Cleveland State University
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TECHNICAL REPORT

ANALYSIS OF WATER CONSERVATION MEASURES BY INDUSTRY SECTOR

Project SG 447-2013

Conducted by Cleveland State University

For Ohio Lake Erie Protection Fund

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Introduction

This document reports on the completion of the project "Analysis of Water Conservation Measures by Industry Sector" commissioned by the Ohio Lake Erie Commission and Lake Erie Protection Fund. This project surveys the literature and presents an overview of water withdrawal and conservation measures to support the Ohio Department of Natural Resources (ODNR) and the Ohio Lake Erie Commission as they seek to advise the Governor and the Commission on the Development, Implementation, and Coordination of Lake Erie Programs and Policies.

Cleveland State University research team created and analyzed an inventory of best practices in water conservation measures by industry sector that are the largest consumers of water in the state of Ohio. During this project, the ODNR Division of Soil and Water Resources acted in an advisory role for the research team.

The technical report describes five outputs of the project:

(1) Report on an inventory of best management and technology practices in water withdrawal and conservation in hardcopy and electronic format;
(2) A presentation of the materials for placement on appropriate websites and for use by agency representatives to communicate the finding in summary form;
(3) Proposal to present the project findings in five public forums and professional conferences;
(4) Two planned academic journal article submissions;
(5) A teaching module distributed to three departments at Cleveland State University.

Additionally, the technical report addresses activities undertaken during this research with discussion of relevant timelines and deliverables.

All materials developed as final products of the project have been recorded in electronic format and provided to the Ohio Lake Erie Commission and the ODNR.

Description of the Project and Methodologies

This project was undertaken to support the Ohio Lake Erie Commission and the ODNR to advise the Governor and the Commission on the development, implementation, and coordination of Lake Erie programs and policies. The results of this project can be used to assist the State of Ohio to develop and implement water conservation and efficiency programs.

The research process was conducted in five main phases:

(1) Creating a framework to research critical information on water withdrawal and conservation measures;
(2) Identifying databases, appropriate literature, sources, and agency departments with existing best practices of water withdrawal and conservation;
(3) Selecting titles, abstracts, and manuscripts with best practices in water conservation and technologies;
(4) Summarizing data in a standardized format, conducting analyses of water usage by different industries, and developing an inventory of best water management practices in an easy to disseminate format;
(5) Discussing the preliminary results and finalizing the results of the project.

Our methodology was based on gathering and analyzing regulatory documentation, best management practices, and new technologies in the area of water use and conservation by sector. To create an inventory of relevant materials, three broad clusters of literature were under review: academic publications, sector-based studies, and best practices of state agencies.

Water-intensive sectors were identified using two different databases. The first data analysis was conducted by using IMPLAN input-output industrial data for the state of Ohio. Using the 2012 data (latest data available) on the *Water, sewage and other systems* sector (IMPLAN industry code 33), we identified water-intensive industries by applying IMPLAN's technical input-output coefficients. To do this we analyzed (1) industry's total expenditure on water, measured in dollars and (2) the ratio of an industry's expenditure on water to the industry's total expenditures, measured as unit expense on water. The resulting list of industries from this analysis identified the largest buyers of water in the state of Ohio. The industries were classified according to the North American Classification System (NAICS). Only industries that purchase water were included in this analysis.

The second data analysis was based on ODNR data of permitting companies for water withdrawals. The resulting list of industries from this analysis identified the largest users of water. This list was produced using ODNR classification of main water usage purpose.

The primary challenge of these analyses was identifying that main water usage purposes cannot be identified by the NAICS code of a company. Still, the NAICS-based analysis did allow us to compare the largest water use industrial sectors with the largest users by the water usage purpose in the state of Ohio.

Project Activities and Timeline

The project was conducted at collaboration with agency advisers. At the beginning, the research team was advised by Ted Lozier and Mike Hallfrich from the Division of Soil and Water Resources at ODNR (as suggested in the proposal). Due to administrative changes at ODNR, the project was finalized under the advice of Mike Hallfrisch.

From June 1, 2013 to August 31, 2013 the research team developed a framework for the literature review and conducted a search of literature on water conservation measures by industry sectors within academic publications, sector-based studies, nongovernment organization research, and government agency practices. The inventory of academic literature reviewed under the project with a short description of each study (Appendix 1) was presented to agency advisers.

From September 1, 2013 to November 30, 2013 two data analyses were conducted, the analysis of IMPLAN water-intensive sectors in Ohio and the analysis of data collected by ODNR for permitting purposes. Both analyses (Appendix 2) pointed to the selection of industries by water use purposes featured in the report of best practices on water withdrawal and conservation measures “Water Resource Sharing Ohio’s Future: Water Efficiency Manual for Industrial, Commercial, and Institutional Facilities” (submitted together with this report). The list of prospective industries was also considered from a prospective of industrial clusters that represent economic base of Ohio’s economy or its growing industries.

The final list of industries included:

(1) Power Plants
(2) Iron and Steel Industry
(3) Chemical Industry
(4) Petroleum Refining Industry
(5) Food Processing
(6) Mining
(7) Hydraulic Fracturing
(8) Agriculture
(9) Golf Courses, Amusement Parks, and Other Recreation Facilities

Besides the specific industries, the study identified general principles and practices for sustainable water management and reviewed best practices in water use for commercial, industrial, and institutional facilities that are applicable to all industries.

From December 1, 2013 – February 28, 2014, the research team reviewed the literature and analyzed the water conservation measures proposed in best practices in selected industries. We also reviewed the costs of the adoption of conservation measures in multiple examples and case studies selected for the report. Due to a significant variation of the costs not only for different industries, but also for companies within the same industry, a much broader study supported by sufficient resources is required to conduct a feasibility analysis for all industries proposed in our report. This prospective study would require significant resources to be devoted to data collection and compliance by industries and individual companies to reveal their expenditures for implementation of water conservation measures and practices. Within this time period, the interim results of the project were presented to ODNR. The research team discussed with the agency advisor the data analyses results, findings in academic literature, and the structure for the final report. We also deliberate on the role of advisory board and other outside advising during the study. Throughout this process, the research team delivered interim progress report to the agency advisor and the Ohio Lake Erie Commission.

From March 1, 2014 to May 31, 2014 the research team wrote the final report and the presentation (in PowerPoint format – submitted with this report). We also developed a teaching module (Appendix 3) and conducted consultations with other departments within Cleveland State University on prospective teaching of the module based on the project findings. The research team designed and wrote a plan for two academic articles based on the study findings (Appendix 4). The research on the articles is ongoing and we are in the process of writing and submitting the articles to appropriate outlets. During this timeframe, the research team planned to delivere public presentations of the project findings at five public events (Appendix 5). After the completion of the draft of the final report, we disseminated it to external reviewers (individuals and organizations). The list of reviewers developed in part through suggestions from, and with the approval of ODNR. In May 2014, the request for a short no-cost extension was filed with the Ohio Lake Erie Commission to allow more time for reviewing the draft of the final report by external reviewers and presenting the report to ODNR. The new deadline for the project, June 27, 2014, was approved by the Ohio Lake Erie Commission. To date, the draft of the report has been reviewed by four outside reviewers. In addition, ODNR disseminated the draft of the final report within their agency to multiple reviewers and provided synthesized comments from their multiple reviewers. All suggested changes were made to the draft of the report.

At the presentation to ODNR, the research team discussed the dissemination of the study findings. We offered to the ODNR all studies that were reviewed in the report in PDF format/electronic version and suggested the structure of a websites that can be used a model to modify ODNR website for dissemination of the best practices by different industries (http://www.edaincubatortool.org/toolkit.html).

To achieve the goal of this project, the following planned outputs/products were delivered:

- two reports: interim report (descriptive report and financial accounting) and final report (this technical report on the project and the report with the inventory of water conservation management practices);
- two academic articles are planned and in progress to be submitted to peer-reviewed water-related professional journals within six months of the end of the project period;
- a PowerPoint presentation that will be used at public meetings and uploaded to applicable websites;
- presentation of the project results to ODNR with following discussion on the project results;
- at least five public forum(s) and/or other professional conferences within the State of Ohio;

- teaching module on water conservation that will be used for graduate-level classes in urban sustainability, environmental finance, environmental policy and environmental planning fields at the Levin College; the module will be shared with faculty colleagues in CSU Colleges of Engineering, Science, and Law.

All products are (and will) acknowledging support from the Ohio Lake Erie Commission and the Lake Erie Protection Fund.

One challenge we experienced during this project was on engaging the advisory committee for the project. In early consultations with agency advisors it was recommended that we engage with outside advisors on a one-to-one basis and close to the completion of the project send the draft of the report to outside reviewers and organizations. The research team followed this suggestion.

FINAL ACCOUNTING

The financial reporting at Cleveland State University lags by 90 days from the project completion date. The signed financial statement will be provided by the university not later than September 27, 2014.

Project Abstract

ANALYSIS OF WATER CONSERVATION MEASURES BY INDUSTRY SECTOR

Conducted by Cleveland State University (CSU)

The basic objective of this project was to gather, organize, and catalogue information on existing best management practices (BMP) for water use sectors. This project was completed by identifying water-intensive sectors using the Ohio IMPLAN data and the Ohio Department of Natural Resources' (ODNR) data showing companies with the capacity to withdraw more than 100,000 gallons a day along with their actual annual withdrawal amounts. The research team produced a report including: 1) A general toolkit for all entities with a potential to undertake water efficiency efforts including a self-assessment checklist, steps for a successful water efficiency program, technical and financial feasibility frameworks for BMPs, and water auditing tools and methodologies; 2) BMPs that apply to most commercial, industrial, and institutional facilities; and (3) Industry-specific BMPs for the following sectors: Power Plants; Iron and Steel Industry; Chemical Industry; Petroleum Refining Industry; Food Processing; Mining; Hydraulic Fracturing; Agriculture; Golf Courses, Amusement Parks, and Other Recreation Facilities. Other products include: presentation to ODNR; five public forums and conferences; two academic articles; a teaching module taught in 10 classes across four colleges at CSU; and electronic report available to the public at the CSU and ODNR websites.

APPENDIX 1. Inventory of academic literature

	Classification	Author(s)	Year	Title	Methods	Questions/Goals/Findings/etc.
1.	++ INT MODEL TECH *SECTOR	Gao et al.	2008	An analysis of industrial water conservation potential and selection of key technologies based on the IWCPA model	Based on 1980 data on the level of technology, technological progress, and water efficiency, the study uses the bottom–up modeling approach; the end-of-pipewater use analysis method; and the cost-benefit analysis method to establish the industrial water conservation potential analysis (IWCPA) model. Taking 2002 as the baseline year, the IWCPA is used to simulate and calculate water demand and water conservation potential of China's industries under different technology scenarios between 2003 and 2030.	This paper analyses the changes in the water efficiency of the production processes and technologies in five high-water-consuming sectors (HWCS; thermal power, iron and steel, paper production, textiles, and petrochemical) since 1980. The study concludes that the main factors constraining water conservation include: backward technologies and processes; irrational industrial scale and composition and raw materials composition; as well as regional distribution. Based on the assessment of different technologies for individual sectors and across sectors, key priority technologies are proposed for five HWCS. Lastly, the paper, based on an uncertainty analysis of the parameters used in the model, talks about the impact of water pricing and other factors on future water demand and water conservation potential by industrial sectors. The paper also finds that the water conservation potential of key common technologies accounts for over 60% of water consumption by HWCS. The economic benefits from improving production processes are far greater than those from reuse or recycling technologies only.

