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## 5. SUMMARY AND LESSONS LEARNED

The project team has developed tools and metrics to assess hydrologic alterations resulting from anthropogenic changes to the watershed. These tools can be applied at multiple watershed and subwatershed scales. Three different types or classes of tools (and metrics) were developed during this project:

1) **Basinwide Screening** tool designed to identify areas with significant hydrologic impairments at regional (i.e. basinwide) scales.

2) **Watershed Assessment** tools and metrics designed to assess and measure the cumulative impact of changes on the land surface (land cover and flow path alterations) on watershed hydrology. These tools (stream power, CN surface/wetland water retention, pathways) are especially useful for scenario testing, comparing different types and combinations of restorative actions, and/or hypothetical “what-if” analyses. In general, these tools are spatially but not temporally explicit.

3) **Hydrologic Assessment** tools and metrics designed to assess and measure the in-stream impact of changes on the land surface (land cover, flow path and channel alterations) on the fundamental characteristics of flow, i.e. magnitude, frequency, timing, duration, and rate-of-change in Great Lakes watersheds. In general, these tools are temporally, but not spatially explicit and highly effective testing time-dependent hypotheses using site-specific data.

## 5.1 Metrics

Conceptually, the project team envisioned a non-dimensional Hydrologic Benefit Index that measures the degree to which specific restoration or improvement actions contribute positively to environmental flows. Because of fundamental spatial and temporal scale incompatibilities between the instream and watershed tools, it is not possible (or appropriate) to create a single integrated metric to assess the relative value of hydrologic improvements.

The project team developed a suite of metrics based on both the watershed tools and the in-stream assessment tools that can be applied individually or as a group over a range of spatial and temporal scales. These metrics were normalized by the difference in base case (presettlement) conditions and worse case (paved paradise) conditions so that between-watershed comparisons could be made. Moreover, the hydrologic benefits (or impacts) of different types or combinations of restorative actions can be compared using these tools and metrics. The metrics developed include: Percent Stream Power Change, Power Change Metric, Power Change Ratio, CN Change Metric; Diversion Ratio, Pathway Alteration Metric, and Potentially Restorable Wetlands.

Four pilot watersheds were selected for further analyses: the Shiawassee watershed in Michigan; the St. Joseph watershed in Michigan, Indiana, and Ohio; the Milwaukee watershed in Wisconsin; and the Paw Paw watershed in western Michigan. These watersheds represent regions with different hydrologic regimes, different landcover and land uses, and different water use/supply regimes. These tools were applied to these watersheds to test real-world applicability under different scenarios.

## 5.2 Summary of Results

Results of these comparisons showed that change in stream power (discharge) from presettlement to current conditions varied greatly within and among the demonstration watersheds. In general, the greater the change in land cover from presettlement conditions, the greater the change in stream power. The highest percent change was in the Milwaukee watershed with an average percent change of 150%. The St. Joseph watershed had an average percent change of 122%, and the Paw Paw and Shiawassee watersheds had stream power changes of 90 and 78%, respectively. Change in stream power generally was higher in downstream reaches than in headwater reaches. Power Change metric values were highest in the St. Joseph and Milwaukee watersheds with values of 22 and 21 respectively, and lowest in the Shiawassee and Paw Paw watersheds with values of 10.5 and 9, respectively.

With respect to landcover, both the St. Joseph and Milwaukee watersheds are highly altered. Results show that changes from presettlement to agricultural landcover can be as hydrologically significant as changes from presettlement to urbanized landcover. Scenario testing within the Milwaukee and Shiawassee watersheds also showed that loss of wetlands reduces water retention and may significantly increase discharge and stream power at subwatershed and catchment scales.

The project team considered the potential effects of flow path changes (pathway analyses) that considered such factors as withdrawal location, the type withdrawal, the amount of water diverted, consumed, and/or returned, and the type of source and receiving waters. Due to data limitations, pathways analyses were performed on three of the four pilot watersheds. The proportion of return flow volumes ranged from 1.81% to 5.53% of the total volume of receiving waters. These volumes are relatively small and may not be detectable (or measurable) at watershed or subwatershed scales. In fact, none of the in-stream hydrologic assessment tools had the resolution or sensitivity to detect flow augmentation (or depletion) due to flow path diversions in these watersheds.

