspx) from broken sewer mains and the repair and/or replacement of water mains can also be costly but well worth the expense over the long term.

With time and appropriate planning and funding, much can be done to restore and sustain the carrying or storage capacity of an aquifer. A number of measures can be employed to help restore the water budget. On the input/water gain side of the equation this means restoring groundwater infiltration/recharge capacity from rainfall events. On the outputs/water losses side of the equation this means a reduction in water demand through improved water conservation efforts, meter replacements for an accurate accounting of monthly water use, the repair of leaky water mains, reduction in impervious surfaces, and addressing the causes of infiltration and inflow).

3. Summer Water Supply Demand. Another consideration is the high summer demand for landscape and garden irrigation - at a time when rainfall events are the least and when demand frequently doubles the water supplier's winter withdrawal rate. This demand has been estimated by EPA, on average, as 10 to 30 gallons per person per day. The use of improved irrigation technologies that monitor local weather and/or the soil moisture content should be employed to reduce this demand and to help sustain a water budget that is capable of sustaining its many needs.

4. Pollutant Discharges. The connection between groundwater infiltration/recharge capacity and groundwater pollution potential is clear. Watersheds with highly permeable and porous soils and/or with fractured bedrock have a high capacity to capture and store this rainwater as groundwater, and for this same reason are at risk of contamination from pollutant discharges to or below the ground. To help your team identify the pollution risk potential of groundwater in your watershed, a GIS map will be provided to your team following registration. Look for locations within your watershed that are classified as high or medium yield aquifers. These aquifers are not only great for groundwater recharge and storage, they are also the most vulnerable to contamination from pollutants that are discharged to the ground; especially from water soluble pollutants and volatile organic compounds that are not easily filtered or adsorbed as this groundwater flows through the aquifer as a contaminant plume (see the introductory videos in Section 4 for further discussion on groundwater contamination).

Groundwater pollutants include septic system discharges (nitrate and/or ammonium, pathogens, household cleaning products, disinfectants prescription drugs), toxic and hazardous materials, wastes (solvents, lawn/garden fertilizer and pesticides), auto service stations, dry cleaning, "junk" yards, unlined landfills, industry, farm operations, and back yard mechanics.

Chemically the contaminants from these landuses fall into one of the following categories: petroleum products (solvents, fuel oil, gasoline, and gasoline additives), fertilizers, heavy metals, pesticides, pathogens (bacteria and viruses), and most recently pharmaceuticals. Their solubility in groundwater not only makes the aquifers highly vulnerable to contamination when discharged to the environment, this groundwater can be withdrawn for use as drinking water when contamination occurs within the area of influence of a pumping well, defined in Massachusetts as a Zone II (see: http://www.epa.state.il.us/water/groundwater/maximum-setback-zones/conedepr.gif , or when groundwater is discharged to a river, lake or pond.

Two recent US Geological Survey (USGS) studies shed further evidence on where contamination events have the greatest probability and frequency. Squillace et al. (2002) discovered groundwater contamination was greatest in watersheds with the highest population density while another USGS study (2001) that comparing urban vs. rural pollution frequencies, found water supply well withdrawals in urbanized watersheds had a much greater incidence of contamination from MTBE (a gasoline additive to improve combustion efficiency) and other volatile organic hydrocarbons. Internet links to these studies are in Section 5, Selected Readings, of this guidance for further study.

5. Inadequate Water Supply Development and Protection Planning. Communities that undergo rapid growth and development may be unable to set aside watershed land as future well sites or to establish appropriate zoning and non-zoning controls for the protection of the watershed from inappropriate land development practices and uses. On the other hand, towns that are proactive when growth pressures are approaching their borders are in the best position to identify and set aside land for future well water withdrawals while vacant land in a natural state is available for purchase. In Massachusetts the minimum land area for wellhead protection (Zone I protection area) is approximately 13 acres. Otherwise, it may be too late to find properties with the necessary acreage for Zone I protection.