2.	-R INT SECTOR TECH *SECTOR	Gumbo et al.	2003	Industrial water demand management and cleaner production potential: a case of three industries in Bulawayo, Zimbabwe	Three industries of wire galvanizing, soft drink manufacturing and sugar refining were studied in Bulawayo, Zimbabwe to identify potential opportunities for reducing water intake and material usage and minimizing waste.	The results show that the wire galvanizing industry could save up to 17% of water by recycling hot quench water through a cooling system. The industry can eliminate by substitution the use of toxic materials, namely lead and ammonium chloride and reduce the use of hydrochloric acid by half through using an induction heating chamber instead of lead during the annealing step. For the soft drink manufacturing industry water intake could be reduced by 5% through recycling filter-backwash water via the water treatment plant. Use of the pig system could save approximately 12 m^3/month of syrup and help reduce trade effluent fees by Z$30/$m^3$ of ‘‘soft drink’’. Use of a heat exchanger system in the sugar refining industry can reduce water intake by approximately 57 m^3/100 t ‘‘raw sugar’’ effluent volume by about 28 m^3/100 t ‘‘raw sugar’’. The water charges would effectively be reduced by 52% and trade effluent fees by Z$3384/100 t ‘‘raw sugar’’ (57%). Proper equipment selection, equipment modification and good house-keeping procedures could further help industries reduce water intake and minimize waste.

3.	INT ECON Methodology	Holt et al.	2000	Analysis of the role of waste minimization clubs in reducing industrial water demand in the UK	The paper identifies the effectiveness of a series of industrial waste minimization clubs in UK in reducing the demand for water.	An overview of some of the clubs show how there is a major discrepancy between potential and implemented water savings, whilst a more detailed analysis of three specific examples show how water demand and cost to the company can be reduced, with the project paying for itself within around 1 year. It appears that companies are able to reduce water consumption by approximately 30%. If this level of saving was taken up by the entire industrial sector in England and Wales, water consumption could be reduced by approximately 1500 Ml/day.
4.	++ ECON SECTOR *SECTOR MODEL Policy Theory *Follow the author	Schaible	1997	Water conservation policy analysis: An interregional, multi-output, prima-dual optimization approach	An interregional, multi-output, normalized restricted-equilibrium model of field-crop agriculture is estimated within the context of a multistage, programming-based system estimation procedure. Data: Western United States (i.e. the Pacific Northwest—Idaho, Oregon, Washington)	Implicit, total economic-cost functions endogenize behavioral, opportunity adjustment costs of fixed and allocable land and water resources. Crop-specific, Marshallian water demand elasticities are estimated for restricted and unrestricted water substitution environments. Elasticities are inelastic but water price policy reform can be an effective water conservation policy tool. When groundwater use is restricted, effective conservation policy requires more dramatic water-price policy reform.

5.	ECON INT Theory	Bhatia et al. (UNDP World Bank Report)	1994	Water conservation and pollution control in Indian industries: How to use water tariffs, pollution charges, and fiscal incentives		Mentions that the fragmented "Command-and-control" approach to management of water resources has failed, both economically and environmentally. Thus, the focus has shifted towards the importance of "treating water as an economic good", with specific attention being on the use of economic instruments for the conservation of water and improvement in environmental quality. Finds that: 1-water prices, effluent charges, and fiscal incentives are effective demand management tools for improving water quality and managing the use of total water resources. 2- The determination of effluent charges and options, costs of treatment, and consequences of downstream externalities. 3-water demand management in the industrial sector provides several benefits such as reducing costs to society. 4- Investment and operational costs of water supply augmentation and pollution control projects will be kept under control when staff working in the sector start to give enough consideration to demand management options during project preparation. The focus of the report is primarily on the developing countries.

6.	ECON INT Theory *Follow the author	Howe	2005	The Functions, Impacts and Effectiveness of Water Pricing: Evidence from the United States and Canada	Water pricing case studies in United States and Canada	Analyses what is considered to be different 'prices' of water: those which depend on the services that are provided, on the revenues structures, and on the types of water markets to which the users may have access to. Conflicting roles of water pricing are also discussed, like the validity of the arguments based on economic efficiency; the generation of adequate revenues for operation, maintenance and expansion of the water system; and the 'equitable' treatment towards water users.
7.	TECH MODEL Methodology *Follow the author	Dunn et al.	2001	Process integration design methods for water conservation and wastewater reduction in industry	----	Is part 2 of a 3 part series of papers addressing operational techniques for applying mass integration design in industry with special focus on water conservation and wastewater reduction. The paper presents a design technique for any number of wastewater streams containing multiple contaminants. The technique comprises a single non-linear optimization program to minimize wastewater discharged or maximize the amount of recycled wastewater. This program is developed based on general water allocation principles and uses the transshipment model theory to allow the shipment of wastewater (referred to as sources or warehouses) to process water users (referred to as sinks, demands or customers). A detailed case study of industrial significance, highlighting land treatment technology is included to illustrate the proposed methodology and various process scenarios are evaluated within this

						case study to demonstrate the general applicability of the proposed optimization program.
8.	MODEL ECON INT Theory	Wang & Lall	2002	Valuing water for Chinese industries: a marginal productivity analysis	A marginal productivity approach is developed for valuing industrial use of water and applied using data from Chinese industrial firms, where water, as well as capital, labor and raw materials, are treated as inputs to a production function.	Models on price elasticity of water demand associated with the marginal productivity approach are developed and estimated for different Chinese industrial sectors.
9.	SECTOR *SECTOR Methodology *Follow the author	Yang & Dziegielewski	2007	Water use by thermoelectric power plants in the United States	Multiple regression	Mentions that thermoelectric power generation is responsible for the largest annual volume of water withdrawals in the US. Identifies significant determinants of unit thermoelectric water use. Suggests that there is a great potential for water conservation in existing thermoelectric power plants.
10.	-R ECON INT	Mylopoulos et al.	2007	Demand management aspects of urban water policy in the industrial sector: the case of the city of Thessaloniki, Greece	Survey	Deals with consumers' perception of water issues in the industrial sector, and examines and analyses water use patterns, water conservation methods and water pricing issues. Issues presented are the contribution of water to production processes, water consumption levels, water conservation options, the possibility of construction of a dual water supply system, the evaluation of different pricing policies, the willingness to pay (WTP) and the potential impact of a price increase.

						Shows that there is limited use of recycling methods, few pollution control practices and small effect of industrial water price on water consumption levels. As far as industrial consumers are concerned, they present inaccurate perception of water consumption levels and low willingness to pay for the improvement of water services.
11.	INT SECTOR *SECTOR MODEL Methodology Theory	Dong et al.	2013	Regional water footprint evaluation in China: A case of Liaoning	Case study of Liaoning Province, a typical heavy industrial province in North China. Input–output analysis method was employed to evaluate regional water footprint.	The "Agriculture" and "Food and beverage production" sectors are found to have the highest water footprint, water intensity, water exports, and water trade balance. Based upon Liaoning realities policy implications and suggestions are made, including industrial and trade structure adjustment, application of water efficient technology and management measures, and appropriate capacity-building efforts.
12.	-R INT SECTOR Policy	Vernon et al.	2005	Collaborative Policymaking: Local Sustainable Projects	Case study Qualitative	This paper evaluates a collaboration adopted by a British district council in the formulation of a local strategy for promoting the adoption of sustainable practices (including water conservation) by tourism Sector. The key findings of the study emphasize the role of the public sector in promoting ''bottom-up'' forms of governance, the temporal dynamics of the process, and the reality of innovation in policymaking.

13.	-R SECTOR *SECTOR Policy *Follow the author	Baumgart-Getz et al.	2012	Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature	Meta-analysis of both published and unpublished studies Uses a statistical technique to summarize the adoption literature.	Identified the following variables as having the largest impact on adoption: access to and quality of information, financial capacity, and being connected to agency or local networks of farmers or watershed groups. Includes several water conservation articles.
14.	-R INT MODEL Methodology	Zhao et al.	2009	National water footprint in an input–output framework—A case study of China 2002	Input–output analysis	Presents a framework of calculating national water footprint (NWF) with input–output method. Finds that agriculture, construction, electricity, gas and water production and supply, machinery and equipment are the top four sectors of net virtual water importers. And light industry and wholesale and retail trade and passenger transport, chemicals, electric equipment, telecommunication equipment, and instrument (sectors 21, are the sectors holding top amount of virtual water export.
15.	SECTOR *SECTOR ECON Methodology *Follow the author	Matsumura & Mierzwa	2008	Water conservation and reuse in poultry processing plant—A case study	Case study	Water conservation and water reuse concepts in food industry are presented in this paper. Rational water use strategies to identify operational flaws were evaluated by improvements at operational issues and physical losses identification. Some sectors with high water consumption and wastewater generation were identified, and the feasibility of water reuse practices was evaluated. To identify sectors with high water consumption, their consumption was prioritized by classification of water volume

						using the ABC curve concept (Solano, 2003), where it is graphically possible to identify the highest water consumers (see page 836-837 for more details). A reduction by almost 31% in water consumption was achieved as a result of this study. It can be concluded that water conservation and water reuse programs are important tools for industry economy and its sustainability, and for the environment by preserving freshwater resources.
16.	-R INT	de Loe et al.	2001	Adaptation options for the near term: climate change and the Canadian water sector	Case study	Discusses issues relating to the selection of proactive, planned adaptation measures for the near term (next decade). A set of selection criteria is offered, and these are used in three cases to illustrate how stakeholders can identify measures appropriate for the near term. Cases include municipal water supply in the Grand River basin, Ontario; irrigation in southern Alberta; and commercial navigation on the Great Lakes. In all three cases, it is possible to identify adaptations to climate change that also represent appropriate responses to existing conditions; these should be pursued first. Includes info regarding water conservation
17.	MODEL TECH Methodology	Sotelo-Pichardo et al.	2011	Optimal retrofit of water conservation networks	Mathematical model	Presents a new general mathematical programming model for the optimal retrofit of material conservation networks considering recycle, reuse and regeneration schemes.

