IHA APPLICATIONS

This database is a summary of many of the applications of the ***Indicators of Hydrologic Alteration*** (IHA) software. Entries are listed according to author, with the name of the body/s of water highlighted in bold type. Individual users of IHA submitted some of the entries, and those persons have authorized themselves as contacts to obtain addition information. Other information was culled from public documents, published reports, journal articles and business correspondence.

The reasons for IHA usage fall into four categories:

1. Hydrologic Research: Use of the IHA software in assessing changes in hydrologic conditions (e.g. river flows, lake levels) over time, including changes caused by water management activities (dams, diversions, ground water pumping), climate shifts, changes in land use, etc.

2. Ecological Research: Use of the IHA software in assessing connections between hydrologic conditions (or changes in these conditions) and ecological responses, including studies of the influence of specific hydrologic conditions on species, plant community types, or ecological processes such as sediment transport, and salinity distributions.

3. Environmental Flow Recommendations: Use of the IHA software to develop recommendations for environmental flow protection (also commonly referred to as instream flows or ecosystem flows). Papers in this category may include application of the "Range of Variability Approach" (RVA) component of the IHA software.

4. Other: All other uses of the IHA software that do not fit into the above categories.

IHA DATABASE

Alber, M. & Flory, J. 2002. The Effects of Changing Freshwater Inflow to Estuaries: A Georgia Perspective. *Georgia Coastal Research Council.* **3**

The intrusion of saltwater in the upper Florida aquifier is of increasing concern due to population growth and the increase in water demands. The changes in salinity regime impacts plants, animals and fish in Georgia's estuaries. A flow management model is being sought to address these issues. IHA analysis was applied to the **Altamaha River,** and the **Satilla River**, in Georgia. For the Altamaha River, IHA analysis revealed greater daily water level fluctuations now than in the Past, but no alterations in the timing of floods. IHA analysis on the Satilla River indicated 'significant increases in winter maximum and minimum flows, and in measures of both the slope of the hydrograph and high-pulse behavior'.

Allen, D. Flow Alteration in Rivers Of The Great Lakes Basin: Extent And Effects. Business Correspondence. **2**

Rivers of the **Great Lakes Basin** have experienced significant alteration of their flow regimes, affecting fish assemblages and entire ecosystems. However, no systematic evaluation of the extent and effects of flow alteration of Great Lakes tributaries have been made. This project seeks to: (1) characterize hydrologic regimes of rivers of the **Laurentian Basin,** (2) assess the influence of dams and changing land use on flow regimes, (3) determine how flow alteration affects the fish assemblage, and (4) map flow patterns, dam locations, and other relevant data in an interpretive map using GIS. We examined the magnitude, frequency, duration, timing, and rate of change of flow at USGS gages using the IHA software. Contact: David Allan; School of Natural Resources and Environment; University of Michigan; Ann Arbor, MI 48109-1115; Dallan@umich.edu.

Armstrong, D.S. and G.W. Parker. 2003. Assessment of Habitat and Streamflow Requirements for Habitat Protection, Usquepaug-Queen River, Rhode Island, 1999-2000. Open-File Report 02-438. **3**

This case study is being used to help determine the instream flow requirements for the Pawcatuck River system. The rivers in this case are **Fisherville Brook, Locke Brook, Queen River** and **Usquepaug River.** In addition to habitat, water quality, and fish population analysis, the RVA was used to help determine the flow requirements for these water bodies.

Armstrong, D.S., G.W. Parker, and G.W. Richards. 2004. Evaluation of Streamflow Requirements for Habitat Protection by Comparison to Streamflow Characteristics at Index Streamflow-Gaging Stations in Southern New England. *Water-Resources Investigations Report 03-4332,* US Dept. of the Interior, U.S.G.S. **3**

The study area, in Southern New England, included sections of Massachusetts, Rhode Island, Connecticut and New Hampshire. The purpose of the study was to analyze hydrologic conditions and to identify and protect critical habitat needed to sustain aquatic life during low flow periods in the summer months. The three assessment tools used were the IHA (RA), Tennant, and the New England Aquatic-Base-Flow methods. A 25-year period (1976-2000), for 23 index streamflow gaging stations was used for analysis. RVA was used for the **Squannacook River** (MA), **Branch River** (RI), **Wood River** (RI), **Little River** (CT), **South River** (MA), and **Green River** (MA). The results of the study will help in developing flow goals in Massachusetts.

Armstrong, D.S., T.A. Parker, and G.W. Richards. 2000. Assessment of Habitat, Fish Communities, and Streamflow Requirements for Habitat Protection, Ipswich River, Mass., 1998-1999. Report to the Massachusetts Division of Fisheries & Wildlife. **3**

Reduced streamflows, particularly during low-flow periods, are causing a loss of habitat that supports the biological integrity of the Ipswich River. The Range of Variability Approach was used, along with other methods, to determine streamflow requirements for the Ipswich River Basin. The rivers analyzed were the **Ipswich River, Martins Brook, Norris Brook, Boston Brook, Fish Brook,** and **Howlett Brook.** Simulated flows under no withdrawals were used to determine monthly mean flows and other flow statistics used in the RVA to define a flow regime that mimics the river's natural flow.

Baker, D.B. R.P. Richards, T.T. Loftus, and J.W. Kramer. 2004. A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and States. *Journal of the American Water Resources Association.* April, 2004: 504-522. **1**

A selection of IHA parameters were used to assess stream flashiness midwestern streams and compare the results of IHA analysis to the Richards-Baker Flashiness Index (R-B Index) and the CVD (used by N.L.Poff, 1996. A Hydrogeography of Unregulated Streams in the United States and an Examination of Scale-Dependence in Some Hydrological Descriptors. *Freshwater Biology*. 36:71-91.) The parameters used to indicate flashiness, according to the suthors, were average rate of flow increase or decrease, frequency and duration of high pulses, and number of flow reversals. **One hundred streams** were randomly selected from 446 streams, in the midwest, that had no data gaps for the study period

Beauchamp, V., and J.C. Stromberg. 2001. Assessment of Hydrologic Alteration of the Lower Verde River and Possible Ecological Consequences. (Poster) Fifteenth Meeting of the Arizona Riparian Council. Tucson, AZ. **2**

IHA software is being used to look at changes in flow regime caused by operation of Horse-shoe and Bartlett Dams on the **Verde River** in Arizona. This project is part of a dissertation looking at how alterations to the flow regime impact successional processes in riparian areas. The data for pre-dam construction was from the years 1913-1938, and the post-dam data was from 1949-199. Among the changes in post-dam conditions were a decrease in winter flow volume and an increase in summer flow volume, and a difference in the timing of the average annual flow event. A decrease in the recruitment of riparian tree species is a probable response to the change in flow conditions. Contact: Vanbeau@imap4.asu.edu.

Baeza Sanz, D. & D. Garcia del Jalon. 2004. The natural variability approach. Application to five rivers in the Ebro basin, Spain. *Politecnica University of Madrid,* Spain web site. **1**

The IHA was used to analyze the effects of human induced flow alterations on five rivers in the Ebro basin in Spain. The rivers with the highest degree of alteration were the **Gallego** and the **Aragon Rivers.** The **Jalon River** showed the least degree of modification from the natural flow regime. The **Segre** and the **Gusadalope Rivers** showed a moderate degree of alteration. The analysis used data from 20 years prior to alteration, and 20 years post alteration.

Benjamin, L. & R.W. Van Kirk. 1999. Assessing instream flows and reservoir operations on an eastern Idaho river. *Journal of the American Water Resources Association* 35:898-909. 1

The IHA was used to assess instream flows and dam operations on the **Henry's Fork** in Idaho. IHA analysis, for the river below Island Park Dam, showed a decrease in the magnitude of low flow events, an increase in the magnitude of high flow events, a decrease in flow predictability, and an increase in interannual flow variability.

Big Rock Power Partners. 2003. California Trout First Stage Consultation Study Recommendations and Comments for the Big Rock Power Partners. FERC Project No 12113. Internet available. 3

Big Rock Power Partners' proposed diversion on **Willow Creek** (CA) would leave insufficient water, in most months, to maintain ecological integrity and fish passage. CalTrout recommended use of the IHA to provide a hydrologic assessment of Willow Creek. The results of the IHA analysis will help in developing a flow prescription for the power plant operations.

Black, A.R., O.M.Bragg, R.W. Duck, & J.S. Rowan. 2002. Development of a method to assess ecological impact due to hydrological regime alteration of Scottish rivers. *IAHS* Publ. No. 276, 2002, pp. 45-51. 4

The Water Framework Directive (WFD) of the European Union is the main organization that is behind the development of protocols for assessing anthropogenic impacts on the hydrology of lakes and rivers in Scotland. The IHA methodology used as a basis for creating a new methodology called the Dundee Hydrological Regime Assessment Method (DHRAM). This tool will be used to assess anthropogenic hydrologic impacts on Scotland's rivers and lakes. The eleven Scottish rivers analyzed using the IHA were**: River Leven, North Calder, Clyde, South Calder, Megget, Eas Gobhain, Upper Tay, Farrar, Elliot, Garry, and North Esk.** Contact: Robert W. Duck, r.w.duck@dundee.ac.uk.

Bragg, O.M., A.R. Black, and R.W. Duck. 1999. Anthropogenic Impacts on the hydrology of rivers and lochs: Literature Review and proposed methods. University of Dundee Report No. W98(50)I1. 4

After an extensive review of literature, methods and assessment tools, the authors recommended that the IHA/Range of Variability Analysis be used to assess water bodies across all of **Scotland**. A new model will be developed that will be re-calibrated for Scottish conditions.

Braun, David. 2004. Business Correspondence. 2

The Alabama Chapter of The Nature Conservancy will use the IHA extensively for analyzing flow data in the **Alabama-Tombigbee-Mobile Bay** system. The IHA analysis is part of the conservation planning work for the Mobile Delta/Bay project.

Brooks, Mark. 2004. McGill University, Montreal, Canada. Business Correspondence. 3

The **Rio Indio,** in Panama, may be dammed to divert water to the Panama Canal if there is expansion of the canal. An IHA and RVA was used to determine the ecological flow requirements of the Rio Indio. Daily flow values, using data from 1976-1995, provided a characterization of the Indio's natural flow regime. The analysis will provide some guidance to river managers regarding how to maintain the natural flow variability of the river following dam construction. This study is in conjunction with the Smithsonian Tropical Research Institute in Panama City.