2b. RESOURCES FOR COMMUNITY INVESTIGATION

Optimally, the communities that share a local watershed should consider the development and use of groundwater for water supply production as a collaborative, intermunicipal approach of cost sharing and joint protection planning – as each community's decision on one or more land uses has the potential to affect groundwater quality and quantity for the resource they collectively share.

If you are not sure where to start your investigation, you may want to begin by learning about the local, municipal role to help you highlight an area to pursue for the protection of groundwater.

Municipal Master/Comprehensive Plans. If one exists for your community, does the plan address the protection of groundwater and surface water? Have your town leaders considered a "smart growth" approach to water resource management planning and protection that takes into account the impacts of current and future development and how these impacts affect groundwater production and quality? If they exist, how do the strategies proposed address the importance of a sustainable and safe supply in the years ahead that also addresses habitat protection? Has land development and population growth within your watershed been in conflict with the achievement of this goal? If so, why and what alternatives would your team propose to address these shortcomings? Identify the compatibility of existing land uses and those proposed for your watershed in locations with water supply production wells. Based on your assessment of landuses within the Zone of Contribution (Zone II) to these wells, are these aquifers at risk of contamination? What source protection measures are being carried out within your community that addresses the compatibility of current and future landuses in Zone IIs for water supply, water quality protection? Why should these aquifers be protected from inappropriate land uses? Have you identified any inappropriate landuses within a Zone II that has been grandfathered by aquifer protection zoning? If so, what other source protection measures are underway to address these grandfathered uses?

Issues Facing Municipalities. City and town decision makers are beginning to understand the necessity of getting the facts straight on the makeup of the underlying hydrogeology of their watershed as a first step to planning for future landuse decision making. Having this knowledge is critical to deciding appropriate use and location of future land development – allowing for landuses that are compatible for the protection of groundwater as a safe drinking water source while sustaining the watershed's capacity for groundwater recharge and storage.

Environmentalists say water suppliers and town Department of Public Works should be doing more to restore water (balance) budget by: a) implementing groundwater infiltration measures that reduce the losses resulting from impervious surfaces; b) reducing demand by implementing water conservation measures through the replacement of inefficient water fixtures and practices; c) reducing demand by repairing leaks to aging water distribution systems, and d) replacing defective sewer mains and stormwater conveyance systems that cause groundwater dewatering. When considering the costs involved, are these reasonable proposals? Consider the views of the water supplier and those of the environmentalists.

This issue is being heavily debated in Massachusetts between these groups (Recent News Clips - June newsclip, also under "Primary Resources for 2010, http://www.maenvirothon.org/currentissue.htm). For the purpose of deciding how your community is measuring up in protecting groundwater for these competing needs, your teams should begin by being acquainted with the Massachusetts Water Policy (2004) for its recommendations – at http://www.mass.gov/Eoeea/docs/eea/water/waterpolicy_2004.pdf. Use these recommendations as your guide. Identify accomplishments, short comings and proposals for protecting groundwater. You may also want to consider plans that address the potential impacts from climate change resulting from an increased frequency and intensification of rainfall events that are separated by longer droughts, public water supply shortages and decreases in soil moisture over some inland regions during the summer (see: http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf (Frumhoff et. al. 2007).

Envirothon teams from past events have learned that use and management of the natural resources requires a "big picture" understanding of people as well as nature. The laws of ecology tell us that for every action there are many unpredictable consequences. Initiating a plan for the installation and production of a water withdrawal and/or land development without a full understanding of the watershed's geology is a mistake as its physical properties, above and below the surface, govern the limits for rainwater infiltration and groundwater storage, contamination vulnerability, and consequently can have unintended consequences in its capacity to affect groundwater quantity or quality. In view of the changes that frequently accompany population growth and land development, proactive watershed-based, groundwater protection planning is a topic worthy of exploring, especially in rural communities' not experiencing growth pressures - yet are on the cusp of urbanization. Is your community vulnerable to these growth pressures? If so, are plans in place or in the works to address groundwater protection? Are other communities that share this watershed engaged to address the collective need of the towns?
Examine where land development, water use, wastewater discharges, and interbasin transfers of water and wastewater have occurred and/or are expected. Massachusetts Audubon's recently released 2009 report entitled "Losing Ground Beyond the Foot Print: Patterns of Development and their Impact on the Nature of Massachusetts" at