						The model considers the reconfiguration of existing networks to satisfy stricter process and environmental constraints considering the repiping for the network, the reuse of the existing treatment units, the modification for the capacity and performance of the existing units and the installation of new treatment units to reduce the overall operating cost through the reduction of the use of fresh sources. The objective function accounts for the minimization of the total annual cost associated to the retrofit process. This retrofit process involves simultaneously economic (because the reduction of the fresh sources costs) and environmental (because the reduction of the waste streams discharged to the environment and with a better quality) improvements. The applicability of the proposed model is proved through a set of example problems addressed, where no numerical complications were observed. In addition, the proposed approach is general and it can be applied to any specific case with the information required.
18.	-R INT SECTOR *SECTOR	Huang et al.	2012	The impact of local crops consumption on the water resources in Beijing	Water footprint calculation Case study of Beijing	Based on the production perspective, improving water and fertilizer management has great potential for reducing the blue and grey water footprints of crops in the farming stage. However, the challenge is how to inspire farmers to participate in the activities of reducing water consumption and pollution. Increasing farmers', especially female farmers' access to related technologies can

						have a positive impact on the sustainable use of water in Beijing.
19.	-R INT MODEL Methodology	Wang et al.	2013	An input-output approach to evaluate the water footprint and virtual water trade of Beijing, China	Input-output analysis	By combining an input-output model with intersectoral water flows, this paper describes a modified input-output model to calculate the direct, indirect and gross water footprint intensity and the gross water footprint of different sectors in Beijing in 2002 and 2007. The results show declines in the agricultural and industrial water footprints for these years. The grey water footprint, which reflects environmental pollution caused by human production and consumption, was also calculated and suggests that the shortage of water resources, rather than water pollution, is the main problem in Beijing. Adjustments in the industrial structure, along with virtual water importing, should be prioritized as water-saving strategies for Beijing.
20.	-R SECTOR *SECTOR	Zektser et al.	2004	Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States	Case study	The southwestern United States—this paper's study region—is home to large urban centers and features a thriving agro-industrial economic sector. This region is also one of the driest in North America, with highly variable seasonal and inter-annual precipitation regimes and frequent droughts. The combination of a large demand for usable water and semi-arid climate has led to groundwater overdraft in many important aquifers of the region. Groundwater overdraft develops when long-term

						groundwater extraction exceeds aquifer recharge, producing declining trends in aquifer storage and hydraulic head. In conjunction with overdraft, declines in surface-water levels and streamflow, reduction or elimination of vegetation, land subsidence, and seawater intrusion are well documented in many aquifers of the southwestern United States. Reviews case studies of groundwater overdraft in the southwestern United States, focusing on its causes, consequences, and remedial methods applied to counter it.
21.	R SECTOR *SECTOR	Northcutt & Jones	2004	A survey of Water Use and Common Industry Practices in Commercial Broiler Processing Facilities	Survey	A survey of commercial broiler processing facilities across the US was conducted to determine overall water use and what may influence it. Over 38% of the respondents reported that they recycle water, and a significant relationship was observed between the amount of water recycled and the size of facility.
22.	-R INT SECTOR ECON	Charara et al.	2011	Water use efficiency in the hotel sector of Barbados	Data were collected from the Barbados Water Authority and from onsite surveys; consumption patterns were compared with international studies which had established environmentally acceptable benchmarks.	Unit water consumption was somewhat correlated with the number of rooms, average room rate, property size and number of employees. The lack of success in reducing hotels' water consumption is tied to the fact that water bills represent less than 5% of their annual expenses. A model for unit water consumption was derived using two influential variables: the annual number of guest nights and the number of employees. Ways of fostering sound water practices

						include promotion among guests of the need to save water, schemes to promote the financial benefits of water conservation by relating unit water pricing to total consumption and awareness-raising among hotel managers.
23.	++ SECTOR ECON Theory Methodology *Follow the author	Abbott & Cohen	2009	Productivity and efficiency in the water industry		The paper reviews the various measures that have been used to gauge the levels of productivity and efficiency in the water sector, with particular reference to input and output data requirements of these measures. It also summarizes the key structural findings that have been determined from this research, particularly with respect to economies of scale and scope, public versus private ownership and the impact of regulation. Ultimately, it considers potential areas for potential future research, such as the effect of environmental management activities (including water conservation) and regulation on productivity and efficiency, the role of wastewater as a potential source of potable or 'fit-for-purpose' water and the relationship between water supply and urban planning.
24.	SECTOR *Follow the author	Carvalho et al.	2013	Sustainable airport environments: A review of water conservation practices in airports		The paper presents information regarding water consumption in globally important airports in order to provide a basis for studies that guide policies and decision-making toward a sustainable management of these environments during the planning and execution of construction, expansion and modernization projects.

						In airport complexes, most of the water is used to meet non-potable demands, making them potential environments for implementing conservation practices aimed at reducing these demands – such as water metering and installation of water saving fixtures – and also for searching for alternative sources, such as rainwater and treated greywater or domestic sewage effluent.
25.	-R SECTOR INT Methodology	Chowdhury & Al-Zahrani	2013	Characterizing water resources and trends of sector wise water consumptions in Saudi Arabia	Nonlinear equations are developed to predict the domestic, industrial and agricultural water demands.	The paper investigates water resources and trends of water consumptions in Saudi Arabia. Focuses on agricultural, domestic and industrial sectors.
26.	-R INT Policy	Graaff et al.	2012	The development of soil and water conservation policies and practices in five selected countries from 1960 to 2010		The paper analyses top-down and participatory measures of soil and water conservation in five countries (i.e. Indonesia, Ethiopia, Tunisia, Spain and Bolivia).
27.	-R ECON Policy	Dinar & Subramanian	1998	Policy implications from water pricing experiences in various countries	Reviews water pricing experiences across 22 countries in various sectors and over time.	The paper compares both the fixed and the variable rates for urban, agricultural and industrial sectors. Main findings are that fixed rates vary greatly between countries, while per unit rates are in a reasonable range. For urban and agricultural water, all developing countries, and some developed countries, set charges on the basis of average rather than marginal cost of supply. The willingness of countries to undertake water pricing reforms and successfully implement them cannot be solely explained by their water scarcity levels nor by the size of their budget deficits.

						However, high income countries are relatively more open to reforming water pricing policies.
28.	INT ECON SECTOR *SECTOR	Dupont & Renzetti	1997	Water Use in the Canadian Food Processing Industry	Survey	The objective of this paper is to bridge this gap in our understanding of water use in the agri-food sector. Four aspects of water use (intake, treatment prior to use, recirculation and discharge) are examined for the Canadian food processing industry and three of its subsectors. Price and output elasticities are estimated using plant-level data from a 1991 survey of water-using firms. Results indicate that all aspects of water use are sensitive to economic factors. Implications for government policies are identified.
29.	SECTOR *Follow the author	Elton & Wolfe	2012	Water Efficiency and the Professional Plumbing Sector: How Capacity and Capability Influence Knowledge Acquisition and Innovation	Semi-structured interviews and a survey were used to gather the data. The authors considered how the program participants incorporated the GPP curriculum into their 'day-to-day' practices and operations post-certification. They also investigated participants' motivating factors and cross-referenced these findings to their overall assessment of the program.	Repositioning the plumbing industry will required a cultural shift because the plumbing community has been mostly ignored in discussions of the larger environmental agenda and priorities. This repositioning will require substantial rethinking and retraining. New knowledge will need to be transmitted about emerging water efficient technologies, public policies and practices, as well as the rationale for use in residential and Industrial, Commercial, and Institutional (ICI) sectors. The GreenPlumbers Program (GPP) initiated this knowledge transfer process. Originating in Australia and expanded to the US, the GPP is a national training and accreditation program for professional plumbers. Their focus has been on upgrading skills and awareness of water efficiency, conservation, and the professional

						plumbers' roles in the contemporary environmental context. This paper reports on the efficacy of the GPP's curriculum and the process of transferring explicit water efficiency knowledge.
30.	-R INT ECON	Zhou et al.	2013	Drops of Energy: Conserving Urban Water to Reduce Greenhouse Gas Emissions		This paper measured the climatic co-benefit of water conservation based on a water flow analysis. The results showed that the estimated energy consumption of the total water system in Changzhou, China, reached approximately 10% of the city's total energy consumption. 77% of the energy savings through water conservation was indirect, while the industrial sector was found to be more energy intensive than other sectors within the entire water system, accounting for nearly 70% of the total energy use of the water system. In addition, four sustainable water management scenarios would bring the co-benefit of reducing the total energy use of the water system by 13.9%. To promote sustainable water management and reduce greenhouse gas emissions, China would require its water price system, both for freshwater and recycled water, to be reformed.
31.	++ SECTOR *SECTOR TECH	Feeley et al.	2008	Water: A critical resource in the thermoelectric power industry		The US Department of Energy's (DOE) National Energy Technology Laboratory (NETL) is engaged in a research and development program to reduce freshwater withdrawal (total quantity of water utilized) and consumption (portion of withdrawal not returned to the source) from existing and future thermoelectric power generating

						facilities. The Innovations for Existing Plants (IEP) Program is currently developing technologies in 5 categories of water management projects to reduce water use while minimizing the impacts of plant operations on water quality. The paper outlines the freshwater withdrawal and consumption rates for various thermoelectric power generating types and then estimates the potential benefits of The Innovations for Existing Plants (IEP) program technologies at both the national and regional levels in the year 2030.
32.	-R Polciy	Michelsen et al.	1999	Nonprice water conservation programs as a demand management tool	The paper examines the types and number of major nonprice conservation programs (e.g. education, public information, appliance retrofit and ordinances) that have been implemented during an 11-year period in seven cities in the southwestern United States. A cross sectional, monthly time series residential water demand model, with parameters to control for variation in prices, temperature, precipitation and other factors, was used to empirically investigate the effectiveness of nonprice conservation programs in reducing water demand.	The paper found significant reductions in use ranging between 1.1 percent and 4.0 percent per program. Because of the lack of information, the authors were unable to distinguish the effectiveness of individual or specific types of programs. Beyond finding that non-price programs can be effective in reducing demand, questions regarding the efficiency and benefits to be achieved by conservation remain. As a step towards separating and evaluating the effects of individual programs, program benefits and efficiency, we recommend that utilities maintain more detailed and consistent information regarding the implementation of their non-price programs.

33.	-R ECON SECTOR *SECTOR Methodology	Kajenthira et al.	2012	A new case for promoting wastewater reuse in Saudi Arabia: Bringing energy into the water equation		Saudi Arabia is the third-largest per capita water user worldwide and has addressed the disparity between its renewable water resources and domestic demand primarily through desalination and the abstraction of non-renewable groundwater. This study evaluates the potential costs of this approach in the industrial and municipal sectors, exploring economic, energy, and environmental costs (including CO2 emissions and possible coastal impacts). This paper suggests that in Saudi Arabia, the implementation of increased water conservation and reuse across the oil and natural gas sectors could conserve up to 29% of total industrial water withdrawals at costs recovered over 0-30 years, depending on the specific improvement. This work also indicates that increasing wastewater treatment and reuse in six high-altitude inland cities could save a further $225 million (2009 dollars) and conserve 2% of Saudi Arabia's annual electricity consumption.
34.	SECTOR TECH	Karthik et al.	2011	Closing water loop in a paper mill section for water conservation and reuse	Case study of a specific industry	The study was conducted at a large-scale integrated pulp and paper industry. The study conducted at laboratory for recycling of effluents was aimed at reducing water foot print of the paper mill. Paper machine section effluent was identified for treatment and reuse based on the flow and characteristics. Chemical aided clarification and simple membrane filtration systems were used for water recovery. Closing the water loop through suitable treatment for reuse of

						wastewater in the paper mills provides an assured and continuous source of water.
35.	SECTOR TECH	Kiran-Ciliz	2003	Reduction in resource consumption by process modifications in cotton wet processes	Case study of a specific industry	A series of cleaner production (CP) options mostly related to water and energy conservation were identified in a selected enterprise focusing on the reduction of water consumption in the regeneration process, water and chemical savings in the dyeing process, heat recovery from the blowdown which was discharged into the waste water treatment plant, and also heat recovery of process waste water. The results of the calculations made during the feasibility stage proved that these CP options were worth implementing.
36.	SECTOR *SECTOR	Knox et al.	2012	Water regulation, crop production, and agricultural water management—Understanding farmer perspectives on irrigation efficiency	Qualitative	The paper reviews the concept of irrigation efficiency in a temperate climate, considers the farmer perspectives, and supports using the 'pathway to efficiency' as a means to assist farmers and the water regulator in achieving better irrigation management and abstraction control.
37.	++ ECON Policy Methodology	Mohapatra & Mitchell	2009	Groundwater Demand Management in the Great Lakes Basin—Directions for New Policies		Demand-side management should be used to maximize the efficiency of groundwater use. Implementation of conservation measures would decrease the volume of water use and also exert less pressure on the water distribution system as well as the wastewater treatment system. Allocation of ground water in the Great Lakes basin must conform to priorities established at the community level. Groundwater pricing should reflect the full costs arising from ground water use.