Brunke, M. 2002. Floodplains of a regulated southern alpine river (Brenno, Switzerland): ecological assessment and conservation options. *Aquatic Conservation: Marine and Freshwater Ecosystems*. Vol. 12 (6): 583-599. 2

Brenno River, an alpine river in Switzerland, was analyzed partially using the IHA software. The primary parameter that was examined was the flood frequency category. The Brenno River's mean annual discharge has been reduced to 27% of the nature flow due to water abstractions and dam operations. Legislation that protects the floodplains of the river system does not include hydrological processes. The author recommends that such protection, including small and medium sized controlled floods, be considered as a conservation option.

Campbell, S.G., Flug, M., & R.B. Hanna. 2002. Hydrologic Analysis for River Ecosystem Management. *Hydrology Days*. 4

The IHA software was incorporated into the *Environmental Resources Analysis System* (ERAS), which is a spreadsheet based computer package. The ERAS was developed to analyze the **Green & Yampa Rivers** in the Upper Colorado River Basin. "ERAS provide access to historic data sets, scientific information, statistical analysis, model outputs, and comparative methods."

Carabetta, Mark. 2004. The Nature Conservancy of Connecticut. Business Correspondence. 1

The IHA will be used to by the Connecticut Chapter of The Nature Conservancy to analyze priority watersheds. The systems that will be analyzed are **Eight Mile River, Salmon River, Natchaug River, Hollenbeck River,** and the **Saugatuck River.** The study will use DEP records of diversion and dams, water supply impoundments, and land use data to develop a chronology of changes for each watershed. USGS flow data will be used to analyze hydrologic alteration in the watershed, before and after specific events. There will be a review of literature and watershed characteristics (% stratified drift, % impervious surface, watershed size, etc.). The analysis will help to determine if altered hydrology is a significant threat to biodiversity in these basins. An attempt will be made to define the "acceptable regime" for each stream studied.

Cassin, J. Fuerstenberg, R. Kristanovich, F. Tear, L. & K. Witing. 2004. Application of Normative Flow on Small Streams in Washington State - Hydrologic Perspective. *Conference Proceeding, American Society of Civil Engineering.* 2

Two urban streams in King County, Washington were chosen to examine the relationship between hydrology and biologic responses. The study is part of the larger King County study where flow alteration has drastically effected the fish population, including salmon.

City of Austin, 2002. Barton Springs Zone Scientific Inventory. Watershed Protection and Development Review Department; Environmental Resource Management Division. June 24, 2002. 2

The City of Austin, Texas is investigating flow into the **Barton Springs** Aquifier and the ecological conditions present in the streams that flow into the aquifier. They are gathering data on sediment, water quality, aquatic populations and habitats. The stream-flow analysis, using the IHA, will help to evaluate the effects of stream flow on the biological communities.

Currier, P. 1996.Wetland monitoring and development of wet meadow biocriteria for the Platte River in central Nebraska. 1996. Proceedings of the EPA *Wetlands: Biological Assessment Methods & Criteria Development Workshop;* Sept 18-20; Boulder, CO. 2

The IHA was used as part of an assessment of the **Platte River** in Nebraska. Paul Currier, of the Platte River Whooping Crane Maintenance Trust, presented the preliminary results of the IHA analysis. This analysis was part of an assessment of riparian habitat necessary for cranes, waterfowl and other avian species.

Dangelmaier, G. 2004. Importance of natural flow variability for Atlantic salmon in the regulated river Surna, Mid-Norway: An Application of the IHA-methodology and an analysis of habitat time series. Diploma thesis at the University of Stuttgart, Dept. of Wasserbau/SINTEF Energy Research. 1

In 2003, the Norwegian parliament selected river Surna as one of several national salmon water courses, and mitigations will be given priority in these rivers to protect the Atlantic salmon. **River Surna** has an altered flow regime due to hydropower regulation since the late 1960's. To enable salmon friendly hydropower operation and suggest mitigations that might mimic more of the natural flow, we made an attempt to rank and give priority to indicators of hydrologic alteration (Norwegian adaptation of the IHA) of relevance for maintenance of preferable habitat conditions for Atlantic salmon as the targeted species, at various parts of the river.

Duberstein, J. & W. Kitchens. 2003. Tidal forest communities on the lower Savannah River floodplain. *Proceeds from the Ecological Society of America 2003 Annual Meeting*. 2

The authors are investigating the forest community structure of the lower **Savannah River** floodplain in regard to it's hydrologic history. Development, impoundment, harbor dredging, and diversions have all impacted the natural ecosystem. Tree species composition core samples and age, soil properties, and distance from the nearest channel were recorded and analysis presented.

Eisele, M., A. Steinbrich & C. Leibundgut. 2003. Assessment of Impacts on Stream Flow Magnitude and Variability based on the Natural Flow Paradigm. *Institute of Hydrology, Albert-Ludwigs-University of Freidburg i.Br.* Poster. 1

The integrity of river ecosystems is related to the natural stream flow variability. The authors present IHA and RVA results for **River Seefelder Aach** (SW Germany), **River Wurm** (SW Germany), **River Lein** (SW Germany), **River Aare** (Switzerland), **River Danube** (SW Germany/Switzerland), and **River Inn** (S Germany).

El Dorado Irrigation District. 2000. Request for Proposals: Project 184 Relicensing; Environmental Impact Report & Environmental Studies Related to Relicensing. 3

The El Dorado Irrigation District, in California, selected the IHA to be used as the tool for analysis by Contractors as a condition of submitted proposals. The subsequent results of the IHA analysis will be used as part of the data for the **American River** relicensing procedure (FERC project 184).

Elkins, Duncan. 2001. An Analysis of Historic Flows in the Satilla River Using Two Statistical Methods. *Proceedings of the 2001 Georgia Water Resources Conference.* March 26-27, 2001. Kathryn J. Hatcher, Ed. Institute Ecology, The University of Georgia. 1

Historical flows for the **Satilla River** watershed were analyzed using the Trend Analysis function of the IHA software. Significant changes in the seasonality of flows were observed, most notably, extreme winter flows increased while extreme summer flows decreased. These observations were used to direct a series of hydrologic yield calculations that demonstrate that the variability in hydrologic yield for winter storms has increased significantly over the period of record (1931 - present).

Ellingson, A.L. & W.L. Fisher. 2003. Geographic Comparison of Impoundment Effects on Illinois River and Mountain Fork River, Oklahoma. Internet Abstract: www.edu/reu/reu_project_ellingson.html. 1

Two USGS gage stations were used for a temporal and geographic comparison of the flow characteristics of the **Illinois River** and the **Mountain Fork River** in Oklahoma. The study, using the IHA software, demonstrated how flow regime changes with the addition of anthropogenic alteration.

Fausch, K.D., Y Taniguchi, S Nakano, G.D. Grossman, & C.R. Townsend. 2001. Flood disturbance regimes influence rainbow trout invasion success among Holartic regions. *Ecological applications* 11: 1438-1454. 2

The article hypothesis is that hydrologic alteration is a cause for the rainbow trout 'invasion' in rivers and streams. Streamflow data was analyzed using the IHA software. Waterways of the Pacific Coast, Southern Appalachian Mountains, Colorado, Hokkaido Island (Japan), and Honshu Island (Japan) were the study areas. Years of streamflow records varied from 11 to 91 years. The waterways analyzed were:
Pacific Coast : **Sonoma Creek**, CA, **Deer Creek**, CA, **Elder Creek**, CA, **Redwood Creek**, CA, **Salmon River**, CA, **Rogue River**, OR, **Steamboat Creek**, OR, & **S. Santium River**, OR
Southern Appalachian Mountains: **Davidson River**, NC, **Coweeta Creek**, NC, **Tellico River**, TN, **Little River,** TN, **Yadkin River**, NC, **Nolichunky River**, TN, **Watauga River**, NC & **Clinch River**, VA
Colorado: **Rio Grande**, **Dolores River, Arkansas River, Gunnison River, Colorado River, White River, Cache la Poudre River,** & **Yampa River**
Hokkaido Island: **Saru River, Goshiribetsu River, Tokachi River, Toyohira River, Ishikari River, Abashiri River, Shokotsu River,** & **Teshio River**
Honshu Island: **Miya River, Kumozu River, Kamanashi River, Iruma River, Sai River, Jintzu River, Koyoshi River,** & **Kitakami River**

FERC Document #22261.pdf. 2002. Correspondence dated March 6, from American Rivers and 10,000 Years Institute. 3

American Rivers and 10,000 Years recommended the use of IHA analysis for the **Lewis River** Hydroelectric Projects: Merwon Hydroelectric Project No. 935; Yale Hydroelectric Project No. 2071; Swift No. 1 Hydroelectric Project No. 2111; Swift No. 2 Hydroelectric Project No. 2213. The request was made to examine the flow regime for the Lewis River Basin to restore ecological function. The Swift Bypass reach had essentially dewatered an entire section of the river.

FERC Project Nos. 935, 2071, 2111, 2213. (2001). Lewis River Hydroelectric Projects. Internet available at FERC website. 3

The hydrologic regime of the **North Fork Lewis River**, Washington, will be analyzed, using the IHA, comparing pre- and post-project statistics. This study is one of several that will attempt to propose

ecologically beneficial flows for the Lewis River and the streams and creeks that feed into it. This information is available in several locations on the FERC site, however, for easy access see "Study Plan Document WTS 4-1; Pacificorp/Cowlitz PUD."

FERC Project No 2100 (2001).Oroville Facilities Relicensing. Environmental Work Group Draft Study Plan. November, 2001, SPW2. Internet available at FERC web site. **3**

The comprehensive study plan includes hydrological analysis. The IHA will be used to compare current and historic flow conditions of **Feather River**, upstream of the Oroville Dam facility. The results of the analysis will provide input to an adaptive management program that will include channel forming flow releases.

Finch, Bill. 1998. Upstream dams disrupt the Delta's Flow of life. *Mobile (AL) Register*, December 20, 1998. **2**

The IHA was used as part of a comprehensive assessment of the Mobile-Tensaw Delta in Alabama, conducted by environmental reporters and scientists working for the Mobile Register newspaper. Their analysis emphasized the fact that low flow conditions in the **Tombigbee** and **Alabama Rivers** have increased greatly as a result of hydropower dam operations. The reporters explain some of the ecological consequences for biota that require dry floodplains or low river conditions.

Flug, M., S.G. Campbell & R.B. Hanna. 2002. Complexities of Ecosystem and River Management Decisions. *Second Federal Interagency Hydrologic Modeling Conference.* Las Vegas, Nevada, July 28-Aug 1, 2002. **4**

The Environmental Resources Analysis System (ERAS) incorporates some results from IHA analysis. The ERAS is a prototype decision support system (DSS) developed for the Colorado River Recovery Implementation Program. The IHA was used to analyze sites on the **Green River** (Utah) on a site on the **Yampa River** (Colorado).