http://www.massaudubon.org/losingground/ provides useful information for your team to consider because it highlights Massachusetts' growth patterns, past and present. In addition, teams should consider the many challenges of water resources planning to satisfy the ever growing demand by man's societal needs while at the same time protecting water dependant ecosystems (Postel, 2000) https://waterportal.sandia.gov/literature/globaltrends/waterscarcity.pdf

Further discussion on protecting water resources with "smart growth" can found by these EPA documents: http://www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdfl; http://www.epa.gov/smartgrowth/pdf/growing_water_use_efficiency.pdf

While the restoration of groundwater recharge in urban settings has its benefits, it could also have its detriments if not addressed correctly. When carried in the absence of having knowledge of an aquifer's capacity for recharge and storage, especially when groundwater recharge is limited, it is possible that a groundwater table's elevation will rise to levels that cause basement flooding and damage to underground sewer mains and electrical conduits. In extreme events this would include street flooding.

Also worth investigating is the after affects resulting from the loss forest cover from clear cutting and the development of this acreage with the addition of impervious surface cover (pavement and roof tops). Can you identify in the historical records of your community or watershed any changes in water supply demand, water table elevation changes, and/or the reduction or loss of stream flow? Have town measures been enacted to reduce the impacts from these changes?

Water Quality Protection from future land uses that are incompatible with water quality protection. Has your Board of Health enacted regulations for the registration, proper storage, and use of toxic and hazardous materials and wastes in your town; especially in high yield aquifer locations where groundwater infiltration capacity is the greatest and where the potential for groundwater contamination from inappropriate landuses and activities, including discharges from vehicles discharging petroleum products from roadway accidents is the greatest?

Does your community have zoning bylaw(s)/ordinance(s) and/or regulation(s) with the controls to protect groundwater from inappropriate land development patterns and uses within the zone of contribution or Zone II of a public supply well? See: http://www.mass.gov/dep/water/modgwpd.pdf. If yes, how do the boards and commissions in your community issue its permits and/or licenses and otherwise enforce its rules and regulations that comply with a MassDEP requirement that a town provide zoning or non-zoning controls to prohibit in appropriate landuses within Zone IIs? Most if not all towns with public supply wells have mapped their Zone IIs and have these "overlay maps" accompany their zoning prohibitions.

Water Supply Demand. Water withdrawal volume data for water supply production can be obtained from the compliance reporting records that are filed by the local water supplier with the Massachusetts Department of Environmental Protection (MassDEP). The information on these forms identifies each source and its annual and monthly production, and its overall compliance with the MassDEP's water-use efficiency standards. This information can be obtained from your public water supplier. Ask for a copy of the Annual Statistical Report (ASR) they are required to submit to MassDEP each January.

An ASR identifies the withdrawal volume from the watershed for every source, by watershed basin, and the supplier's compliance with the following MassDEP standards:

- Unaccounted-for-water (UAW) of ten percent or less. UAW losses should not be greater than 10 percent of the metered water withdrawal that the supplier is unable to account for it full consumption and use. Losses that fall within this category could be the result of water main leakage, meters that are malfunctioning or are over sized, and unmetered municipal use.
- Residential gallons per capita per day of 65 gallons or less.
- Successful water conservation education and outreach activities that promote water efficient fixtures and practices.

Reducing demand through water conservation helps to insure that the water supply withdrawal does not exceed the water budget of the watershed; that the source is also capable of sustaining the needs of population growth and ecosystem functions.