						A differential pricing structure would help conserve water in the residential and industrial sectors. A user-friendly database on ground water use, quality and quantity for the entire Great Lakes basin is also essential. New policies for sustainable groundwater allocation, regulating water prices for water conservation, conservation education, pollution prevention, recycling and reuse of water as well as effective information management provide new directions for managing the groundwater demand in the Great Lakes basin.
38.	INT SECTOR *SECTOR TECH Methodology	Monaghan et al.	2013	More 'crop per drop': constraints and opportunities for precision irrigation in European agriculture		This paper summarizes the drivers for change, and the constraints and opportunities for improving agricultural water management through uptake of precision irrigation technologies. A multi-disciplinary and integrated approach involving irrigation engineers, soil scientists, agronomists and plant physiologists will be needed if the potential for precision irrigation within the field crop sector is to be realized.
39.	MODEL Methodology	Lee & Dinar (The World Bank)	1995	Review of integrated approaches to river basin planning, development and management	Policy research working paper	A review of models for river basin development operations, management, water quantity and quality, recreational demand, countryside planning, and multiple objective planning. Does not focus on a specific country. Reviews works of European, Asian and American scholars and/or entities.

40.	-R INT SECTOR TECH	Nandy et al.	2007	Water conservation through implementation of ultrafiltration and reverse osmosis system with recourse to recycling of effluent in textile industry	Case study of textile industry in India	The paper addresses to a case study in one of the textile units on upgradation of a full scale effluent treatment plant comprising chemical, biological, tertiary and advanced treatment processes. Based on the adequacy assessment of chemical and biological processes, improvement in the performance of the unit processes were achieved through optimization of coagulant dosage for chemical coagulation and build-up of active biomass in the activated sludge system. In addition, application of membrane separation processes comprising ultrafiltration and reverse osmosis units are also highlighted including disposal of reverse osmosis (RO) rejects through evaporator leading to zero liquid effluent discharge. The treatment scheme implemented resulted in conservation of around 55% of fresh water demand for industry.
41.	-R INT ECON	Oledan	2001	Challenges and opportunities in watershed management for Laguna de Bay (Philippines)	Cast study of Laguna lake in Philippines	The Laguna Lake Development Authority has instituted an environmental-user fee or pollution-charge system that has given corporations an incentive to construct and use wastewater treatment plants at a lower cost than the required fees for dumping waste into Laguna de Bay. User fees provide more flexibility about how and when a user or industrial facility cleans up its manufacturing process. Many medium- and large-sized domestic and multinational corporations have achieved at least 30–50% reductions in pollution loads. The user fees also encourage industry water conservation.

						Other creative approaches to conserving Laguna de Bay include 'Environmental Armies' that consist of volunteers who clean up river banks, demolish illegal fish pens and install low-cost garbage traps at the river's mouth. 'Poison Awards' are given annually and publicly to companies that continue to dump large amounts of waste into lake tributaries. Organizers also name a 'Most Improved Company' to provide a positive incentive.
42.	+ ECON SECTOR *SECTOR Methodology	Pereira et al.	2012	Improved indicators of water use performance and productivity for sustainable water conservation and saving		Water use concepts and performance descriptors that may be useful in defining conservation and saving of water are discussed with the aim of improving the overall performance and productivity of water use. New indicators are proposed which include consideration of water reuse and aim to assist in identifying and providing clear distinctions between beneficial and non-beneficial water uses. An analysis of productivity concepts useful both in irrigation and elsewhere is provided together with suggestions for where commonly used terms, such as the broadly used "water use efficiency" among others, would be better avoided in irrigation engineering and given much more narrowly defined meanings in agronomy and biological sciences. Particular attention is given to economic issues in water productivity. The analysis is completed with

						various case study applications at irrigation farm and system scales. It is recommended that a set of terms (not necessarily those developed here) be widely adopted that will provide a basis for easy, certain communication and provide widespread common understanding of the issues which must be faced to develop approaches to achieve efficient water use.
43.	-R INT ECON MODEL	Reynaud	2003	An Econometric Estimation of Industrial Water Demand in France		The study investigates the structure of industrial water demand by estimating the derived demand for water on a sample of industrial establishments located in the south-west of France. Production technologies are represented by short-term variable cost functions and approximated by a translog form. Industrial water use is modeled as having three components: the quantity of water bought to a water utility, the quantity of autonomous water and the quantity of water treated prior to use. We include in this framework water effluents, which are considered as a by-product of the production process, emitted by firms. Each of the three water components is treated as a separate input and all are estimated as a system of simultaneous equations. The model is estimated on a sample of 51 industrial plants in the Gironde district observed from 1994 to 1996 using Seemingly Unrelated Regression (SUR) and Feasible Generalized Least Squares (FGLS). Results of estimations

						show that industrial firms are sensitive to water price inputs.
44.	-R INT ECON Policy	Saletha & Dinar	2000	Institutional changes in global water sector: trends, patterns, and implications		Water institutions, defined jointly by the interactive roles of water law, water policy, and water administration, are undergoing unprecedented changes worldwide. Despite country-specific variations, these institutional changes observed in the global water sector do evince certain common patterns and clear trends. This paper aims to (i) unravel the nature and origin of these trends and patterns, and (b) evaluate their implications for global water sector policy, based on a review of water institutional changes in 11 countries: Mexico, Chile, Brazil, Spain, Morocco, Israel, South Africa, Sri Lanka, Australia, China, and India. The review suggests that institutional changes within the water sector occur due to the role of both endogenous factors (e.g., water scarcity, performance deterioration, and financial non-viability) as well as exogenous factors (e.g., macroeconomic crisis, political reform, natural calamities, and technological progress). These factors act together to raise the opportunity costs of institutional change, reduce the corresponding transaction costs, and create a pro-reform climate. From a policy perspective, the synergy from these factors can be exploited well with a sequential reform strategy where water sub-sectors and institutional components are prioritized in terms of their relative performance impact, fiscal significance,

						facilitative roles for downstream reforms, and political acceptability.
45.	-R SECTOR *SECTOR	Subhadra	2011	Water management policies for the algal biofuel sector in the Southwestern United States		Algal biorefinery-based integrated industrial ecology has received increased attention as a sustainable way of producing biofuel, food, high value products and feed ingredients in the Southwestern United States (US). However, these regions already face serious freshwater supply issues. Hence, new policies and regulations for water management and use is a high priority for the sustainable development of an algal biofuel sector to meet liquid fuel needs in the US without hampering the regional hydrologic pattern.
46.	+ MODEL Methodology	Tan et al.	2008	A methodology for the design of efficient resource conservation networks using adaptive swarm intelligence		The implementation of resource conservation schemes in industry can be enhanced through the application of systematic design methodologies. In particular, process integration methods allow resource consumption and waste generation in industrial plants to be reduced through the identification of efficient material reuse/recycle schemes. Various approaches, ranging from graphical pinch analysis to mathematical programming, have been developed by different researchers. Mathematical programming techniques provide considerable flexibility in the representation of network design problems, although in many cases, these approaches result in mixed integer non-linear programming (MINLP) models which are difficult to solve. This paper presents a simplified approach using a zeroeone

						programming or ‘‘knapsack’’ formulation for the design of industrial material reuse/recycle networks. It is possible to solve the resulting model using an efficient heuristic algorithm based on adaptive particle swarm optimization. Two sample applications are provided to illustrate the methodology. The first case shows the application of the methodology to the implementation of industrial water conservation and the second case demonstrates its use in the design of a hydrogen gas reuse/recycle scheme in a refinery.
47.	-R INT SECTOR	Tewari et al.	2009	Efficient water use in industries: Cases from the Indian agro-based pulp and paper mills	Case study of agro-based pulp and pare mills in India	Agro-based pulp and paper mills in India are one of the most polluting industries; in addition, they are high consumers of raw water. Growing scarcity of high quality freshwater as well as stringent regulatory standards is compelling these units to explore appropriate water management options. Based on data obtained through a questionnaire survey and plant visits, this work provides an overview of the water use and effluent treatment status in Indian agro-residue and recycled pulp and paper mills. The challenges faced by this sector are reviewed and practices adopted by progressive units to minimize freshwater use are illustrated through case studies.

48.	INT ECON Methodology	White & Fane	2007	Designing Cost Effective Water Demand Management Programs in Australia		This paper describes recent experience with integrated resource planning (IRP) and the application of least cost planning (LCP) for the evaluation of demand management strategies in urban water. Two Australian case studies, Sydney and Northern New South Wales (NSW) are used in illustration. LCP can determine the most cost effective means of providing water services or alternatively the cheapest forms of water conservation. LCP contrasts to a traditional approach of evaluation which look only at means of increasing supply. Detailed investigation of water usage, known as end-use analysis is required for LCP. End-use analysis allows both rigorous demand forecasting, and the development and evaluation of conservation strategies. Strategies include education campaigns, increasing water use efficiency and promoting wastewater reuse or rainwater tanks. The optimal mix of conservation strategies and conventional capacity expansion is identified based on levelised unit cost. IRP uses LCP in the iterative process, evaluating and assessing options, investing in selected options, measuring the results, and then reevaluating options. Key to this process is the design of cost effective demand management programs. IRP however includes a range of parameters beyond least economic cost into the planning process and program designs, including uncertainty,

						benefit partitioning and implementation considerations.
49.	INT ECON	Wolfe & Hendriks	2011	Building towards water efficiency: the influence of capacity and capability on innovation adoption in the Canadian home-building and resale industries	This study used qualitative methods to assess the 'tacit knowledge' as a critical variable for innovative realtors and builders. The authors also assessed the Legislative environment and the builders' organizational cultures to generate new and proactive insights for residential water efficiency.	The pressure on water and wastewater infrastructure in Canadian municipalities continues to rise with the need for increased capacity and upgrades. Demands to extend and maintain municipal infrastructure means that capital costs threaten to swallow municipal budgets. A water efficiency strategy has helped some municipalities to maintain or reduce their residential and commercial water consumption. This demand adjustment then allows the municipality to defer some capital investment. But relying solely on municipal governments to see that water demand policies are implemented, and enforced, is unwise. Government priorities and responsibilities change, citizen interests evolve and funding programs can be cut. Yet the private sector's contribution to promoting and sustaining residential and commercial water efficiency initiatives remains an untapped opportunity for collaboration. Conventional explanations for this neglect are that the private sector has been slow to embrace efficiency innovations because they are not economically viable and because buyers are not interested. The challenge is how to assess innovative builders and then translate the findings for policy-makers in Alberta, British Columbia and Ontario, Canada.