Franzin, W.G. Department of Fisheries and Oceans; Winnipeg, Canada. Business Correspondence. **2**

The Department of Fisheries and Oceans is involved in water allocation issues in a medium sized prairie river, the **Assiniboine**, a tributary of the Red River of the North. Issues mainly relate to conservation of fishery resources, and healthy river conditions that are impacted by irrigation, municipal and agri-industry withdrawals in a very closely regulated river. Basically, spring peak flows are stored for use later in the season and to control flooding. Post-dam flows are much higher in winter than pre-development as the reservoir is drawn-down to accept spring run-off. As the available water is allocated (presently about 50%) our concerns for ecosystem integrity increase especially with respect to the prairie drought cycle and potential effects of global climate change. No publication on this IHA application as yet. Contract: franzinw@dfo-mpo.gc.ca.

Freitas, G. 2004. Business Correspondence. **3**

IHA analysis, and the ESWM framework, will be used as part of the assessment tools for dam licensing in Mato Grosso, Brazil. The environmental agency for Mato Grosso is FEMA (Fundacao Estadual do Meio Ambiente).FEMA has chosen the **Cuiaba River Basin** as the pilot program for using the IHA software and the ESWM framework.

Galat, David L. & Robin Lipkin. Characterizing the Natural Flow Regime of the Missouri River Using Historical Variability in Hydrology. 1999. Final Report to Missouri Dept. of Conservation. **1**

Many conservation organizations have identified the reestablishment of the natural flow regime of the **Missouri River** as essential to reestablish the rivers ecological health. An IHA analysis was applied "to evaluate contemporary Missouri River hydrology relative to historical conditions." The River's range of discharge variation was characterized before and after mainstem flow regulation. The pre-regulation interval, for the whole river system, was defined as 1929-1948. Analysis indicated "Flow regulation of the mainstem Missouri River was associated with significant alterations in many of the 32 hydrologic indicators." A thorough analysis is presented in this publication.

Galat, D.L. and R. Lipkin. 2000. Restoring ecological integrity of great rivers: historical hydrographs aid in defining reference conditions for the Missouri River. *Hydrobiologia*. 442/423 : 29-48. **3**

The IHA and RVA were applied to 11 locations on the **Missouri River**, including a location on the lower **Yellowstone River**. The Missouri River was divided into three sections for the analysis: upper basin, middle basin, and lower basin. Data was obtained for the years before (1929-1948) and after (1967-1996) mainstem impoundment. An additional variable was added to the "Magnitude and duration of annual extreme discharge

conditions", Julian date of the vegetation growing season 1-day minimum flow (March 1-Oct 31). Flow guidelines, and their benefits to the environment, are offered to more closely approximate a natural flow regime.

Gergel, S.E., M.G. Turner, J.R. Miller, J.M. Melack & E.H. Stanley. 2002. Landscape indicators of human impacts to riverine systems. *Aquatic Sciences.* (64): 118-128. **2**

Landscape indicators are discussed as a means of gaining insight about the impact of human activities on aquatic ecosystems. These indicators are intended to complement other traditional indicators. The IHA is discussed and evaluated. The authors suggest that the IHA has not been tested in a variety of ecoregional settings.

Haase, C. Stephan. 2002. Preliminary Hydrologic Analysis of Surface Water Flows in the Bayou Bartholomew, AR-LA. Nature Conservancy Report. **1**

Frequency and low-flow duration analyses were conducted for four localities to determine flood and low-flow characteristics, using the IHA software. To evaluate potential long-term stream flow alteration within the **Bayou Bartholomew** associated with anthropogenic factors such as land clearing, and changes in agricultural practices and consumptive water use patterns.

Halleraker, J.H., K.T. Alfredsen, G. Dangelmaier, A. Harby, R. Lund, H. Sundt, K. Svelle & O. Ugedal. 2004. Which parts of the hydrograph are essential for maintenance of Atlantic salmon habitats in the regulated river Surna, Mid-Norway. *5th International Symposium on Ecohydraulics,* Madrid 12-17, September 2004. **2**

In 2003, the Norwegian parliament selected river Surna as one of several national salmon water courses, and mitigations will be given priority in these rivers to protect the Atlantic salmon. **River Surna** has an altered flow regime due to hydropower regulation since the late 1960's. To enable salmon friendly hydropower operation and suggest mitigations that might mimic more of the natural flow, we made an attempt to rank and give priority to indicators of hydrologic alteration (Norwegian adaptation of the IHA) of relevance for maintenance of preferable habitat conditions for Atlantic salmon as the targeted species, at various parts of the river.

Hardy, T.B. A Conceptual Framework and Technical Approach for Assessing Instream Flow Need in the Water Resources Inventory Area No. 1 in Washington State. 2000. *Report, March 7, 2000.* **3**

This report recommends that the IHA be used to help determine the flow regime for rivers and streams in area WRIA1 in the state of Washington. In addition mimicking a more natural flow regime, Hardy recommends analysis of fisheries, water quality, channel morphology, invertebrates and sediment composition and movement.

Hatton, Brian & M. Bevelhimer. 2003. Assessing the Cost and Benefits of Instream Flow Mitigation at Hydroelectric Plants. *Student Abstracts: Environmental Science at ORNL. & Presentation at US Department of Energy Workshop.* Summer, 2003. **3**

The purpose of the study was to evaluate the economic costs of dam re-operation to the environmental benefits. The projects chosen for investigation had a recent change in instream flow and had fish monitoring data available. An IHA analysis was done on the stream flows before and after operational changes. Biological data showed that the environmental benefits were significant and the costs of setting minimum flows was significant as well.

Herricks, E.E. & J.P. Suen. 2003. Ecological Design in Taiwan's Rivers: Performance Expectations Considering Hydrologic Variability. From the *International Workshop on Ecohydraulics and Eco-rivers Engineering.* October 2-3, 2003. **2**

The authors elaborate on the need for integration of hydrology, hydraulics, ecology, and engineering in improving and maintaining ecosystems. They then describe the reasons that the IHA had to be altered for Taiwan rivers. The outcome was a tool called the Taiwan IHA (TIHA). Using the TIHA, analysis was presented for the **Keelung River** in Taiwan. Analysis was also done for the **Tahan River.**

Hohl, C. 2003. Effects of changing climate regime on the runoff in three study catchments. Diploma thesis, Department of Hydraulic and Environmental Engineering, Norwegian University of Science and Technology. 1

A Norwegian extended version of the IHA approach have been used in the Norwegian **rivers Gisnaas**, **Jondalselva** and **Øye** representing three different run-off regimes, to evaluate the effects of changing climate on the run-off and hence the aquatic ecosystems in parts of Norway

Illston, T.(The Nature Conservancy) & R. F. Vining (US Army Corps of Engineers). 2004. Sustainable Rivers Project Status Report. February 25, 2004. 3

The IHA was used to inform the process of determining ecological flows for the **Upper Connecticut River.** The IHA was also used for analyzing the flow on the **Bill Williams River,** below the Alamo Dam. The data will be used to help develop ecological flow prescriptions. The flows on the **French River** (PA), were analyzed with the IHA and presented to the US Army Corps of Engineers. This research is all a part of the Sustainable Rivers Project of The Nature Conservancy.

Instream Flow Council. 2002. *Instream Flows for Riverine Resource Stewardship.* Publ., Instream Flow Council. 4

This resource book, by the Instream Flow Council, reviews flow assessment tools available to scientists, water managers and practitioners. The IHA and RVA are summarized and reviewed. Included in the discussion are the objectives, scale of application, ease of use, limitations, assumptions, strengths, and the Council's critical opinion.

Irwin, E.R. & M.C. Freeman. 2002. Proposal for Adaptive Management to Conserve Biotic Integrity in a Regulated Segment of the Tallapoosa River, Alabama, USA. *Conservation Biology* (16)5:1212-1222. 3

The IHA was used to analyze the flow regime of the **Tallapoosa River**, between Harris Dam and the headwaters of Martin Reservoir. Pre-dam flows (1924-1950) and post-dam flows (1984-1996) were calculated. The dam operations peaking flows threaten the river ecosystem, particularly native biota. The authors recommend dam re-operation and possible study targets.

Johnson, Scot. 1999. Business Correspondence. 1

Over the last few years, with the help of others, I have collected, reformatted, and applied historic **Mississippi River** gage records to the IHA software. After a lot of experimentation regarding what kind of analyses might be useful and/or insightful, I completed the following: (1) Trend analysis for the St. Paul gage records. (2) IHA analysis of pre-dam versus post-dam water levels at the St. Paul, Red Wind and Winona gages. (3) IHA analysis of early dam water level regulations compared to current dam regulations for all pools in the St. Paul District with mid-control points. The Range of Variability parameters were within 1+/- standard deviation of the early dam regulation means. Contact: scot.Johnson@dnr.state.mn.us

Jones & Stokes and Yates, G. 2000. Draft hydrologic opportunities and constraints for habitat restoration on the Cocopah tribal lands along the Colorado River. December. Phoenix, AZ. Prepared for Cocopah Indian Tribe, Yuma, AZ. Business correspondence. 2

IHA statistics were used to characterize changes in the flow regime along the lowermost reach of the **Colorado River** following construction of Lake Mead in 1935 and Lake Powell in 1963. Although the overall decrease in flow is obvious to the casual observer, IHA provided a quick means of quantifying the changes. Mean and median flows were greatly decreased in all months of the year. Peak flows from tributaries such as the **Gila River** were brief and of negligible magnitude compared to the pre-existing Colorado River floods. The analysis demonstrated that restoration of native riparian vegetation couldn't depend on overall flows for seed dispersal, soil moisture replenishment, salt leaching, and geomorphic rejuvenation. Contact: Gus Yates: gusy@mother.com

Kauffman, J. Instream Flows for Riverine Stewardship. Presentation. *Virginia Department of Game and Inland Fisheries.* Internet Available: www.dep.virginia.gov/waterresources/pdf/kauffman523.pdf. 2

Kauffman states that no universal method is appropriate for determining flow regimes in all streams. He states that a combination of methods is needed to address all ecosystem components. The IHA & RVA are presented as a tool to help determine instream flows. Fish recruitment flow curves are presented for the **James River** in Virginia.

Kiesling, Richard L. 2003. Applying Indicators of Hydrologic Alteration to Texas Streams-Overview of Methods With Examples From the Trinity River Basin. *US Geological Survey Fact Sheet 128-03*. 1

A subset of the IHA parameters were selected to analyze **Trinity River, West Fork Trinity River, East Fork Trinity River** and **Mountain Creek**, Texas. Streamflow data for the 5 gaging stations ranged from 43 - 80 years. The author suggests that IHA analysis can provide a first assessment of the ecological risks to aquatic ecosystems due to human altered flow regimes. The Texas Water Plan is currently in the process of freshwater resource management plans.