To learn more about this MassDEP requirement and how well your town is doing with these performance standards, go to this MassDEP website: http://www.mass.gov/dep/water/resources/rgpcd06.htm

Much has yet to be fully realized from water conservation. EPA reported recently that since the 1.6 gallons per flush federal standard has been in effect for since 1992, and despite the improvement in toilet performance, over 40% of toilets in use today are still of the older, higher-water use type. EPA estimates that the replacement of these older 5 to 7 gallons/flush toilet with one of the water efficient units can save the average home up to 10,000 gallons per year. The reduction in water withdrawals from the watershed can be huge when these older units are replaced. Can you envision how this reduction in withdrawal from water conservation affects cash flow of the water supplier? Do you have a proposal to address this shortcoming?

Impervious Pavement and Roof Tops. Has your community established rules (bylaws/ordinances/regulations) to restore groundwater recharge losses from the watershed resulting from stormwater runoff from past and new developments; especially when large areas of the watershed are covered with pavement and roof tops? Also, has your town been identified as an US EPA Stormwater Phase II NPDES permit regulated community? This regulatory program requires towns to locate and map their storm drains and to a develop plan for reducing water quality impacts to affected inland and coastal waters. If your town is a Phase II (Stormwater MS4) community, what actions are underway to address this federal requirement? The list of towns designated under this federal rule can be found at: http://www.mass.gov/dep/water/wastewater/stormlis.htm For a detailed discussion on Phase II requirements and best management practices (BMPs) consult the following website: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

3. SOURCES OF INFORMATION

MASSACHUSETTS ENVIRONMENTAL AGENCIES

The key state agency involved in the identification, evaluation, and protection of groundwater is the Department of Environmental Protection:
http://www.mass.gov/dep/water/waterres.htm
MassDEP Sustainable Water Resources: http://www.mass.gov/dep/water/local.htm
MassDEP Stormwater Program:
http://www.mass.gov/dep/water/wastewater/ov_storm.htm
U.S. Geological Survey: http://ma.water.usgs.gov/basins/ims.html

INTRODUCTORY VIDEOS

Groundwater Video – Annenberg Media
Approximately three-quarters of Earth's surface is covered by water. But most fresh water comes from underground. Topics of this program include aquifers, rock porosity and permeability, artesian wells, the water table, cave formation, sinkholes, and how groundwater may become contaminated.
http://www.learner.org/resources/series78.html?pop=yes&pid=332#
Reining in the Storm -- One Building at a Time – a must view! http://www.clu-in.org/studio/reining.cfm
Groundwater Quality Protection Video: "Groundwater Video" from Quinte Ontario, Canada explains how groundwater can be contaminated:
http://www.quinteconservation.ca/web/index.php?option=com_wrapper&Itemid=75

WATERSHED HYDROLOGY

Delineate the Boundaries of your Watershed
http://www.stormwatercenter.net/Slideshows/delineating_boundaries_files/frame.htm
The processes and characteristics of watersheds that define the availability of water.
http://ga.water.usgs.gov/edu/watercyclesummary.html

MASSACHUSETTS WATERSHEDS

http://www.mass.gov/Eoeea/docs/eea/water/watersheds_map.pdf

HYDROLOGICAL IMPACTS OF URBANIZATION

Hydrological Impacts of Urbanization:
http://www.epa.gov/OWOW/nps/urbanize/report.html#02
Urbanization Impacts on Aquatic Resources:
http://www.michiganlanduse.org/resources/councilresources/Urbanization_Impacts_Aquatic_Resources.pdf

A MUNICIPAL PERSPECTIVE TO WATER USE AND CONSERVATION

A virtual tour of Sharon's water resources
A slideshow presentation with photos, facts and figures to help you get a better understanding of the challenges facing Sharon's water supply as the town grows.
http://www.sharonfoc.org/water/water_optimized.pdf

GROUNDWATER RESOURCE PROTECTION PLANNING

Protecting Water Resources With Smart Growth
http://www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdf
Groundwater Quality Protection - defining strategy and setting priorities:
http://siteresources.worldbank.org/EXTWAT/Resources/4602122-1210186362590/GWM_Briefing_8.pdf
Nonpoint Education for Municipal Officials (NEMO) http://nemo.uconn.edu/index.htm