50.	ECON Policy Methodology	Olmstead & Stavins	2009	Comparing price and nonprice approaches to urban water conservation		Water conservation is typically achieved through prescriptive regulations, including the rationing of water for particular uses and requirements for the installation of particular technologies. A significant shift has occurred in pollution control regulations toward market-based policies in recent decades. We offer an analysis of the relative merits of market-based and prescriptive approaches to water conservation, where prices have rarely been used to allocate scarce supplies. The analysis emphasizes the emerging theoretical and empirical evidence that using prices to manage water demand is more cost effective than implementing non-price conservation programs, similar to results for pollution control in earlier decades. Price-based approaches may also compare favorably to prescriptive approaches in terms of monitoring and enforcement. Neither policy instrument has an inherent advantage over the other in terms of predictability and equity. As in any policy context, political considerations are also important.
51.	ECON SECTOR MODEL Methodology	Yang et al.	2012	Site-specific and regional on-farm rice water conservation analyzer (RiceWCA): Development and evaluation of the water balance model	Case study	Rice farming in the Lower Colorado River basin of Texas, US, is a major economic engine and a major water consumer. The Lower Colorado River Authority (LCRA) and the San Antonio Water System (SAWS) sponsored a joint project from 2004 through 2009 to study the feasibility of developing and conserving water to provide sufficient water to farmers in the Lower Colorado River basin, while allowing transfer of water to the

						city of San Antonio. A major focus of the project was the development of a web-based rice water conservation analyzer (RiceWCA) to evaluate field- and regional-level costs, water savings, and yield benefit associated with implementing on-farm conservation measures, including precision leveling, multiple inlets, conservation tillage, lateral improvement, tailwater recovery, and a production system based on growing high-yielding water efficient cultivars. This paper describes the development and evaluation of the crop development and water balance components of RiceWCA.
52.	BSTM	D'Arcya & Frost	2001	The role of best management practices in alleviating water quality problems associated with diffuse pollution		This paper introduces the concept of best management practices for the control of diffuse pollution. It considers where they are appropriate, and how the concept of a best management practice approach differs from the conventional means of controlling pollution by regulating each point source, in relation to established environmental quality standards and available dilution.
53.	ECON SECTOR BSTM	Handfield et al.	1997	'Green' value chain practices in the furniture industry	Data from interviews of five environmental managers in the furniture industry; case study; qualitative	The paper develops a taxonomy of environmentally-friendly ('green') best practices within the operations management value chain. This taxonomy is then extended to develop a group of propositions concerning the role of management in promoting environmentally-friendly practices. The results suggest that in order to be successful, environmental management strategies must be integrated into all stages of the value chain, which

						includes all of the processes spanning product design, procurement, manufacturing and assembly, packaging, logistics, and distribution. While the potential for environmental performance improvement in all five of the companies is evident, all of them demonstrated 'pockets' of environmentally-friendly practices (EFP) in different areas of their respective value chain functions. The propositions and results emerging from the analysis also suggest that reacting to regulations is no longer sufficient. World-class EFP must anticipate and pre-empt changing environmental regulations and customer expectations, and proactively prepare products, processes and infrastructure for these changes without sacrificing competitive advantage.
54.	SECTOR BSTM	Hilson & Murck	2000	Sustainable development in the mining industry: clarifying the corporate perspective	Case study of mining industry	The articles aims at answering the question of how sustainable development applies to mining companies themselves, and what steps a mine must take in order to improve the sustainability of operations. Since mining processes have the potential to impact a diverse group of environmental entities, and are of interest to a wide range of stakeholder groups, there is ample opportunity for the industry to operate more sustainably. Specifically, with improved planning, implementation of sound environmental management tools and cleaner technologies, extended social responsibility to stakeholder groups, the formation of sustainability partnerships, and improved training, a mine

						can improve performance in both the environmental and socioeconomic arenas, and thus contribute enormously to sustainable development at the mine level.
55.	BSTM	Margerum	1999	Integrated Environmental Management: The Foundations for Successful Practice		The author draws on twenty-three case studies from the United States and Australia, a survey of 285 Australian stakeholders and the literature to produce a framework for Integrated Environmental Management. The framework identifies 20 elements that—if attained—will increase the likelihood of successful operationalization of IEM. These elements address structuring of an integrated approach, operation of stakeholder processes, and outputs and outcomes.
56.	BSTM	Delmas & Toffel	2004	Stakeholders and environmental management practices: An institutional framework		The paper aims at answering the question of why some firms adopt environmental management practices beyond regulatory compliance. It leverages institutional theory by proposing that stakeholders – including governments, regulators, customers, competitors, community and environmental interest groups, and industry associations – impose coercive and normative pressures on firms. However, the way in which managers perceive and act upon these pressures at the plant level depends upon plant- and parent-company-specific factors, including their track record of environmental performance, the competitive position of the parent company and the organizational structure of the plant.

57.	BSTM	Berry & Rondinelli	1998	Proactive corporate environmental management: A new industrial revolution		Corporations in North America, Europe, Japan and in most newly industrializing nations are embracing environmental protection as part of their international competitive strategies. This article analyses the trends and reasons behind shifting to proactive environmental management.
58.	BSTM	Post & Altman	1994	Managing the Environmental Change Process: Barriers and Opportunities	Qualitative	This article addresses the challenge of transforming today's organizations into economically and environmentally sustainable enterprises and discusses the various barriers to change that have been identified in the companies we have studied.
59.	BSTM	Mitchell	2005	Integrated water resource management, institutional arrangements, and land-use planning		A systems, holistic, or ecosystem approach is often advocated for water management, and has led to the emergence of integrated water resource management, or IWRM. Such an approach can be interpreted as `comprehensive' or `integrated', and analysts, planners, and managers need to understand the difference. Edge or boundary problems always are encountered when applying a holistic approach, and design of institutional arrangements cannot eliminate these problems but can minimize them. IWRM often does not have a statutory basis, which can lead to implementation challenges. By linking IWRM to land-use planning and official plans at the local level, IWRM can be given credibility, as well as be systematically connected to land-based issues.

KEY:
++ Very important article
+ Important article
R Review only
-R Quick review only
INT International studies
MODEL Develops/uses a model (e.g. input-output)
TECH Technology Track
*SECTOR Sector of particular interest
SECTOR Sector-base track
ECON Economic influence
BSTM Best management practices

APPENDIX 2. Data Analysis

Analysis Based on IMPLAN Data

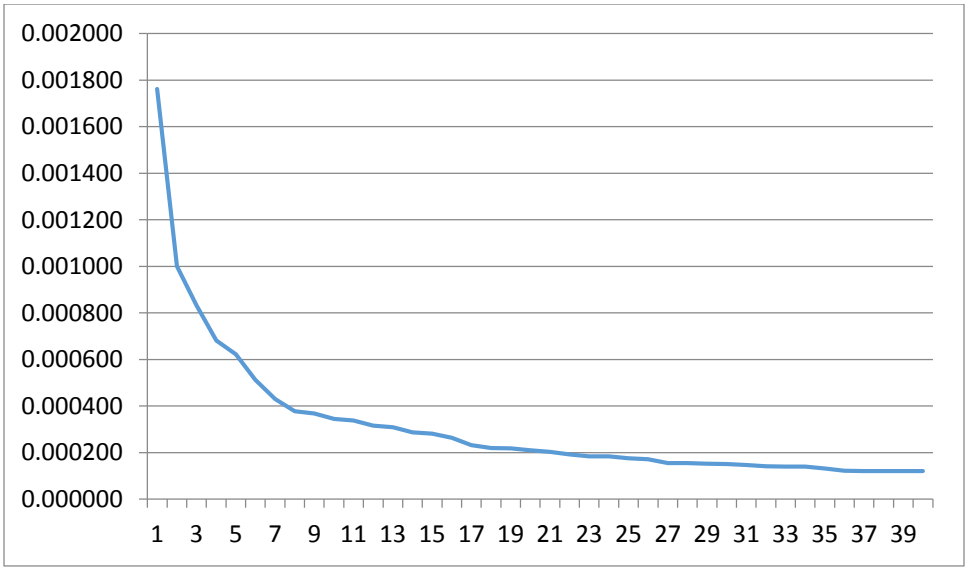
Table 1. Industries that Buy Water from the Industry "Water, Sewage and Other Systems" in Ohio, $

Source: IMPLAN Data 2012

IMPLAN_Description	naics	% Water, sewage and other systems
Junior colleges, colleges, universities, and professional schools	611	0.001763
Travel trailer and camper manufacturing	3362	0.001001
Motor home manufacturing	3362	0.000833
Other state and local government enterprises	n.a.	0.000682
All other crop farming	1119	0.000622
State and local government electric utilities	n.a.	0.000513
Fruit farming	1113	0.000429
Tree nut farming	1113	0.000377
Sugarcane and sugar beet farming	1119	0.000368
Vegetable and melon farming	1112	0.000345
Car washes	8111	0.000338
Other accommodations	721	0.000315
Postal service	491	0.000309
Hotels and motels, including casino hotels	721	0.000288
Grain farming	1111	0.000281
Waste management and remediation services	562	0.000264
Leather and hide tanning and finishing	3161	0.000232
Child day care services	624	0.000220
Facilities support services	5612	0.000218
Oilseed farming	1111	0.000210
Tire manufacturing	3262	0.000203
Pulp mills	3221	0.000193
Wood kitchen cabinet and countertop manufacturing	3371	0.000184
Other Federal Government enterprises	n.a.	0.000184
Individual and family services	624	0.000176
Wet corn milling	3112	0.000171
Transit and ground passenger transportation	485	0.000155
Paint and coating manufacturing	3255	0.000155
Personal care services	8121	0.000152
State and local government passenger transit	n.a.	0.000151
All other basic inorganic chemical manufacturing	3251	0.000147
Bread and bakery product manufacturing	3118	0.000142
Other amusement and recreation industries	713	0.000139
Ferrous metal foundries	3315	0.000139
Poultry processing	3116	0.000132
Water transportation	483	0.000122
Fitness and recreational sports centers	713	0.000121
Mineral wool manufacturing	3279	0.000121

All other miscellaneous wood product manufacturing	3219	0.000121
Iron and steel mills and ferroalloy manufacturing	3311	0.000120
Nonferrous metal foundries	3315	0.000119
Civic, social, professional, and similar organizations	813	0.000111
Automotive equipment rental and leasing	532	0.000108
Other pressed and blown glass and glassware manufacturing	3272	0.000107
Nursing and residential care facilities	623	0.000105
Food services and drinking places	722	0.000104
Paperboard Mills	3221	0.000101
Knit fabric mills	3132	0.000100
Bare printed circuit board manufacturing	3344	0.000099
Hunting and trapping	1142	0.000098

Figure 1. Purchases of Water, Sewer and Other Systems' Services in Ohio, 2012



Analysis Based on ODNR Data

Part 1 Water use by NAICS

Table 2. Amount of Water Used by NAICS Industries

Rank	NAICS	Industry	Number of companies	Ground water	Surface water	Total water	Percent
1	5511	Management of Companies and Enterprises	13	51,293.53	4,206,025.14	4,257,318.67	30.5%
2	5617	Services to Buildings and Dwellings	11	35,089.30	2,919,190.86	2,954,280.16	21.2%
3	2382	Building Equipment Contractors	5	196.25	1,851,815.41	1,852,011.66	13.3%
4	2213	Water, Sewage and Other Systems	76	76,876.75	1,178,064.01	1,254,940.76	9.0%
5	2211	Electric Power Generation, Transmission and Distribution	7	-	1,219,399.68	1,219,399.68	8.7%
6	9211	Executive, Legislative, and Other General Government Support	71	38,244.09	922,055.23	960,299.32	6.9%
7	3311	Iron and Steel Mills and Ferroalloy Manufacturing	2	-	485,707.34	485,707.34	3.5%
		Subtotal	**185**	**201,699.92**	**12,782,257.67**	**12,983,957.59**	**Sum: 93.1%**
8	5413	Architectural, Engineering, and Related Services	6	108.48	168,518.35	168,626.83	1.2%
9	2131	Support Activities for Mining	1	1,535.65	161,627.00	163,162.65	1.2%
10	9221	Justice, Public Order, and Safety Activities	6	17,546.71	141,930.52	159,477.23	1.1%
11	7139	Other Amusement and Recreation Industries	157	12,505.82	50,093.38	62,599.20	0.4%
12	2123	Nonmetallic Mineral Mining and Quarrying	28	48,088.35	4,934.45	53,022.80	0.4%
13	3273	Cement and Concrete Product Manufacturing	9	17,006.24	29,447.40	46,453.64	0.3%
14	2381	Foundation, Structure, and Building Exterior Contractors	5	350.20	42,086.96	42,437.16	0.3%
15	9241	Administration of Environmental Quality Programs	9	1,761.19	39,476.30	41,237.49	0.3%
16	3251	Basic Chemical Manufacturing	3	9,419.22	28,305.00	37,724.22	0.3%
17	1114	Greenhouse, Nursery, and Floriculture Production	61	1,510.23	31,052.97	32,563.19	0.2%