King County Department of Natural Resources and Parks, Water and Land Resources Division. 2003. Normative Flow Project. Memo July, 15.2003. 3

King County's Normative Flows Project is focused on investigating the relationships between hydrologic and biologic change in an effort to restore the salmon population. IHA analysis is being used to characterize the general hydrologic integrity of King County. This project is extensive and covers flow-floodplain relationships, flow-biology relationships, and indicators of human activity. Extensive monitoring of fish communities, distribution and migration, riparian vegetation, and invertebrate community composition is being conducted on rivers and streams.

King County. 2000. Habitat Limiting Factors and Reconnaissance Assessment Report, Volume 1. December, 2000. 3

An IHA and RVA analysis was done for two sites on the **Green River** in the state of Washington. The results suggested an overall loss in the river flow dynamism. The King County assessment is part of the program to help in the recovery of salmon and steelhead in the Pacific northwest. The report also suggests possible improvements to the IHA/RVA methodology.

Kirby, C.W. 2003. Benthic Macroinvertebrate Response to Post-Development Stream Hydrology and Hydraulics. Ph.D. Dissertation. George Mason University. *Proquest Digital Dissertations.* Internet available.

Fifteen streams in the Ridge and Valley, the Piedmont, and Coastal Plain in Fairfax County, Virginia were studied. The IHA methodology was used to calculate the differences in hydrological characteristics prior to, and after watershed development. The hydrologic characteristics were compared to benthic macroinvertebrate health.

Koel, T.M. 2000. Ecohydrology and development of ecological criteria for operation of dams. Project Status Report 2000-02, May 2000. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse WI. 2

Target criteria for operations of **Illinois River** navigation dams were developed using the Range of Variability Approach in the IHA software. Hydrologic parameters were developed for a pre-dam period (1879-1899) and post-dam period (1979-1999). Only five of the 33 parameters were within upper and lower target values set at +/-1 standard deviation from the mean values. Of greatest concern for native aquatic organisms in the Illinois River are the increased frequency of hydrograph reversals, increased rates of hydrograph fall and rise, and increased frequency of flood pulses. Contact: todd_koel@nps.gov

Koel, T.M. 2000. Abundance of age-0 fishes correlated with hydrologic indicators. Project Status Report 20003-03, May 2000. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Cross, WI. 2

A canonical correspondence analysis was performed to relate fish data to IHA parameters. Fish data were collected annually since 1957 at 26 sites along the **Illinois River** in Illinois. Gradients explaining the most variability in the fish data were numbers of hydrograph (river stage) reversals, maximum one-day stage levels, and high pulse duration. Most flood and low pulse counts and minimum stage levels were also important. Non-native fish species appeared to have benefited from unnatural hydrologic variability introduced by operations of navigation dams. Contact: todd_koel@nps.gov

Koel, T.M. & R.E. Sparks. 2002. Historical patterns of river stage and fish communities as criteria for operations of dams on the Illinois River. *River Research and Applications* (18) 1: 3-19. 3

The IHA was used to evaluate the hydrologic changes in the **Illinois River** eight gage locations. Of the 33 hydrologic parameters, all by one parameter had high or moderate hydrologic alteration based on the historic range (RVA). The authors state that dam operations could be changed so that water level variability can approximate that of the historic regime from the late 1800's.

Kovach, Charles. 2000. Trend analysis of water quality in the Little Manatee River, FL. FDEP, Tampa, FL. Business Correspondence. 1

The IHA was used as part of an assessment of water quality changes, in the **Little Manatee River,** over the past 20 years. Correlations were drawn between water quality changes, hydrologic changes, and patterns of land use in the watershed. The IHA was also applied to the **Peace River, Alafia River** and **Hillsborough River.** Contact: charles.kovach@dep.state.fl.us

KRIS Russian River Project. Internet Document: www.krisweb.com. 3

An IHA analysis was done for **Dry Creek**, California comparing the hydrographs before and after the building of the Warm Springs Dam (1984). The results were that the magnitudes of the monthly hydrographs were altered. The average winter flow magnitudes have been reduced and summer base flows have increased. Peak rates were also altered. The analysis is part of a comprehensive study to plan for the protection of Pacific salmon in the Russian River Basin.

Lambert, Christi. Tracking an Invisible Threat: Hydrologic Sleuthing on the Altamaha River. The Nature Conservancy Case Study. 1

The Nature Conservancy's **Altamaha River** Program, in Georgia, has recognized the importance of the river's natural flow regime in regard to the integrity of the freshwater ecosystem. An IHA analysis was applied and had surprising results. "The IHA results indicated that the river's daily water level fluctuations are greater today than in the past, but the river's average monthly flows and the size and timing of its annual floods have hardly changed at all from pre-dam conditions (prior to 1950s)." "Results also indicated that baseflow conditions during the low flow period of the year have dramatically declined."

Latterell, J.J., K.D. Fausch, C. Gowan and S.C. Riley. 1998. Relationship of Trout Recruitment to Snowmelt Runoff Flows and Adult Trout Abundance in Six Colorado Mountain Streams. *Rivers*, Vol. 6, No. 4 pp 240-250. 2

This 8-year study was on the relationship between trout abundance and recruitment and the magnitude, duration and frequency of peak flows. The IHA was used to analyze 3 flow variables. The streams studied were the **North Fork Cache la Poudre River, Colorado Creek, Walton Creek, Jack Creek, Little Beaver Creek,** and the **South St. Vrain Creek.** Eight years of USGS flow data was utilized for analysis.

Leibundgut, C., M. Eisele & A. Hildebrand. 2000. Einzugsgebietsbezogene Bewertung der Abfluss - und Stoffdynamik als Grundlage eines Bewertungsverfahrens, *Hydrologische Gute*. zum operationellen Einsatz im nachhaltigen Flussgebietsmanagement. Institue of Hydrology, Univ. of Freiburg. 1

This internet available document gives a description of the IHA methodology.

Leibundgut, C. and A. Hildebrand. 1999. Natural Runoff and Runoff Dynamics. In Geller, W. (Ed) *River Basin Management - Challenge to Research.* Proceedings of the international conference 8-9 June 1999. Report of the UFZ Centre for Environmental Research Leipzig-Halle GmbH, Magdeburg Dependency, 31/1999 Eng. Version**.** 4

Hydroecological studies of water protection have been restricted to stretches of waters and their habitats. The authors "postulate an integrated view on a catchment area level, as is set down in the EU Water Framework Directive...The choice of parameters for assessing the runoff dynamics is based on the procedure of IHA." The procedure will be adapted to German and European requirements.

Magilligan, Francis J.2002. Changes in Hydrologic Regime by Dams. 2002 Denver Annual Meeting, Geological Society of America. Session No. 87. 1

The IHA was applied to numerous dammed rivers across the US for which approximately 30 years of USGS gage data were available. "The most significant changes across these 21 selected sites occur in minimum and maximum flows over different durations." Additionally, "…results indicate that the major pulse of dam construction during the previous century has dramatically altered hydrologic regimes on a nation-wide scale, for both large and small rivers."

Magilligan, F.J.& K.Nislow. Long-Term Changes in Regional Hydrologic Regime Following Impoundment in a Humid-Climate Watershed. Unpublished paper. Internet available. www.dartmouth.edu/Magilligan. 1

A hydrologic analysis, using IHA and log-Pearson Type III flood frequency analysis, was done on 13 rivers and tributaries, in the Upper Connecticut River watershed. Those rivers included the mainstem Connecticut **River** (NH, VT), **Ompompanoosuc R.** (VT), **Black R.** (VT), **Ottaqueechee R**. (VT), **West R.** (VT), **Ashuelot R** (NH). **Otter Brook** (NH), **Sugar R.** (NH), and the **Mascoma R**. (NH). The overall results

were that the hydrologic impacts of dams in humid environments could be as significant as the impact on large reservoirs in more arid areas. Further, the most prominent result of impoundment seems to be in the magnitude and duration of extreme high flows.

Maingi, J.K. & S.E. Marsh. 2002. Quantifying hydrologic impacts following dam construction along the Tana River, Kenya. *Journal of Arid Environments.* Vol. 50, No. 1: 53-79. **2**

Pre-dam and post-dam discharge data for the **Tana River,** in Kenya, were analyzed using the IHA. The results indicated a significant augmentation of minimum river flows and a reduction in peak flows. The conclusion was that the hydrologic alterations will have a negative impact on the riverine forest along the river.

Marangelo, P. Low Flows in the Upper Clinton River during the Summer of 2003. *The Nature Conservancy.* Report from the Michigan Chapter. **2**

The IHA was used to analyze the flow on the **Clinton River** in Oakland County, Michigan. The purpose of the study was to quantitatively compare a protracted low flow period in the summer of 2003 to 40 years of gauge data in a river that supports a globally significant mussel population. The analysis found that low flows in 2003 were unprecedented in the upper Clinton River both in terms of the magnitude of discharge and duration of low flows.

Marangelo, P. 2004. The Nature Conservancy of Michigan. Business Correspondence. **1**

The IHA was used to characterize flow trends in an agricultural watershed using 70 years of USGS gauge data for the **Shiawasee River** in Shiawasee and Saginaw Counties, Michigan. Both minimum flows and peak flows appear to be increasing over time. The findings are counterintuitive in that we expected to see decreasing low flows. However, the findings are consistent with trends observed at USGS gauges throughout the lower peninsula of Michigan.

In another study, the IHA was used to analyze the **Rouge River** in Kent County, Michigan. The purpose was to characterize flow trends in a rapidly developing watershed with 40 years of USGS gauge data, and to explore whether earlier portions of the hydrological record can be used to develop flow targets in terms of select IHA parameters for a viability assessment of the river. Similar to the Shiawasee, both minimum flows and peak flows appear to be increasing over time. The findings are counterintuitive in that we expected to see decreasing low flows.

Maryland Department of Natural Resources. 2003. Habitat Assessment of the Potomac River from Little Falls to Seneca Pool, Appendix A. **3**

The IHA was used , for streamflow on the **Potomac River**, as part of Maryland's Flow-by Study. Although the analysis showed changes to the historic stream flow characteristics, they were not statistically significant. However, there were several factors that might have influenced the results. The 'historic data' from 1930 postdates two low-head dams, and their were water releases from 2 other dams that may have masked the results. The Flow-by Studies are continuing and they are collecting data from the recent drought induced low flow conditions. The study includes the assessment of the fish population, mussels, water quality, macrohabitats, and aquatic plants.

