Section 1: Introduction

Background – Nonpoint Source Pollution and NEMO

The Southwestern United States, including the State of Arizona, is the fastest growing region in the country. Because the region is undergoing rapid development, there is a need to address health and quality of life issues that result from degradation of our water resources.

Water quality problems may originate from both “point” and “nonpoint” sources. The Clean Water Act (CWA) defines “point source” pollution as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged" (33 U.S.C. § 1362(14)).

Although nonpoint source pollution is not widely defined under the CWA, it is widely understood to be the type of pollution that arises from many dispersed activities over large areas, and is not traceable to any single discrete source. Nonpoint source pollution may originate from many different sources, usually associated with rainfall runoff moving over and through the ground, carrying natural and manmade pollutants into lakes, rivers, streams, wetlands and ground water. It is differentiated from point source pollution in that, for some states such as Arizona, there are no regulatory mechanisms by which to enforce clean up of nonpoint source pollution.

Nonpoint source pollution is the leading cause of water quality degradation across the United States, and is the water quality issue that NEMO, the Nonpoint Education for Municipal Officials program, and this watershed based plan will address.

Nationally, NEMO has been very successful in helping to mitigate nonpoint source pollution. The goal of NEMO is to educate land-use decision makers to take proactive voluntary actions that will mitigate nonpoint source pollution and protect natural resources. In the eastern United States (where the NEMO concept originated), land use authority is concentrated in municipal (village, town and city) government. In Arizona, where nearly 80% of the land is managed by state, tribal and federal entities, land use authorities include county, state and federal agencies, in addition to municipal officials and private citizens.

In partnership with the Arizona Department of Environmental Quality (ADEQ, 2003) and the University of Arizona (U of A) Water Resources Research Center, the Arizona Cooperative Extension at the U of A has initiated the Arizona NEMO program. Arizona NEMO attempts to adapt the NEMO program to the conditions in the semiarid, western United States, where water supply is limited and many natural resource problems are related to the lack of water, as well as water quality.
Working within a watershed template, Arizona NEMO includes: comprehensive and integrated watershed planning support, identification and publication of Best Management Practices (BMP), and education on water conservation and riparian water quality restoration. Arizona NEMO maintains a website, http://www.ArizonaNEMO.org that contains these watershed based plans, Best Management Practices fact sheets, and other educational materials.

Watershed-Based Plans

Watershed-based plans are holistic documents designed to protect and restore a watershed. These plans provide a careful analysis of the sources of water quality problems, their relative contributions to the problems, and alternatives to solve those problems. Furthermore, watershed-based plans present proactive measures that can be applied to protect water bodies. In watersheds where a TMDL has been developed and approved or is in the process of being developed, watershed-based plans must be designed to achieve the load reductions called for in the TMDL.

In collaboration with the local watershed partnerships and ADEQ, NEMO will help improve water quality by developing a realistic watershed-based plan to achieve water quality standards and protection goals. This plan will identify:

- Areas that are susceptible to water quality problems and pollution;
- Sources that need to be controlled; and
- Management measures that should be implemented to protect or improve water quality.

The first component of the planning process is to characterize the watershed by summarizing all readily available natural resource information and other data for that watershed. As seen in Sections 2 through 5 of this document, these data are at a broad-based, large watershed scale and include information on water quality, land use and cover, natural resources and wildlife habitat.

It is anticipated that stakeholder-groups will develop their own detailed planning documents. This document may cover a subwatershed area within the NEMO Watershed-based Plan, or include the entire watershed area. In addition, stakeholder-group local watershed-based plans will incorporate local knowledge and concerns gleaned from stakeholder involvement and will include:

- A description of the stakeholder / partnership process;
- A well-stated, overarching goal aimed at protecting, preserving, and restoring habitat and water quality, and encouragement of land stewardship;
A plan to coordinate natural resource protection and planning efforts;

A detailed and prioritized description of natural resource management objectives; and

A detailed and prioritized discussion of best management practices, strategies and projects to be implemented by the partnership.

Based on EPA’s 2003 Guidelines for the Award of Section 319 Nonpoint Source Grants, a watershed-based plan should include all nine of the elements listed below.

- **Element 1: Causes and Sources.** Clearly define the causes and sources of impairment (physical, chemical, and biological).

- **Element 2: Expected Load Reductions.** An estimate of the load reductions expected for each of the management measures or Best Management Practices to be implemented (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

- **Element 3: Management Measures.** A description of the management measures or Best Management Practices and associated costs that will need to be implemented to achieve the load reductions estimated in this plan and an identification (using a map or a description) of the critical areas where those measures are needed.

- **Element 4: Technical and Financial Assistance.** An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

- **Element 5: Information / Education Component.** An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing management measures.

- **Element 6: Schedule.** A schedule for implementing management measures identified in this plan that is reasonably expeditious.

- **Element 7: Measurable Milestones.** A schedule of interim, measurable milestones for determining whether the management measures, Best Management Practices, or other control actions are being implemented.