18	3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	1	-	28,663.60	28,663.60	0.2%
19	6117	Educational Support Services	1	-	26,365.00	26,365.00	0.2%
20	3274	Lime and Gypsum Product Manufacturing	3	22,835.86	1,381.94	24,217.80	0.2%
		Total	**475**	**334,376.86**	**13,536,140.53**	**13,870,508.39**	**99.5%**

Table 3. List of the Top Seven Industries by Water Use

Rank	NAICS	Industry	Number of companies
1	5511	Management of Companies and Enterprises	13
2	5617	Services to Buildings and Dwellings	11
3	2382	Building Equipment Contractors	5
5	2211	Electric Power Generation, Transmission and Distribution	7
7	3311	Iron and Steel Mills and Ferroalloy Manufacturing	2

Figure 2. Amount of Water Used by the Top 20 Industries (2000-2011)

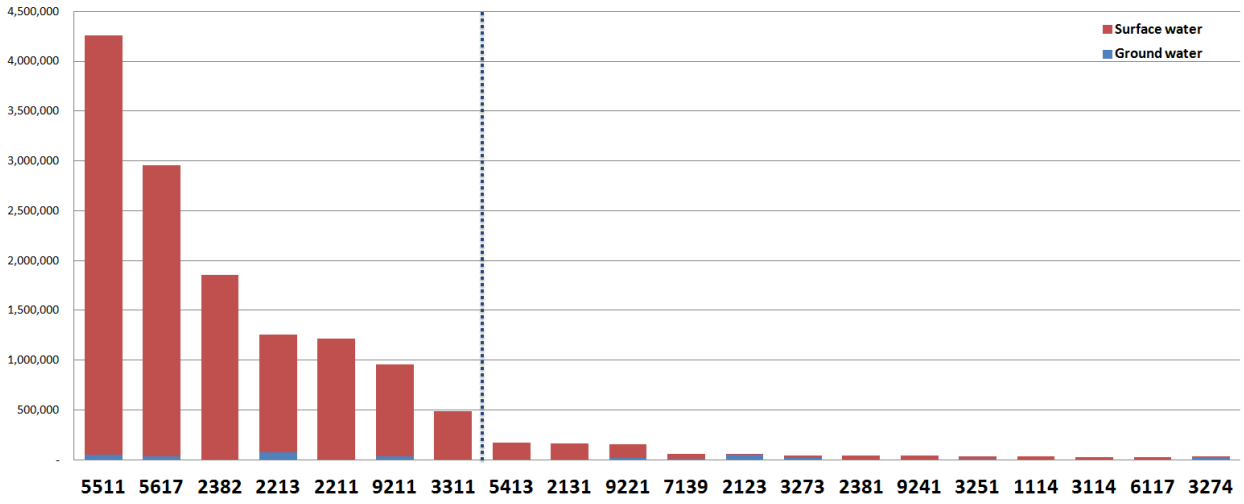
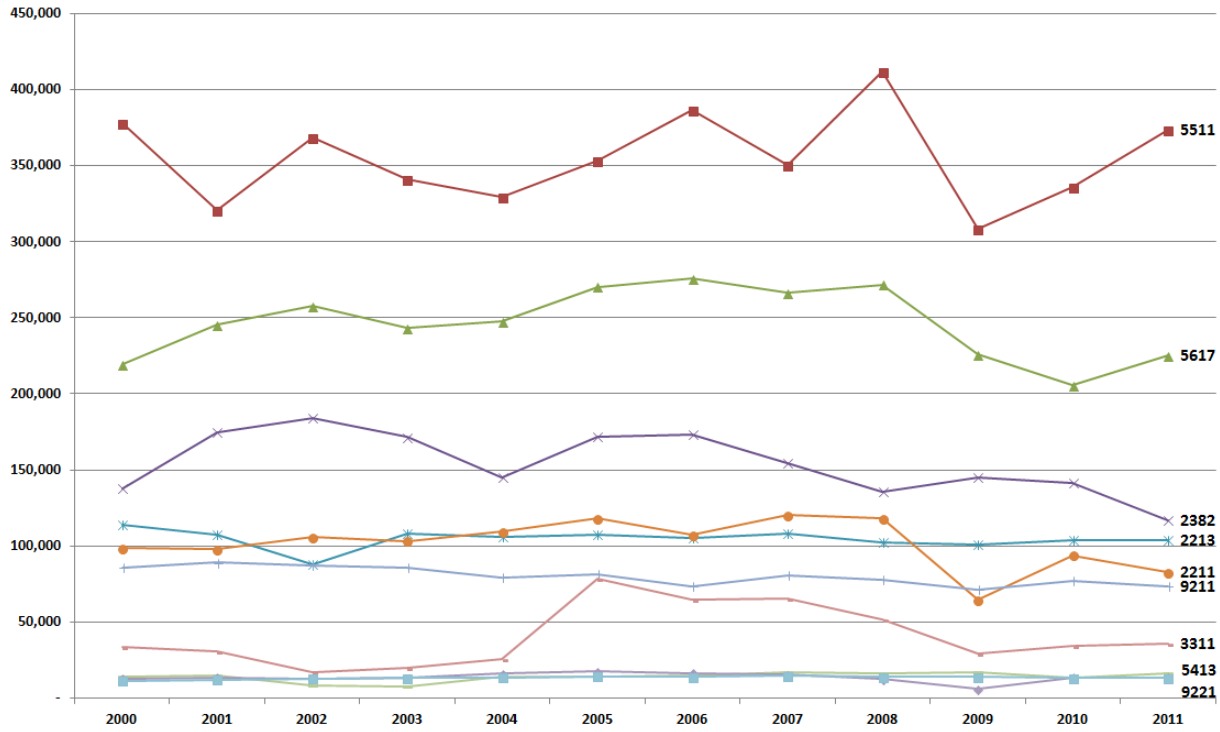


Figure 3. Changes in Water Use by the Top 10 Industries (2000-2011)

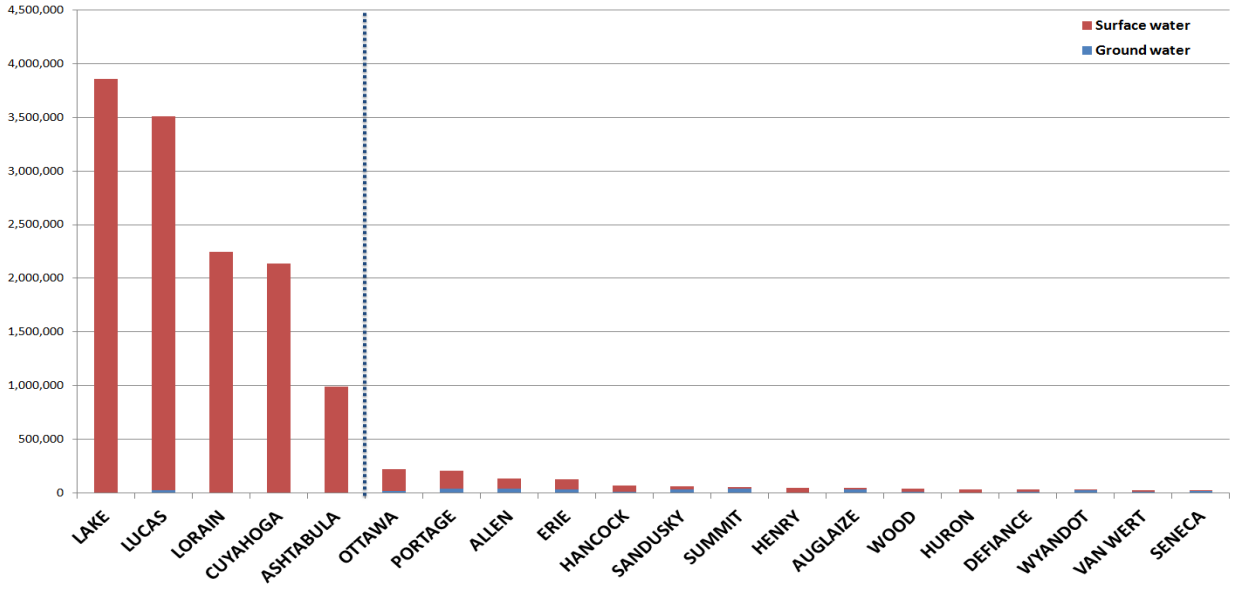


NAICS	Industry description
5511	Management of Companies and Enterprises
5617	Services to Buildings and Dwellings
2382	Building Equipment Contractors
2213	Water, Sewage and Other Systems
2211	Electric Power Generation, Transmission and Distribution
9211	Executive, Legislative, and Other General Government Support
3311	Iron and Steel Mills and Ferroalloy Manufacturing
5413	Architectural, Engineering, and Related Services
2131	Support Activities for Mining
9221	Justice, Public Order, and Safety Activities

Table 4. Water Use by County

Rank	county	Number of companies	Ground water	Surface water	Total water	Percent
1	LAKE	84	1,333.1	3,855,843.6	3,857,176.7	27.7%
2	LUCAS	47	25,298.8	3,486,174.5	3,511,473.2	25.2%
3	LORAIN	51	436.2	2,246,094.4	2,246,530.6	16.1%
4	CUYAHOGA	32	204.4	2,136,921.2	2,137,125.6	15.3%
5	ASHTABULA	22	1,035.6	991,721.3	992,756.9	7.1%
Subtotal		**236**	**28,308.1**	**12,716,754.9**	**12,745,063.1**	**91.0%**
6	OTTAWA	37	18,610.4	200,696.0	219,306.5	1.6%
7	PORTAGE	45	35,511.3	170,322.9	205,834.2	1.5%
8	ALLEN	27	34,395.0	95,354.7	129,749.6	0.9%
9	ERIE	25	31,381.2	93,811.0	125,192.2	0.9%
10	HANCOCK	22	11,693.1	53,875.4	65,568.4	0.5%
11	SANDUSKY	30	27,493.1	29,990.6	57,483.7	0.4%
12	SUMMIT	21	35,824.2	13,084.3	48,908.5	0.4%
13	HENRY	13	1,451.8	42,117.6	43,569.4	0.3%
14	AUGLAIZE	15	27,139.9	15,453.4	42,593.3	0.3%
15	WOOD	28	10,794.8	26,310.7	37,105.5	0.3%
16	HURON	26	3,170.5	28,361.7	31,532.2	0.2%
17	DEFIANCE	11	9,649.0	18,257.4	27,906.4	0.2%
18	WYANDOT	15	19,916.6	3,587.0	23,503.7	0.2%
19	VAN WERT	12	10,224.7	10,671.5	20,896.2	0.1%
20	SENECA	22	12,578.4	6,876.5	19,454.9	0.1%
Total		**585**	**318,142.0**	**13,535,535.6**	**13,843,667.7**	**99.3%**

Figure 4. Water Use by County (2000-2011)