Mathews, R.E. 1999. Aquatic biodiversity conservation: translating the natural flow paradigm into water policy. Science into Policy: Water in the Public Realm, AWRA Symposium Proceedings. **3**

IHA was used to evaluate pre- and post-impact gage data and output from a daily hydrologic model to develop and refine potential water management approaches in the **Apalachicola-Chattahoochee-Flint River** Basin. Graphical display of IHA output was streamlined to allow quick visual assessment of multiple runs of several gages. IHA analysis of successive iterations assisted modelers in refining reservoir operations that mimic the natural flow regime. These results were presented to U.S. Army Corps of Engineers and state representatives during water allocation formula negotiations for the Appalachicola-Chattahoochee-Flint River Basin. Contact: rmathews@tnc.org

Metcalfe, R.A., V.Y. Smakhtin, & C. Krezek. 2003. Simulating and Characterising Natural Flow Regimes. Waterpower Project Science Transfer Report 1.0, Ontario Ministry of Natural Resources. 14pp. 3

Ontario, Canada requires the creation of Water Management Plans (WMP's) for their watersheds. The IHA was used, in combination with the HYMAS v1.10 and CFA v.3.0, to describe the flow regimes for **rivers in Ontario**. The IHA was used primarily to determine the ramping rates. The WMP's will have enforceable operational requirements for the management of water flows and levels. There are also Aquatic Ecosystem Guidelines to ensure the protection & enhancement of the riverine ecosystem. VEC's (Valued Ecosystem Components) will also be part of the evaluation and management strategy.

McHorney, Richard. 2004. Business Correspondence. 1

The IHA software was used to analyze the flow on the **Westfield River** in Massachusetts for The Nature Conservancy. The US Army Corps of Engineers had been considering a re-operation of two of their dams that had been built for flood control. The results showed that the Corps had been very successful in the primary goal of reducing peak flows, but didn't have much effect on the rest of the hydrograph.

Meador, M.R. 1998. Assessing relations between streamflow variability and fish community structure at large geographic scales. U.S. Geological Survey, Water Resources Division, Raleigh, NC. Business correspondence. 2

Data collected from 1993-1998 as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program were analyzed to assess patterns in fish community structure relative to streamflow variability. Eight measures of streamflow variability for the NAWQA sites were generated. Fish community structure was characterized by using total species richness and the percentages of tolerant and omnivore individuals. NAWQA data were separated into four Level II ecoregions containing at least 25 sites each – the **Ozark/Ouachita-Apalachian Forests, Southeastern USA Plains**, **Western Interior Basins and Ranges** and the **Western Cordillera**. The results suggest that across the varying climatic and physiographic settings of ecoregions, streamflow variability related to the timing and predictability of high-flow events may significantly influence fish community structure. Contact: Mrmeador@usgs.gov

Meixler, Marcia S. December 2001. Hydroecology and conservation mapping: A tool community planning around the Great Lakes of New York. 4th Progress Report, Cornell University. 1

The multi-disciplinary study by Cornell University is aimed at restoring land and stream segments that have highly altered streamflow and habitat degradation, in the coastal watershed of the **Great Lakes of New York**. A GIS Model of streamflow alteration called STRMALT has been developed. The IHA software was used to compare flows under natural conditions with the current conditions. The factors identified by IHA were then built into the GIS STRMALT model.

Meixler, M., M. Bain, Almeida, R. & Loucks, D.P. 2004. Stream alteration mapping: A component of the map enhancement need. Internet document: http://www.dnr.cornell.edu/hydro2/greatlakes/strmalt.htm. 1

The study explores the link between water quality and flow regime in the Great Lakes region. An IHA analysis was conducted in the four upstate New York watersheds of **Smoke, Northrup, Sterling** and **Sandy Creeks.** Eleven years of daily flow data, from five drainage basins in each of the four watersheds, was used for the analysis. The IHA was used in conjunction with the Watershed Information Management System (WIMS).

Meyer, J.L. et al. 2002. Indicators of Hydrologic Alterations in Response to a Changing Climate. North American Benthological Society. Annual meeting. 1

The IHA was used as a tool for identifying significant impacts of future climate change on the **Cle Elum River** in Washington, and the **Apalachicola-Chattahoochee-Flint Rivers** in the southeastern United States. "This paper describes ecological changes likely to occur in response to the changing hydrologic regime estimated for the next 50 years.

Missouri Department of Conservation. 2004. Salt River Watershed - Hydrology. Internet available: www.mdc/mo.gov/fish/watershed/salt. 2

The Clarence Cannon Dam, on the **Salt River**, was built starting in 1970 and completed in 1983. Water quality is a major issue due to low flows. IHA & RVA analysis was done using pre-dam data from 1923-1970, and post-dam data from 1983-1996. This data will be used to help determine the instream flow requirements necessary to improve water quality.

Natural Heritage Institute. 2003. Re-operating Reservoirs to Restore Fluvial Processes and Augment Water Supplies in California Central Valley. Final Phase. Report to National Fish & Wildlife Foundation. **3**

This project demonstrates a means of restoring the natural hydrologic regime and fluvial functions in California's central valley. The Natural Heritage Institute proposes to use the IHA to quantify and compare the historic peak flow events to current flow regimes. The results will help determine stream flow targets to restore the fluvial process. The proposal in this report will link existing reservoirs with groundwater banks in order to restore the natural functions of a river.

Natural Heritage Institute & Instituto Technologico y Estudios Superiores de Monterrey. 2002. A Physical Assessment of the Opportunities for Improved Management of the Water Resources of the Bi-National Rio Grande/ Rio Bravo Basin. *Workshop to Design the Information Management System-Workshop on Rio Conchos Environmental Flow Restoration.* June 25, 2002. **3**

This document is a summary of a workshop held at the Universidad Autonoma de Ciudad Juarez on June 19-20, 2002. The hypothesis is that the San Gabriel reservoir and the Luis Leon reservoir, on the **Rio Florido**, can be re-operated in a manner that more closely mimics the natural flow regime. Changes in two other diversions, in both flow regime and point of diversion, were discussed. It was recommended that the IHA be used to understand how the flow regime has changed from the unaltered state. The IHA would be used on the **Rio Conchos,** and then the reservoir outflows can be assessed.

Nicklow, J. Optimization of dam operations to minimize water level fluctuation. Business correspondence. **1**

The Illinois Chapter of The Nature Conservancy (TNC), in cooperation with Dr. John Nicklow, Assistant Professor of Civil Engineering at Southern Illinois University Carbondale (SIUC), is making significant strides towards a coordinated river management plan for the **Illinois River**. This plan is intended to reduce unnatural water level fluctuations caused by independent navigation dam operation and mitigate fluctuations that result from agricultural and urban runoff. Dr. Nicklow and his team of research assistants are currently developing a comprehensive optimal control methodology and decision support model that will directly evaluate long – or shot-term optimal multi-dam operations to reach pre-specified objectives. The methodology is based upon a computational interface created between an unsteady state, hydraulic simulation model and evolutionary optimization techniques known as genetic algorithms and simulated annealing. In addition, in order to directly accommodate ecosystem related objectives, the research team plans to investigate historical hydrologic alteration along the Illinois River and incorporate the IHA into the overall optimal control model.

Normandeau Associates. 2000. An instream flow study in support of relicensing of the Piney Hydroelectric Station. (Clarion River, Pennsylvania). Business correspondence. **2**

IHA software was used to contrast inflow and outflow regimes at a peaking hydro station (**Clarion River, PA).** These analyses supplemented an effort to model assemblage-level consequences of high frequency; high amplitude flow variability using generalized microhabitat criteria and a "habitat template" approach. Study results highlighted a need to provide stable "flow windows" in spring to enhance reproductive success by many resident fishes, thus contributing to system rehabilitation. Contact: Douglas A. Nieman, dnieman@normandeau.com

Normandeau Associates, Inc. 2000. Tapoco Project, FERC No. 2169. Calderwood Bypass and Tailwater Area Aquatic Habitat Assessment. Final Study Plan, 10/1/2000. Internet Available: FERC document. **3**

This Study Plan was prepared in association with the Tapoco Hydroelectric Project relicensing process. The Calderwood bypass, on the **Little Tennessee River** in North Carolina and Tennessee is being assessed regarding instream flow requirements for aquatic biota and aquatic habitat. The flow regime variability will be assessed using the IHA.

Normandeau Associates. 2001. Flow Regime and Aquatic Habitat Assessment for the Cheoah River Downstream of Santeetlah Reservoir North Carolina. Part 2: Ecological Analyses of Flow Regime and Flow Management Alternatives. **3**

This study was part of the environmental assessment in the FERC relicensing of the Tapoco Project, (FERC Project No. 2169), on the **Cheoah River**, North Carolina. The IHA analysis was based on a 30 year USGS gage record of another stretch of river since there were no records available at the project site.

Olden, J.D. and N.L. Poff. 2003. Redundancy and the choice of hydrologic indices for characterizing streamflow regimes. *River Research and Applications* .(19) 2: 101-121. 4

This study reviews 171 hydrologic indices used by researchers to characterize flow regimes. Long term streamflow records from 420 sites in the United States are used for analytical purposes. The authors offer a framework to guide researchers in choosing indices for their projects.

Ontario Ministry of Natural Resources. 2002. The Waterpower Science Strategy: Understanding Stream Processes and the Effects of Altered Flow Regimes on Riverine Ecosystems. *Waterpower Project.* 3

This report sets forth the theories behind the required water management planning directive in Ontario, Canada. The report cites the RVA as a method to determine the natural flow regime. The report adopts the view that the flow regime of rivers must contain the hydrologic parameters that the IHA & RVA analyze. All of the components of the natural flow regime, including interannual variability will be addressed in each watershed planning document.

Pacific Gas and Electric Company. 2000a. Hydrologic Analysis of Unimpaired and Observed Streamflows in the Pit 3, 4, and 5 Reaches of the Pit River, California. Business correspondence. 3

The IHA was used to produce flow statistics of two data sets: observed streamflows for three reaches, and synthesized unimpaired streamsflows for the three reaches in the **Pit River.** The period of record for both of the data sets was 1970-1999. The data were developed during the hydropower relicensing process, and an interdisciplinary group may use the flow statistics as a starting point for characterizing flow patterns and magnitudes in the two reaches.