STORMWATER RUNOFF MITIGATION

http://www.stormwatercenter.net/Slideshows/impacts%20for%20smrc/sld001.htm
Water Wise Handbook for Municipal Managers in the Ipswich Watershed – Highlights 20 tools that municipalities can use to protect water supplies, manage stormwater, preserve open space, educate residents, and restore the Ipswich River:
http://www.ipswichriver.org/waterwise/
Developing Successful Runoff Control Programs For Urbanized Areas (includes Massachusetts case study communities) http://ntl.bts.gov/DOCS/RUNOFF.html
Low Impact Development: http://www.mass.gov/envir/smart_growth_toolkit/pages/SG-slides-lid.html; http://www.mass.gov/envir/smart_growth_toolkit/pages/CS-lid-pinehills.html
Open Space Residential Development
http://www.mass.gov/envir/smart_growth_toolkit/pages/SG-slides-osrd.html
Introduction to Local Stormwater Bylaws
http://www.mapc.org/regional_planning/LID/Stormwater_Bylaws_LID.html
EPA Managing Wet Weather with Green Infrastructure:
http://cfpub.epa.gov/npdes/home.cfm?program_id=298

MAPS

Historic Massachusetts Maps: http://docs.unh.edu/nhtopos/massachusetts.htm
Massachusetts Drainage Basin Maps: http://ma.water.usgs.gov/basins/ims.html
OLIVER -- The MassGIS Online Data Viewer:
http://maps.massgis.state.ma.us/massgis_viewer/index.htm

REDUCING DEMAND THROUGH WATER USE EFFICIENCY MEASURES

Massachusetts Water Conservation Standards
http://www.mass.gov/Eoeea/docs/eea/water/water_conservation_standards.pdf
EPA Water Sense: http://www.epa.gov/WaterSense/
Water: Use it Wisely http://www.wateruseitwisely.com
City of Toronto - Water Efficiency Plan http://www.toronto.ca/watereff/plan.htm
Water Saver Program - Case studies of cost savings
http://www.toronto.ca/watereff/case_studies.htm
Energy Efficient Water Fixtures
http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13050

LOCAL INFORMATION SOURCES

Potential Town Contacts:

- Town Planner
- Public Water Supply Superintendant
- Public Works Engineer or Manager
- Highway Department Manager
- Health Department Director

Regional Planning Agency Contact:
http://www.pvpc.org/resource_center/affiliate-agencies.shtml
Watershed Contacts: http://www.mass.gov/dfwele/river/watershed/

4. SELECTED READINGS

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EPA. Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies. Pp. 34
http://www.epa.gov/smartgrowth/pdf/growing_water_use_efficiency.pdf

EPA. Protecting Water Resources through Smart Growth.
http://www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdf

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http://www.tpl.org/content_documents/landandwater_opflow_article.pdf

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http://www.nrcs.usda.gov/technical/stream_restoration/PDFFILES/CHAPTER3.pdf

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http://books.google.com/books?id=B3H5rHTLdN4C&printsec=frontcover&dq=Ground+Water+and+Surface+Water:+Perfect+Together&source=gbs_similarbooks_s&cad=1#v=twopage&q=&f=false

Frumhoff, Peter C. et. al. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, Solutions. Union of Concerned Scientists.
http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf

Howard, Ken W. F. and Rauf G. Israfilo (editors). Current problems of hydrogeology in urban areas, urban agglomerates, and industrial centres.
http://books.google.com/books?id=tpIEXpMuE1QC&printsec=frontcover&dq=Ground+Water+and+Surface+Water:+Perfect+Together&source=gbs_similarbooks_s&cad=1#

Massachusetts Audubon Society. 2009 Losing Ground Beyond the Foot Print: Patterns of Development and their Impact on the Nature of Massachusetts.
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