Instream analyses were completed using data from 17 USGS stream gages within the four demonstration watersheds where >20 years of continuous data were available. Both single and two-period (historical and recent) analyses performed on eight of the gages with especially long periods of record. Results were comparable between the single and two-period analyses. Analysis of the gage data showed that low flows – both seasonal (summer/fall) flows and annual low flow events – have increased over time in all four watersheds. However, there were no consistent trends in changes to high flows (high flow events and spring flows) among watersheds or among sites within the same watershed. Conversion to developed and agricultural land cover and/or channel modifications could lead to increased low flows due to increased ‘efficiency’ of the stream network. These changes could also be caused by regional climatic patterns as well. In general, flashiness increased in all watersheds since the 1970s, which may be attributable to changing land cover/land use during that time.

### 5.3 Dissemination

These tools and metrics have been applied by The Nature Conservancy to identify, guide, and evaluate on-the-ground restoration projects designed to restore hydrologic function to agricultural land and drainage channels in pilot catchments and subwatersheds in the Shiawassee and St. Joseph watersheds. These tools are also being applied in the St. Joseph watershed by The Nature Conservancy as part of the Joyce Foundation’s Maumee River restoration project. The Nature Conservancy and the Southwest Michigan Regional Planning Commission are also using these tools to assess potential hydrologic impacts of proposed development (build-out analyses and scenario testing) in the Paw Paw watershed as part of a larger U.S. EPA-supported Section 319 project.  In the Milwaukee River watershed, staff at the University of Wisconsin - Milwaukee is coupling these tools will an innovative hydrologic assessment tool based on neural net analyses to identify and guide on-the-ground hydrologic and habitat restoration activities by MMSD and other local communities.

Members of the project team gave numerous presentations at professional conferences and workshops, met with advisory group members, and staff from Federal, State, and Local resource management, protection, and planning agencies.  The project team also presented and shared results with NGO’s and funding entities that support and/or implement on-the-ground actions and projects in the Great Lakes basin.  A list of presentations and meetings is provided in Appendix III.

A project description, tool and metric summary, copies of presentations, and project results for the four pilot watersheds are available on the Applied Ecological Services website, which will be linked to tool-based websites in the basin.  This website also contains links to access project reports, appendices, and to download the tools developed (or used) in this project.  Applied Ecological Services, The Nature Conservancy, and Habitat Solutions will continue to provide technical support for the use of these tools.

### 5.4 Lessons Learned

<u>Datasets</u>

- The effects of land cover change and/or in-stream channel modifications on flow regime may be masked by regional climatic patterns and long-term trends. The project team applied several techniques to normalize regional climatic patterns in order to more clearly isolate the impacts of land cover change and/or in-stream channel modifications on flow regime. Results suggest that climatic patterns and long-term trends are regional and affect the pilot watersheds more or less equally.

- Water use and water supply information are typically reported by political subdivision and/or community – not by watershed or subwatershed. This reporting structure makes it difficult to attribute water use to a specific watershed or subwatershed. For this project, local Nature Conservancy staff assisted the project team by identifying data sources and/or by providing local data on water use and water supplies (when available) for each of the pilot watersheds. In many cases, regional datasets lacked the resolution necessary to perform meaningful analyses, and/or the data were formatted or organized in ways that made the data virtually unusable.

- Jurisdictional boundaries created artificial data barriers that limited the accuracy, precision, and usability of these data. Hydrologic and pathways analyses were severely limited by lack of data and/or data incompatibility within the St. Joseph watershed (Ohio, Michigan, and Indiana). Integrated hydrologic and land cover datasets that are internally consistent across jurisdictional boundaries are needed to properly assess and compare hydrologic alterations due to changes in land cover and land use.

- Many of the hydrologic and land cover/land use datasets were out-of-date. Some of the data used in this study were several decades old, as the datasets had not been updated or kept current by the agencies/entities responsible for their creation.

- Of particular note, the project team has developed methods to estimate current and historical water retention of wetlands within the basin. However, wetland coverages are dated and incomplete which limits application of this tool at a basinwide scale. Most of the NWI wetlands data are based on imagery acquired more than three decades ago. Certainly there have been some changes in the distribution and quality of wetlands since that time.

<u>Landscape/Watershed Assessment</u>

- Watershed assessment tools developed during this project can be used as screening (or scoping) tools and metrics to identify hydrologic impairments, and explicitly link those impairments to the landscape. These tools (stream power, CN surface/wetland water retention, pathways) are especially useful for scenario testing, comparing different types and combinations of restorative actions, and/or hypothetical "what-if" analyses.
- The project team developed and implemented a new approach that compares CN numbers for each 30 m pixel within a watershed over different time periods to evaluate the maximum potential for hydrologic improvement (or degradation). This CN change tool was integrated with the stream power analyses tool to identify areas on the landscape that maximized hydrologic impacts and assess the local and cumulative stream power response to changes on the landscape. This approach directly links changes in land cover to changes in stream

power on a pixel-by-pixel basis. The project team developed a CN Change metric to quantify the hydrologic response resulting from landscape changes within a watershed.

- The CN change tool yielded unusual results for wetland areas. Wetlands are considered hydrologically to be impervious surfaces under the standard CN land cover classification. Results suggested that conversion of wetlands to row crop agriculture (or other land cover type) would yield significant hydrologic benefits. Classifying wetlands as impervious surfaces does not make hydrologic sense. The project team developed an algorithm that links wetland type to hydrology and modifies the wetland CN values accordingly. Before performing these analyses, the CN values must be changed to reflect the actual water storage potential of wetlands.

- There are numerous models available that are designed to evaluate and model water supply and distribution systems in many western States. The project team used the WEAP (Water Evaluation and Planning) system – Stockholm Environmental Institute, to explore water use/pathway assessments in the pilot watersheds. The WEAP tool provides a systematic way to develop a water budget for a basin, watershed, or subwatershed that incorporates both natural and anthropogenic landscape and hydrologic features.

- Application of the WEAP model was severely limited by datasets that: 1) are unavailable or don't exist (the data are not being collected), 2) partitioned or summarized in ways that make it difficult, if not impossible, to evaluate or model water supply and/or water distribution systems in a watershed.

- Irrespective of currently available water supply/distribution models, <u>tools and models specifically designed for flow path analyses</u> are not readily available nor have they been applied to the Great Lakes basin. There is a need to more fully develop and systematically apply flow path analysis tools and models to Great Lakes watersheds.

<u>Hydrologic Assessment</u>

- The In-stream tools were found to be much more effective testing time-dependent hypotheses using site-specific data. These in-stream tools are temporally scalable and can be tuned to characterize and test the fundamental characteristics of flow (magnitude, timing, frequency, duration, and rate of change) at local scales. Moreover, the fundamental characteristics of flow have been linked to ecological parameters, which makes these tools useful for ecological assessments.

- Some of the hydrologic assessment tools (specifically the IHA), are not as sensitive to certain types of hydrologic alteration as originally anticipated. Moreover, the IHA tool has been applied in an "ad hoc" manner (i.e. to address specific questions in single watersheds at a local scale), but has not been used as tool to systematically evaluate hydrologic alteration across a range of watersheds. Results of this work suggest that many of the in-stream tools are not suitable as regional screening or scoping tools.

- The R-B flashiness index seems to be a reliable indicator of hydrologic alteration. The R-B flashiness index tool can be used for initial screening and between site comparisons within a watershed to identify systems with significantly altered peak flows, and the IHA tool (and perhaps other tools) can be used to better understand the causes of those altered flows.

Metrics

- Initially, the project team envisioned a non-dimensional Hydrologic Benefit Index that measures the degree to which specific restoration or improvement actions contribute positively to environmental flows. Because of fundamental spatial and temporal scale incompatibilities between the instream and landscape/watershed tools, it is not possible (or appropriate) to create a single integrated metric to assess the relative value of hydrologic improvements.

- The project team developed a suite of Hydrologic Benefit metrics based on both the watershed assessment tools and the in-stream assessment tools that can be applied individually or as a group over a range of spatial and temporal scales. Integration of newly developed tools and metrics may provide a way to assess the sustainable value of intact natural processes and the integrity of the pathways along which natural processes operate.

- These metrics were normalized by the difference in base case (presettlement) conditions and worse case (paved paradise) conditions so that between-watershed comparisons could be made. This was done so that hydrologic benefits (or impacts) resulting from different types or combinations of restorative actions could be compared using these tools and metrics.

- Identification of appropriate on-the-ground restoration opportunities has been difficult as most restoration projects do not highlight potential hydrologic benefits. Review of existing datasets and the literature reveals a paucity of data focused on the hydrologic response (i.e. flow regime) of restoration projects. A change in the restoration paradigm is necessary to fully achieve the ecological benefits that could be derived from improved water quality and water quantity in the Great Lakes basin.

Final Thoughts

- Not all restoration projects yield hydrologic benefits, and not all hydrologic “improvements” yield measurable benefits. This is a site specific problem and there are no easy answers. The learning curve has been steep, and frankly, this will continue to be a complex and difficult process.