Pacific Gas and Electric Company 2000. Stanislaus Relicensings: Study Plans for FERC Projects No. 2005, No. 2067, No. 2118 & No. 2130. 3

Four FERC relicensing projects, involving the Pacific Gas & Electric Company, have study plans that include water use, water quality, aquatic resources, botanical resources, wildlife resources, cultural & recreational resources, and general hydrology. In anticipation of recommending a flow regime, an historical analysis of instream flow will be performed. The method of analysis chosen is the IHA. The waterways that will be analyzed are **Summit Creek, Kennedy Creek, Deadman Creek, Clark Fork** and the **South Fork Stanislaus River.** The study will help to determine peaking flows and ramping rates and possibly other flow components.

Pacific Gas and Electric Company. 1999. Hydrologic Analysis of Unimpaired and Observed Streamflows in the North Fork of the Mokelumne River, California. Business Correspondence. 3

The IHA was used to produce flow statistics of two data sets: observed streamflows for 16 reaches, and synthesized unimpaired streamflows for the 16 reaches in the **North Fork** of the **Mokelumne River.** The period of record for both of the data sets was 1970-1997. The data were developed during the hydropower relicensing process, and an interdisciplinary group used the flow statistics as a starting point for characterizing flow patterns and magnitudes in the 16 reaches.

Pacific Gas and Electric Company. 2000. Hydrologic Analysis of Unimpaired and Observed Streamflows in the Rock Creek and Cresta Reaches of the North Fork of the Feather River, California. Business Correspondence. 3

The IHA was used to produce flow statistics of two data sets: observed streamflows for two reaches, and synthesized unimpaired streamflows for the two reaches of the **North Fork** of the **Feather River**. The period of record for both of the data sets was 1974 - 1997. The data were developed during the hydropower relicensing process, and an interdisciplinary group used the flow statistics as a starting point for characterizing flow patterns and magnitudes in the two reaches.

PacifiCorp. 2002. Klamath Hydroelectric Project Study Plans (FERC Project No. 2082). Internet available at FERC website. 3

This study was undertaken as part of the re-licensing procedure for FERC. The information provided by this study will help to determine what hydrologic alterations are caused by the dam operations on the **Klamath River.** An IHA analysis will be performed on specific flow regime scenarios.

Parker, G.W. and D.S. Armstrong. 2002. Preliminary Assessment of Streamflow Requirements for Habitat Protection for Selected Sites on the Assabet and Charles Rivers, Eastern Massachusetts. U.S. Geological Survey Open-File Report 02-340. 3

Streamflow requirements, for the protection of habitat, were examined for several reaches in the **Assabet River** and **Charles River Basins.** A Range of Variability Approach (RVA) analysis was conducted on a 30-year period of record (1969-1998) for five mostly rivers. IHA analyses were performed for **Squannacook River** (MA), **Nashoba Brook** (MA)**, Old Swamp River** (MA), **Branch River** (RI) and **Sevenmile River** (MA). Results of this study will be used to assess requirements of summer low flows (July-September).

Paulic, M. 1998. Update on the Apalachicola-Chattahoochee-Flint/Alabama-Coosa-Tallapoosa Rivers Comprehensive Study/Basin Commissions. *Ambient Newsletter.* Vol. 2, No. 3. 3

The strategy that Florida is considering using for the restoration and maintenance of the **Apalachicola River & Bay** system is the natural flow paradigm. The use of the IHA & RVA will be used to provide Florida with a way to evaluate alternative water management scenarios for the ACF basin.

Pegg, M.A. and C.L. Pierce. Classification of reaches in the Missouri and lower Yellowstone Rivers based on flow characteristics. U.S. Geological Society, Biological Resources Division, Iowa Cooperative Fish and Wildlife Research Unit, Department of Animal Ecology, Iowa State University, Ames, IA. Business correspondence. 1

Several aspects of flow have been shown to be important determinants of biological community structure and function in streams, yet direct application to large rivers has been limited. Using a multivariate approach, we grouped flow gages into hydrologically similar units in the **Missouri** and **lower Yellowstone Rivers** and developed a model based on flow variability parameters that could be used to test hypotheses about the role of flow in determining aquatic community structure. This model could also be used for future comparisons as the hydrological regime changes. A suite of hydrological parameters for the recent, post- impoundment period (1/10/66 – 9/30/96) for each of 15 gages along the Missouri and lower Yellowstone Rivers was initially used. Preliminary graphical exploration identified five variables for use in further multivariate analyses. Six hydrologically distinct units composed of gages exhibiting similar flow characteristics were then identified using cluster analysis. Discriminant analyses identified the 3 most influential variables as flow per unit drainage area, coefficient of variation of mean annual flow, and flow constancy. Contact: Clay Pierce, cpierce@iastate.edu

Peterson, D. 2001. The development of process-based restoration strategies for re-vegetating floodplain sites along the Sacramento River, CA. Master's thesis title. California University, Chico, CA. Dept. of Biology. Business correspondence. 2

Sacramento River Project is developing alternative strategies for re-vegetation of floodplain sites. These process-based strategies manipulate, or mimic, the natural, physical, and ecological processes that control riparian forest recruitment and succession. The IHA software was used to analyze the historic timing of spring peak flows for the **Sacramento River**, CA. An experiment was established using an RVA approach to determine the riparian plant community response to alternate flood timing. Flood timing was found to significantly affect the species composition of seedling cohorts, but inter-specific competition played an important role in subsequent survival. Both ecological and physical factors play important roles in determining the species composition of process based restoration sites. Contact: dpeterson@tnc.org

Pike, Shawn. 2000. Offstream storage investigations – third progress report on determining impacts of offstream storage diversions on Sacramento River flows, Indicators of Hydrologic Alteration results. Internal memo, The Resources Agency, Dept. of Water Resources, Sacramento, CA. 3

Analyzed **Sacramento River** flows during three periods (before Shasta Dam, after Shasta dam but before Trinity Dam, post-Trinity dam) at four different stream gauging stations. IHA analysis revealed substantial changes in monthly flow volumes; reductions in the one-, three- and seven-day maxima; Julian date of maximum annual flow; and hydrograph rise and fall rates. The CA Dept. of Water Resources is using this analysis to assess hydrologic changes that may have had most impact on cottonwood establishment and growth. This information could be used to design flow experiments for restoring cottonwood forests.

Potyondy, J.P. & E.D. Andrews. 1999. Channel Maintenance Considerations in Hydropower Relicensing. *StreamNotes.* Stream Systems Technology Center. April, 1999. 1

The authors discuss the importance of considering channel maintenance flows for FERC relicensing projects. The channel flows are necessary to move bed material and to maintain sediment balance, to maintain riparian

vegetation, and to prevent vegetation from entering the channel. The IHA is recommended for summarizing the hydrologic regime in relicensing projects and for considering post-project flow alternatives.

Quinn, J. 2001. *Stream Fisheries Newsletter, January-February 2001.* Arkansas Game & Fish Commission. **3**

The Arkansas Game & Fish Commission's stream program on the **Arkansas River** is compiling data on fish communities, water quality, and water quantity. The IHA analysis done for the Arkansas River will help the Commission negotiate with the Corps of Engineers for improved flows for the river.

Richard, GA., PY, Julien & DC Baird. Morphological Changes of the Rio Grande Downstream from Cochiti Dam. Unpublished Draft. **1**

There has been a change in water and sediment input to the **Rio Grande** after the construction of the Cochiti Dam in 1973. The dam was built for the purposes of flood control and sediment detention. Data collected between 1918 and 1992 were used for an IHA analysis. The IHA analysis revealed that the three most relevant parameters were maximum flow, the mean annual flow and the duration of the high flows.

Richter, B.D., J.V. Baumgartner, J. Powell, and D. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. *Conservation Biology*. (10) 4:1163-1174. **1**

This article describes the IHA software, and its applications for flow management. An IHA analysis of the **Roanoke River**, North Carolina, is used as the case study.

Rivera, J. 2004. Patuca River Flow Assessment. Business correspondence. **3**

The Honduras government is planning another **Patuca River** project. An IHA analysis will be done as a flow assessment tool. Brian Richter, of the Sustainable Waters Program, will be assisting in the IHA analysis. Experts with expertise in water quality, hydraulics, fish biology, fluvial geomorphology, and and floodplain forestry will likely be a part of the assessment team.

Sacramento Municipal Utility District. 2002. Upper American River Project; FERC Project No. 2101: Plenary Group Meeting. August 2, 2002. **3**

An IHA analysis will be used in this study as part of the relicensing plans on the **South Fork American River** and its tributaries. The information obtained will be used to develop an overall hydrology plan for the Chili Bar Project. The results of the IHA analysis will be included in the Licensee's draft environmental statement report that is sent to FERC. The flow data will be taken from USGS gage data from the years 1976-2001, except for the annual peak flows, which will be taken from 1925-2001. The Licensee on this project is Pacific Gas and Electric Company.

San Juan River Basin Recovery Implementation Program-Biology Committee. 2004. *Meeting Summary*, May 4-6, 2004, Farmington, New Mexico. **3**

An IHA and RVA analysis was done for the **San Juan River** using streamflow data from a gage near Bluff, Utah. The data for the pre-impoundment period was 1929-1962. The results suggest that the current flow recommendations do not necessarily result in mimicking the natural hydrograph. The data also suggests that there could be better management for high flow releases. The IHA analysis was presented by Tom Westch of HabiTech, Inc.

Sanz, D.B. & D. Garcia. 2003. Avances y Aspectos No Resueltos En La Estimacion de Regimenes de Caudales Ecologicos. E.T.S.I. Montes. Internet document: www.us.es/ciberico/sevilla305.pdf. **3**

This paper examines various methods for determining flow requirements for rivers in Granada. The IHA is discussed, and the authors suggested that this method could be applied to **rivers of Tajo**.

Schmidt, G., O. Gretzschel, M. Volk & M. Uhl. 2004. A concept for the scale-specific simulation of water-bound material fluxes in the project FLUMAGIS. (document in German language). **1**

From English abstract: "In order to reach the environmental targets of the EC water framework directive on different scale levels, a concept for the scale specific simulation of water-bound fluxes in the project FLUMAGIS is presented." The authors review various methods of analysis, including the IHA software. They considered the IHA to be part of a rigorous parameter building process. The region being investigated is the **Ems River** in North Rhine-Westphalia, a large and polluted area.

Schmidt, J.C. & M.A. White. 2003. The Hydrologic Regime of the Snake River in Grand Teton National Park. Draft Report: Utah State University. **3**

The study is concerned with the hydrologic effects of the Jackson Lake Dam releases. The stream flow data was divided into three categories: 1903 - 1916 pre-dam flows; 1917 - 1956 post-dam construction; and 1957 - 2002 post Palisades reservoir completion and filling. An IHA analysis was done for the **Snake River** near Moran. The IHA results confirmed the flow regime had changed greatly following the completion of the Palisades Dam.