- **Element 8: Evaluation of Progress.** A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being
made towards attaining water quality standards and, if not, the criteria for determining whether the plan needs to be revised or, if a Total Maximum Daily Load (TMDL) has been established, whether the TMDL needs to be revised.

- Element 9: Effectiveness Monitoring. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established in the Evaluation of Progress element.

These nine elements help provide reasonable assurance that the nonpoint source of pollution will be managed to improve and protect water quality and to assure that public funds to address impaired waters are used effectively.

Watershed-based plans are holistic documents that are designed to protect and restore a watershed. These plans provide a careful analysis of the sources of water quality problems, their relative contributions to the problems, and alternatives to solve those problems. Furthermore, watershed-based plans will deliver proactive measures to protect water bodies. In watersheds where a TMDL has been developed and approved or is in the process of being developed, watershed-based plans must be designed to achieve the load reductions called for in the TMDL.

**Purpose and Scope**

This watershed based plan includes a characterization and classification for the Upper Gila Watershed to support pending water quality improvement projects and to provide educational outreach material to stakeholders and watershed partnerships. It provides an inventory of natural resources and environmental conditions that affect primarily surface water quality.

In addition to the classification, this plan provides methods and tools to identify problem sources and locations for implementation of Best Management Practices to mitigate nonpoint source pollution. Although these chapters are written based on current information, the tools developed can be used to update this report and reevaluate water quality concerns as new information becomes available.

The watershed characterization includes physical, biological, and social data in a geographic information system (GIS) database format, as both mapped and tabulated data, as collected from available existing and published data sources. No additional data were collected.

It also includes descriptions of environmental attributes and identification of water quality problems by incorporating water quality data reported in The DRAFT Status of Water Quality in Arizona - 2004: Arizona’s Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), ADEQ’s biennial report consolidating water quality reporting requirements under the federal Clean
Water Act. The ADEQ water quality data, TMDL definitions, and further information for each stream reach and the surface water sampling sites across the state can be found at: www.adq.state.az.us/environ/water/assessment/assess.html.

The watershed classification includes the identification of and mapping of important resources, and ranking of 10-digit HUC subwatersheds (defined later in this section) based on the likelihood of nonpoint source pollutant contribution to stream water quality degradation.

Following the classification, this watershed plan includes general discussions of recommended nonpoint source Best Management Practices (BMPs) that will need to be implemented to achieve load reductions, as well as to achieve other watershed goals. These watershed management activities are proposed with the understanding that the land-use decision makers and stakeholders within the watershed can select the BMPs they feel appropriate and revise management activities as conditions within the watershed change.

The Upper Gila Watershed is located in the southeastern portion of the state of Arizona, bounded by the city of Globe to the east, and the state of New Mexico to the west, as shown in Figure 1-1.

**Methods**

GIS and hydrologic modeling were the major tools used to develop this watershed plan. Two types of information represent geographic features in a GIS: locational and descriptive data. Locational (spatial) data is stored using a vector or a raster data structure. Vector data are object based data models which show spatial features as points, lines, and/or polygons. Raster data models represent geographical space by dividing it into a series of units, each of which is limited and defined by an equal amount of earth’s surface. These units are of different shapes, i.e. triangular or hexagonal, but the most commonly used shape is the square, called a cell. Corresponding descriptive (attribute) data for each geographic feature are stored in a set of tables. The spatial and descriptive data are linked so that both sets of information are always available.
Planning and assessment in land and water resource management requires spatial modeling tools so as to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Upper Gila Watershed included AGWA, SWAT, and RUSLE, as described below.

The Automated Geospatial Watershed Assessment Tool (AGWA) is a GIS-based hydrologic modeling tool designed to evaluate the effects of land use change (Burns et al., 2004). AGWA provides the functionality to conduct all phases of a watershed assessment. It facilitates the use of the Soil and Water Assessment Tool (SWAT), a hydrologic model, by preparing the inputs, running the model, and presenting the results visually in the GIS. AGWA has been used to illustrate the impacts of urbanization and other landscape changes, and to simulate sediment load in the watershed. AGWA was developed under a joint project between the Environmental Protection Agency (EPA), Agricultural Research Service (ARS), and the University of Arizona. SWAT was developed by the ARS, and is able to predict the impacts of land management practices on water, sediment and chemical yields in complex watersheds with varying soils, land use and management conditions (Arnold et al., 1994). The Revised Universal Soil Loss Equation (RUSLE) was also used to estimate soil loss from different land use types (Renard et al., 1997).

The watershed classifications incorporate GIS-based hydrologic modeling results and other data to describe watershed conditions upstream from an impaired stream reach identified within Arizona’s Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), and simulate impacts due to mine sites (erosion and metals pollution) and grazing (erosion and pollutant nutrients).

The Upper Gila Watershed is defined and mapped by the U.S. Geological Survey using the six-digit Hydrologic Unit Code (HUC). The United States is divided and sub-divided into successively smaller hydrologic units of surface water drainage features, which are classified into four levels, each identified by a unique hydrologic unit code consisting of two to eight digits: regions (2 digit), sub-regions (4 digit), accounting units (6 digit), and cataloging units (8 digit) (Seaber et al., 1987).