Part 2. Water use by primary use of facilities

Table 5. Water Use by Primary Use of Facilities

Rank	Primary use of facilities	Number of companies	Ground water	Surface water	Total water	Percent of water use
1	POWER	14	-	10,338,938.1	10,338,938.1	74.1%
2	PUBLIC	189	144,645.3	2,317,075.7	2,461,721.0	17.7%
3	INDUSTRY	55	32,243.3	774,492.0	806,735.4	5.8%
4	MINERAL EXTRACTION	73	183,688.2	34,929.4	218,617.6	1.6%
5	AGRICULTURE	175	8,019.2	37,788.7	45,807.9	0.3%
6	MISC	51	3,530.8	35,348.7	38,879.5	0.3%
7	GOLF COURSE	172	7,814.4	27,965.6	35,780.1	0.3%
	Total	**729**	**379,941.3**	**13,566,538.1**	**13,946,479.5**	**100.0%**

Figure 5. Water Use by Primary Use of Facilities (2000-2011)

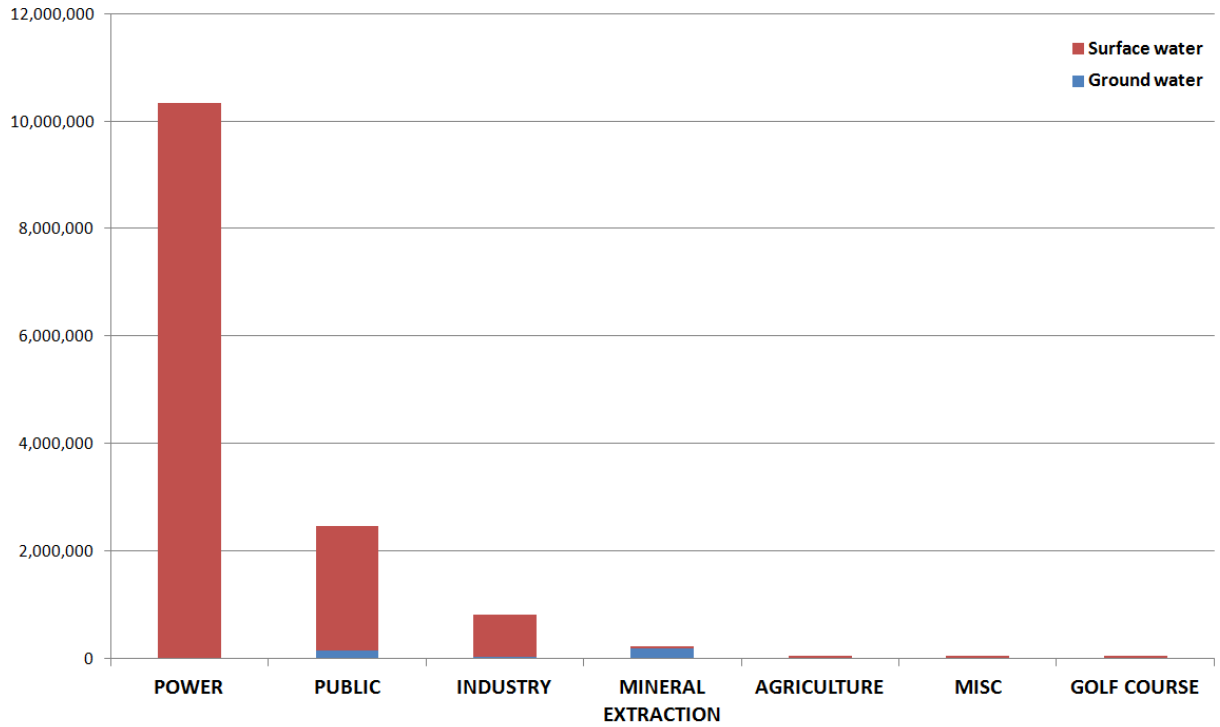


Figure 6. Water Use by Primary Use of Facilities (2000-2011)

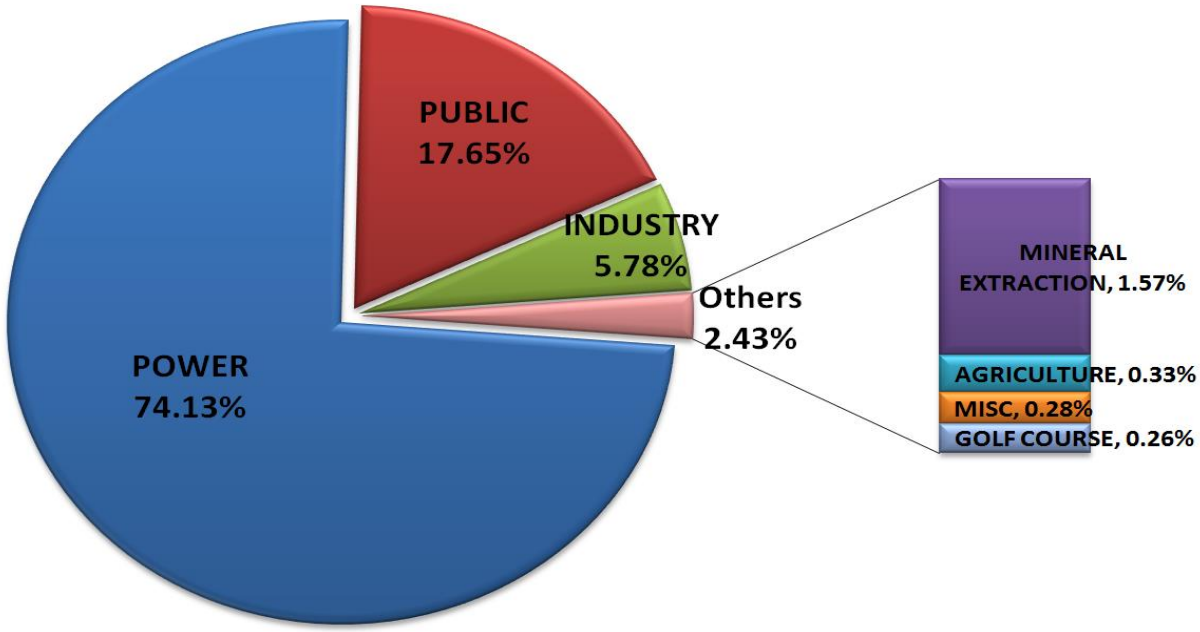


Table 6. Top Companies in Power

Rank	Company name	COUNTY	NAICS		Industry	Ground water	Surface water	Total water	Percent
1	FIRST ENERGY-GENERATION CORP	LAKE	N/A	N/A		0.0	3,291,989.0	3,291,989.0	31.8%
2	TOLEDO EDISON-BAY SHORE PLANT	LUCAS				0.0	2,919,114.0	2,919,114.0	28.2%
3	AVON LAKE ELECTRIC GENERATING STATION	LORAIN				0.0	1,851,815.4	1,851,815.4	17.9%
		TOTAL				0.0	8,062,918.4	8,062,918.4	78.0%

Table 7. Top Companies in Public

Rank	Company name	COUNTY	NAICS		Industry	Ground water	Surface water	Total water	Percent
1	CITY OF TOLEDO-DIVISION OF WATER	LUCAS	N/A	N/A		0.0	356,477.0	356,477.0	14.5%
2	CITY OF CLEVELAND-NOTTINGHAM WATER PLANT	CUYAHOGA				0.0	313,215.9	313,215.9	12.7%
3	CITY OF CLEVELAND-DIV OF WATER	CUYAHOGA				0.0	286,465.7	286,465.7	11.6%
4	CITY OF CLEVELAND-GARRETT MORGAN WATER PLANT	CUYAHOGA				0.0	232,011.7	232,011.7	9.4%
5	CITY OF CLEVELAND-CROWN WATER PLANT	CUYAHOGA				0.0	215,977.8	215,977.8	8.8%
6	CITY OF AKRON-WATER SUPPLY BUREAU	PORTAGE				260.6	149,991.0	150,251.6	6.1%
7	CITY OF AVON LAKE-MUNICIPAL UTILITIES	LORAIN				0.0	91,181.1	91,181.1	3.7%
8	CITY OF LORAIN-UTILITY DEPARTMENT	LORAIN				0.0	50,749.4	50,749.4	2.1%
9	CITY OF LIMA-DEPARTMENT OF UTILITIES	ALLEN				0.0	48,927.0	48,927.0	2.0%
		TOTAL				260.6	1,744,996.6	1,745,257.2	70.9%

Table 8. Top Companies in Industry

Rank	Company name	COUNTY	NAICS		Industry	Ground water	Surface water	Total water	Percent
1	ARCELORMITTAL CLEVELAND INC.	CUYAHOGA	N/A	N/A		0.0	317,882.7	317,882.7	39.4%
2	REPUBLIC STEEL	LORAIN				0.0	167,824.7	167,824.7	20.8%
3	BP HUSKY REFINING, LLC	LUCAS				1,535.7	161,627.0	163,162.7	20.2%
		TOTAL				1,535.7	647,334.3	648,870.0	80.4%

Table 9. Top Companies in Mineral extraction

Rank	Company name	COUNTY	NAICS	Industry	Ground water	Surface water	Total water	Percent
1	LAFARGE CORPORATION	OTTAWA	N/A	N/A	2,544.8	28,524.3	31,069.1	14.2%
2	MARTIN MARIETTA MAGNESIA SPECIALTIES	SANDUSKY			18,506.2	0.0	18,506.2	8.5%
3	LAFARGE NORTH AMERICA INC	ERIE			14,308.5	0.0	14,308.5	6.5%
4	NATIONAL LIME & STONE COMPANY-CAREY	WYANDOT			11,687.8	0.0	11,687.8	5.3%
5	HANSON AGGREGATES MIDWEST-SLYVANIA	LUCAS			11,529.4	0.0	11,529.4	5.3%
6	HANSON AGGREGATES MIDWEST-SANDUSKY CR STONE	ERIE			11,485.5	0.0	11,485.5	5.3%
7	NATIONAL LIME & STONE COMPANY-LIMA 1	ALLEN			11,018.2	0.0	11,018.2	5.0%
8	NATIONAL LIME & STONE COMPANY-FINDLAY	HANCOCK			9,193.6	0.0	9,193.6	4.2%
9	WEBER SAND AND GRAVEL INC	DEFIANCE			7,531.6	0.0	7,531.6	3.4%
10	HANSON AGGREGATES MIDWEST-BLOOMVILLE	SENECA			5,670.2	0.0	5,670.2	2.6%
11	NATIONAL LIME & STONE COMPANY-BUCYRUS	CRAWFORD			5,607.8	0.0	5,607.8	2.6%
12	NATIONAL LIME & STONE COMPANY-BUCKLAND	AUGLAIZE			5,202.3	0.0	5,202.3	2.4%
13	BLUFFTON STONE COMPANY	ALLEN			4,656.3	0.0	4,656.3	2.1%
14	GRAYMONT DOLIME (OH) INC	OTTAWA			4,329.7	0.0	4,329.7	2.0%
15	CUSTAR STONE COMPANY	WOOD			3,685.6	0.0	3,685.6	1.7%
		TOTAL			126,957.3	28,524.3	155,481.6	71.1%

Table 10. Top companies in Agriculture

Rank	Company name	COUNTY	NAICS		Industry	Ground water	Surface water	Total water	Percent
1	WILLOWAY NURSERIES, INC	LORAIN	N/A	N/A		0.0	6,492.5	6,492.5	14.2%
2	WILLOWAY NURSERIES, INC	LORAIN				0.0	5,408.1	5,408.1	11.8%
3	KLYN NURSERIES, INC	LAKE				0.0	3,989.0	3,989.0	8.7%
4	WILLOWAY NURSERIES, INC	ERIE				0.0	3,797.4	3,797.4	8.3%
5	COTTAGE GARDENS INC	LAKE				344.1	3,072.5	3,416.6	7.5%
6	RIDGE MANOR NURSERIES, LLC	LAKE				0.0	2,157.4	2,157.4	4.7%
7	C M BROWN NURSERIES, INC	LAKE				418.2	1,295.0	1,713.2	3.7%
8	BUURMA FARMS INC	HURON				512.2	742.8	1,255.0	2.7%
9	K W ZELLERS & SON, INC	STARK				1,212.1	0.0	1,212.1	2.6%
10	WIERS FARM INC	HURON				443.5	606.3	1,049.8	2.3%
11	LAKE COUNTY HOLDINGS DBA LAKE COUNTY NURSERY	LAKE				0.0	808.2	808.2	1.8%
12	BUURMA FARMS, INC	CRAWFORD				0.0	797.2	797.2	1.7%
		TOTAL				2,930.2	29,166.4	32,096.5	70.1%

Table 11. Top Companies in Miscellaneous

Rank	Company name	COUNTY	NAICS		Industry	Ground water	Surface water	Total water	Percent
1	PROVIDENCE METROPARK-ISAAC LUDWIG MILL	LUCAS	N/A	N/A		0.0	9,539.4	9,539.4	24.5%
2	PICKEREL CREEK WILDLIFE AREA	SANDUSKY				1,377.1	7,273.6	8,650.7	22.3%
3	CITY OF KENT-WATERFALL	PORTAGE				0.0	4,581.2	4,581.2	11.8%
4	GEAUGA LAKE	GEAUGA				432.8	3,926.7	4,359.6	11.2%
5	RENO BEACH-HOWARD FARMS CONSERVANCY DISTRICT	LUCAS				0.0	3,037.2	3,037.2	7.8%
		TOTAL				1,809.9	28,358.2	30,168.1	77.6%

APPENDIX 3. Teaching module based on the project findings

Water Withdrawal and Best Management Practices Teaching Module

Lesson Summary

Overview

Although over 70% of Earth's surface is covered with water, less than 1% of this water is available for human consumption. In this lesson, students study the concept of water withdrawal and discuss policy and program related best management approaches that can be applied to conserve this critical resource.

Objectives

- Identify sources of water available for consumption and common withdrawal techniques
- Understand the need for water conservation due to the limited fresh water supply
- Explore approaches to assess water consumption
- Explore strategies for conserving water within various organizations
- Compare the benefits and drawbacks of using different water management techniques.

Suggested Time

One 45-90 minute class, depending on depth of coverage and class activity

Suggested Reading

Zhang, Z. and Balay, J. (2014). "How Much is Too Much?: Challenges to Water Withdrawal and Consumptive Use Management." Journal of Water Resource Planning and Management 140(6)), 01814001.

Great Lakes-St. Lawrence River Basin Water Resource Council http://www.glslcompactcouncil.org/

Water Use, Withdrawal and Consumption:
http://www.gracelinks.org/1249/water-use-withdrawal-and-consumption-what-does-it-all-mean

EPA: Clean Water Act

Texas Best Management Practices for water withdrawal and use:
https://www.twdb.texas.gov/conservation/BMPs/Ag/index.asp

Part 1: Managing the Water Supply

Begin the lecture by asking the students if they know the source of their home water supply. Show maps of the Ohio Watershed and ask students to identify their watershed and if there are any water related programs currently in place.
https://www.google.com/search?q=ohio+watershed+map&rlz=1C1CHFX_enUS505US505&espv=2&es_sm=122&tbm=isch&imgil=4xpxgNJN3rafYM%253A%253Bhttps%253A%252F%252Fencrypted-tbn1.gstatic.com%252Fimages%253Fq%253Dtbn%253AANd9GcTIIGXemewV33n1h15SrELI93PqhfDNLmiXamewM2ZpKQpiK9GaBA%253B816%253B1056%253BWFaAQkO3DgyUrM%253Bhttp%25253A%25252F%25252Fwwwapp.epa.ohio.gov%25252Fdsw%25252Fnps%25252FNPSMP%25252FWAP%25252FWoall.html&source=iu&usg=__pS-QkbtMGerrm_vKh2MiPKlcH5U%3D&sa=X&ei=yPJ8U_TNAqeb8AG3lYFg&ved=0CCoQ9QEwAA#facrc=_&imgrc=4xpxgNJN3rafYM%253A%3BWFaAQkO3DgyUrM%3Bhttp%253A%252F%252Fwwwapp.epa.ohio.gov%252Fdsw%252Fnps%252FNPSMP%252Fphotos%252FWatershedGroups_7-8-05.jpg%3Bhttp%253A%252F%252Fwwwapp.epa.ohio.gov%252Fdsw%252Fnps%252FNPSMP%252FWAP%252FWoall.html%3B816%3B1056

Use the attached power point lecture to discuss approaches to assess water use and best management practices to conserve water.

Part 2: How Much Water Do You Use Per Day?

Begin by asking the students if they know how much water they use each day. Have the students complete the water usage worksheet http://www.pbslearningmedia.org/asset/ess05_doc_lpawateruse/. Discuss ways that water could be conserved in their own homes and then discuss how this might be applied to policy.

Additional Multimedia Resources

- **Global Water Distribution** Flash Interactive
- **Water Treatment Plant** QuickTime Video
- **Conserving Water at Home** QuickTime Video
- **Water Conservation: Israel** QuickTime Video
- **Water Conservation: Mexico** QuickTime Video
- **Water Conservation: Denver, CO** QuickTime Video

Extension (Optional)

- Invite a guest speaker from the local water conservation department to come to your class and provide detailed information about the process of water withdrawal, distribution and/or best management practices.
- Review recent water related legislation and compare to the policy and practices discussed in the lecture.

- Take a field trip to a local water treatment plant or water withdrawal operation to expose students firsthand to the complex process of water treatment and reinforce the need for water conservation.

Check for Understanding

Have each student write an article or editorial discussing his or her ideas about a water related topic. Let students know that they will need to support their ideas using information they learned from the lecture and class discussion. You may also want to encourage students to conduct additional research online and/or seek out individuals in the community to interview about local efforts regarding their chosen topic.

The Digital Library for Earth System Education (www.dlese.org) offers access to **additional resources** on this topic.

Classes and Primary Faculty Instructors for Water Withdrawal/Conservation Module Distribution

Levin College of Urban Affairs

UST 542 Environmental Finance
N. Zingale, J. Piccorelli

UST 553 Urban Sustainability
W. Kellogg

UST 652 Environmental Policy
S. Kaufman

UST 653 Environmental Planning II: Regional Landscapes
W. Kellogg

UST 655 Environmental Risk and Decision Making
W. Bowen

College of Science

EVS 506 Ecosystem Science
J. Wolin

EVS 520 Rivers and Watersheds of NE Ohio
J. Wolin,

EVS 570 Stream Ecology
J. Wolin

College of Engineering

CVE 563 Water Resources Engineering
N. Delatte

College of Law

LAW 671 Environmental Law and Regulation
H. Robertson

APPENDIX 4. Description of two academic articles based on the study findings

Abstract for Article #1

A recent project completed for the Ohio Department of Natural Resources revealed that there exist various "understandings" of what constitutes water consumption. Water applied to agricultural crops and transpired through respiration is one form of consumption; however, other forms of consumption may include: water as a primary ingredient for beverage making; as a solvent or cleaner for material manufacturing, as a coolant for the energy sector; or as a fracturing compound for mineral, natural gas and oil extraction. From a policy perspective, the form of consumption is indistinguishable and has resulted in several states developing broad sector based consumption factors that do not take into account the way the water is consumed or how if there is a detrimental or long-term impact to the water cycle.

According to Shang and Balay (2014), rules and regulations are needed to govern water withdraw and consumption in a similar way that the Clean Water Act resulted in strict controls on discharges to streams. This project investigates the concept of water consumption through an analysis of literature and published water consumption factors related to water cycle impacts emanating from different forms of consumption. The outcome is expected to provide policy makers with greater clarity on what it means to "consume" water. Furthermore, the research could provide policy makers and regulators with alternative water consumptive language to be applied to various industries and water related practices.

Zhang, Z. and Balay, J. (2014). "How Much is Too Much?: Challenges to Water Withdrawal and Consumptive Use Management." Journal of Water Resource Planning and Management 140(6)), 01814001.

Possible venues:

1. Journal of Water Resource Planning and Management
2. Water Resource Management (Journal)
3. Journal of National Resource Policy Research

Abstract for Article #2.

Under the Great Lakes-St. Lawrence River Basin Water Resources Compact the states in the Great Lakes basin are required to develop administrative programs regarding withdrawal and consumptive use of water from the lakes, tributary streams, and ground water in the basin. Diversion of water out of the Great Lakes basin, a threat to the ecological integrity and economic vitality of the Great Lakes region, was the basis of the Compact among the states and the US and Canada. This paper describes a research project that assisted the State of Ohio in developing its technical assistance program to water users in the Lake Erie watershed. Programs in other Great Lakes states were first reviewed as benchmarks. An economic development model and state agency data were used to identify the most significant water users in the state. Results were used to guide the review of best practices across several economic sectors (public water supply, industry, agriculture, etc.) from additional state-level programs, US federal programs, and international practices in business and NGOs. Program elements were compared to the original state Advisory Board recommendations and assessed in terms of comprehensiveness and alignment with best practices.

Possible Venues:

1. Journal of Great Lakes Research (would need publication fee for this journal)
2. Local and State Government
3. Society and Natural Resources

Professional Water Newsletters and Magazines:

Ohio Water Environment Federation
Ohio American Water Works Association
Water Management Association of Ohio, *The Ohio Water Table*

APPENDIX 5. Dissemination of project findings at public events

Levin College Annual Research Conference

The Levin College hosts a research conference at the beginning of the fall semester in which faculty and doctoral students present recent research results. This year's event will be held August 20 on campus at Cleveland State University. The team already has been accepted to present at this conference.

Cleveland Water Alliance

CWA is an alliance of over 25 regional organizations from the public, private and nonprofit sectors, including several regional universities, industry and government agencies such as the Cleveland Metroparks and Northeast Ohio Regional Sewer District. CWA has in the past sponsored and organized a speaker series, and we anticipate it will do so again this coming year. Dr. Kellogg is on the CWA steering committee and will offer a presentation on the current project for one of the sessions. Previous sessions were held at the City Club.

Corporate Sustainability Roundtable

The Monte Ahuja College of Business Administration at Cleveland State University hosts the Corporate Sustainability Roundtable once per month during the academic year. Dr. Kellogg has ties to the organization and will offer a presentation on the current project for one of the sessions.

Planning and Zoning Workshop

Cleveland Section of the Ohio American Planning Association

The Cleveland Planning and Zoning workshop is held each October in greater Cleveland and is attended by practicing planners, local zoning administrators and elected officials. We will submit a proposal to conduct a workshop based on the research project to the APA, due May 30, 2014.

Water Management for the Oil & Gas Industry Seminar

The Ohio Shale Institute will be holding a seminar on water management in September of 2014. The faculty for the seminar include Professor Jeffrey Dick from Youngstown State, Professor Nick Zingale from Cleveland State, Andrew Thomas from the Energy Policy Center at Cleveland State, and Tim Schwendemen from Affinity Consultants. Among the topics will be a section on Water Withdrawal & Storage that will include a review of relevant regulations as well as best management practices for the industry. The seminar is planned for September 2014.