Schuler, G.and C. Apse. 2000. Analysis of hydrologic alteration on Delaware River tributaries. The Neversink River Program. Internal working paper, The Nature Conservancy. **3**

The IHA was used to analyze how the hydrologic regimes of the **East Branch Delaware River, West Branch Delaware River,** and **Neversink River** have changed since the construction of water supply dams on each of these major Delaware River tributaries. Since the flow regime of each river was found to have been significantly altered, the RVA capabilities were employed to provide flow targets that might be utilized in determining more appropriate dam releases to each of the tributaries. Contact: capse@tnc.org

Scoggins, M. Effects of hydrologic variability on macroinvertebrate-based biological assessments of streams in Austin, TX. City of Austin, Watershed Protection Department. Austin, TX. Business correspondence. **2**

The city of **Austin**, TX, has been using Rapid Biological Assessments in urban and sub-urban streams for the last 7 years in an effort to expand and improve its environmental monitoring programs. Central Texas weather is characterized by flashy spates, long dry periods and is distinct from the temperate climates where the RBA's were developed. In addition, to these naturally dramatic hydrological cycles, urbanization and its high levels of impervious cover further exaggerate stream flow patterns, producing greater runoff volumes, higher peak flows and less baseflow. 19 hydrologic statistics were calculated using historical USGS flow data for **11 study streams** and compared to available City of Austin benthic macroinvertebrate data using analysis of variance and multiple regression. A field study was also conducted to evaluate the effects of antecedent hydrologic conditions on biological assessments of 3 streams of differing development condition (high, medium, low) during a 6-month spring flow season. Results show that both long-term hydrologic character of streams in this area as well as immediately antecedent hydrologic conditions have a significant effect on the results of RBA's, which is compounded, in urbanized streams. Hydrologic variability should be utilized as a template in interpreting biological assessments using the RBA metric. Contact: mateo.scroggins@ci.austin.tx.us

Scott, Elizabeth. 2004. State of Rhode Island; Dept. of Environmental Management. Business Correspondence. **1**

We had the USGS apply the IHA program to assist in our evaluation of a groundwater withdrawal permit application and subsequently, considered the statistics generated by the program during the course of developing instream flow standards for Rhode Island. We found it to be helpful in those applications – whether we will utilize the software in evaluating future permit applications is uncertain. By way of information, the instream flow standards that we are developing are based upon modifications to the US F&W ABF approach, similar though not entirely the same as proposed by CT.

Scruton, D.A. 2001. Business correspondence. **2**

We intend to investigate the effects of large-scale forest harvesting on river hydrology of watersheds in the **Bay St. Georges** area of Newfoundland Forest Service and the pulp and paper company who harvested in these watersheds. An exploratory analysis of hydrological changes was inconclusive. We intend to re-analyze this data with the metrics contained in the IHA software. If the results are promising, we intend to expand the analysis to a variety of gauged watersheds across the island of Newfoundland. Contact: David Scruton, Fisheries and Oceans, scrutond@dfo-mpo.gc.ca

Shaw, D.T. 2001. The impacts of upstream dams, groundwater withdrawals and climate variability on baseflows of Altamaha River, Georgia. Internal Report, The Nature Conservancy, Altamaha River Bioreserve, Darian, GA. **2**

IHA was used to analyze trends in low-flow statistics on 5 coastal plain streams in the **Altamaha River Basin** and four in adjacent watersheds in Georgia to gain a better understanding of the causes of apparent declines in Altamaha baseflows. The effects of upstream hydropower dams were shown to be less serious that previously thought, but proposals for numerous new dams in the Piedmont pose a significant future threat. By analyzing streamflow from relatively unimpacted watersheds of different sizes throughout the Altamaha and adjacent basins, it was found that the baseflow decline appears to be the result of regional

climate variability that is manifested as an increase frequency of drought since about 1980. However, intensive groundwater pumping in the coastal plain may be reducing the ability of aquatic ecosystems to survive and recover from droughts. The proposal of a warmer climate and more frequent drought in the Southeast elevates the importance of protecting groundwater flows that sustain physiological refuge for aquatic biota and add resiliency to aquatic ecosystems. Contact: dshaw@tnc.org

Shiau, J.T. and Wu, F.C. 2004. Feasible Diversion and Instream Flow Release Using the Range of Variability Approach. *Journal of Water Resources Planning and Management,* Vol. 130, No 5:395-404. **3**

The RVA was used as a tool for determining the feasibility of a combination of flow diversion and instream flow release for a proposed diversion weir. The operational goal is to make the post-diversion flow attain the target ranges at the same frequency that occurred in the pre-diversion flows. **Peinan Creek**, where the diversion is proposed, is home to endangered aquatic species. **Luyeh Creek,** a tributary of Peinan Creek, was also evaluated using the RVA.

Shiau, J.T. and Wu, F.C. 2004. Assessment of hydrologic alterations caused by Chi-Chi diversion weir in Chou-Shui Creek, Taiwan. *River Research and Applications.* (20) 4: 401-412. **3**

The IHA and the RVA were used to analyze flow conditions caused by a weir on **Chou-Shui Creek** in Taiwan. The results found that there were large hydrologic alterations following weir construction. This was especially true for the low flows. The authors state that a proposed water release plan, increasing the instream flow to 40 m^3/s and reducing monthly withdrawals would promote a natural stream biota.

Smeltzer, M. and N. Lassettre. 1999. Using historical geomorphic analysis to characterize pre-dam flow regimes in ecologically meaningful terms. *Stream Notes*, July 1999. Rocky Mountain Research Station, US Forest Service, Fort Collins, CO. **2**

This study applied the IHA to the **upper Owens River** near Mammoth Lakes, California, to evaluate hydrologic changes that have occurred since construction of a hydropower dam in 1941. Based upon these hydrologic changes, hydraulic evaluation of the area of floodplain inundated at various flow levels, and historic aerial photos, the authors were able to explain the changes in riparian vegetation that have occurred since dam construction.

Southern California Edison Company. 2003. FERC Project No. 382; Exhibit E; Report on Water Use and Quality. **3**

An IHA analysis was done for the diverted reach of the **Kern River**. The results indicated that the hydrology is substantially different during the winter months(1954 - 2000). The complete hydrologic data is contained in *Borel Hydroelectric Project* (FERC No 382) *Kern River Basic Hydrology Information,* June 26, 2001.

South Florida Water Management District. 2002. Final Draft MFLs for the Luxahatchee River. Appendix R. 11/18/02. Internet available. www.sfwmd.gov **3**

The South Florida Water Management District is identifying methods that could be used to establish minimum flows for the **Northwest Fork** of the **Loxahatchee River** and Estuary. An additional application of the IHA will be its use with salinity data, rather than with flow data. "Results of natural or historical conditions would be compared to existing or predicted conditions of salinity."

State of the Nation's Ecosystems: Technical Notes. Fresh Waters: pp 246-256. Internet available: www.heinzctr.org **1**

An IHA analysis was done for **867 sites** across the United States for a 20-year period beginning about 1930 and three 10-year periods (1970's, 1980's and 1990's). David Raff, Department of Civil Engineering, Colorado State University conducted the data analysis.

State Water Resources Control Board. 1999. Final Environmental Impact Report for implementation of the 1995 Bay/Delta Water Quality Control Plan. State Clearinghouse No. 97-122056. November 1999. California Environmental Protection Agency. **3**

The Range of Variability Approach (RVA) was used to assess the impact of various flow alternatives on aquatic habitat in **rivers** in the **Sacramento-San Joaquin** system, and **tributaries** to the **San Francisco Bay/ Sacramento-San Joaquin Delta Estuary**. Simulated flows for the period of hydrologic record for each of the flow alternatives were compared with flow target ranges to evaluate the relative suitability of the alternatives in meeting ecological objectives. The differences among the flow alternatives in the rate of non-attainment of the target ranges were minor. No significant impacts on riverine aquatic habitat were therefore predicted with any of the flow alternatives.

Steward, C. Business correspondence. **3**

Tacoma Power used IHA software to analyze pre- and post-dam hydrologic regimes for the **Cowlitz River** in southwest Washington State as part of the relicensing proceedings for the Cowlitz hydroelectric projects owned. The goal was to assess the existing flow regime with reference to historical flows, and to develop project operation guidelines and instream flow regulations that would create and maintain desirable ecological conditions in the lower Cowlitz River, including spawning, rearing, and migratory habitat for ESA-listed species of salmon and steelhead. The Range of Variability Analysis was used to identify and select appropriate "target" flows (i.e., ecologically desirable), minimum streamflows, and "pulse" flows to aid smolt migration and to promote channel complexity. These concepts and the supporting statistical analyses were presented in the context of a larger flow proposal, portions of which were incorporated into terms and conditions required by state and federal regulatory agencies. Contact: csteward@wolfenet.com

Stewardson, M.J. & C.J. Gippel. 2003. Incorporating Flow Variability into Environmental Flow Regimes Using the Flow Events Method. *River Research & Applications* (19): 459-472. **3**

The authors present a new approach, the 'Flow Events Method' to address how the flow regime effects biological and geomorphic communities. The **Snowy River,** in New South Wales, Australia., is used as a case study. The IHA and RVA is discussed, and it is suggested that the RVA can be developed that will consider physical habitat conditions. The Flow events Method incorporates variability into environmental flow regimes. It provides an assessment of flow regimes based on ecosystem processes instead of hydrological statistics.

Strange, E. 1998. Flow Regime Limitations of Colorado Trout Populations: Perspectives for Watershed Management. *Trout Unlimited* report. **2**

Water development impacts on trout fisheries were assessed using the IHA and RVA to evaluate pre- and post- development flow conditions. The study concluded that flow regime alterations in many of the Colorado's rivers threaten the future sustainability of existing trout fisheries and the river ecosystems upon which they depend. IHA analysis was done using historic flow data for the **South Platte River, Cache la Poudre River, Arkansas River, Rio Grande, Conejos River, Gunnison River, Taylor River, upper Colorado River, Blue River, Eagle River, Fryingpan River,** and the **Yampa River.**

Suen, Jian-Ping, E.E. Herricks & J. W. Eheart. 2004. Ecohydrologic Indicators for Rivers of Northern Taiwan. *ASCE/ EWRI World Water and Environmental Resources Congress 2004;* June 27-July 1, 2004; Salt Lake City, UT, USA. **2**

The Taiwan Ecohydrology Indicator System (TEIS) was inspired by the IHA for specific regions in northern Taiwan. The TIHA (Taiwan IHA) was developed by Suen & Herricks. The ecohydrological indicators integrate ecological, hydrologic, and human management objectives. The **Tahan River** was used for a case study.

Swanson, S. 2002. Indicators of Hydrologic Alteration. *Resource Notes, No. 5, Hydrology.* National Science and Technology Center. **1**

Swanson, a River Modeling Specialist with the National Science & Technology Center, states that the NSTC is using the IHA software using USGS streamflow data. He describes the IHA software, RVA, and Trend Analysis. Staff at the NSTC are using the IHA approach on a project in southern Arizona. He further states that this approach has significant application to other locations within the Bureau of Land Management.

System Operations Advisory Committee. 1999. Report on Biologically Based Flows for the Yakima River Basin. Report to: The Secretary of the Interior. May 4, 1999. Yakima, Washington. **3**

The purpose of the report was to provide Congress & the Secretary of the Interior with a review of factors affecting anadromous fish resources in the **Yakima River**, and to determine biologically based flows for increasing salmon and steelhead abundance. The IHA and RVA analysis were chosen by the SOAC as the method to be used to develop and implement normative flow regimes that would improve aquatic ecosystem conditions in the Yakima River basin. The information obtained will be used to evaluate the interim flow recommendations. Investigations will continue to assess the relationship between flow regime and anadromous salmonid production and abundance in the watershed.

Taylor, V., R. Schulze, and G. Jewitt. 2003. Application of the Indicators of Hydrological Alteration method to the Mokomazi River, KwaZulu-Natal, South Africa. *African Journal of Aquatic Science.* 28(1): 1-11. 1

This paper presents an application of the RVA to simulated streamflows at 2 sites on the **Mokomazi River** in order to assess the extent of alteration caused by human induced changes to the hydrological regime.

Tharme, R.E. 2003. A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers. *River Research and Applications*. **19**: 397-441. 4

Over 200 environmental methodologies, in 51 countries, are currently being used worldwide to assess environmental flows. this paper focuses on environmental flow methodologies in the categories of hydrologic, hydraulic rating, habitat simulation, and holistic methodologies. The IHA and RVA are reviewed in depth in the 'Hydrological methodology' section.

Theiling, C., S. Johnson, and J. Wlosinski. 2000. The analysis of gage records to identify and quantify changes using the "Indicators of Hydrologic Alteration" (IHA) software. Presentation at the Fillmore Mississippi Heritage Conference, May 3-4, 2000. 1

The IHA was used to evaluate water level (stage) and discharge records for the **Upper Mississippi River.** Twenty USGS streamgage stations with 60-70 years of data, and 162 Corps of Engineers water stage locations with 60-100 years of data were analyzed to evaluate effects of lock-and-dam management. Significant and marked trends or changes were detected in many IHA parameters.

The Nature Conservancy, Biohydrology Department. 1996. IHA Analysis of Poultney River. 1

There was no pre-dam data available for the **Poultney River** because there was no streamflow monitoring before the dam was built. Post-dam data was analyzed. Some hydrologic characteristics appeared to change abruptly around the year 1970. An examination of dam operations was recommended to identify the cause of such change.

The Nature Conservancy of California. 2003. Internal Report. Water Initiative Report. 2

The IHA will be used to assess the ecological flow regimes needed to protect and restore the ecosystems on the **Sacramento River, San Jaquin River** basin and it's tributaries, the **Stanislaus, Tuolumne & Merced Rivers. Santa Clara River** staff will also be conducting an ecological flow assessment.

The Nature Conservancy Great Lakes Program. 2003. Developing Methods to Analyze, Protect, and Restore Flow Regimes in the Great Lakes Basin. April 2003. Business correspondence. 3

The Annex 2001 and the Council of Great Lakes Governors' Water Management Working Group have made the protection of flow regimes a priority to improve the ecological integrity of the Great Lakes region. The Ecological Flow Components (EFC) method will be used. The EFC, an evolution of the IHA software, breaks the flow pattern into 3 components: flood, high, and low flow, then analyzes the five characteristics for each of these components. The EFC and flow duration curve method will define the current flow conditions, describe historic flow regimes, and estimate natural flow regimes.

Thoms, M. & Fiona Dyer. 2004. Final Report, Project R2004, Development of a Framework for the Sustainable Rivers Audit. *Cooperative Research Centre for Freshwater Ecology*. Australia. 1

The IHA is noted as one method used to assess alterations in hydrologic regimes. The authors indicate that the IHA would have to rely on simulated data because many Australian rivers to not have lengthy instream flow data available. The authors also state that different methods of assessment are used in the various watersheds and propose that the same methods be used for consistency.

Tøfte, L., Jenssen, A., Harby, A. 2004. Development of parameters for assessing hydrological variation and their impact on fish populations. Methods and application in Norway. 5th International Symposium on Ecohydraulics, Madrid 12-17 September 2004. 2

A Norwegian extended version of the IHA approach have been used in the **Rivers Orkla, Halsaelva** and **Saltdalelva** to link hydrological variation to long datasets of salmonids (growth, densities and migrations of Atlantic salmon, sea trout and sea char) to find correlation or lack of thereof.

Tøfte, L.S., Jensen, A. 2004. "Does climate change scenarios recreate biological relevant hydrological variation in discharge series?" Presented at EGU General Assembly 2004, abstract in Geophysical Research Abstracts, Volume 6, 2004. 2

A Norwegian extended version of the IHA approach is used in the **Rivers Orkla** (regulated), **Halsaelva** (unregulated) and **Saltdalelva** (unregulated) to link hydrological variation to long datasets of salmonids (growth, denisities, migrations of Atlantic salmon, sea trout and sea char) to predict possible implication of climatic change on fish biological relevant IHAs.

Trungale, J. Texas Parks and Wildlife Resource Protection. Business correspondence. 1

One of my duties as surface water hydrologist for the River Studies program at Texas Parks and Wildlife is to review water rights applications for impacts on instream flows. Our preference, for major projects, is to do site specific studies to assess impacts on habitat from changes in flow, however this is not always practical. In many instances I use IHA in preliminary analysis of effects of new water right diversions on **Texas streams and rivers.** In most cases these involve diversion to off-channel reservoirs. I run the historical hydrology, gages or naturalized, through the program and then run modeled stream flows based on various scenarios for pumping capacity and instream flow restrictions. In making my runs, I set up a batch file to output parametric, non-parametric and RVA results. Contact: Joe Trungale, TX Parks & Wildlife, Resource Protection; PO Box 1685, San Marcos, TX 78667-1685.

University of Natal, Pietermaritzburg, South Africa. 2004. Antropogenic Impacts of Dams. *Class Notes.* Internet: www.beeh.unp.ac.za/hydro. 1

The IHA is discussed. Case studies for two South African rivers, using IHA analysis, are presented. Fifty-two years of streamflow data were used to analyze the **Noordkaap River** and the **Vaal River.**

U.S. Geological Survey. 2002. Preliminary Assessment of Streamflow Requirements for Habitat Protection for Selected Sites on the Assabet and Charles Rivers, Eastern Massachusetts. Internet document: http://water.usgs.gov/pubs/of/ofr02-340/html/preliminary.html. 3

The IHA/RVA was used to help determine the instream flow requirements for the Assabet and Charles River basins. The five waterways chosen for the analysis were the **Squannacook River, Nashoba Brook, Old Swamp River, Branch River,** and **Sevenmile River.**

Water Resources Commission, The Commonwealth of Massachusetts. 2001. Stressed Basins in Massachusetts. December 13, 2001. Internet available: www.state.ma.us 1

The Water Resources Commission (WRC) defined their definition of a "stressed basin" and subsequent methods for applying the stress definition. The IHA is used as a tool to gauge stress, but is limited to streams where historic gage data is available. IHA analysis was done for many MA rivers, although the only ones named in the report were: the **Quinebaug River, Housatonic River, Connecticut River, Blackstone River,** and the **Charles River.**

Wilcox, P.R., J.C. Schmidt, and P.E. Grams. 2002. Review of Idaho Power Company Documents Concerning Sediment-Related Impacts of the Hells Canyon Dams on the Snake River in Hells Canyon. Document # 3. FERC document Appendix-d.pdf. Ferc Project #1971. 3

The Idaho Power Company (IPC) used the IHA, in addition to other analyses, in its assessment for FERC relicensing process. An IHA analysis was used to determine the changes in the mean daily discharge, under present operating conditions, compared to a free flowing state. However, IPC failed to analyze the Hourly discharges. The three dams on the **Snake River** that comprise the Hells Canyon Complex are operating under a single license that expires July 2005.

Wildhaber, M.L., V.M. Tabor, J.E. Whitaker, A.L. Albert, D.W. Mulhern, P.J. Lamberson, & K.L. Powell. 2000. Ictalurid Populations in Relation to the Presence of a Mainstem Reservoir in a Midwestern Warmwater Stream with Emphasis on the Threatened Neosho madtom. *Transactions of the American Fisheries Society:* 129: 1320-1336. 2

Ictalurid populations, including those of the Neosho madtom, have been monitored in the **Neosho River** basin since the Neosho madtom was listed as threatened in 1991. The Neosho madtom presently occurs only in the Neosho River basin, in which the hydrologic regime has been altered by construction and operation of reservoirs. One of the objectives was to assess changes in icturalid densities and hydrology in relation to the presence of a mainstem reservoir in the Neosho River basin. The hydrology at study sites was characterized using IHA as calculated with stream gauge information from the USGS. The effects of the dam on flows

were demonstrated by changes in short- and long-term minimum and maximum flows. Positive correlations between observed Neosho madtom densities and increased flows in winter and spring months as well as the date of the 1-d annual minimum flow indicate the potential importance of the timing of increased flows to Neosho madtoms.

Williams, J.G. and Kondolf, G.M. 1999. Rehabilitation Concepts for lower Clear Creek, Shasta County, California. Unpublished report to the US Fish & Wildlife Service, Red Bluff, CA. Business correspondence. **2**

The IHA was used to analyze flow regimes in **Clear Creek**, Shasta County, California, before and after construction of Whiskeytown Dam, a component of the Central Valley Project. Information from the analysis was used to inform a reconnaissance level investigation of the effects of changes in sediment transport on the morphology and habitat value of Clear Creek. Conceptual recommendations for habitat restoration were developed from the geomorphic analysis. Contact: jgwill@den.davis.ca.us

Young, L.M.. 2003. Understanding Instream Flow Protection. *PA Fish and Boat Commission.* 02/19/03. **3**

The Range of Variability Approach will be used, along with the PA/MD Instream Flow Model, to determine instream flow protection levels in the **Delaware River Basin.**