Within the six-digit HUC, subwatershed areas were delineated on the basis of the eight-digit cataloging HUC, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

Within this report, both HUC units and subwatershed names are used to clarify location. This watershed assessment uses the following HUC watersheds:

- The Upper Gila Watershed (150400)
- Upper Gila (15040002)
  - Railroad Wash (1504000208)
  - Apache Creek (1504000207)
  - Animas Valley (15040003)
  - Animas Valley (1504000300)
  - San Francisco River (15040004)
To rank the 10-digit HUC subwatershed areas that are susceptible to water quality problems and pollution, and to identify sources that need to be controlled, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types (Guertin et al., 2000; Miller et al., 2002; Reynolds et al., 2001). This methodology has been selected as the basis by which subwatershed areas and stream reaches are prioritized for the implementation of BMPs to assure nonpoint source pollution is managed.

Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized as a method by which to quantify common sense. In classical set theory, an object is either a member of the set or excluded from the set. For example, one is either tall or short, with the class of tall men being those over the height of 6’0”.

Using this method, a man who is 5’11” tall would not be considered in the tall class, although he could not be considered ‘not-tall’. This is not satisfactory, for example, if one has to describe or quantify an object that may be a partial member of a set. In fuzzy logic, membership in a set is described as a value between 0 (non-membership in the set) and 1 (full membership in the set). For instance, the individual who is 5’11” is not classified as short or tall, but is classified as tall to a degree of 0.8. Likewise, an individual of height 5’10” would be tall to a degree of 0.6.

In fuzzy logic, the range in values between different data factors are converted to the same scale (0-1) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the characteristics of the input, and in the case above, the degree of tallness was iteratively added in intervals of 0.2. An example of a continuous data set would be graphing heights of all individuals and correlating a continuous fuzzy member value to that graph. A user defines their membership functions to describe the relationship between an individual
factor and the achievement of the stated goal. Using the example above, a tall individual of the degree 0.2 would be 5‘ 8” tall.

The development of a fuzzy membership function can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. Another benefit of this approach is that it provides for the use of different methods for combining individual factors to create the final classification and the goal set. Fuzzy membership functions and weighting schemes can also be changed based on watershed concerns and conditions.

Our general approach was to integrate watershed characteristics, water quality measurements, and modeling results within a multi-parameter ranking system based on the fuzzy logic knowledge-based approach, as shown schematically in Figure 1-2. The process was implemented within a GIS interface to create the subwatershed classifications using five primary steps:

1. Define the goal of the watershed classification (in this example, dissolved / total metals water quality impairment to streams due to mine activity);
2. Assemble GIS data and other observational data;

Figure 1-2: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.
3. Define watershed characteristics through:
   a. Water quality data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report;
   b. GIS mapping analysis; and
   c. Modeling / simulation of erosion vulnerability / potential for stream impairment (in this case, from soils in mine site areas and proximity to abandoned mine sites).

4. Use fuzzy membership functions to transform the vulnerability / impairment metrics into fuzzy membership values; and

5. Determine a composite fuzzy score representing the ranking of the combined attributes, and interpret the results.

This approach requires that a goal be defined according to the desired outcome and that the classification be defined as a function of the goal, and is therefore reflective of the management objective. For the watershed classification, the goal is to identify critical subwatersheds in which BMPs should be implemented to reduce nonpoint source pollution.

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), was used to classify each monitored stream reach based on its relative risk of impairment for each of the chemical constituent groups. The constituent groups include metals, organics, turbidity/sediment, and nutrients. Two levels of risk were defined: High and Low. For example, if elevated concentrations of metals, such as copper and mercury, are found above standards, the water body would be classified as 'High' risk if ADEQ has currently assessed it as being "Impaired" for that constituent group. Conversely, a water body is classified as 'Low' risk if there are no exceedences in a constituent group and there are sufficient data to make a classification. Classifications were conducted at the 10-digit HUC subwatershed scale, resulting in the ranking of thirty-one subwatershed areas within the nearly 7,350 square mile area of the Upper Gila Watershed.
Structure of this Watershed Based Plan

This watershed based plan includes eight sections and four appendices. The watershed characterization, including physical, biological, and social characteristics, are discussed in Sections 2 through 4. Important environmental resources are discussed in Section 5, and subwatershed classifications based on water quality attributes including concentrations of metals, sediment/turbidity, organics, and nutrients are found in Section 6. Watershed management strategies and BMPs are provided in Section 7, and the Watershed Plan is presented in Section 8.

The full tabulation of the ADEQ water quality data and assessment status is provided in Appendix A. Appendix B is a list of selected technical references applicable to the Upper Gila Watershed, Appendix C discusses the Revised Universal Soil Loss Equation used in the modeling, and Appendix D describes the AGWA tool.
References:


