Okanagan Fish and Water Management Tool Project Assessments: Record of Management Strategy and Decisions for the 2005-2006 Fish-and-Water Year

K.D. Hyatt, C. Bull, and M.M. Stockwell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, BC
V9T 6N7

2009

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2897

Fisheries and Oceans / Pêches et Océans

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2897

2009

OKANAGAN FISH AND WATER MANAGEMENT TOOL PROJECT ASSESSMENTS: RECORD OF MANAGEMENT STRATEGY AND DECISIONS FOR THE 2005-2006 FISH-AND-WATER YEAR

by

K.D. Hyatt[1], C. Bull[2], and M.M. Stockwell[1]

[1]Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, BC V9T 6N7

[2]Glenfir Resources
465 Lower Bench Road
Penticton, B. C. V2A 8V4

Cat. No. Fs 97-4/2897E ISSN 0706-6473

Correct citation for this publication:

Hyatt, K.D., Bull, C., and Stockwell, M.M. 2009. Okanagan Fish and Water Management Tool project assessments: Record of management strategy and decisions for the 2005-2006 fish-and-water year. Can. Manusc. Rep. Fish. Aquat. Sci. 2897: ix + 68 p.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

ACKNOWLEDGEMENTS

The operational deployment and testing of the Fish-and-Water Management Tools decision support system (hereafter identified as FWMT) in the Okanagan during 2005-2006 was made possible by the dedication and hard work of many individuals from several organizations:

- Richard Klinge and Bob Clubb from Douglas County Public Utility District (DCPUD) in Washington State provided not only monetary support but also the necessary confidence to implement multiyear trials to determine fish production benefits that may be achieved through deployment of a new generation of fish-and-water management tools.
- Deployment and testing of the FWMT-DSS is executed under the authority of the three-party (Fisheries & Oceans Canada-DFO, BC-Ministry of Environment-MOE, Okanagan Nation Alliance-ONA) Canadian Okanagan Basin Technical Working Group (COBTWG) chaired by Elmer Fast (DFO). Mr. Fast's exceptional commitment to COBTWG activities in general and the FWMT project in particular contributed to its success during 2005-06.
- Brian Symonds of BC-Water Stewardship Division (WSD) continued to inject technical expertise and advice based on decades of experience as a "front-line" manager of the Okanagan Lake and River System. Although a well deserved promotion removed Brian as the Okanagan "water manager of record" during 2005-06, we are indebted to him for his continued interest and support of operations group efforts to deploy and test FWMT.
- Don McKee of the WSD Office in Penticton had "big shoes" to fill as Brian Symond's replacement during 2005-06. In spite of a steep learning curve associated with operations of the OLRS, deployment of FWMT, and a climatically challenging year, Don came through with flying colours.
- Deanna Machin, of the Okanagan Nation Alliance, ably administered the "umbrella" contract providing financial support to various program components from DCPUD. We also thank Pauline Terbasket for providing policy guidance on behalf of the ONA when required.
- Kari Long, Howie Wright and staff members of the Okanagan Nation Alliance collected field information under contract on a range of indicators that inform FWMT elements in real-time or to verify FWMT utility.
- Paul Rankin and Barry Hanslit from DFO helped design and execute acoustics, trawl and survey work associated with assessing annual to seasonal production variations of juvenile sockeye salmon in the Okanagan River and Osoyoos Lake.
- Finally, congratulations are due to all members of the 2005-2006 FWMT Operations Team who demonstrated that exceptional levels of interagency and inter-party collaboration have the potential to produce exceptional levels of success for integrated resource management.

ABSTRACT

Hyatt, K.D., Bull, C., and Stockwell, M.M. 2009. Okanagan Fish and Water Management Tool project assessments: Record of management strategy and decisions for the 2005-2006 fish-and-water year. Can. Manusc. Rep. Fish. Aquat. Sci. 2897: ix + 68 p.

At the beginning of each month from January 2006 to June 2006 updated snow survey reports from the BC Ministry of Environment River Forecast Centre (RFC) were fed into the FWMT system. Snow reports included measurements of current snow-packs, recent climatic conditions, and forecasts of what might be expected in terms of future runoff. The Fish Water Management Tool combined this data with real-time information on fish stocks and river and lake conditions to predict the impacts of a wide range of water storage and release scenarios on both fish and other water users. The most practical scenarios were reviewed by the Operational Team who then sought consensus on the best flow release pattern.

The process of balancing water budgets was complicated by changing weather early in the season and by an early and voluminous runoff later on. In the closing months of 2005 a very low snow-pack for the basin resulted in expectations of a drought season. Flows were kept to a minimum to retain the greatest possible volume in Okanagan Lake.

The onset of the New Year brought heavy snow loads shifting the outlook from drought to flood. To keep Okanagan Lake close to target elevations, releases from Okanagan Dam had to be increased to the maximum level commensurate with safeguarding sockeye eggs from scour conditions.

As spring approached, snow-packs were closer to normal but the weather remained cool and the start of runoff was initially delayed. By the third week in May, however, a rapid runoff began. Inflows to Okanagan Lake were high as were tributary flows to Okanagan River. Releases from Penticton Dam had to be scaled back to avoid flooding around Oliver and Osoyoos Lake and this caused Okanagan Lake to rise. Towards the end of May, Okanagan Lake was approaching full pool and rising quickly. The runoff was earlier, higher and more rapid than expected but was handled without flood damage and without surpassing the target level for Okanagan Lake.

This operational year was described as a “banner year” by both water managers and fisheries scientists. The Fish Water Management Tool was used extensively and the Operational Team cooperated closely to make wise water balance decisions that benefited all interests. Flooding was avoided and the highest level of protection was provided for sockeye and kokanee populations. The year wrapped up with congratulatory notes from both the head of the Water Stewardship Division and the Chair of the Canadian Okanagan Basin Technical Working Group.

RÉSUMÉ

Hyatt, K.D., Bull, C., and Stockwell, M.M. 2009. Okanagan Fish and Water Management Tool project assessments: Record of management strategy and decisions for the 2005-2006 fish-and-water year. Can. Manusc. Rep. Fish. Aquat. Sci. 2897: ix + 68 p.

Au début de chaque mois, de janvier à juin 2006, des relevés nivométriques mis à jour du centre de prévisions des régimes fluviaux (River Forecast Centre) du ministère de l'Environnement de la C.-B. ont été enregistrés dans le système d'outils de gestion des eaux et des poissons (FWMTS). Les relevés nivométriques comprenaient des mesures récentes des stocks nivaux, les conditions climatiques récentes et des prévisions de l'écoulement futur. L'outil de gestion des eaux et des poissons a permis d'intégrer ces données aux données en temps réel sur les stocks de poissons et les conditions du lac et de la rivière, afin de prévoir les effets d'une vaste gamme de scénarios de stockage et d'apport d'eau sur les poissons et d'autres utilisateurs de la ressource. L'équipe d'experts a examiné les scénarios les plus réalistes, et elle a ensuite cherché à obtenir un consensus sur le meilleur régime d'apport d'eau.

Des conditions météorologiques variables au début de la saison et un écoulement précoce et abondant par la suite ont compliqué le processus menant à l'équilibre du bilan hydrique. Au cours des derniers mois de l'année 2005, le très faible enneigement dans le bassin laissait présager une saison sèche. Les écoulements ont été maintenus au minimum afin de conserver le plus grand volume d'eau possible dans le lac Okanagan.

Au début de la nouvelle année, d'importantes accumulations de neige ont modifié les prévisions, qui sont passées de la sécheresse au risque d'inondation. Pour maintenir le lac Okanagan à des niveaux proches des niveaux cibles, on a dû augmenter au maximum les débits au barrage Okanagan, tout en prenant soin de protéger les œufs de saumon rouge de l'affouillement.

À l'approche du printemps, le stock nival était plus près de la normale, mais la température demeurait froide et le début de l'écoulement des eaux de fonte a été retardé. Cependant, à la troisième semaine de mai, les eaux ont commencé à s'écouler rapidement. Les apports d'eau dans le lac Okanagan étaient élevés, de même que les apports des tributaires dans la rivière Okanagan. On a dû abaisser les débits sortants au barrage Penticton afin d'éviter des inondations aux environs d'Oliver et du lac Osoyoos, ce qui a entraîné une hausse du niveau du lac Okanagan. Vers la fin du mois de mai, le lac Okanagan approchait de sa capacité maximale et son niveau s'élevait rapidement. L'écoulement a été plus précoce, plus important et plus rapide que prévu, mais les interventions ont permis d'éviter des dommages attribuables à des inondations et ce, sans dépasser le niveau cible pour le lac Okanagan.

Cette année d’exploitation a été qualifiée d’« année exceptionnelle », tant par les gestionnaires des eaux que par les spécialistes des pêches. L’outil de gestion des eaux et des poissons a été largement utilisé et l’équipe des experts a collaboré étroitement afin de prendre des décisions plus éclairées sur le bilan hydrique qui ont été à l’avantage de toutes les parties intéressées. Les inondations ont été évitées et les populations de saumon rouge et de kokani ont bénéficié de la plus grande protection. Alors que l’année se terminait, des messages de félicitations ont été reçus de la part du chef de la division sur l’intendance des eaux (Water Stewardship Division) de la Colombie-Britannique et du président du groupe de travail technique du bassin de l’Okanagan (Canadian Okanagan Basin Technical Working Group).

INTRODUCTION

Significant declines in Okanagan sockeye salmon (*Oncorhynchus nerka*) production have occurred during several intervals over the past 50 years in spite of curtailment of both marine and freshwater harvest (Hyatt and Rankin 1999, Stockwell and Hyatt 2003). In Canada, this issue has become a focus for activities of the Okanagan Basin Technical Working Group (**COBTWG**) which is composed of representatives from Canada's Department of Fisheries and Oceans (**DFO**), the British Columbia Ministry of Environment (**MOE**) and the Okanagan Nation Alliance (**ONA**). In 1998, Douglas County Public Utility District (**DCPUD**) expressed an interest in working with COBTWG to increase production of Okanagan sockeye salmon. Increased sockeye production constitutes a DCPUD mitigation requirement of the Federal Energy and Regulatory Commission (**FERC**) license (and, more recently, their Habitat Conservation Plan) associated with operation of the Wells hydropower dam on the Columbia River in Washington State (Bull 1999).

Personnel from DCPUD identified an emphasis in their terms of reference for pursuit of stock enhancement or restoration options that would provide:

- readily quantifiable benefits,
- sockeye salmon production benefits of about 100,000 smolts per annum,
- an economically attractive opportunity relative to alternate approaches,
- potential to achieve regulatory approval by several levels of government, and
- project development and operational deployment within 3 years or less.

The COBTWG acknowledged these requirements and provided additional criteria based on their commitment to the conservation and restoration of Okanagan fisheries resources within an "ecosystem based management framework". These criteria included:

- restoration activities that would provide benefits at the single species level to sockeye and at the ecosystem level to other, high value, indigenous fish species (i.e. provide ecosystem benefits),
- manipulations of fish or habitat that would be amenable to formal risk assessment as one component of benefit-cost analysis,
- application of an adaptive management process for manipulations of fish or habitat (i.e. adaptive management involves adoption of an incremental approach to project implementation, a commitment to assessment and monitoring prior to, during and after project completion and cyclical review of information to make key decisions).

Following review of various project options (Bull 1999) and further consideration of the criteria above, a consensus emerged among COBTWG members by 2001 that a water management option (Fish-and-Water Management Tools Project) was their top priority given that:

- analyses by Summit Environmental (2002) and Hyatt et al. (2001) indicated changes to water management practices had the potential to increase average, sockeye production by roughly 15 %,
- costs to achieve this increase were economically competitive with other options (e.g. spawning channel development),
- implementation of the water management option could be achieved within the context of the existing Canada-BC, Okanagan Basin Water Agreement (i.e. no special regulatory approvals were required to implement water management actions contemplated under this option),
- initial development, testing, refinement and deployment of an FWMT decision support system could be completed within 3-4 years,
- provision of decision support tools to key resource managers (i.e. fish and water managers) to improve water management practices for sockeye production would also provide benefits for other high value fish species such as kokanee (*Oncorhynchus nerka*) or rainbow trout (*O. mykis*),
- knowledge of fish-water interactions was sufficiently advanced to support formal risk assessments of potential changes in water management procedures for fish and other water users, and
- alterations to seasonal water storage and/or release practices could be implemented through an adaptive management procedure.

FWMT SYSTEM CONTEXT

The Okanagan River and associated valley-bottom lakes (Figure 1) are managed as a water storage and regulation system, with most of the storage (340 Mm^3) provided by Okanagan Lake as regulated by the control structure at the city of Penticton, B.C. Minor additional storage is provided in headwater reservoirs of smaller tributary streams (principally for domestic and agricultural use) and in Skaha and Osoyoos lakes. Key considerations in the regulation of the Okanagan Lake and River System (OLRS; Hourston et al. 1954) include:

- minimizing flooding damage around Okanagan Lake and along the Okanagan River downstream of Okanagan Lake,
- protection of fisheries values (e.g. Okanagan River sockeye eggs and alevins and Okanagan Lake shore spawning kokanee eggs and alevins),

- satisfying domestic and irrigation water supply demands,
- support of recreation, navigation & tourism by maintaining acceptable water levels for boat docks, launching-ramps and for river-float tourist businesses.

The Okanagan Basin Agreement (OBA; Anon. 1973) emphasized protection of the local sockeye salmon population because it was one of two remaining viable sockeye populations in the Columbia River system, and the only salmon population spawning and rearing principally within the Columbia River basin in Canada. Okanagan sockeye salmon spawn in October in the Okanagan River between Vaseux and Osoyoos lakes, principally in the 5 km of river immediately downstream of Vaseux Lake (Stockwell and Hyatt 2003). Egg and alevin development to swim-up occur between October and early May (Hyatt and Stockwell 2007). Sockeye fry rearing occurs in the north basin of Osoyoos Lake on a year-round basis (Hyatt and Rankin 1999).

Okanagan River flows can affect the sockeye population in the following ways:

- migration to the spawning grounds may be impaired (with resulting pre-spawn mortality and/or reduced gamete viability) as a result of high flows,
- high summer flows due to melting snow-pack and coldwater input from the Similkameen River into the Okanagan River downstream of Osoyoos Lake reduce water temperatures (Hyatt and Stockwell 2003) which may influence mortality during upstream migration from Wells Dam pool to Osoyoos Lake,
- eggs and alevins can be impacted (physical damage and inability to survive in the water column) if redds are scoured as a result of flood control water releases during the pre-emergence incubation period,
- eggs and alevins can be desiccated if incubation period flows are reduced substantially from flows during the spawning period,
- seasonal distributions, growth and survival of sockeye fry rearing in Osoyoos Lake are influenced by temperature and oxygen conditions modified by changes in the quality and quantity of Okanagan River inflow.

In order to mitigate these impacts, the Canada-British Columbia Report on the OBA (Anon. 1973) specified preferred fishery flows for the Okanagan River at Oliver (Table 1).

A review by Bull (1999) suggested that between 1983-1998 water management decisions frequently departed from compliance with seasonal lake elevation and preferred river discharge levels recommended by the OBA. Discussions with “front line” fisheries and water managers in several FWMT workshops held during 2000-2003 suggested that difficulties in maintaining OBA compliance (Okanagan Basin Study 1974, OBIA 1982) were related to the complexity of balancing fisheries, flood control and water allocation benefits throughout the year, given large uncertainties in:

- forecasts of annual and seasonal water supplies,
- the exact timing of salmon life history events (spawning, egg incubation, etc.) that control their vulnerability in a particular year to losses from flood-and-scour or drought-and-desiccation processes,
- the magnitude of fish losses likely to be caused by deviations from recommended lake level or river flow ranges (*e.g.* during flood or drought conditions; Summit 2002),
- risk of “significant property” losses associated with seasonal maintenance of “fish friendly” lake elevation and river discharge levels given either flood or drought events.

FWMT SYSTEM DESCRIPTION

During 2001, the Canadian Okanagan Basin Technical Working Group (COBTWG) initiated a fish and water management tools (FWMT) project (Hyatt *et al.* 2001) to develop a set of quantitative, decision-support models to reduce uncertainties and improve the basis for water management decisions that influence annual production variations of fish. Creation of a user friendly, decision support system involved several phases of work including:

- a data and information assembly phase (ongoing since 2001),
- a fish-and-water management “business analysis” phase (2001-02),
- a models and information processing tools design phase (2002-03),
- a models and system tools building phase (2003-04), and,
- a testing and refinement phase (2004-present, see Alexander and Hyatt eds. 2005 for complete documentation of the FWMT system).

The resultant FWMT decision support system (Figure 2) and associated software provide a multi-user, gaming environment based on a set of five, coupled, “state-of-the-science” sub-models. FWMT software resides on a common server accessed through standard web-browser technology from several locations by a team of natural resource managers representing private industry, First Nations, federal and provincial interests. It is beyond the scope of the current document to provide a complete explanation of interactions among the five sub-models that form the core of FWMT. Detailed descriptions of the design and functional properties of the FWMT system can be found in either the FWMT User Manual (Alexander et al. 2008) or the draft Record of Design document (Alexander and Hyatt *eds*. 2005). However, briefly here, seasonal variations in precipitation, air temperature and water temperature serve as common drivers of four biophysical models (Figure 2). These models deal with climate and hydrology interactions, air and water temperature interactions, timing of kokanee spawning and egg incubation success at Okanagan Lake beaches, plus timing and success of sockeye salmon life-history events initiated with spawning in the Okanagan River in mid-October and concluded 14 months later in the winter prior to smolt migration from Osoyoos Lake.

Okanagan water management rules reflecting the contents of the OBA and historic practices of water managers are formalized in a fifth, water-management, “rules” model. The management rules model facilitates FWMT user-specified, choices among seasonal water storage or release options that influence socioeconomic and ecological risk factors or events (Table 2). These occur at several sites distributed from Okanagan Lake and the city of Kelowna in the north to Osoyoos Lake and the town of Osoyoos in the south near the Canada-U.S. border (Figure 1).

The 5 coupled sub-models represent a synthesis of quantitative, cause and effect relationships (among climate, water supply variations, fish, infrastructure and property) used to predict the consequences of seasonal to daily water management decisions for fish and other water users including:

- kokanee production outcomes in the upper watershed (Okanagan Lake),
- sockeye salmon production outcomes in the lower watershed (Okanagan River, Osoyoos Lake) and,
- damage and economic losses associated with urban and agricultural infrastructure and property under flood or drought conditions at riparian locations bordering the Okanagan River and valley bottom lakes.

FWMT operates in retrospective-mode on historical data sets, in real-time-mode on current data, or in prospective-mode on synthetic-futures data to allow resource managers to identify decision options to solve complex fish-and-water management problems. Of particular relevance here, when used in real-time-mode, the FWMT system automatically loads hourly data once a day on Okanagan Lake and River elevations, water temperature and flows to a database through satellite links from multiple sites (Okanagan Lake, Penticton Dam, Okanagan River at Penticton, Okanagan River at Oliver, etc.). These data drive various sub-models and inform a suite of approximately 50 indicators that help FWMT software users interpret changes in water management risk factors (Table 2). Most indicators are available within the FWMT application during use as predicted (P) or measured (M) observations (see “Source” section of Table 2). In addition, other diagnostics information may be retrieved through a tab-and-menu design that allows connection of FWMT users to various url-sources of site-specific indicator observations. Examples are: daily observations of accumulated snow-pack from Mission Creek or Brenda Mine snow-pillows, daily rainfall at Environment Canada meteorological stations in the Okanagan valley, and hourly discharge at Water Survey of Canada sites such as Mission Creek or Inkaneep Creek.

Although most indicators may be routinely accessed from within the FWMT application, a group of at least 14 additional indicators are acquired from sources outside of the application (see “Outside FWMT” section of Table 2). For example, riparian property owners and members of other non-government organizations often communicate their preferences to resource managers about the maintenance of particular seasonal patterns of lake levels or river discharge. Although the OBA specifies seasonal patterns and priorities for management of such patterns, regional concerns regarding perceived risks of flooding, drought, loss of fisheries or recreational values do serve as general “pressure indicators” that managers consider when employing particular FWMT scenarios as a basis for specific decisions. Similarly, ongoing field assessment activities, supported by the FWMT project, provide key indicators to verify whether FWMT predictions are a reliable basis for fish-and-water management advice. Thus, seasonal sampling programs to document the timing, duration, or outcome of particular biophysical events (e.g. use of spawning habitat by adult sockeye, timing of sockeye fry emergence, etc.) provide an array of important status and trend indicators. These indicators are used to inform in-season use of the FWMT application (e.g. confirm FWMT prediction that sockeye fry are clear of flood-and-scour risk associated with decisions to increase discharge above egg/alevin scour thresholds). They are also used for post-season assessments of fish-and-water management outcomes (e.g. fish production, economic gains or losses associated with FWMT use).

FWMT designers recognized from the outset that the complexity of sub-model interactions, masses of numeric output, and scores of potential indicators could limit the utility of FWMT to target users (i.e. front-line, fish-and-water managers). To overcome this problem, system software provides a user friendly interface that converts complex numeric outputs from model simulations into key performance indicators (e.g. sockeye egg or fry losses; dollar value of insurance claims for flood damage etc.). FWMT performance indicators are expressed in a graphical form that follows a familiar “traffic-light” principal (green = go ahead; amber = exercise caution; red = stop or risk certain damage). The graphical user interface (GUI) and traffic-light indicators largely eliminate requirements for managers to identify precise numeric outcomes to achieve prudent water management decisions. The user friendly GUI also allows ready participation in collective decisions by new, entry-level, FWMT-system users.

FWMT was first put into use in 2004/2005 (Hyatt and Bull 2007). In this report, we review the performance of FWMT during its second year of operational use and testing in 2005/2006. The purpose of the report is to provide a record of:

- environmental conditions and selected traits of the subject fish stocks at the start and then throughout the 2005/2006 fish-and-water management year (Oct-05 to Nov-06),

- the sequence of water storage and release strategies necessitated by climate variations in the Okanagan during the Oct-05 to Oct-06 portion of the water management year,
- experience with in-season use and testing of the FWMT decision support system,
- advice and management options identified by the FWMT operations team,
- subsequent actions taken by water managers and their outcomes,
- strengths and weaknesses of FWMT as a decision support system, and
- recommendations for changes or refinements to either FWMT or processes supporting its use by the FWMT Operations Team (OT).

In the near term, this information will be used to refine both FWMT application software and OT effectiveness. In addition, the contents of a series of record of management strategy (ROMS) reports are intended to serve as key information sources for a multi-year assessment due in 2013. This assessment will determine the extent to which deployment of FWMT has contributed to conservation and restoration objectives for the subject salmon populations (Okanagan River sockeye salmon, Okanagan Lake kokanee salmon).

HYDROLOGY AND WATER MANAGEMENT IN THE OKANAGAN BASIN

The Okanagan is a snowmelt-dominated system, with the spring freshet, from April through June, accounting for as much as 90% of the annual inflows (Dobson 2004). By July, the freshet declines and inflows to the system remain low for the summer, fall, and winter. Because of the arid to semi-arid climate in the valley, most summer precipitation evaporates or soaks into the ground and does not contribute directly to surface water flow.

The wide fluctuations between spring and summer flows are tempered dramatically by water regulation. Okanagan Lake receives about 80% of all the surface water draining into the Okanagan Basin and has sufficient storage capacity to store 100% of this inflow in one out of three years and at least 66% of the inflow in eight out of ten years. However, in roughly one in four years, characterized by above average snow-pack, the equivalent of 50% or more of freshet inflows must be released to avoid flooding. Storage during spring runoff reduces the risk of flooding and retains water for release later on, during lower flow periods. With a surface area of 35,000 hectares and an operating range of 1.22 m, Okanagan Lake can store up to 420 million cubic meters (Canada – British Columbia Okanagan Basin Agreement, 1974). This capacity is usually sufficient to regulate lake levels as well as the volume and the timing of flows in the Okanagan River.

Water released from Penticton Dam at the outlet of Okanagan Lake flows south down the Okanagan River through Skaha and Vaseux lakes before entering Osoyoos Lake and then proceeding south for 124 km to join the Columbia River (Figure 1). Several tributary streams join the river between Okanagan and Osoyoos lakes. For most of the year their contribution is relatively small, but during a wet spring, their composite volume can add as much as 57 cms to the volume released from Okanagan Lake (BC Lands, Forests & Water Resources, 1975). A more complete description of the hydrology of the Basin can be found in Glenfir Resources (2006).

Water storage reduces the risk of flooding, ensures water is available for use in the dry summer months, and provides suitable lake levels for kokanee and river flows for sockeye. The decision of how much water to store at any particular time is not an easy one. During spring freshet the amount of water entering the system far exceeds the amount that can be released through the dam at the outlet of lake. Therefore, the lake must be lowered before freshet to a level sufficient to store most of the freshet inflows. When inflow volume surpasses the volume of storage plus outflow, billions of dollars worth of real estate may be flooded. On the other hand, if the lake is drawn down too far prior to freshet, resultant summer water shortages will not satisfy both irrigation and aquatic ecosystem needs.

High levels of coordinated effort are needed to estimate the storage requirement for any particular year, manipulate lake levels and river flows to match uncertain climatic conditions, alter decisions constantly to keep up with changing circumstances and trade off gains and losses among a wide range of interest groups. An annual operating plan provides targets for lake levels and river flows at various times of the year but the volume of incoming water varies tremendously depending on snow-packs and climatic conditions. This challenges both adherence to the annual plan and compliance with fisheries provisions of the Canada-BC Okanagan Basin Water Agreement (Bull 1999). The Fish-and-Water Management Tool facilitates water regulation decisions by providing extensive real time field information and by showing in advance the outcomes of any number of management choices (Hyatt and Bull 2007).

METHODS

DEPLOYMENT AND IN-SEASON USE OF FWMT

The authority for fish, habitat and water management decisions in British Columbia is shared between Canada’s Department of Fisheries and Oceans (DFO) and the Province of British Columbia’s Ministry of Environment (BC-MOE). The Okanagan Nation Alliance (ONA, a First Nation government) also is involved and has a constitutionally guaranteed access to fisheries resources for food, ceremonial and societal purposes. Consequently, fish-and-water management decisions involve the exercise of delegated authority by personnel in each of several federal, provincial and First Nation groups. Participation of key personnel from these groups is essential to the development and routine use of any decision support tools involving fish-and-water management. In consideration of this, the three party Canadian Okanagan Basin Technical Working Group (DFO, BC-MOE and ONA) formed a FWMT project steering committee (chaired by Dr. Kim Hyatt) to act as a source of "agency" expertise and to provide decision making authority for FWMT system deployment, testing and refinement.

FWMT system use is incorporated into a stepwise pre-season, in-season, and post-season process as follows:

Pre-season Process

1. The FWMT Steering Committee meets in the late summer to early fall to confirm Operations Team (OT) lead members and alternates for the coming fish-and-water management year.

2. OT members review the management cycle and activities from the previous year and recommend changes or refinements to either the FWMT system or OT processes (Hyatt and Bull 2007).

In-season Process

3. The FWMT system is initialized with "startup" values (Hyatt et al. 2006) for year-specific sockeye and kokanee numbers and biological traits (start, peak and end spawning dates; sex ratio, magnitude of egg deposition etc.). In the absence of snow-pack and annual water yield predictions prior to February 1st, default all-year average snow-pack and water-yield values are used in FWMT to create a startup base-case to identify an "expected" seasonal water management pattern and associated options (e.g. similar to the "predicted" portion of Figure 3a-d).

4. The BC Ministry of Environment River Forecast Centre (RFC) conducts snow surveys at the beginning of each month from January through June with small additional surveys on May 15th and June 15th. Within about a week of the survey, a regional analysis is made of the snow-pack information to provide a prediction of the amount of water which will enter the system for the year. Estimates are provided for an average forecast, a low forecast (1 standard deviation lower than the average), and a high forecast (1 standard deviation higher than the average) on Feb. 1st, March 1st, April 1st and May 1st in a given fish-and-water cycle year.

5. By the 10th day of the month, a member of the OT enters the inflow forecasts into FWMT where it is combined with real-time field information (e.g. daily values for discharge and water temperature imported automatically from Water Survey of Canada stations).
6. Between the 10th and 15th days of the month, individual OT members access FWMT through the internet and run a series of simulations or “scenarios” to predict the effects of various release and storage patterns on fish (sockeye and kokanee salmon) or other water users (irrigators, recreational boaters). Scenarios that look useful are shared with the rest of the OT via e-mail (Alexander et al. 2008).

7. OT members then review risk factors (Table 2) and potential impacts associated with either flood or drought conditions that a given water-management scenario suggests may affect socioeconomic or ecological elements or events throughout the valley.

8. FWMT users initially interpret the likelihood of impacts from a given risk factor or process by examination of whether key indicators (flood risk in Okanagan Lake, sockeye egg-scour risk at Oliver etc.), portrayed in graphical output from a given FWMT-scenario, exceed hazard thresholds set to warn of moderate (amber) to acute impacts (red).

9. At their discretion, users may then examine supplementary sources of pressure, status and trend indicators (Table 2), accessed from within or external to the FWMT application, to reach an informed opinion about the potential risk and impacts associated with an impending water management decision.

10. Scenario(s), supplementary indicator observations, and interpretive materials are generally shared among OT members via direct e-mail communication or by accessing support information submitted by and for users within a narrative-archive table that may be accessed on-demand within the FWMT application.

11. Around the middle of the month OT members teleconference to discuss projected outcomes from the subject scenario(s) and, whenever possible, to reach consensus on the preferred flow release plan for the next interval lasting several days to a month.

12. In times of rapidly changing climatic conditions and inflow patterns, OT members run scenarios, confer and make decisions to change release patterns whenever necessary – sometimes as often as every few days.

Post-season process

13. In October or November a “post-season review” meeting is held to consider inflows that occurred, the forecasts that were predicted, the water release decisions that were made, and the results that were produced.
14. Following the post-season review meeting, a report of: FWMT scenarios developed, indicators used, advice provided, decisions made, outcomes achieved and recommendations for the future is assembled in a word document to provide an annual record of the performance of both the FWMT System and the Operations Team.

RESULTS

PRE-SEASON MANAGEMENT STRATEGY

A pre-season management strategy meeting was held on November 8, 2005 followed by a teleconference on January 10, 2006. Subjects discussed included:

- the overall strategic objective for the year, i.e. “manage water storage and release decisions such that kokanee and sockeye salmon would be afforded protection from undue lake level or discharge variations without incurring significant increases of collateral damage to other interests from flood or drought events”,
- appointments to the Operations Team (Table 3),
- dates for Operations Team teleconferences,
- decision process steps,
- start-up numbers and values for kokanee and sockeye (Hyatt et al. 2006),
- data entry methods (such as methods for entering inflow forecast data and methods for adjusting sub-model values),
- acquisition of data, information and their management (e.g. methods for archiving scenarios, indicator information and key management decisions).
- tasks, timelines, and responsibilities for the year,
- ONA “umbrella contract” arrangements with DCPUD for 2005-2006,
- FWMT project authority and coordination through the COBTWG (Hyatt and Machin 2005).

IN-SEASON MANAGEMENT SUMMARY FOR 2005 - 2006

October – December 2005

River flows at Oliver were held at 10cms during sockeye salmon spawning in October to meet requirements of the Okanagan Basin implementation agreement (Figure 3d). This resulted in Okanagan Lake levels declining to slightly below the ideal target for lake-shore spawning by kokanee in mid-October.

Cold, dry weather in early winter resulted in snow-packs that averaged only 74% of normal by the end of December (Figure 4). Okanagan Lake levels remained below the preferred winter benchmark (Figure 3a) and the River Forecast Centre was predicting a possible drought year ahead. To increase the likelihood that Okanagan Lake would eventually fill to meet the preferred early summer targets, Water Stewardship released only minimum flows at Penticton. The OBA requires river flows of no less than 50% of those maintained during sockeye salmon spawning. Flows peaked on Oct. 19, 2005 (Hyatt et al. 2006), therefore, sockeye incubation interval flows at Oliver were set at 5-6 cms beginning November 5 (Figure 3d).

January 2006

Given the appearance of continued drought conditions, Water Stewardship reduced outflows at the Penticton Dam to only 3.5 cms on Jan 4-9 (Figure 3b). However, flows from unregulated downstream tributaries maintained the minimum 5 cms discharge required at Oliver (Figure 3d). On a January 10th conference call, the OT agreed that, given prevailing conditions, low release flows were in order but recommended 6 cms as the “fish friendly” flow-minimum at Oliver. In mid to late January a series of wet frontal systems and heavy snowfalls returned the snow-pack to a level close to the all-year average (Figure 4).

February 2006

By early February, conditions had significantly changed. The snow-pack and the level of Okanagan Lake rose to levels higher than the all year average. Moreover, weekly net inflows from tributaries to Okanagan Lake during 4 of the previous 5 weeks were running well above the all-year average (Figure 5). The February 1 snow water index was 106% of normal (compared with 74% on January 1). The new RFC prediction was for cumulative inflows of 570 M m^3 by July 31st to Okanagan Lake (Table 4). The threshold for potential flood-risk is 430 M m^3 so in-season expectations shifted from consideration of risk factors associated with drought to those associated with a freshet period flood.

Water managers responded quickly, increasing releases at Penticton Dam from 5.5 cms to approximately 25 cms between February 1 and February 4 (Figure 3b) which triggered an amber-hazard warning of elevated scour-risk for sockeye eggs and fry at Oliver (Figure 3d). Because water release changes were made without prior consultation with the OT, some of its members requested more timely consultation in advance of water management decisions. In a subsequent conference call the OT member from Water Stewardship suggested increasing release rates from Okanagan Lake to 26 cms to reduce Okanagan Lake levels to the March 1st target of 341.7 m and the April 1st target of 341.6 m prior to spring-freshet inflows. He felt that Okanagan lake level would remain sufficiently high to protect kokanee eggs and river flows at Oliver would be just below the 28.3 cms red-hazard, flood-and-scour threshold for sockeye eggs and fry.

DFO personnel subsequently provided FWMT scenarios assuming a range of future net-inflow values from the RFC estimate of 570 M m^3 to an even higher estimate of 712.5 M m^3 (Figure 6a-d). These scenarios suggested ample opportunity existed to avoid undue flood risk at the time of spring freshet even if February water releases were maintained at less than 25 cms to provide higher levels of protection for kokanee and sockeye salmon. DFO and MOE fisheries representatives on the OT recommended reducing dam releases from 25 cms to 21-22 cms. FWMT scenarios indicated that although this would raise Okanagan Lake levels above the March 1st and April 1st targets (Figure 6a), it would not result in lakeshore flooding and the June 2006 preferred target would still be met. Fisheries personnel suggested this management regime could be re-evaluated in 2 weeks upon release of the next (*i.e.* March 1st) RFC inflow forecast.

OT consensus on outflows could not be reached and Water Stewardship Head, Brian Symonds, was asked to review the information from both fisheries and water management perspectives to recommend a solution. On Feb 15th, MOE fisheries representative Andrew Wilson met with water managers Brian Symonds, Don McKee and Ray Jubb to compile and review several FWMT scenarios to consider whether the DFO-MOE “fisheries” proposal to reduce Penticton Dam water releases would unduly compromise flood control plans. Given Mr. Symond’s past experience and the limited flood-risk FWMT-scenarios suggested at cumulative inflows even higher than the RFC forecast, a consensus was reached that water releases could be safely reduced to 19 cms for 2 weeks and then raised to 22 cms until April 8. This proposal met with immediate approval of all OT members. This was a milestone in FWMT use as a credible decision support system and showed its potential for facilitating interest-based negotiations and consensus-based decisions.

By February 30th snow loads remained close to the all year average (Figure 4) and FWMT Scenario-316 remained applicable. A cold snap reduced inflows to Okanagan Lake causing lake levels to fall and an FWMT amber-alert for kokanee. An amber-alert level close to the end of the kokanee incubation period (Figure 6a) was considered tolerable. As milder weather returned, the rate of decline for Okanagan Lake levels slowed and the OT recommended a discharge increase at Penticton Dam from 17.5 to 22 - 24 cms to create additional storage space in the lake in anticipation of freshet inflows. Inflows from tributaries downstream from Okanagan Lake were carefully monitored to ensure that the sum of their discharge plus that from the dam was not sufficient to exceed the scour threshold of 28.3 cms at Oliver (Figure 6d).

During the last week of February, outflows were reduced to 17 cms (Figure 6b) to accommodate maintenance work on the Penticton Dam gates and repair work on the "Newbury Riffles" downstream of Vertical Drop Structure 12. Following the work, releases were increased to 18-20 cms. Heavy rain, with more predicted, prompted the OT to recommend Penticton Dam water releases be increased to 21-22 cms as soon as possible. FWMT anticipated minimal risk of lake level reductions and completion of kokanee fry emergence by March 10th.

March 2006

By early March, above normal snow-packs (110%) combined with warmer weather and rain suggested development of FWMT scenarios employing above average annual inflow estimates. FWMT scenarios again showed that even if annual inflows were on the high side of the RFC estimates, water releases could be maintained at levels that would satisfy both flood control (Figure 6a) and fish production objectives (Figure 6d). Accordingly, the OT reached consensus that outflows would be maintained at 24 - 26 cms for 2 weeks, provided unregulated tributary inputs remained close to average (Figure 5). This would help managers to meet the April 1 Okanagan Lake level target to minimize freshet flood risk in May and June. On March 6, Water Stewardship announced their plan was to release 25.6 cms with flows expected to reach 28.6 cms at Okanagan Falls and 26.8 cms at Oliver. FWMT users were able to monitor daily flows at Oliver to verify that the 28.3 cms scour threshold for sockeye eggs and alevins was not exceeded (Figure 6d, near March 10th).

In late March, WSD managers requested consideration of reducing Penticton Dam discharge to allow repair of a previously scoured area of dike armour at a downstream Newbury riffle structure. DFO personnel approved provided this would not result in water releases exceeding the 28.3 cms scour threshold for sockeye eggs and fry at Oliver at a later date. Lowering Penticton Dam releases to 7 cms caused Skaha and Vaseux lake-levels to drop well below target. Flows from Okanagan Lake were subsequently increased to about 33 cms to restore these levels. River flows downstream in the sockeye spawning areas were maintained below the 28.3 cms scour threshold. The use of Skaha Lake as a balancing reservoir during this period resulted in much more even flow rates downstream and there were no instances of scouring at the Oliver spawning grounds.

As March drew to a close, snow-water equivalents were average and cool, dry weather slowed tributary inputs. FWMT Scenario-337, based on March 24 information, showed an average snow-pack, along with cool, dry weather and an expectation that warming temperatures and spring rains would soon increase tributary inflows. Various FWMT Scenarios suggested progressive reductions in outflows from Penticton Dam would be required to delay redd-scour until sockeye fry were fully emerged at the end of April. FWMT sub-model predictions indicated 100% sockeye fry emergence would be complete by May 2.

The OT agreed to maintain discharges of approximately 22 cms for the first 2 weeks of April. Flows would be adjusted downward to avoid sockeye scour if unregulated tributary inputs of 6 cms or more pushed discharge at Oliver over the sockeye egg-fry scour threshold of 28 cms.

April 2006

At the beginning of April, the level of Okanagan Lake was on target and snow pillow records for Mission Creek and Brenda Mine matched the all-year average (Figure 4). Seasonal air temperatures and precipitation were also normal. Tributary inflows were beginning to increase. An updated scenario could not be run in early April because April RFC inflow estimates were not available and the FWMT system is programmed not to run after the first of the month without them. The OT recommended Penticton discharges of around 17 cms to hold Okanagan Lake levels steady with resultant flows of roughly 20.5 cms at Oliver. Heavy rainfall on April 7 and 8 increased tributary inflows and caused Okanagan Lake to rise slightly. Air temperatures remained cool or average.

By mid-April, the FWMT application had been refreshed with new RFC inflow estimates to support scenario generation. Weather forecasts predicted generally dry, cool conditions making "fish friendly" and flood-averse water strategies readily achievable. Air temperatures below seasonal norms resulted in only slight increases to tributary inflows such that Penticton Dam release rates of 17-17.5 cms were resulting in flows of about 20 cms at Oliver. Given water temperature and accumulated thermal unit (ATUs) inputs, the FWMT sockeye sub-model continued to predict 100 % sockeye emergence by May 1-3 (Table 5). Until then, river discharges at Oliver needed to be kept under 28 cms and preferably under 25 cms. Weekly fyke-net sampling in the Okanagan River indicated general agreement between the observed (April 18-22nd) and predicted (April 23rd for FWMT cohort-2) peak of sockeye fry emergence (Figure 7). Field observations on April 26th indicated catch rates for sockeye fry of less than 50% of that observed on April 18th. Moreover, observations of emerging fry suggested that all fry were in late developmental stages and “emergence ready” such that fisheries constraints on water releases at the Penticton Dam could be relaxed.

Significant mid-to-late April precipitation events (Figure 8, April 15-16th, April 21st) pushed Mission Creek (Figure 1) snow-pack to 15-25% above average (Figure 4) while snow-pack at Brenda Mines continued to “track” the all-year average. These observations suggested that the impending (May 1st) RFC estimate for total water yield might increase to 564-588 Mm^3 for 2006 such that OT members immediately shifted their focus from fisheries conservation to flood protection concerns. New FWMT scenarios were run by April 24th to examine the magnitude of this new flood risk. Specifically, FWMT Scenario-348, "graphs-high" (Figure 9a-d), considered water management options assuming inflows to Okanagan Lake would achieve 652 Mm^3. The latter value was 60-80 Mm^3 higher than the most likely inflow for 2006 (*i.e.* a "worst case" scenario). Scenario-348 output suggested that even if inflows for 2006 achieved 652 Mm^3, a viable water release strategy could still be implemented at the Penticton Dam (Figure 9b) to avoid high risk or significant flood damage to infrastructure around Okanagan Lake (Figure 9a), at Okanagan Falls (Figure 9c) and downstream in the Okanagan River channel at Oliver (Figure 9d).

May 2006

Sockeye fry emergence was virtually complete by May 3rd, 2006 (Figure 7) - a month earlier than observed in 2005. Water releases at Penticton Dam were increased from about 17 cms to approximately 42 cms to help control the rate of increase occurring for Okanagan Lake levels (0.5-1.0 cm per day, Figure 10a) under the influence of rapidly melting snow-packs (Figure 4) and above average tributary inflows (Figure 5).

By the third week in May inflows to Okanagan Lake were much higher than average. Unregulated tributary flows below Okanagan Lake had increased to 35 cms and in order to avoid flooding problems around Oliver and Osoyoos Lake, flows out of Penticton Dam were scaled back to less than 25 cms (Figure 10b). This caused Okanagan Lake to rise rapidly the week of May 25th (Figure 10a). Towards the end of May, Okanagan Lake was approaching full pool and rising quickly. Tributary inflows during the latter half of May peaked far above the all-year average (Figure 5).

By May 26th, releases from the Penticton Dam were increased to 45 cms. Three days later the outflows at Penticton were increased to the maximum recommended channel capacity of 60 cms (Figure 10a). McIntyre Dam above Oliver and Zosel Dam at the outlet of Osoyoos Lake were set wide open but both Vaseux and Osoyoos lakes continued to rise. Osoyoos Lake exceeded the 911.5 ft elevation recommended by the International Joint Commission. Flows in the river channel at Oliver were 70cms and Water Stewardship personnel were beginning to receive expressions of concern from Okanagan riparian property owners and the public.

June 2006

In early June low elevation snow-pack was spent (Figure 4b), high elevation snow-pack was dwindling (Figure 4a), and unregulated tributary flows below Penticton were declining (Figures 10c & d). Given the early runoff, OT members predicted that the all year average reading for the tributary streams below Penticton would be surpassed by a factor of two such that releases from Penticton Dam could be safely increased from 25 to 60 cms. By June 19th, discharges from Okanagan Lake Dam were increased to 67 cms and since this exceeded the 60 cms maximum volume recommended for channel stability at Penticton, it triggered a red hazard warning for flood damage to the channel at Penticton (Figure 10b) but induced only a minor, amber hazard for flood damage in the area of Okanagan Lake (Figure 10a). Flows in Oliver surpassed 70 cms (Figure 10d). However, this served the intended purpose of keeping Okanagan Lake levels down to the target level.

By the end of June the Okanagan Lake and River System was again within target lake elevation and river discharge levels. Environment Canada forecast a drying trend, Okanagan Lake was beginning to drop and Water Stewardship was planning to reduce flows from 62 to 40 cms.

July 2006

Between late June and early July, a drying trend (Figure 8) and the beginning of typical summer weather were accompanied by reductions of tributary inflows to strongly sub-average values (Figure 5). Fish and water managers shifted their focus to summer water supply issues revolving around provision of sufficient flows into Osoyoos Lake to maintain acceptable conditions for juvenile sockeye rearing while also meeting water withdrawal needs for irrigation. OT members suggested the sudden shift between mid-June and mid-July from well above-average to strongly sub-average tributary inflow values was consistent with predictions associated with climate change studies. The latter suggest a shift in seasonality of tributary hydrographs to a higher and earlier peak runoff followed by earlier onset and longer duration of summer-fall drought conditions. OT members agreed such conditions would require adjustments to seasonal water management strategies in order to meet multiple objectives of sustaining fish friendly flows along with agricultural and urban water demands.

From mid to late-July the sum of evaporation and groundwater losses exceeded runoff from upland tributaries. Okanagan River flows subsequently dropped to levels triggering amber hazard-indicators for recreational flows in Penticton Channel (Figure 11b) and, more importantly, for agricultural and domestic water intakes at Oliver (Figure 11c). FWMT scenario projections suggested a strong likelihood for development of a severe temperature-oxygen “squeeze” and loss of rearing habitat for sockeye fry in Osoyoos Lake (Figure 11d).

August-September 2006

Sub-average precipitation during July followed by an even drier August (Figure 12) extended well below average net inflows from tributaries to Okanagan Lake to 10 consecutive weeks (Figure 5). Temperature-oxygen profile observations from Osoyoos Lake surveys confirmed the start of reductions of sockeye fry rearing habitat in Osoyoos Lake in late August. The depth interval exhibiting optimal water conditions (i.e. temp. of $< 17°C$ and oxygen > 4 mg per liter) for sockeye fry rearing exhibited a precipitous decline from approximately 30 m on Aug. 24th to less than a 2m depth interval in Osoyoos Lake by Sept 1st, 2006. FWMT model predictions suggested the volume of water exhibiting optimal conditions for fry rearing could fall to zero in September (Figure 11d).

In FWMT Scenario-366 (Figure 13), DFO fisheries personnel requested that WSD managers consider a pulsed release of 25-35 cms of water at the Penticton Dam for a two week interval starting in late August early Sept (Figure 13b). The objective of the pulsed flow would be to “flush” organic matter from the surface waters of Osoyoos Lake in the hope this might reduce organic loading and biological oxygen demand (BOD) in the deeper waters of the lake. FWMT predictions suggested this would reduce or eliminate the temperature-oxygen “squeeze” (Figure 13e). Because Okanagan Lake had already fallen below preferred elevation targets by late Aug. (Figure 14a), water managers were restricted to increasing flows at Penticton Dam in the third week of September from 15 cms to 20 cms for only a few days (Figure 14b). However, fortuitously, a series of thunderstorms and rapid surface water cooling in the third week of September combined to increase the useable water depth for rearing sockeye fry to an 8-9m interval by Oct. 2, 2006 (Table 6).

POST SEASON ANALYSIS

The sequence of changes to Okanagan Lake elevations (Figure 14a) and Okanagan River flows at Penticton (Figure 14b), Okanagan Falls (Figure 14c) and Oliver (Figure 14d) during 2005-2006 involved no fewer than 18 key decisions (summarized in Table 7). These were considered by Operations Team participants between December 2005 and September 2006. Conditions during this fish-and-water management year fluctuated back and forth between predictions suggesting first a continuation of drought (October 2005 to late January 2006), then anticipation (February 2006) of a future freshet-driven flood, a return to expectations of average water yields and flows (late March-April 2006), followed by conditions threatening imminent risk of a spring flood (early June 2006) and finally, a sudden reversal (late June 2006), to conditions reflecting high risk of a prolonged summer-to-fall drought (July-Aug. 2006). Despite these many changes, OT members were highly successful in developing FWMT supported scenarios to facilitate discussion and subsequent water management decisions that avoided significant losses of salmon in either Okanagan Lake (beach spawning kokanee) or the Okanagan River at Oliver (incubating sockeye eggs and fry).

Perceived threats of drought during the fall to mid-winter and then of flood risk from late winter to early summer defined intervals during which water regulation decisions resulted in flows at Oliver that hovered either just above the drought-and-desiccation threshold (12-13 weeks) or just below the flood-and-scour threshold (at least 5 weeks) for losses of sockeye eggs and alevins (Figure 15). Use of the FWMT system to provide in-season information, scenarios (Table 8) and associated indicators (Table 2) generally allowed OT members to quickly reach a consensus regarding seasonal to weekly water management decisions. Thus, risks of both “property damage” and fish production losses due to discharge variations in the Okanagan River were repeatedly minimized in spite of some very challenging conditions.

Success in minimizing property and fish production losses through the fall-to-spring egg and alevin incubation period for salmon was followed by the threat of drought-induced reductions of sockeye rearing habitat in Osoyoos Lake. Annual plots of seasonal isopleths of critical temperature (17^{o}C) and oxygen (4 mg per litre) levels define optimal water volumes (OWV) for rearing by juvenile sockeye salmon in Osoyoos Lake. The severity of a temperature-oxygen “squeeze” is indicated by the level of convergence of the 17^{o}C and 4 mg per litre oxygen isopleths. Early onset of reduced flows from the Okanagan River during 2006 (Figure 5) was associated with accelerated development of hypoxia in the deeper, hypolimnetic, waters of the lake. The maximum rise of the 4 mg/l oxygen isopleth occurred a month earlier in 2006 than in any previous year of record (Figure 16). When combined with a progressively deepening penetration of the 17^{o}C isopleth, these conditions reduced the optimal water volume (OWV) for sockeye fry rearing in Osoyoos Lake to zero from late Aug. through mid-September. A modest increase in discharge at the Penticton Dam in mid-September, coincident with 12 mm of rainfall and rapid cooling of surface waters, re-established OWV conditions for sockeye fry between 18m in depth and the lake surface by Sept. 30th (Figure 16).

DISCUSSION

This year saw a greater reliance on using the Tool for making water balance decisions. Scenarios were run, shared, discussed and improved. Team teleconferences to discuss strategies were held every 2 weeks and more frequently when necessary. Water managers and fisheries scientists alike mentioned the importance of the Tool, the field data and the team work in supporting their decisions (Appendix 2). They actively restrained outflows on a number of occasions strictly to benefit fish. This would not have been justifiable without the scenarios and field data that demonstrated the level of flood control and the state of fry development.

The Tool accurately predicted the sockeye emergence and frequent field sampling validated it. Emergence occurred one month earlier than last year and this allowed for maximum outflows in time to handle the unexpected early, rapid and voluminous runoff. The challenging runoff brought Okanagan Lake up to the maximum preferred levels and river flows to design capacity. However, problems were avoided by judiciously balancing flows throughout the system.

The spring high water conditions were a stark contrast to the early season drought when flows over the spawning grounds had to be kept to 5 cms. Fisheries biologists who were working in the field at the time felt that in marginal locations there was some, though very limited, mortality of sockeye eggs and alevins due to desiccation (K. Long, ONA biologist – personal communication). That said, fisheries biologists were very pleased with the water decisions and felt this had been a “banner” year for both kokanee and sockeye (Andrew Wilson, MOE biologist – personal communication).

FWMT deployment allowed Team members to share common data sets, develop a common understanding of issues and finally negotiate mutually agreeable water release rates during most of the year.

Determining the appropriate levels of water release through 2005-06 was made more difficult by changing weather patterns. The year began with very low snow-packs and dry conditions resembling a drought. Then snow-packs increased and the predictions switched to an average year. Eventually above average snow-packs, frequent spring rains and an early and very rapid runoff required water balances aimed at preventing flooding.

Team members worked together closely and relied heavily on the Tool to reach a common understanding of the best water management decisions to employ. Many scenarios were worked out and shared and these illustrated the ramifications of each decision to various stakeholders throughout the season. The real time information was particularly important this year and Water Stewardship agreed to hold back flows based on the knowledge that they could implement channel-at-capacity water releases as soon as May 3 was reached and sockeye fry emergence was verified to be complete.

All in all the operational year was an unqualified success and glowing letters of support were put forward by the Head of Water Stewardship and by the Chair of the Canadian Okanagan Technical Working Group (see Appendices 2 and 3).

RECOMMENDATIONS

Year 2005-06, the second operational year for the FWMT, revealed further opportunities for improving the program. Table 9 records problems encountered and suggests recommendations for solving them.

GLOSSARY

Accumulated Temperature Units – the number of degree days (temperature °C x Days) required to complete an event such as egg hatching or fry emergence.

Canadian Okanagan Technical Working Group – the interagency sponsor of the FWMT Project consisting of members from DFO, MOE and ONA

Cumulative Precipitation: The total precipitation in a region since the previous November 1. Usually expressed as a percentage of normal.

Freshet: The substantial rise in water level of a stream or river caused by melting snow in the spring.

Fish Water Management Tool – a computerized program for predicting the impacts of various water storage and release options on fish and property.

Hydrograph: A plot of the level or flow of a river over a period of time.

Normal: is the average value of a parameter over a fixed, usually 30-year, period. At present the normal period is 1971-2000. Thus the normal water equivalent of a snow course is the mean value for the 1971-2000 period, for that sampling date.

Regional Snow-pack Index: The sum of the snow water equivalents at selected representative snow courses in the region. Often expressed as a percentage of normal.

Snow Course: A marked location, free from encroachment, where snow depth and snow water equivalent are measured on a regular basis with standard snow sampling tubes.

Snow Water Equivalent: The water content of a snow-pack at a point, expressed as the depth of water that would result from melting the snow.

Tool – see Fish Water Management Tool

Volume Forecast: A forecast of the volume of water expected to pass a given point on a river (or flow into a lake) in a set time period. This is based on current and antecedent conditions, but assumes normal weather patterns through the forecast period. Units are usually thousands of cubic decameters (kdam^3), which is the same as millions of cubic metres.

LIST OF ACRONYMS

ATU – Accumulated Temperature Units

CMS – Cubic meters per second

COBTWG – Canadian Okanagan Technical Working Group

DCPUD – Douglas County Public Utility District

DFO – Canada Department of Fisheries and Oceans

FWMT – Fish Water Management Tool

IJC – International Joint Commission

Kdam^3 - thousands of cubic decametres = millions of cubic meters

MOE – BC Ministry of Environment

MOU – Memo of Understanding

M m^3 - Millions of cubic meters

m^3/s – cubic meters per second

OBIA – Okanagan Basin Implementation Agreement

ONA – Okanagan Nation Alliance

OT – Fish-and-water Management Operations Team

WSC – Water Survey of Canada

WSD – Water Stewardship Division of the BC Ministry of Environment

RFC – River Forecast Centre of the BC Ministry of Environment

REFERENCES

Alexander, C.A.D., Hyatt, K., and Symonds, B. (eds). 2008. The Okanagan Fish/Water Management Tool: Guidelines for Apprentice Water Managers (v.2.1.000). Prepared for the Canadian Okanagan Basin Technical Working Group, Kamloops, BC and Douglas County Public Utility District, Wenatchee, WA. 130 pp.

Alexander, C.A.D., and Hyatt, K.D. (eds.). 2005. The Okanagan Fish-and-Water Management Tool (Ok-FWMT) Record of Design (v. 1.0.001). Prepared for the Canadian Okanagan Basin Technical Working Group (COBTWG) and Douglas County Public Utility District No. 1 (DCPUD), Draft report submitted to COBTWG and DCPUD, Sept. 2005.

Anonymous. 1973. Canada/British Columbia Okanagan Basin Agreement, Task 162, 1973. Pacific Salmon population and habitat requirements. 44 p.

B.C. Lands, Forests and Water Resources. 1975. Osoyoos flood protection information. Issued by B.C. Water Resources Service.

Bull, C., 1999. Fisheries habitat in the Okanagan River phase 2 – investigation of selected options. Prepared for Public Utility District No. 1 of Douglas County Washington.

Canada – British Columbia Okanagan Basin Agreement, 1974. Technical supplement I Water quantity in the Okanagan Basin. British Columbia Water Resources Service, Victoria.

Dobson, D. 2004. Hydrology and watershed management. Ch. 13 In M. A. Roed and J. D. Greenough (Eds.) Okanagan Geology, British Columbia. 2nd Edition, Kelowna Geology Committee. Sandhill Book Marketing, Kelowna, BC.

Glenfir Resources. 2006. Plan of Study for Renewal of the International Joint Commission's Osoyoos Lake Orders. 158p. Available at: http://www.ijc.org/rel/boards/osoyoos/final_pos_060811.pdf

Hourston, W.B., Clay, C.H., Burridge, E.W., Lucas, F.C., Johnson, D.R., Heg, H.T., McKinley, W.R., Barnaby, J.T., Fulton, L.A., and Gentry, A.A. 1954. The salmon problems associated with the proposed flood control project on the Okanagan River British Columbia, Canada. U. S. Fish and Wildlife Service, Washington State Dept. of Fisheries and Canada Dept. of Fisheries. 109 p.

Hyatt, K.D., and Bull, C. 2007. Fish and Water Management Tools Project Assessments: Record of Management Strategy and Decisions for 2005. Can. Manusc. Rep. Fish. Aquat. Sci. 2808: 37 p.

Hyatt, K.D., Fast, E., Flynn, M., Machin, D., Matthews, S., and Symonds, B. 2001. Water management tools to increase production of Okanagan sockeye salmon. Fish-Water Management Proposal (June 21, 2001) submitted to Douglas County Public Utility Division No. 1, Wenatchee Washington. Canadian Okanagan Basin Technical Working Group Secretariat. 24 p.

Hyatt, K.D., and Machin, D. 2005. Okanagan Fish and Water Management Tool (FWMT): Operational Deployment & Assessment of the FWMT System to Support 2005-06 Fish-and-Water Management Decisions: Year 1 of 8. Proposal (Sept. 2005) submitted to Douglas County Public Utility Division No. 1, Wenatchee Washington. Canadian Okanagan Basin Technical Working Group Secretariat. 34 p.

Hyatt, K.D., and Rankin, D.P. 1999. A habitat based evaluation of Okanagan sockeye salmon escapement objectives. PSARC Working Paper S99-18. Department of Fisheries and Oceans, Pacific Science Advisory Review Committee, Pacific Biological Station, Nanaimo, B.C. 59 p. available at: http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/1999/1999_191_e.htm

Hyatt, K.D., and Stockwell, M.M. 2003. Analysis of seasonal thermal regimes of selected aquatic habitats for salmonid populations of interest to the Okanagan Fish and Water Management Tools (FWMT) project. Can. Manuscr. Rep. Fish. Aquat. Sci. 2618: viii + 27p.

Hyatt, K.D., and Stockwell, M.M. 2007. Fish and Water Management Tool Project Assessments: Observations of Okanagan Sockeye Salmon (*Oncorhynchus nerka*) Egg Incubation Success, Fry Emergence Timing and Associated Environmental Conditions Between 1952-2006. Report to file: JSIDS-SRe 4-07. Salmon and Freshwater Ecosystems Division, Fisheries and Oceans Canada, Nanaimo, B.C. V9T 6N7

Hyatt, K.D., Stockwell, M.M., Wright, H., Long, K., Tamblyn, J., and Walsh, M. 2006. Fish and Water Management Tool Project Assessments: Okanagan Adult Sockeye Salmon (*Oncorhynchus nerka*) Abundance and Biological Traits in 2005. Report to file: JSIDS- SRe 3-05. Salmon and Freshwater Ecosystems Division, Fisheries and Oceans Canada, Nanaimo, B.C. V9T 6N7

Okanagan Basin Implementation Agreement (OBIA). 1982. Summary Report on the Okanagan Basin Implementation Agreement, September, 1982.

Okanagan Basin Study Office. 1974. The Main Report of the Consultative Board, Including the Comprehensive Framework Plan. Prepared under the Canada-British Columbia Okanagan Basin Agreement, March 1974.

Stockwell, M.M., and Hyatt, K.D. 2003. A summary of Okanagan sockeye salmon (*Oncorhynchus nerka*) escapement survey observations by date and river segment from 1947 to 2001. Can. Data Rep. Fish. Aquat. Sci. 1106: 34p + data CD-ROM.

Summit Environmental Consultants Ltd. 2002. Observations and modeling of bed movement and potential redd scour in Okanagan River. Report prepared for the Okanagan Nation Alliance Fisheries Department, Westbank, B.C. Project #635-13.01. 63 p.

Table 1. Preferred flows at Oliver to satisfy sockeye salmon life-history stage requirements specified under the Canada-BC Okanagan Basin Agreement.

Sockeye Life History Stage	**Dates**	**Preferred Range (m^3/sec)**
Adult migration	August 1 - Sept. 15	8.5 - 12.7
Spawning	Sept. 16- Oct 31	9.9 - 15.6
Incubation	Nov. 1 - Feb 15	5.0 - 28.3 Incubation flows ≥ 50% spawning
Fry migration	Feb 16 - April 30	5.0 - 28.3

Table 2. Summary of key events or activities, risk factors or processes and indicators of relevance for users of the Okanagan Fish-and-Water Management Tools (FWMT) decision support system. The majority of indicators are generated within the FWMT system as model predictions (P) or measured observations (O) that are imported in near, real-time. Stars (❖) represent the primary indicators used for ongoing evaluation of changes in risk. A smaller set of supplemental indicators are generated and accessed by users from outside of the FWMT application (see text for further explanation).

Event or Activity	**Risk Factor(s) or Process**	**Pressure, Status and Trend Indicator(s)**	**Source**			
SOCIO- ECONOMIC			**Inside FWMT**		**Outside FWMT**	
Okanagan Lake at Kelowna			**P**	**O**	**P**	**O**
Surface elevation of Okanagan Lake.	Okanagan Lake flooding and associated property damage. Okanagan Lake drought and storage deficit that impacts water access for irrigation and domestic water intakes.	❖ Okanagan daily to seasonal snow-pack values relative to average	X	X		
		❖ BC River Forecast Centre or user specified water supply forecast	X	X		
		o Regional snow-pack and/or rainfall events relative to average				X
		o Okanagan daily to monthly rainfall values relative to average	X	X		
		o Hourly to daily inflows from Mission Creek to Okanagan Lake	X	X		
		o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		❖ Net inflows from tributaries relative to weekly or monthly average	X	X		
		❖ Okanagan L. daily to weekly lake level relative to seasonal targets	X	X		
Okanagan River at Penticton						
Discharge and water level in Penticton Channel	Flood induced damage to Penticton channel and/or flooding and water infiltration of riparian properties. Drought induced exposure of domestic and irrigation water intakes.	o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		o Inflows from tributaries relative to weekly or monthly average	X	X		
		o Riparian landowner commentaries re: specific impacts on property				X
		o Flows in Penticton Channel within range for recreational "tubing"	X	X		
		❖ Okanagan R. daily discharge relative to seasonal targets	X	X		
Okanagan River at Oliver						
Discharge and water level in Oliver Channel	Flood induced damage to channel at Oliver and/or flooding and water infiltration of riparian properties. Drought induced exposure of domestic and SOLID irrigation intake at McIntyre Dam.	o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		o Inflows from tributaries relative to weekly or monthly average	X	X		
		o Riparian landowner commentaries re: specific impacts on property				X
		❖ Okanagan R. daily discharge relative to seasonal targets	X	X		

Event or Activity	Risk Factor(s) or Process	Pressure, Status and Trend Indicator(s)	Source			
ECOLOGICAL			**Inside FWMT**		**Outside FWMT**	
Kokanee Salmon in Okanagan Lake at Kelowna			**P**	**O**	**P**	**O**
Kokanee spawning and incubation success on Okanagan Lake beaches (SE,NE, NW).	Risk of egg/alevin desiccation and loss due to spawn depth and subsequent lake level draw-down between time of egg deposition and fry emergence.	o No. of spawners by lake area (SE, NE, NW)				X
		o Spawn-depth	X			
		o Lake level	X	X		
		o Incubation temperature and accumulated thermal units (ATUs)	X	X		
		o Egg hatch and fry emergence date	X			
		❖ Magnitude of drawdown induced egg/alevin loss during incubation				
Sockeye Salmon in the Okanagan River at Oliver						
Adult salmon access to spawning area(s).	Migration blockage at vertical drop-structures due to high discharge. Access to spawning habitat reduced due to low discharge.	o No. of adult sockeye in riverine spawning grounds	X	X		
		o No. of adult sockeye in specific spawning areas and habitats	X			X
		❖ Discharge relative to migration & spawning compliance range	X	X		
Egg/alevin incubation and fry emergence success.	Flood or drought impacts on egg/alevin incubation and fry emergence success.	o Okanagan daily to seasonal snow-pack values relative to average	X	X		
		o Okanagan daily to monthly rainfall values relative to average	X	X		
		o Okanagan daily to weekly lake level relative to average	X	X		
		o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		o Unregulated tributary discharge by hour	X	X		
		o Okanagan R. incubation temperature and ATUs	X	X		
		o Egg hatch dates	X			X
		❖ Scour and desiccation event-over-threshold drivers	X	X		
		❖ Fry emergence dates	X			X
		❖ Early summer fry recruitment index (no.spawner^{-1}) to Osoyoos L.	X			X
Sockeye Salmon in Osoyoos Lake						
Fry recruitment to Osoyoos Lake.	Flood or drought water-level or flow impacts on fry migration or emergence success.	❖ Discharge of Okanagan River at Oliver relative to emergence and migration compliance range	X	X		
		❖ Early summer fry recruitment index (fry.spawner^{-1}) to Osoyoos L.	X			X

Event or Activity	Risk Factor(s) or Process	Pressure, Status and Trend Indicator(s)	Source			
ECOLOGICAL			**Inside FWMT**		**Outside FWMT**	
Sockeye Salmon in Osoyoos Lake (continued)			**P**	**O**	**P**	**O**
Fry rearing in Osoyoos Lake.	Reduction or loss of preferred rearing habitat due to temperature-oxygen "squeeze" (*i.e.* excessive temperatures in surface waters and low oxygen in deeper waters).	o Calendar day surface temperature in Osoyoos L. exceeds 17°C	X	X		
		o Seasonal depth of 17°C isotherm in Osoyoos Lake	X			X
		o Seasonal depth of 4 mg.l-1 oxygen isoline in Osoyoos Lake	X			X
		o Seasonal depth distribution of sockeye fry	X			X
		o Average or cumulative discharge July-Sept at Oliver	X	X		
		❖ Volume of "optimal" water (VOW) for fry rearing	X			X
		❖ Early summer-to-fall survival of sockeye fry	X			X

Table 3 - Members of the 2005-2006 FWMT Operational Team

Agency	Primary Representative	Alternate
BC Ministry of Environment - Fisheries	Andrew Wilson	Steve Matthews
BC Ministry of Environment Water Stewardship Division	Don McKee	Ray Jubb
Fisheries and Oceans Canada (Stock Assessment)	Kim Hyatt	Margot Stockwell
Fisheries and Oceans Canada (Habitat)	Dean Watts	Nil
Okanagan Nation Alliance	Deana Machin	Howie Wright and Kari Long
ESSA Technologies Ltd.	Clint Alexander (technical advisor)	Nil
Glenfir Resources	Chris Bull (Project Coordinator)	Nil

Table 4. Inflow estimates (Kdam³) to Okanagan Lake entered into the Fish-Water-Management-Tool System for water year 2005-2006. Estimates are provided by personnel from the BC River Forecast Centre at the beginning of each month (Feb to May). The historical average is based on 31 years (1974 - 2005) of data.

Forecast Period (2006)	Uncertainty Type	RFC Estimate (Kdam³)	Historical Average (Kdam³)
Feb 1 - Jul 31	Mean -1StDev	428	302
Feb 1 - Jul 31	**Mean**	**570**	**525**
Feb 1 - Jul 31	Mean +1StDev	713	748
Mar 1 - Jul 31	Mean -1StDev	416	291
Mar 1 - Jul 31	**Mean**	**520**	**507**
Mar 1 - Jul 31	Mean +1StDev	624	723
Apr 1 - Jul 31	Mean -1StDev	330	273
Apr 1 - Jul 31	**Mean**	**490**	**478**
Apr 1 - Jul 31	Mean +1StDev	650	683
May 1 - Jul 31	Mean -1StDev	351	204
May 1 - Jul 31	**Mean**	**450**	**387**
May 1 - Jul 31	Mean +1StDev	549	570

Table 5. FWMT predictions of 100% sockeye egg hatch and fry emergence dates. Predictions in 2005-2006 were based on fixed accumulated thermal unit (ATU) thresholds for sockeye egg hatch and sockeye fry emergence.

100% Hatch Dates			**100% Emergence Dates**		
Cohort 1	**Cohort 2**	**Cohort 3**	**Cohort 1**	**Cohort 2**	**Cohort 3**
18-Jan-06	15-Feb-06	18-Mar-06	8-Apr-06	23-Apr-06	3-May-06

Table 6. Vertical profiles of temperature and oxygen at two mid-lake sampling stations in Osoyoos Lake on 2-Oct-06. Depth intervals highlighted in red provide optimal temperatures and oxygen conditions for sockeye fry rearing.

	Site 0500249			**Site 0500728**	
	North Basin			**Monashee**	
Depth	**Temp (°C)**	**DO (ppm)**	**Depth**	**Temp (°C)**	**DO (ppm)**
1	16.98	9.22	1	16.76	
2	16.72	9.08	2	16.86	9.22
3	16.66	9.05	3	16.85	9.21
4	16.63	9.02	4	16.85	9.19
5	16.58	8.97	5	16.83	9.19
6	16.55	8.94	6	16.77	9.13
7	16.51	8.92	7	16.76	9.09
8	**16.45**	**8.88**	8	16.72	9.05
9	**16.34**	**8.70**	9	16.67	9.03
10	**16.25**	**8.33**	10	16.64	8.99
11	**16.19**	**7.76**	**11**	**16.54**	**8.95**
12	**16.16**	**7.74**	**12**	**16.48**	**8.93**
13	**16.12**	**7.78**	**13**	**16.29**	**8.69**
14	**15.98**	**7.53**	**14**	**16.05**	**8.43**
15	**15.68**	**7.25**	**15**	**15.99**	**8.22**
16	**14.08**	**6.09**	**16**	**15.36**	**7.51**
17	11.51	3.55	**17**	**15.11**	**7.29**
18	10.15	2.56	**18**	**10.93**	**4.33**
19	9.68	2.64	19	10.07	3.12
20	9.53	2.68	20	9.76	3.01
24	9.08	2.72	24	9.20	2.83
28	8.94	2.55	28	9.07	2.54
32	8.84	2.02	32	8.94	2.30
			36	8.87	2.14
			40	8.83	2.05
			44	8.78	2.03
			48	8.74	2.04
			52	8.72	1.97

Table 7. Summary observations, decisions and outcomes associated with FWMT use in 2005-06. Events and decision points are sequential and correspond to numbers superimposed on the seasonal patterns of lake elevation and river discharge by location portrayed in Figure 14.

Event identity and date (see Figure 14)	**Summary of issues, events, advice, decisions & outcomes associated with fish-and-water management supported through FWMT use in 2005-06**
(1) Oct 5 – Jan 31	**Issue(s) - Outlook**: Fall to early winter 2005-2006 lake levels and precipitation patterns suggest continuation of multiple, year interval of below average water supply and potential drought. **Background - Event(s)**: Snow-pack at the Mission Creek (high elevation) and Brenda Mines (low elevation) snow courses are significantly below average. Okanagan Lake exhibits early December water levels below preferred winter benchmark levels suggesting a continuation of 2001-2004 drought conditions in the Okanagan during 2005. **Advice**: Water conservation requires reductions to discharge while maintaining flows of no less than 50% of fall spawning values (*i.e.* maintain discharge at Oliver of no less than 5-6 cms through the winter egg incubation period). **Decision(s)**: Discharge at the Penticton Dam was reduced from approximately 10 cms in late October to 5-6 cms by early November. **Outcome**: Field observations indicate 5-6 cms flows at Oliver are associated with minor, side-channel (natural river section area) and margin-habitat dewatering (shoreline of mid-channel islands). Salmon egg losses in such areas are minor unless exaggerated by winter freezing. FWMT scour and desiccation “report” suggests minor losses of eggs. This corresponds well with direct observations by field crews. Water managers acknowledge concerns that minimum flows remain above the OBA specified threshold for sockeye egg and alevin incubation period.
(2) Feb 1	**Issue(s) - Outlook**: Okanagan Lake achieved preferred benchmark level by late January (Event-2, Panel-E). BC River Forecast Center information on Feb. 1st suggests water management strategy should shift from an expectation of continued drought conditions to an expectation of average snow-packs and associated annual water yields. **Advice**: Shift strategy to management of Okanagan Lake levels and water releases to avoid potential spring-summer freshet and flood events. **Decisions**: Water managers increased late January spill at Penticton Dam (Event-2, Panel-F) to begin moving Okanagan Lake towards preferred water level benchmark for April 1st (green diamond, Panel-E). **Outcome**: Okanagan Lake level falls at accelerated rate.
(3) Feb 14	**Issue(s)-Outlook**: Increased rates of lake level decline have triggered an FWMT amber hazard warning (Panel-E) for impending loss of kokanee. **Decisions**: Discussion among the “parties” produces consensus to reduce

	rate of spill at Penticton (Event-3, Panel-F) until late February when FWMT predictions indicate kokanee will reach 100% emergence threshold. **Outcome**: Okanagan Lake levels stabilize at water levels that avoid kokanee egg or alevin loss prior to fry emergence.
(4) Feb 28	**Issue(s) - Outlook**: FWMT identifies 100% emergence for Okanagan lakeshore kokanee without any losses due to premature reductions in Okanagan Lake levels. **Outcome**: The "kokanee-friendly" lake level objective (Event-4, Panel-E) was met for this portion of the 2005-2006 fish-and-water management cycle.
(5) Mar 14	**Issue(s) - Outlook**: Kokanee emergence complete. **Decision**: Spill at Penticton Dam increased (Event-5, Panel-F) to draft Okanagan Lake but constrained to < 28 cms (Event-5, Panel-H) to avoid scour of sockeye eggs or alevins as per FWMT hazard thresholds and terms of Okanagan Basin Agreement.
(6) Mar 27	**Event**: Risk to incubating sockeye eggs/alevins from flow reductions requested by MOE **Issue**: BC - MOE fisheries staff identify necessity to repair scoured area of dike armour associated with Newbury Riffle. Repair authorized by both MOE and DFO Habitat. Some concern expressed by DFO (Hyatt) that extent and period of flow reductions be minimized given risks to incubating sockeye eggs/alevins and narrowing "window of opportunity" to reach preferred Okanagan Lake level benchmark by April 1st, prior to increases in unregulated snowmelt inputs. **Decision**: Spill reduced to 10 cms for week ending March 31st (Event-6, Panel-F). **Outcome**: Rip-rap armour repaired successfully with minimal impacts.
(7) Apr 4	**Decision**: Resumption of elevated but "sockeye friendly" flows following Newbury Riffle repairs (Event-7, Panels F and H).
(8) Apr 18-30	**Outlook**: Snow-pack and water supply forecasts remain at or just slightly above the all-year average. **Decision**: Penticton Dam water releases (Event-8, Panel-F) reduced to compensate for beginning of early spring snowmelt increases to unregulated tributary inputs at Oliver (Event-8, Panel-H) and to protect final cohort of emerging sockeye alevins. FWMT sub-model suggests need to maintain flows of < 28 cms at Oliver until the May 03 (Event-8, Panel-D) 100% emergence date predicted by FWMT sub model. Don McKee (BC WSD) notes that water managers relied solely on FWMT to make decision to hold off increasing spill until 100% emergence date. **Outcome**: Success in avoiding losses of sockeye salmon eggs or alevins from scour inducing flows during the 2005-06 fish-and-water management cycle.
(9) May 1	**Outlook**: Risk of freshet-induced, flood conditions increasing rapidly with melting snow-pack and weekly net-inputs of water to Okanagan Lake that are higher than the all-year average.

	Events: Rapid rise in Okanagan Lake levels (0.5 to 1 cm per day). Field observations confirm sockeye fry emergence virtually complete by May 1. **Decision**: Water managers immediately increased releases at the Penticton Dam from roughly 17 cms (i.e. 25 cms at Oliver) to 45 cms (i.e. 52 cms at Oliver; Event-9, Panel-H) to reduce rate of Okanagan Lake level rise (Event-9, Panel-E) and future level of flood risk.
(10) May 2-7	**Outlook**: Early May, River Forecast Center update indicates late April surge of precipitation and increase of Mission Creek snow-pack by 15% - 20% above average. Downstream of Okanagan Dam, unregulated tributary inputs push discharge at Oliver to 36 cms in late May (Panel H). **Decision**: Water releases at Penticton Dam constrained to less than 25 cms (Event-10, Panel-F) after mid-May to compensate for steep increases in melt-water inputs from unregulated tributaries (i.e. unregulated tributary inputs increased by roughly 35 cms over a 7 day interval) and associated increases in the hydrograph at Oliver (Event-10, Panel-H). **Outcome**: Okanagan R. discharge at Oliver attained 70cms between May 19-20th under the combined influence of melt water inputs and significant precipitation during May 19-23rd. These events triggered an amber, flood-control warning in FWMT for this site. No flooding occurred in the Okanagan at this point but, during this same interval, the Kettle and Granby Rivers flooded farms and houses in the Rock Creek, Grand Forks, Slocan Valley and Nelson areas east of the Okanagan due to similar rain-on-snow and rapid runoff conditions.
(11-12) June 2-10	**Outlook**: Consensus of FWMT team is that annual flows from snowmelt and spring/summer precipitation in the Okanagan will fall between the all-year average (i.e. Scenario 348 Graphs Average) and one standard deviation above the all-year average (i.e. FWMT Menu, Scenario-348 Graphs-High). Peak flows from unregulated tributary inputs has passed and spill at the Penticton Dam may be safely increased. FWMT Scenario-348 Graphs-High output supports the notion that even if total inflows to Okanagan L. are a full standard deviation (i.e. 33%) higher than the all-year mean, water-supply value, there is a viable water release strategy to avoid flood damage. **Decisions**: Spill rates at the Penticton Dam (Events 11-12, Panel-F) increased to 60 cms "operating capacity" for Penticton Channel. **Outcome**: Discharge levels achieved at Penticton (Panel-B), Okanagan Falls (Panel-C) and Oliver (Panel-D) increase and trigger amber flood hazard considerations in FWMT.
(13) June 10-16	**Outlook**: Significant rain on snow events between June 8-16th produced net weekly inflows from tributaries into Okanagan Lake of 52 million cubic meters or 40% above the all-year average for the week ending June 17th.Peak inputs of unregulated tributaries near Oliver combined with "capacity" spills of 60 cms at the Penticton Dam (Event-13, Panel-F) produced peak discharges at Oliver in excess of 78 cms June 11-12th (Event-13, Panel-H). The combination of 23 mm of rain plus final inputs from melting snow produced a rapid rise (about 1 cm per day) in Okanagan Lake levels during June 9-17th triggering an amber condition,

	flood hazard warning for Okanagan Lake (Event 13, Panel-E) and a red condition, "flood damage" warning within the FWMT System for the Okanagan River at Penticton (i.e. Okanagan R. channel at Penticton exceeded 60 cms "discharge-at-capacity" rating (Event-13, Panel-F). **<u>Decision</u>**: Upper end of "safe" spill levels (< 68 cms) maintained at Penticton Dam to balance upstream and downstream flood risks. **<u>Outcome</u>**: Although heavy precipitation and final snowmelt produced some flooding (3 houses) in the Joe Rich area of Mission Creek (where peak discharges exceeded 80 cms between June 15-16th), flood damage was minor in Okanagan lakeside or Okanagan River locations.
(14) June 17-18	**<u>Outlook</u>**: Drying trends and rapid declines in tributary inputs after June 16th stalled further increases above 342.56 m for Okanagan Lake which had begun to decline by June 18th (Event-14, Panel-E). Flood risk declines throughout system. **<u>Decisions</u>**: Water management increased discharges at the Penticton Dam to 67 cms on June 19th to further increase the rate of decline in Okanagan Lake and to adjust elevations in Skaha Lake.
(15) July 1-10	**<u>Outlook</u>**: Drying trend and beginning of typical summer weather accompanied by continued declines in tributary inputs to late June. No longer any risk of flood throughout system. Fish-and-water managers begin to focus on summer water supply issues revolving around flow to maintain acceptable conditions for juvenile sockeye rearing in Osoyoos Lake and supplying water to meet irrigation needs **<u>Decisions</u>**: Water management begins to decreases discharge at the Penticton Dam on June 19th to further increase the rate of decline in Okanagan Lake and to adjust elevations in Skaha Lake. **<u>Outcomes</u>**: Okanagan Lake elevations declining by 0.5-1.0 cm per day. Flows and lake level changes on track to meet preferred lake elevation benchmark of 342.30 m by July 29th. Risk to water intakes reduced (Event-15, Panels E & F).
(16) Jul 10-15	**<u>Event:</u>** Negative tributary flows at Okanagan Falls and Oliver in mid-July decrease total river flows to risk levels associated with agricultural and domestic water intakes. **<u>Decisions</u>**: Week of July 15, water management increases discharge from 22-32 cms to compensate for negative tributary flows at Okanagan Falls and Oliver (Event-16, Panels G & H).
(17) Aug 19	**<u>Outlook:</u>** Reduced flows in the Okanagan River during Aug-Sept trigger an early onset of temperature-oxygen "squeeze" in Osoyoos Lake (Event 17, Panel F) that threatens juvenile sockeye production. Temperature/oxygen profile data from field crews confirms squeeze is developing. [*Annual plots of seasonal isopleths of critical water temperature (17 ^{O}C) and oxygen levels (4 mg/l) define useable water volume (UWV) available to rearing juvenile sockeye salmon in Osoyoos Lake. The degree of "squeeze" that fry are subjected to is indicated by the level of convergence of the 17 ^{O}C and 4 mg/l O_2 isopleths – UWV is eliminated whenever the isopleths meet*]. Further sampling by field crews in late Aug – early Sept confirm that UWV has deteriorated to a 2 metre

(18) Sep 16	vertical band within the North Basin of the lake. FWMT model predictions suggest that UWV could fall to **zero** during Sept. **<u>Decisions:</u>** Upon request, water managers agree to increase releases at Penticton Dam from 15 - 20 cms for roughly a two week interval to help "flush" organic matter from Osoyoos Lake in the hope that this might reduce organic loading and BOD in the hypolimnion and prevent further reduction in usable depth available to fry (Event 18, Panel F). **<u>Outcome:</u>** Additional water releases, welcome precipitation in mid-to-late September and rapid cooling surface waters in late September combined to relieve squeeze conditions. Ongoing sampling by field crews indicated that useable water depth increased to an 8m band extending from 10 to 18m by October 2.

Table 8. Number of Scenarios formally posted to the "share-with-all" tab. by various users of the FWMT application for the 2005-2006 water-year. Note many more Scenarios are generated by users than are posted to the "share-with-all" location.

Source	**Representative**	**No. of Scenarios**
Fisheries and Oceans Canada - Science	K. Hyatt	14
ESSA Technologies Ltd.	C. Alexander	4
BC Ministry of Environment - Fisheries	A. Wilson	3
BC Ministry of Environment - Water Stewardship	B. Symonds, D. McKee	2
Okanagan Nation Alliance - Fisheries	H. Wright	2
"Guest"	Guest	1

Table 9. Problems encountered in operational year 2005 - 2006 and recommendations for avoiding similar problems in future

Problem Encountered	Recommendations
Entry of RFC forecast information into FWMT was occasionally delayed.	• Have RFC include all Team members on their email distribution list • Investigate costs and methods of automatic retrieval and entry of RFC water predictions.
Teleconferences were occasionally poorly attended.	• Appoint FWMT Team alternates for all members • Continue to set teleconference dates well ahead of time • Provide email reminders 1 week ahead of teleconference • Remind Team members of the importance of continued communication.
The level of interest in, and enthusiasm for, the FWMT Program differs between agency staff members.	• Prepare standards of performance and best practices. • Continue Team discussions of practical risk thresholds and record levels of agreement and disagreement. • Finalize an MOU outlining agency commitment to the Program
Changes to discharges (ramping rates) were sometimes made too quickly.	• Establish guidelines for the optimal and maximum permissible daily rate of change. • Consider adding guidelines to the Operational Plan.
Discrepancies of more than 4.75 °C between real-time and forecast temperatures implements a 20-day smoothing mechanism.	• ESSA has adjusted the code to reduce the frequency of occurrence
Forecasted temperatures are based on historic data from Oliver whereas real-time data is from Ok Falls.	• Improve the Oliver water recorder so that both values originate from there.
Operational decisions were sometimes shared with the Team after the fact.	• Remind water managers to confer with the Team prior to making decisions whenever possible.
Temperatures recorded by WSC stations were considerably warmer than in-gravel temperatures during parts of the year. Using WSC temperatures caused an overestimate of ATUs and predicted a sockeye fry emergence date that was too early.	• Provide an in-model correction factor for in-stream temperature recorders or use temperatures from in-gravel temperature loggers. • Maintain in-season quality assurance and quality control checks and correct incoming data when warranted.

Problem Encountered	Recommendations
The Operating Plan for Okanagan River does not include guidelines for avoiding scour	• Consider adding a guideline to the operating plan which would recognize the need, when possible, to limit flows on the spawning grounds to less than 28 m^3/s from Oct 1 to the completion of fry emergence, • Continue to determine the accuracy of the 30 m^3/s guideline.
Changes in discharge and the rationale for them need to be linked directly to the FWMT	• Establish a standard digital log
Several deliverables were delayed by higher priority work. E.g.quality assurance reviews of Software refinements, the Technical System document, the Hardware Transition document, and the improved Apprentice Guidebook cannot be completed by the Team until after Aug 31, 2006.	• Discuss option of contract extension for this year with client. • In future schedule more frequent performance reviews • Clearly identify deliverables and timelines and discuss problems early in the operational year
Tool will not run without current RFC inflow estimates	• Modify the Tool to accept alternate, “best guess” inflows. • Automatically use default settings when necessary. • Flag values as “non-RFC / temporary” and display on the User Interface.
The Hazard Assessment Report works on a weekly basis while the sockeye emergence report works on a daily basis.	• Access/use the sockeye emergence report for greater accuracy. • Modify the Assessment Report?
Failure to reach consensus on decisions.	• Agree on a formal adjudication process
Some water management notifications were made after the fact	• Discuss whether expectations in regard to consultation should be formally recorded for the uninitiated.
Dam maintenance is generally carried out using fiscal year end funding in February	• When possible carry out dam repairs prior to the onset of sockeye spawning
Gauging stations recently set up on Tributary streams need to be linked with the Tool (e.g. Inkaneep, Vaseux).	• Design methods for using the new gauge readings to provide an estimate of total tributary inflow below Penticton Dam • Arrange for entry to change automatically as new real-time data becomes available • Have user interface highlight differences between real time data and projections for unregulated tributaries.

Problem Encountered	Recommendations
No formal MOU is available to commit agencies to the program	• Assign a higher priority to drafting of an MOU
An electronic narrative is needed to capture the rationale behind FWMT Scenarios	• ESSA will provide a screen mock-up of the narrative entry system to Kim Hyatt for review by July 5th 2006. • Colin Daniel will complete this task.
Creating and sharing of Scenarios is not practiced by all Team members.	• Consider revolving the responsibility for preparing and presenting scenarios
Not all aspects of the Tool are adequately explained	• Explain the colour schemes separating real-time data from projections. • Explain how tributary inflows are estimated
Refinements of the model are needed before existing software is transferred to the long-term hosting site	• Provide an electronic record of water release strategies and decisions within the Tool. • Add an "outlook" section which to describe climatic changes throughout the season • Add messages that prompt the use of latest real-time data when updating. Add messages that prompt the use of latest real-time data when updating scenarios.
	• Debug the sockeye egg abundance over time report. • Change estimate of peak spawning from a weekly to a daily value • Correct confusion resulting from the fact that inflows are reported weekly in some parts of the model and daily in others • Limit the number of simultaneous log-ins to 2 or 3. • Add a table for archiving yearly startup data • Design a procedure for monitoring system health
The Tool requires a permanent host site	• Chair will discuss with temporary host (ESSA) and potential new host (DFO Informatics) • ESSA and Chair to write-up a transitional plan
Some additional tasks identified by the Team are beyond the scope of the present contract.	• Assign these tasks to the deliverable list for the next operational year (cost approximately $11,000)

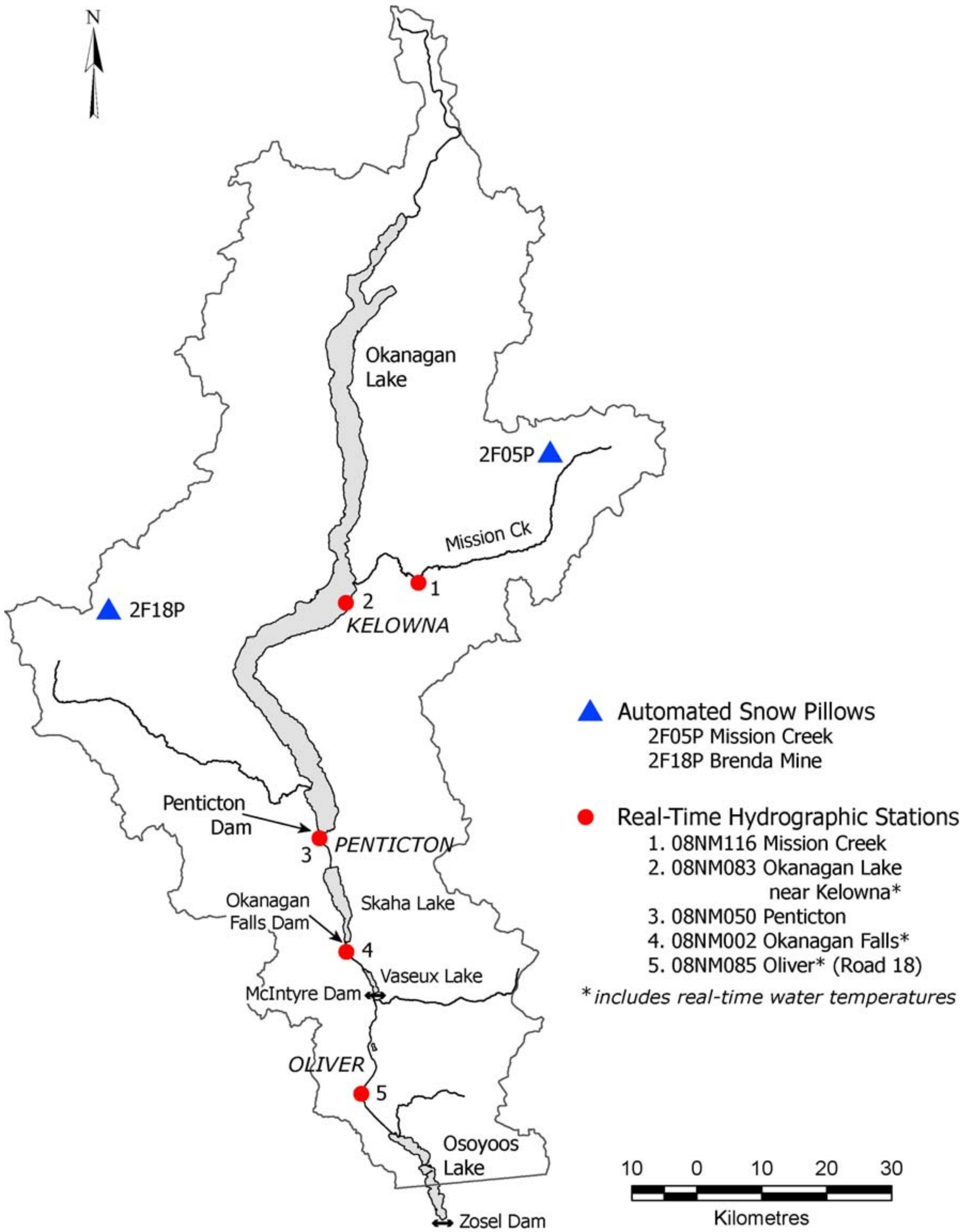


Figure 1. Map of major lakes, dam sites (Penticton, Okanagan Falls, McIntyre, Zosel), monitoring stations (snow-pack, water supply, and temperature) and towns within British Columbia's Okanagan Basin.

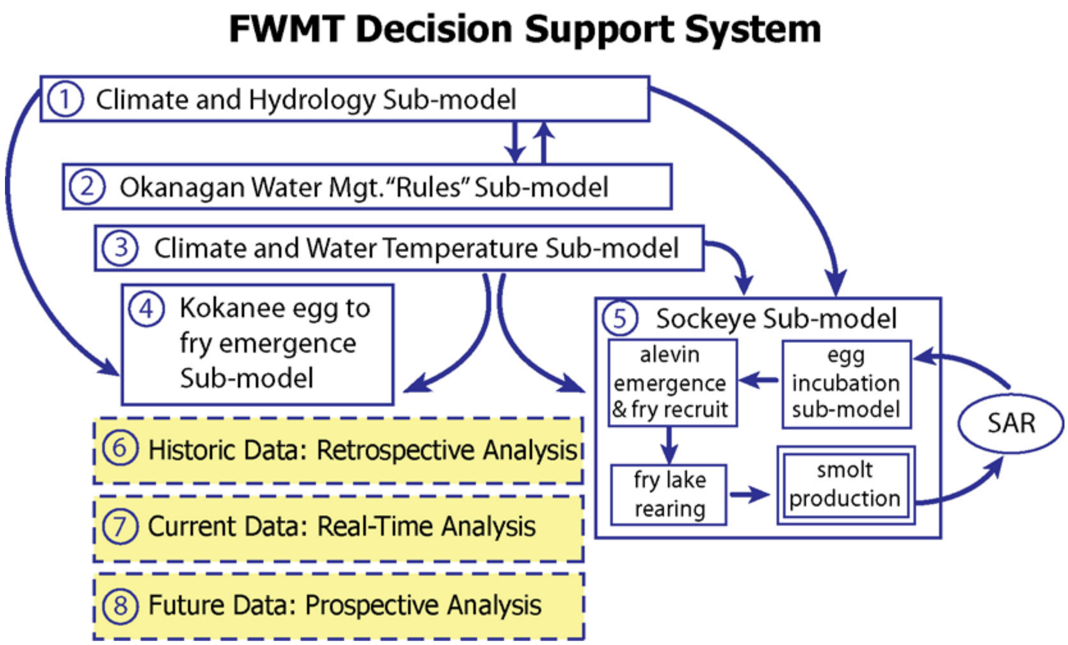


Figure 2. FWMT is a coupled-set of 4 biophysical models of key relationships among climate, fish and water that interact with a water-management rules model used to predict consequences of water management decisions for fish and other water users. FWMT software allows system users to explore water management decision impacts in near "real-time" (current-mode), historic intervals (retrospective-mode) or future intervals (prospective-mode) given data on water supplies, climate and fish population state(s).

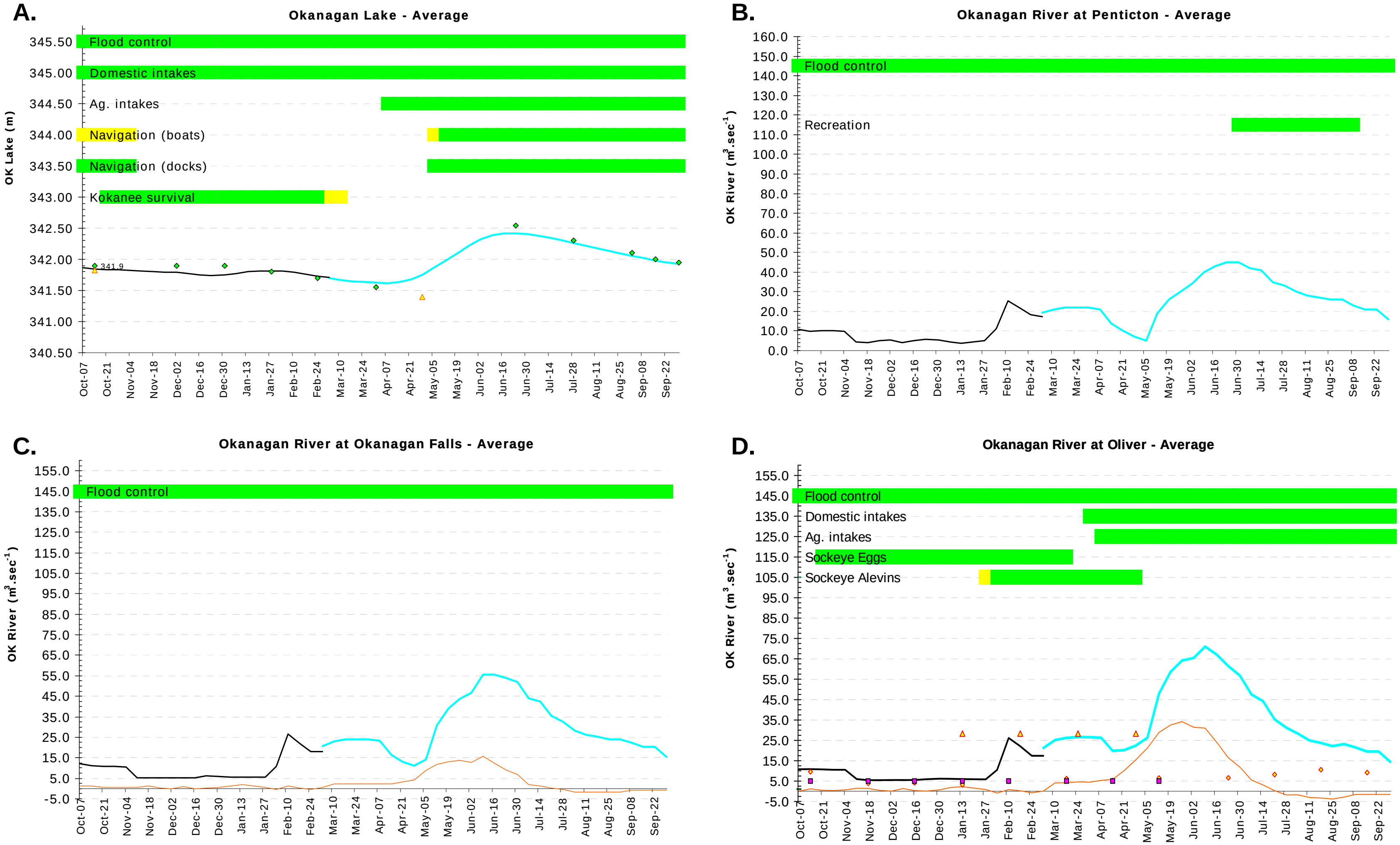


Figure 3. FWMT Scenario run early in the 2005-06 fish-and-water management cycle by Margot Stockwell 27-Feb-06. Solid black lines represent observed lake level elevations or river discharge to date. Blue lines are predicted lake elevations and flows by location, given (a) an RFC or user specified annual inflow forecast and (b) a user specified pattern of water storage or release at the Penticton Dam. Green diamonds (Panel A) are preferred seasonal targets for Okanagan Lake level management. Yellow triangle (Panel A) identifies preferred lower target for Okanagan Lake in late winter in advance of peak, spring-freshet inflows given an above-average snow-pack. Red lines (Panels C and D) are either observed or predicted seasonal inflows from unregulated tributary streams. Red triangles and black rectangles (Panel D) mark the sockeye egg/alevin scour and desiccation thresholds respectively for the Okanagan River at Oliver.

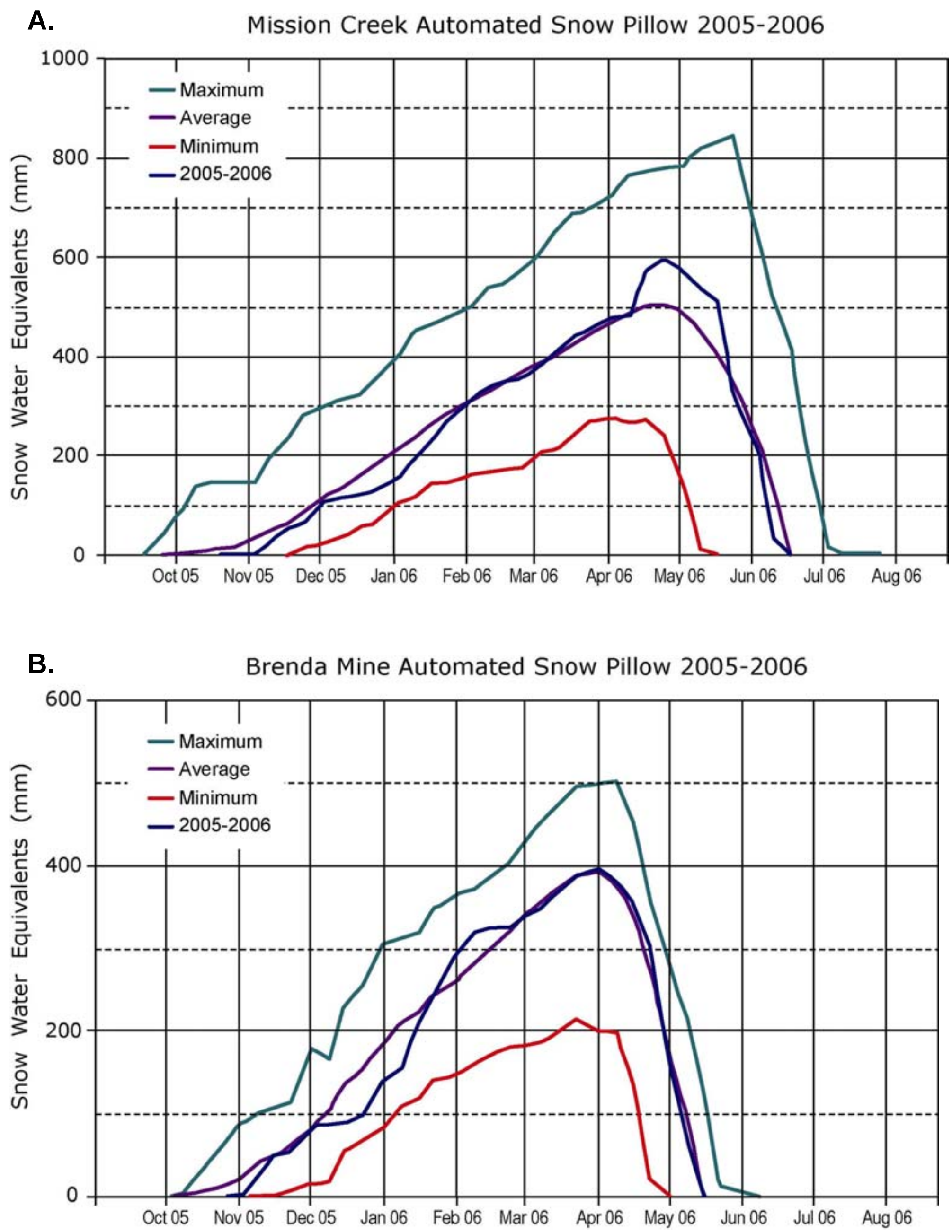


Figure 4. Snow-water equivalents from (A) high elevation (1794m) Mission Creek Snow Pillow station, and (B) low elevation (1453m) Brenda Mine Snow Pillow station for water year 2006 compared to all-year average, maximum and minimum values.
Source: BC Ministry of Environment, Water Stewardship Division available at: http://www.env.gov.bc.ca/rfc/river_forecast/spdokanagan.html (accessed 12-Aug-06).

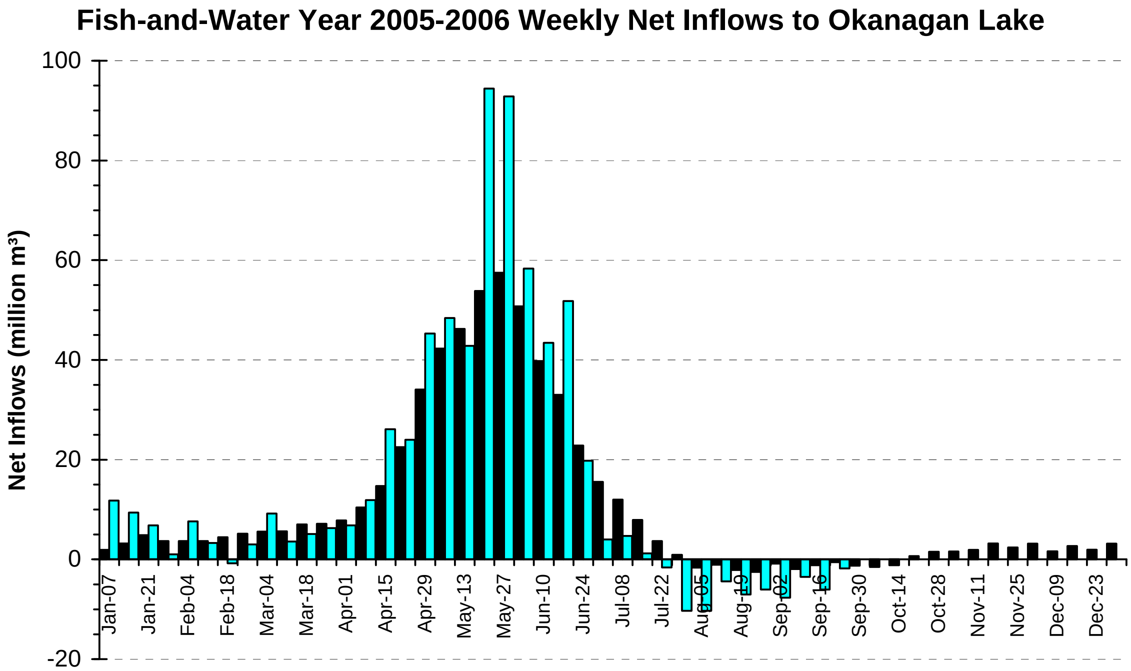


Figure 5. Weekly net inflows from all tributaries into Okanagan Lake for either the current year 2006 (blue bar) or the average across all years (black bar) from 1921-2005.

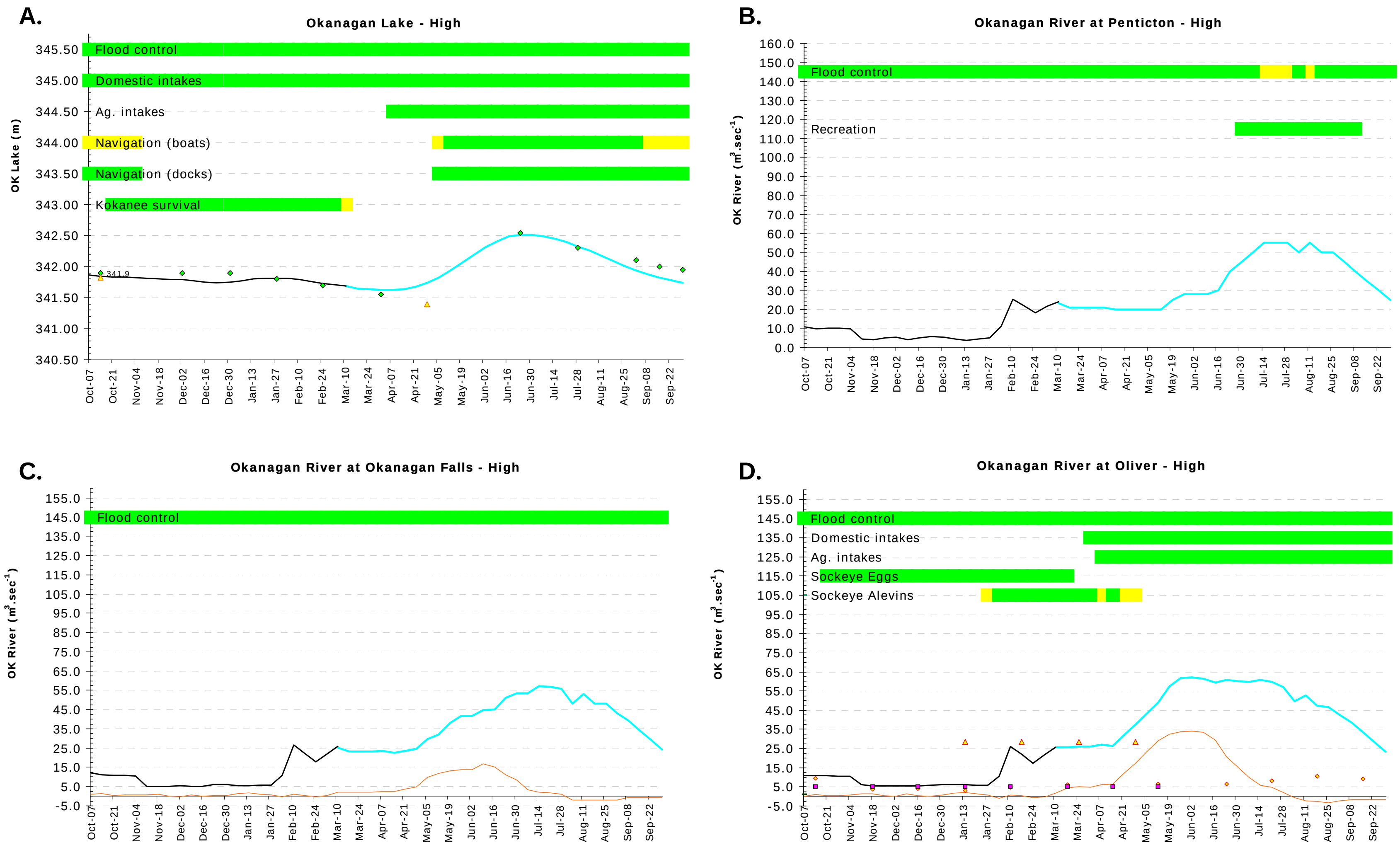


Figure 6. FWMT Scenario 329 (high) run by Kim Hyatt on 13-March-06. Symbols as in Figure 3 above.

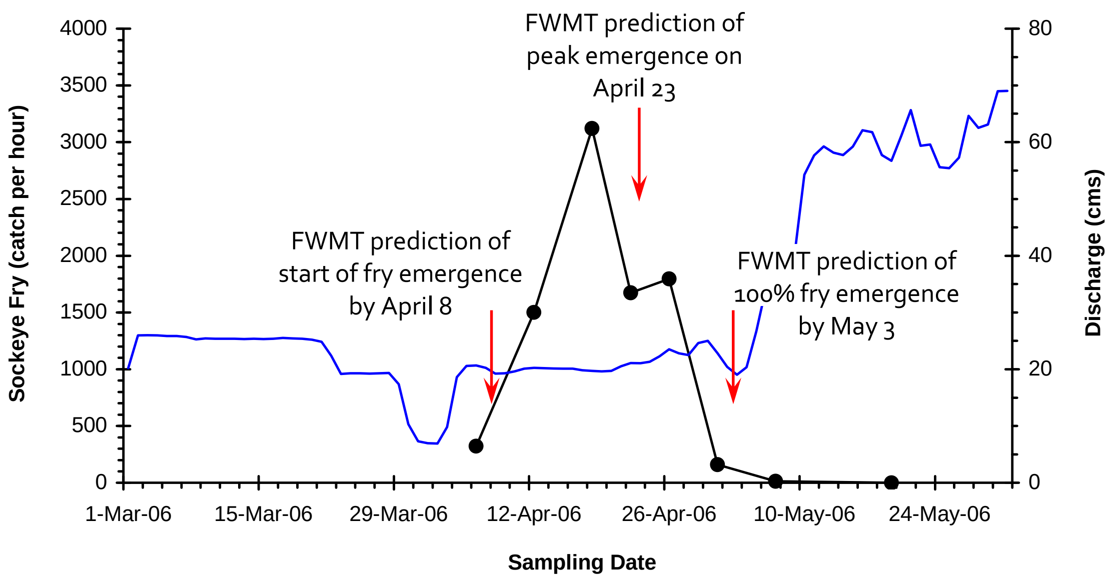


Figure 7. Observations of Okanagan sockeye fry emergence from field sampling during the spring of 2006. FWMT fixed-ATU predictions of the start, peak and end for fry emergence are provided for comparative purposes.

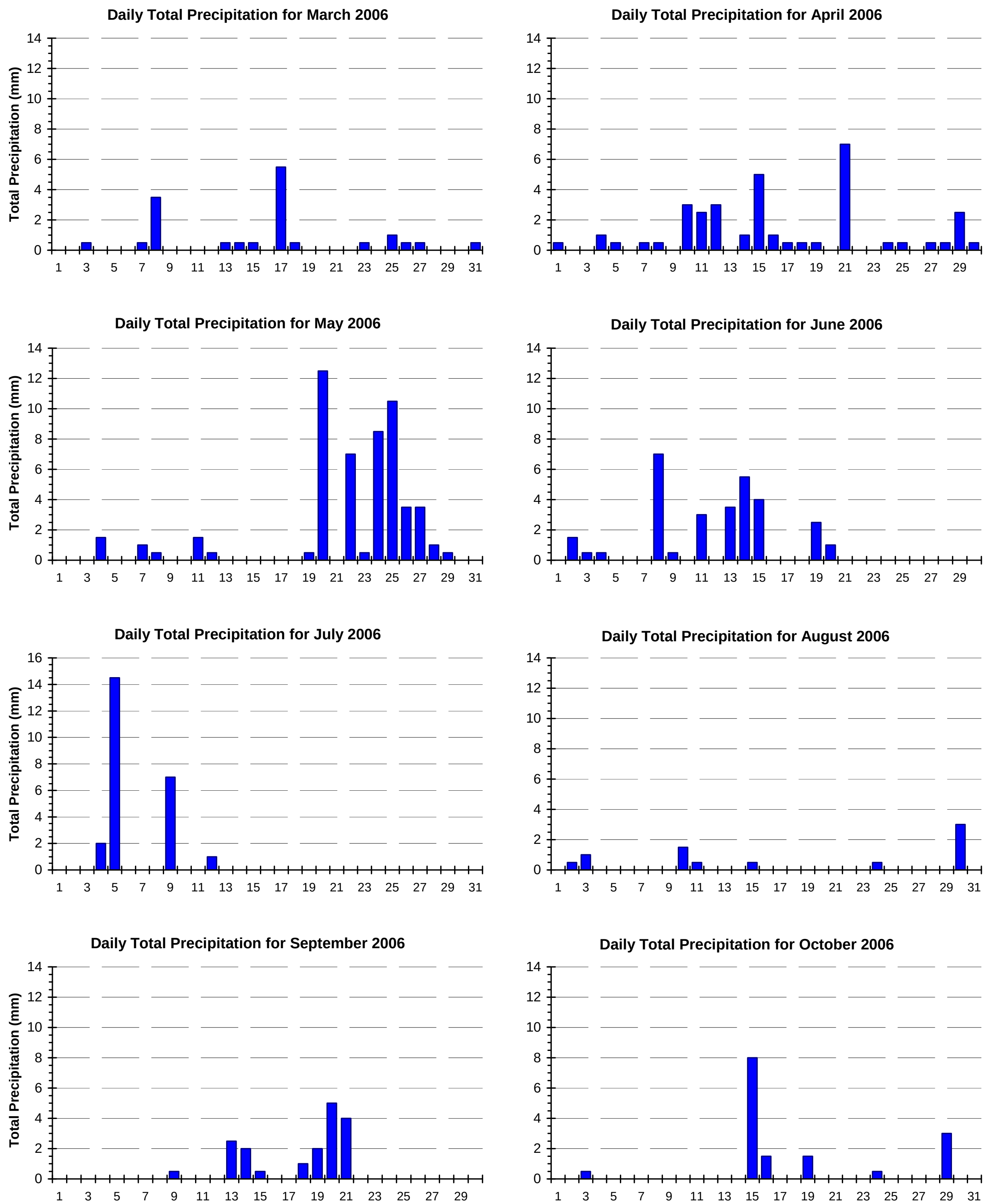


Figure 8. Daily precipitation by month (March to October 2006) at Environment Canada Climate Station Kelowna AWOS (1123695). Data source: Environment Canada, Climate Data Online at: http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html (accessed 6-Aug-08).

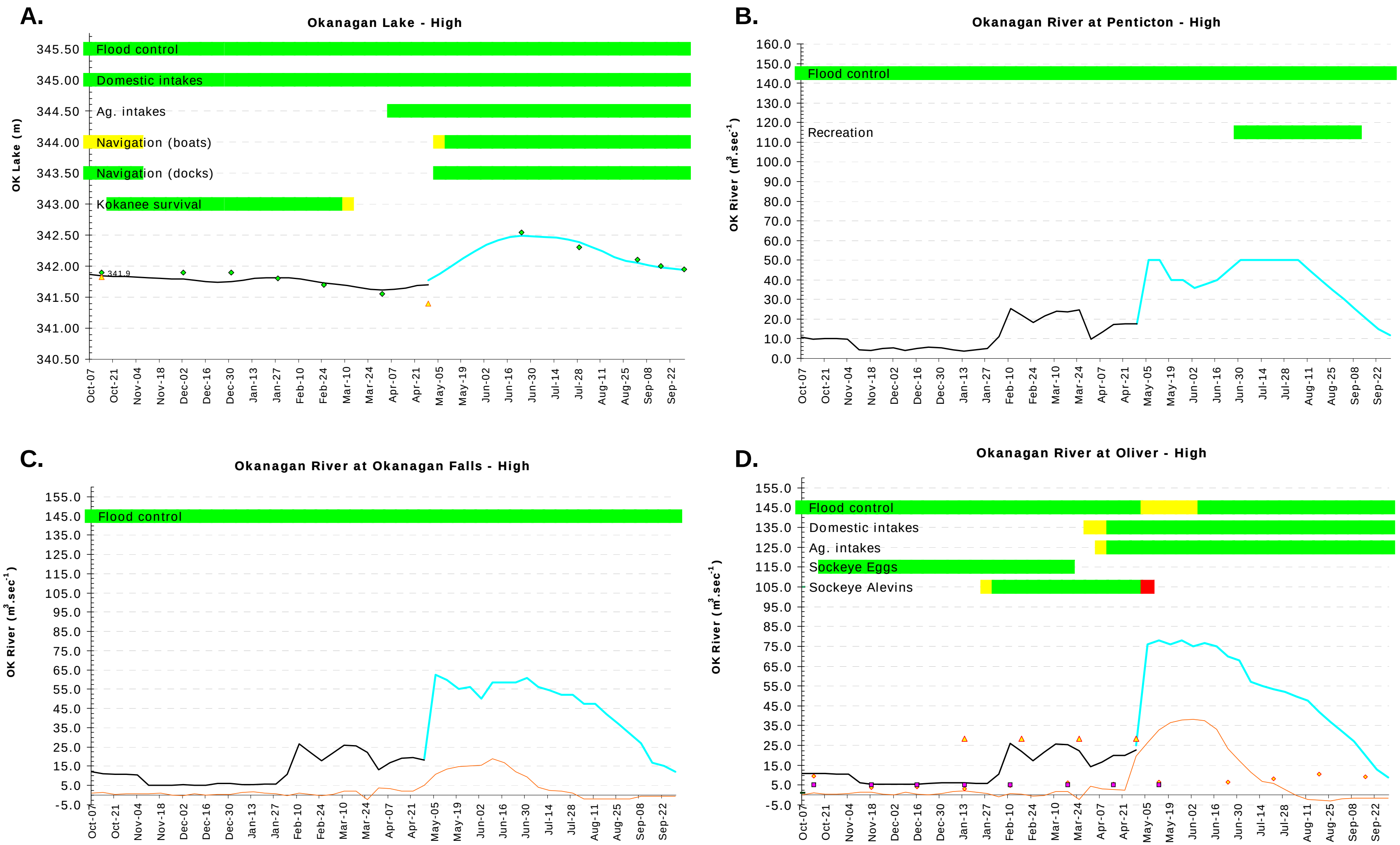


Figure 9. FWMT Scenario 348 (high) run by Kim Hyatt on 29-Apr-06. Symbols as in Figure 3 above.

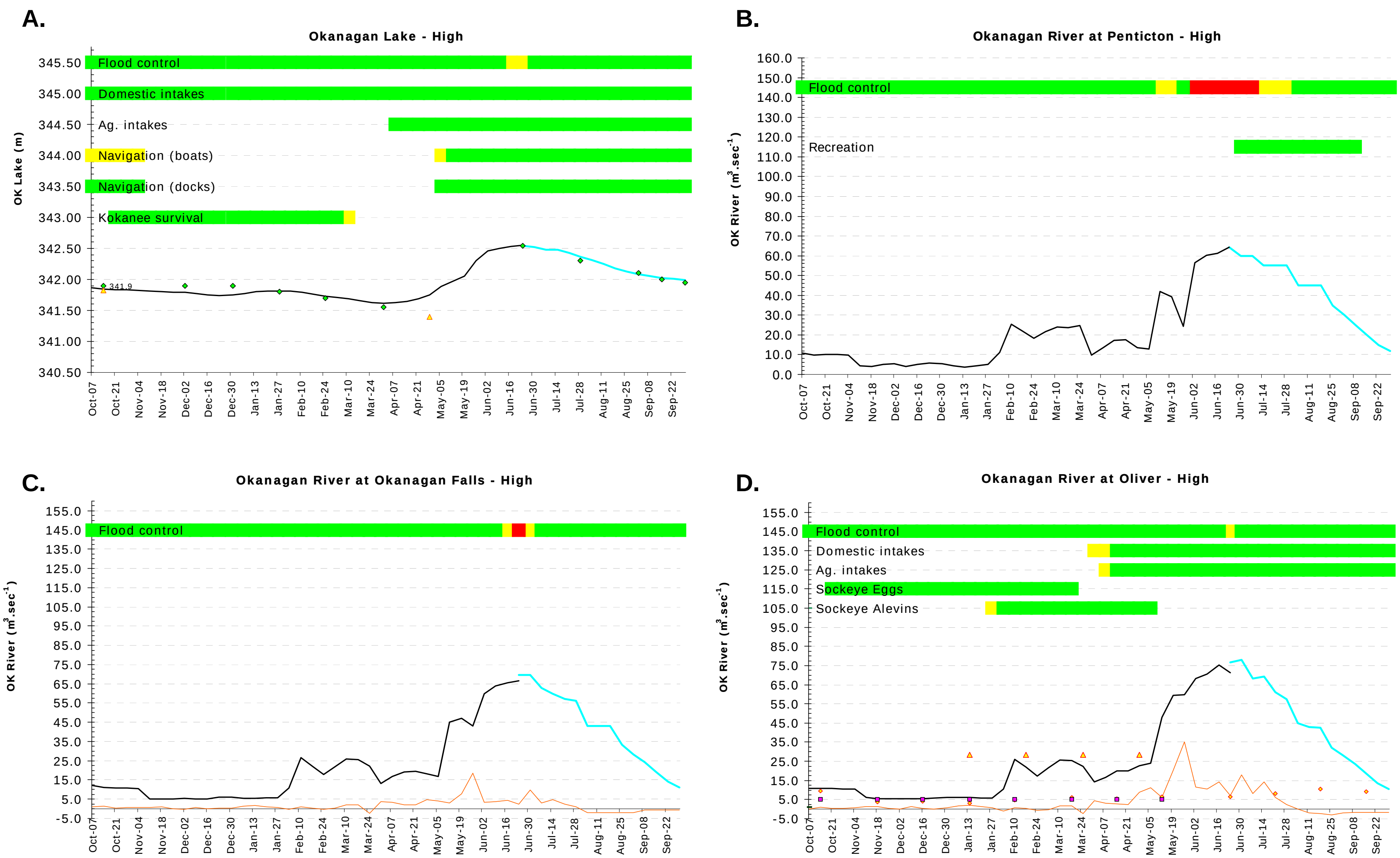


Figure 10. FWMT Scenario 359 (high) run by Kim Hyatt on 21-Jun-06. Symbols as in Figure 3 above.

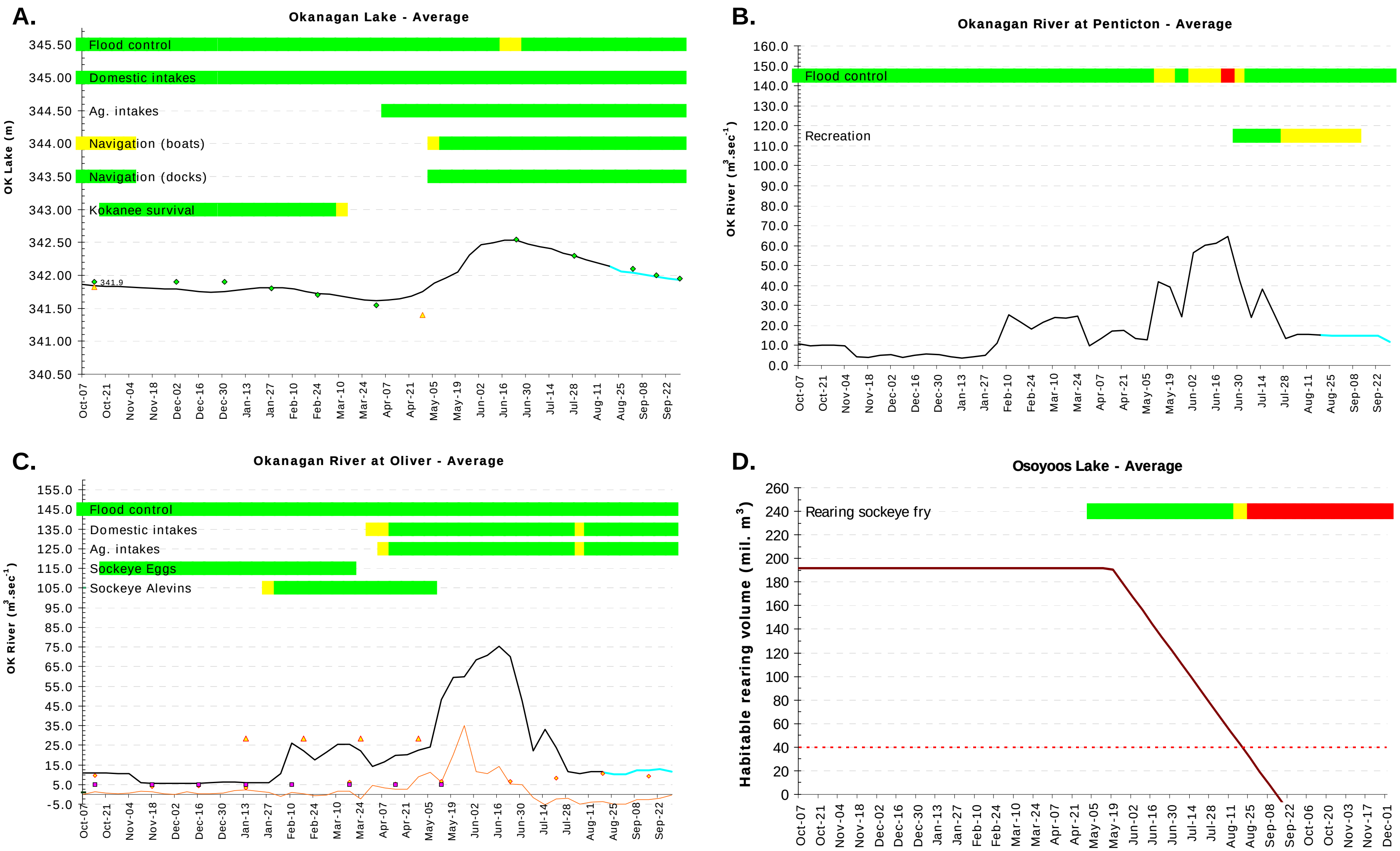


Figure 11. FWMT Scenario 361 run by Kim Hyatt on 21-Aug-06. Symbols as in Figure 3 above.

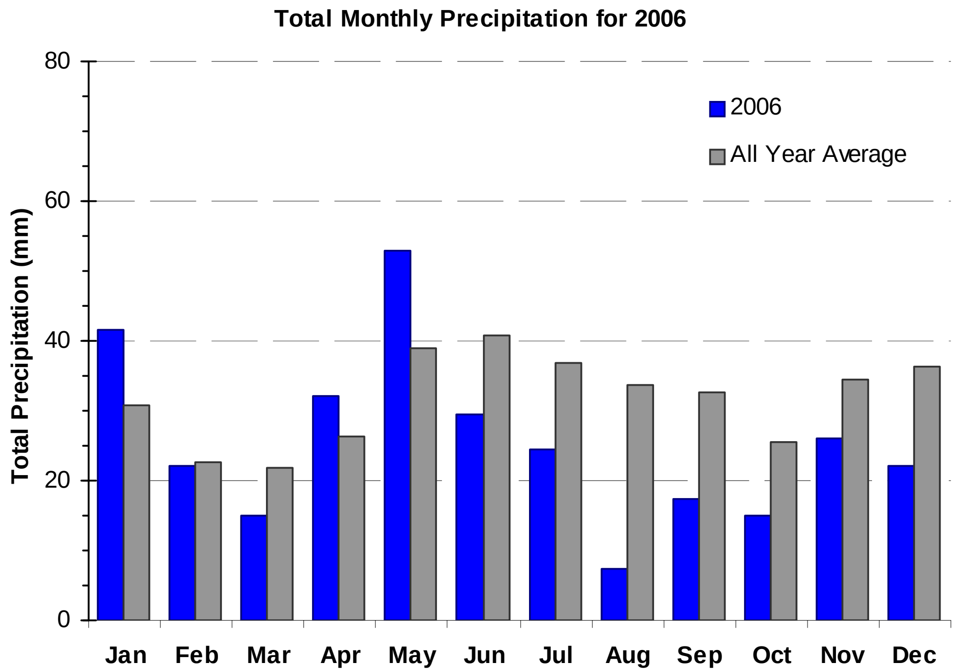


Figure 12. Monthly precipitation at Environment Canada Climate Station Kelowna AWOS (1123695) for 2006. Data source: Environment Canada, Climate Data Online at: http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html (accessed 6-Aug-08).

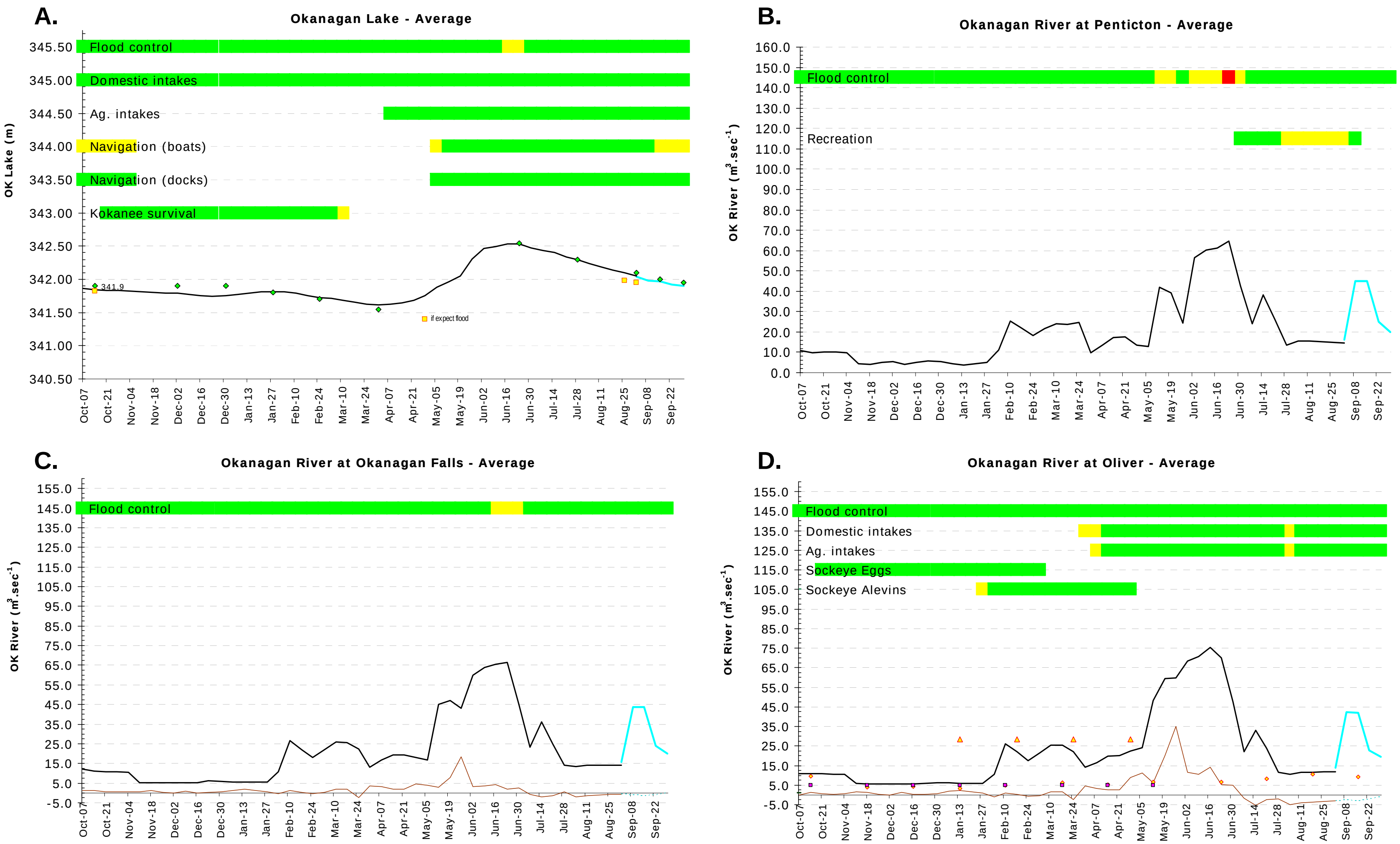


Figure 13. FWMT Scenario 366 run by Kim Hyatt on 31-Aug-06. Symbols as in Figure 3 above.

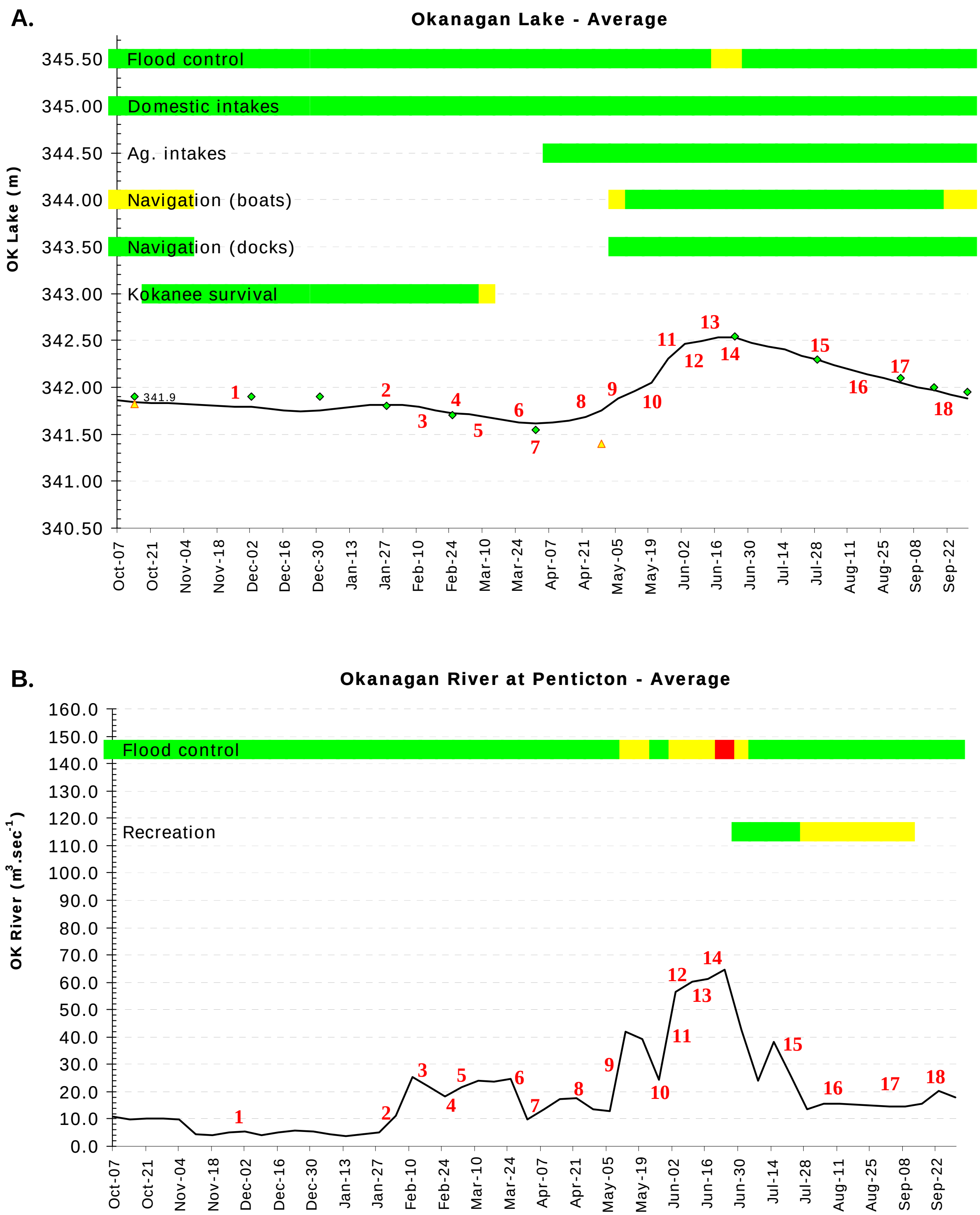
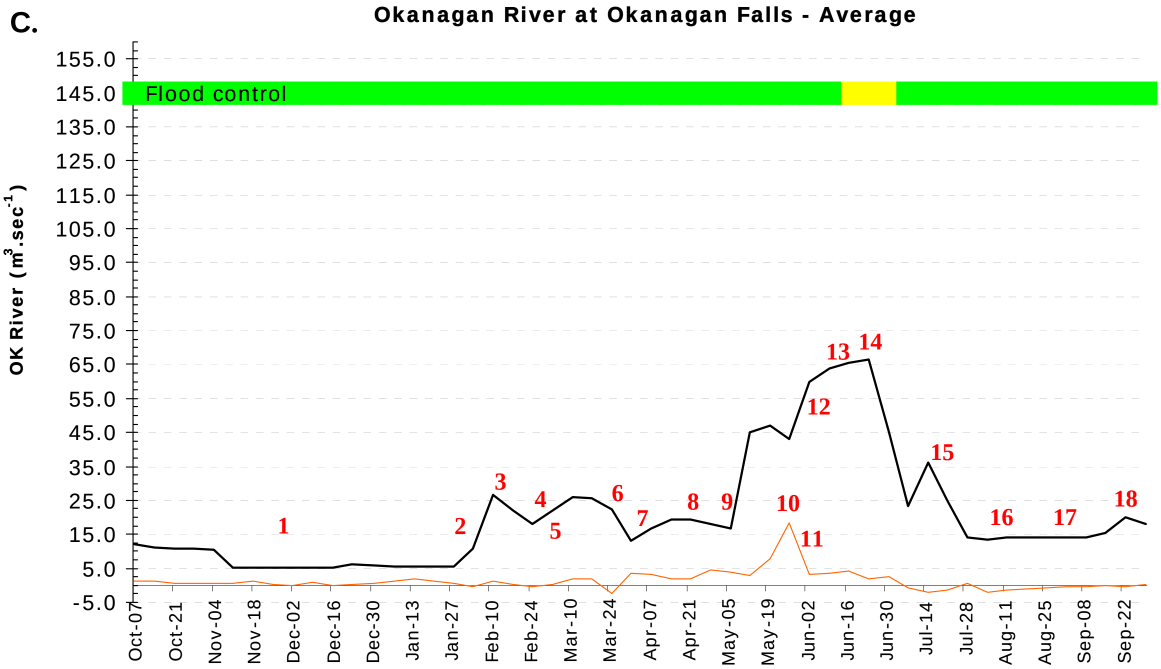


Figure 14. Observed changes to seasonal lake levels and river discharge during the 2005-2006 fish-and-water management cycle. Numbered events and/or decision points correspond to numbered descriptions provided in Table 7.

C.



D.

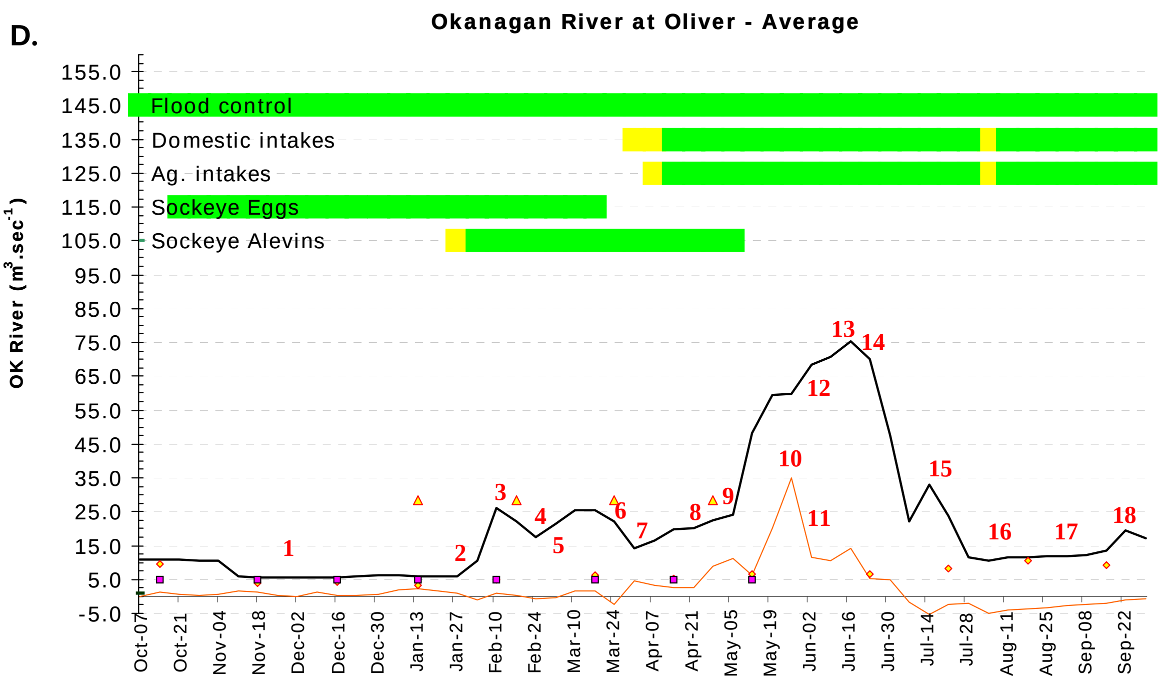


Figure 14. Observed changes to seasonal lake levels and river discharge during the 2005-2006 fish-and-water management cycle. Numbered events and/or decision points correspond to numbered descriptions provided in Table 7.

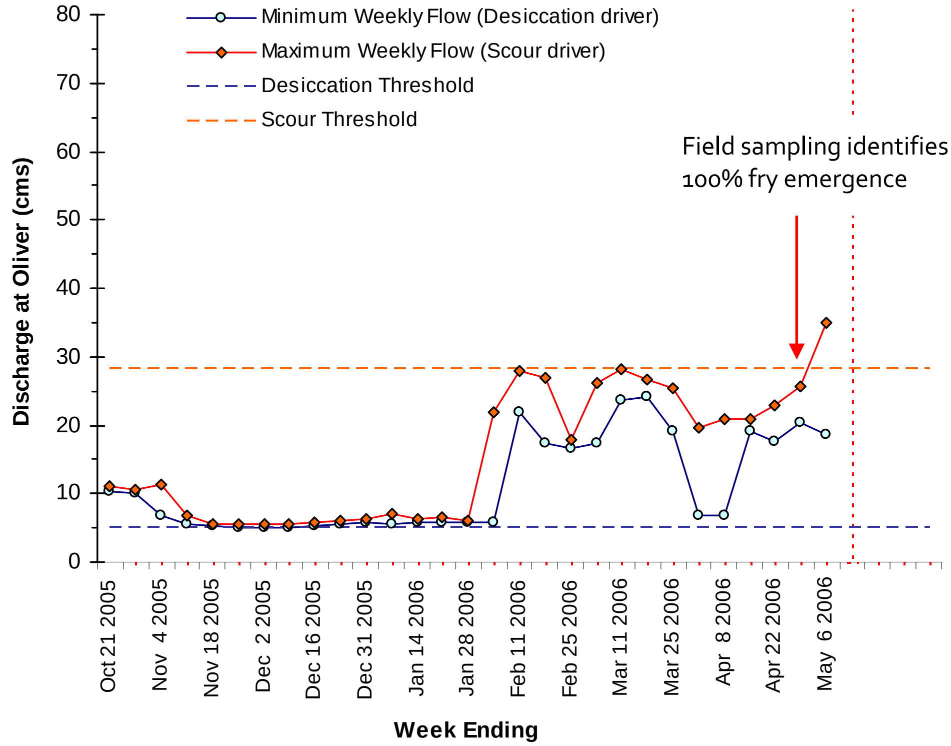


Figure 15. FWMT application report on weekly minimum (blue data points) and maximum discharges (orange data points) at Oliver relative to flood-and-scour (orange dotted line) or drought and desiccation (blue dotted line) thresholds for sockeye egg, alevin or fry losses.

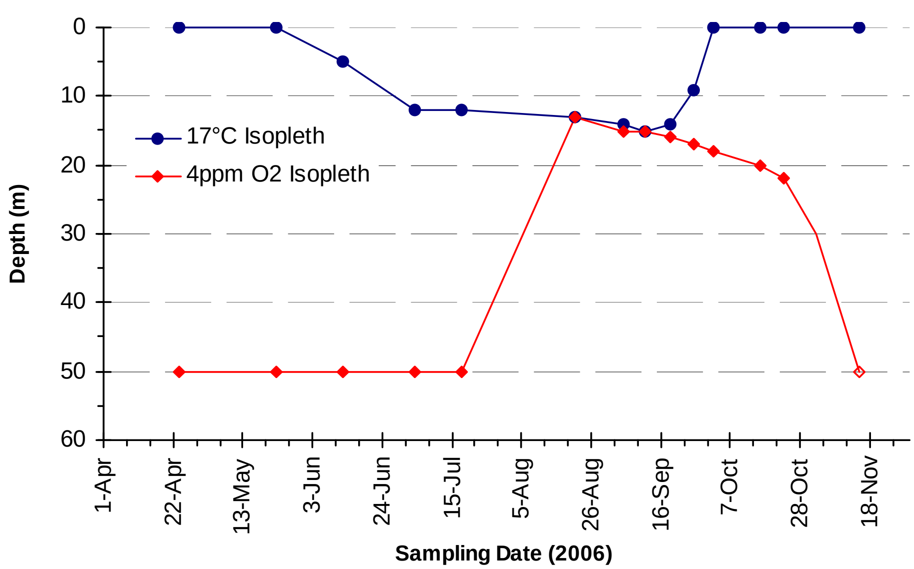


Figure 16. Position of the 17°C and 4ppm O_2 isopleths in Osoyoos Lake in summer 2006. The interval between these lines defines the volume of optimal water for sockeye fry rearing.

Left Blank On Purpose

RECORD OF MANAGEMENT STRATEGY AND DECISIONS
REPORT FOR YEAR 2005-06 - APPENDICES

Appendix 1. Abbreviated summary of “in-season” emails – 2005-06

The original wording has been paraphrased and extensively abbreviated for brevity and clarity. The emails are generally tabulated in chronological order but exceptions are made where two or more emails should be linked because of a common subject. Acronyms are explained in List of Acronyms

Date Time	From	To	Message
Jan 10 13:46	Alexander	Team	• ESSA will design an automatic register for operational decisions but not in time for the present season. • Provides examples of formats that could be used for electronic files that would compare Op team recommendations versus actual flow releases
Jan 10 15:11	Jubb	Alexander Wilson and Bull	• Cold, dry weather in Nov & Dec has resulted in well below (74%) normal snow-packs.
Jan 11 17:07	Hyatt	Stockwell Alexander Machin Bull	• Need a yearly “Start-up Report” that documents peak spawning dates, no. spawners, no. females, no. eggs deposited, & estimated ATUs to 100% hatch and emergence • ATU estimates must account for the temperature variations between WSC recording locations and redds
Jan 16 8:09	Jubb	Team	• Correction needed to Jan 10 teleconference minutes • December low flows as low as 5.4 cms at Oliver fit the rule that incubation flows need to be at least 50 % of the spawning flow • Will try to maintain 6.0 cms for safety and 5.4 cms as absolute minimum.
Feb 3 19:58	Alexander	Team	• Weather has quickly changed from dry to normal
Feb 6 19:05	Alexander	Team	• In last 3 weeks water supply has risen markedly. Both Okanagan Lake and the snow-pack are higher than normal • Higher releases than the present 6-7cms are warranted • All Team members should run scenarios to help with predictions.
Feb 9 13:59	Alexander	Stockwell	• Please create and share a scenario using new start-up values.
Feb 10 15:46	Alexander	Team	• On Feb 1 RFC forecasted average inflows • Scenario 311 (8 iterations) recommends reducing current outflows to benefit sockeye and kokanee given that there seems to be ample buffers against flooding. Flows would be ramped up after sockeye emergence to meet summer lake level targets.

Date Time	From	To	Message
Feb 10 15:37	Jubb	Team	• Water Stewardship is monitoring tributary inflows daily • Inflows have decreased due to cooler temperatures
Feb 13 10:39	Hyatt	Team	• This year the ATUs to 100% hatch will be 595 rather than the 525 default. ATUs to emergence will remain at the default setting. Explanations will be given in the start-up document.
Feb 13 14:00	Alexander	Team	• Penticton Dam releases have been reduced to 25.1 cms but flows at Oliver are 27 cms which is approaching scour level
Feb 13 15:06	Bull	Alexander Hyatt	• Were Hyatt or Alexander consulted when Water Mgt rapidly changed flows from 5.5 to 25+ cms between Feb 1 – Feb 4?
Feb 13 15:18	Alexander	Bull Hyatt	• No consultation on recent changes. • An MOU is needed to clarify the level of consultation expected. • Suggest guidelines for maximum ramping rate
Feb 13 18:55	Hyatt	Bull Alexander	• Need to discuss the need for consultation by email prior to making major sizable changes in water releases.
Feb 14 10:49	Wilson	Team	• Scenario 313 shows that there is ample room to accommodate high inflows without flooding
Feb 14 13:16	Alexander	Bull, Symonds, Jubb, Hyatt	• RFC is now forecasting average rather than dry conditions. • FWMT shows June lake targets can be met even if inflows become 1 SD higher than forecast • Present river flows of 27 – 28 cms are verging on sockeye scour and kokanee desiccation. • The Team recommends S311 reducing dam releases to 21-22 cms by Feb 16 then re-evaluating in 2 weeks time. Lake levels would be higher than the March 1 and April 1 guidelines but would meet the June target.
Feb 14 15:25	Hyatt	Hussey cc Team	• Reminder that DFO Thompson/Fraser Habitat & Enhancement Branch agreed in November 2005 to draft an MOU committing all parties to work with FWMT • Fits DFO Best Management Practices Policy • Request establishment of timelines for completing this task
Feb 20 10:50	Stalberg	Hyatt	• Request for draft MOU is under review
Feb 15 13:44	Wilson	Team	• Per request of Team met with Jubb, Symonds & Mckee and ran several versions of tool. Agreed to reduce outflows to 19 cms for 2 weeks then rise to 22 cms until April 8 per Scenario 316.

Date Time	From	To	Message
Feb 15 16:21	Hyatt	Team	• Strongly agree with Scenario 316. • Invite discussion of any concerns.
Feb 15 17:53	Alexander	Team	• Rapidly changing conditions this time of year call for using the tool every 3-5 days with Op Team discussions held every 2 weeks (more often when needed)
Feb 15 9:43	Bull	Klinge Hyatt Alexander	• Water mgt and fisheries cooperatively ran several iterations of the FWMT to produce a mutually agreeable plan. This is an example of how well the Tool is working
Feb 14 12:57	Alexander	Klinge Hyatt Bull	• The 2 attached images illustrate the decisions that have been made
Feb 16 19:36	Klinge	Bull Clubb	• FWMT has provided Water Mgt with a level of comfort by demonstrating that fish friendly flows can be achieved without flooding.
Feb 28 9:55	Alexander	Team	• RFC & NOAA information show average snow loads. • S 316 is still be valid but tributary inflows need to be watched carefully to avoid scour • The Team should revisit S316 when March 1 RFC inflow predictions are available
Feb 28 13:22	Hyatt	Team	• Recent cold snap reduced Okanagan Lake level and caused an amber alert for kokanee • Milder weather in the last 2-3 days should increase tributary inflows • Average snow conditions shown by RFC & NOAA means S 316 still fits as of Feb 28 • Water Mgt has increased releases from 17.5to 21.3 over the last 2 days • Releases of 22 – 24 are recommended to create some storage space on Ok Lake provided scouring flows can be avoided • FWMT estimates sockeye emergence will occur in late April. Scouring should be avoided until then.
March 1 12:07	Jubb	Bull McKee	• Ok Lake level is stable and warm, wet weather is forecast therefore releases will be increased to achieve 26 cms at Oliver
March 2 9:12	Bull	Hyatt	• Jubb's March 1 email shows Water Management is beginning to notify the Team of flow release decisions. However, the notification comes after the decision was made. • Are Team recommendations sufficiently frequent and flexible for Water Mgt?

Date Time	From	To	Message
March 2 10:29	Alexander	Bull	• Water Mgt should record changes by updating and sharing a FWMT scenario
March 6 10:56	Jubb	Bull	• To provide additional storage capacity on Okanagan Lake Penticton Dam releases have been increased to 25.6 which provides 28.6 at Ok Falls and 26.8 in Oliver • Flows will remain below 28.3 at Oliver
March 6 13:26	Hyatt	Team	• Water Mgt decision to increase flows to 24 cms is prudent given precipitation on Feb 28 and March 3 • Scenario 329 assumes high inflows and provides a more precautionary approach to flooding. It calls for flow reductions from 24 cms to 20 – 21 cms until mid-May to avoid scour. • Tributary inflows need careful monitoring.
March 7 11:21	Jubb	Team	• Mission Creek gauge is often unreliable in winter due to icing. • Ok Lake has dropped 2 cm in the last week but is expected to rise soon. More rain is forecast. • Water levels and flows are being monitored daily.
March 7 12:27	Hyatt	Team	• Some safety cushion is needed to guard against scour because tributary inputs are impossible to accurately predict
March 13 9:14	Alexander	Jubb	• Please request that RFC include Wilson, Wright, Hyatt and Alexander on their email distribution list.
March 13 9:37	Jubb	Team	• Mission Creek readings are still unreliable due to icing problems at the gauge.
March 14 9:46	Alexander	Team	• ESSA server is down. FWMT is presently unusable.
March 14 10:32	Alexander	Team	• ESSA server is operational again. Problem was power outage
March 14 10:32	Stockwell	Team	• Hyatt and Stockwell could not join teleconference because phone-lines were down at DFO. • Stockwell reported by email that lake levels need to drop another 4 cm to meet mid-April target. If the cold, dry weather experienced over the last couple of weeks continues, releases could be increased to 25 cms provided tributary flows are carefully monitored.
March 15 14:35	Hyatt	Team	• S 329 shows that unless inflow projections change radically between now and April 1 all interests can be satisfied.

Date Time	From	To	Message
March 17 13:49	Fast	Stahlberg	• Need the draft MOU ASAP
Mar 20 12:12	Long	Team	• Real-time gauging stations have been established by WSC near the mouths of Shuttleworth, Vaseux and Inkaneep Creeks. These will provide a measure of tributary input
March 21 11:06	Hyatt	Team	• Penticton Dam releases went from 23 cms to less than 7 on March 20 then back up to 33 on March 21. Reason unknown. Scouring is a concern.
March 21 13:23	Jubb	Team	• I assumed McKee had alerted the FWMT team to the variable flows • Dam maintenance necessitated the cutback. The post maintenance releases of 33 cms were made to bring Skaha Lake back to target. • Skaha Lake acted as a balancing reservoir and so flows at Oliver were not affected. • This sequence will be repeated in a few days due to continuing dam maintenance
March 21 13:35	Hyatt	Jubb	• Prior notification would be appreciated.
March 27 12:51	Hyatt	Team	• WSC website is down therefore latest real-time data is not available for the FWMT • S 337 shows we are nearing the time when tributary inflows will increase to 5 – 15 cms. We need to discuss ways of avoiding scour flows (>28.3 cms) during April
March 28 10:55	Hyatt	Team	• WSC website went down on March 24 but is now operable. • Snow conditions are average • Cool, dry weather since March 17 has slowed tributary inputs • Lake levels are close to target • Releases of 22cms are recommended provided tributary inflows remain below 6 cms. • Flows at Oliver are currently 19.2 cms • 75% emergence should occur by April 21. 100% by the end of April.
March 28 13:25	Hyatt	Alexander Bull	• Water Management is beginning to regularly use the Tool Scenarios and this is ideal.

Date Time	From	To	Message
March 30 9:50 and 10:22	Alexander	Campo (Env. Canada)	• FWMT no longer has access to WSC real-time data. Suspect someone changed the access codes.
April 6 18:19	Hyatt	Team	• Snow packs are average and temperatures are at seasonal normal • Releases of 17 cms are holding lake level stable and resulting in flows of 20.5 at Oliver • Emergence is still predicted to be 75% complete by April 21 and 100% complete by the end of April. Monitoring will continue and results will be passed on to the Water Managers
April 7 8:32	Alexander	Team	• Attached snow pillow data shows snow pack average • Are April 1 RFC inflow estimates available? • Has RFC expanded its email distribution list?
April 7 6:36	Bull	Team	• Teleconference poorly attended. Greater level of commitment needed.
April 7 10:30	Alexander	Bull	• ESSA will modify the model so that it will continue to run when RFC forecasts are not available. Default readings will be automatically inserted and the User Interface will alert the user that the system is running on default settings rather than the best available data.
April 10 16:15	Wright	Bull	• On April 6 the peak count of trapped sockeye was 80 in 10 minutes. Most were at a pre- emergent stage. • Increased flows may have promoted early emigration
April 10 17:42	Hyatt	Team	• Present conditions normal. • Rain on April 7 & 8 caused tributary streams and Okanagan Lake to rise. • Present discharges of 17 cms, resulting in flows of 19.5 at Oliver, are not a problem but tributaries need careful monitoring • New Scenario (344) calls for releases less than 25 cms to keep river discharges at Oliver below the 28 cms scour level
April 10 17:47	Alexander	Glenfir & Water Mgt	• High and low inflow estimates have not been entered

Date Time	From	To	Message
April 11 7:47	Chapman (RFC)	Alexander	• High and low inflows are 1 SD which is 160M m³ on either side of 490M m³.
April 17 14:20	Hyatt	Team	• Cool temperatures have moderated tributary inflow • Releases of 17 to 17.5 are resulting in flows of 19.8 at Oliver • Releases are remaining stable and the lake is rising slowly • Refreshed addition of Scenario 345 shows flows will need to be reduced as tributaries rise to avoid scour
April 17 17:52	Wright	Bull & Hyatt	• On April 12th caught 521 fry in 10 minutes • Most were in fully emergent condition
April 17 15:00	Hyatt	Alexander	• There is a 2 degree discrepancy between the temperatures in the Look-up Table of the Tool and real time data
April 18 14:09	Alexander	Team	• . The Tool uses both real-time and forecast water temperatures. If the two data sets differ by more than 4.75 º C, the Tool automatically implements a 20-day smoothing mechanism (it is meant to deal with "glitchy" real-time values such as equipment failure or a probe being pulled out of the water). • Between April 7 and 17 the smoothing mechanism was triggered. The code has been altered to reduce the occurrence of this problem but the smoothing situation will re-occur under future situations such as unseasonably cold or warm conditions. • Although the OK Falls WSC site is used to gather real-time temperature values, the Sockeye Emergence Timing report has been erroneously reporting that the data was from Oliver. This has now been corrected. • The forecast values derived from the air-to-water temperature reconstructions were developed for the Oliver site. The situation would be less confusing if the Oliver water recorder was fixed so that both real-time and forecast values originated from that location. • The hazard report works on a weekly basis while the emergence report works on a daily basis. Thus for the current year the emergence report shows 100% emergence by May 3 while the Hazard Assessment report indicates the end of that week (May 6). The most accurate date is provided in the Emergence Report. • To the complete the Record of Design, Hyatt, Stockwell, and Stiff need to review the temperature submodel modification report that was completed in 2005.

April 19 15:59	Hyatt	Team	• The latest projections are April 22 for peak emergence and May 3 for 100 per cent emergence. Field sampling will validate these estimates.
April 20 16:08	Walsh	Hyatt, Bull & Wright	• Fyke netting results show peak counts of 926 Sockeye per set
Date Time	**From**	**To**	**Message**
April 21 14:07	Hyatt	Walsh et al	• Since Water Management has been asked to stay below scouring flows until emergence is complete it is important to have netting results as soon as possible
April 21 14:07	Hyatt	Walsh et al	• Please continue frequent Fyke netting since we are close to peak migration.
April 21 16:16	Hyatt	Klinge	• FWMT has successfully predicted emergence time (April 21) • The Tool has worked well for both Kokanee and Sockeye this year
May 1 20:53	Alexander	Bull	• Sockeye have emerged. The focus will be on flood management, however water may be required later on to offset the Osoyoos Lake oxygen/temperature squeeze
May 1 10:01	Hyatt	Team	• Field data shows peak emergence occurred between April 18 and 22 • Remaining fry are in late developmental stages • Flow reductions to prevent scour are no longer needed • My newest Scenario (348) is based on late season increases in snow-water equivalents. Inflows will likely be 564 to 588M m^3 but even if inflows are exceptionally high (652M m^3) flooding can be avoided • Conference calls can now be reduced to 1 per month • Osoyoos Lake temperature/oxygen squeeze can be considered as the season progresses.
May 1 12:27	Symonds	McKee & Hyatt	• On April 28 and 29 Water Management purposefully held back flows based on FWMT recommendations and real time data on fry emergence. This would probably not have happened prior to FWMT • Things are improving
May 1 16:05	Walsh	Hyatt, Bull & Wright	• April 18 netting produced 926 Sockeye per 10 minutes • April 26 netting produced 310 Sockeye per 5 minutes
May 9 16:05	Walsh	Hyatt Bull Rankin Wright	• May 1 sampling produced 79 fry in 45 minutes
May 8 16:26	Wright	Hyatt Bull Rankin	• May 7 sampling produced 9 sockeye in 55 minutes

Date Time	From	To	Message
May 27 10:31	Alexander	Team	• Ok Lake has risen rapidly and is presently high • Net inflows are 49 M m^3 higher than average • Scenario 353, run at 495 M m^3 (RFC estimates were 450 M m^3) suggests that to prevent flooding releases should be 55-64 cms over the next few weeks
May 27 11:12	Symonds	Team	• We were holding back releases to minimize flood problems in Oliver and Osoyoos, to facilitate debris removal at the VDSs and to allow ONA to service their fish traps. • As of May 26 we have increased releases to 45 cms • The lake is filling 2 weeks early which leaves less time to release water • We now have little "wiggle room" and complaints about high water are beginning
May 29 9:46	Symonds	Team	• McIntyre Dam and Zosel Dams are wide open but Vaseux Lake and Osoyoos Lakes are rising. Osoyoos Lake will exceed the IJC target of 911.5 ft. Okanagan Lake is approaching full pool and rising rapidly. • We are increasing flows to 60 cms (70 cms at Oliver) • Tributary flows are expected to drop shortly • Fisheries should check performance of the Oliver Riffles
June 1 11:13	McKee	Alexander Symonds Hyatt	• Tributary inflows shown in 356 are not logical • More accurate estimates would increase the value of the Tool
June 1 14:28	Alexander	McKee Symonds Hyatt	• Tributary data will eventually be updated with real-time readings. In the meantime professional judgement is needed to modify estimates. • In scenario 356 estimates are probably 8-10 cms too high.
June 5 12:53	McKee	Alexander Symonds Hyatt	• How are tributary flows estimated for the portion of the graph prior to the decision date?
June 6 11:24	Alexander	McKee Symonds Hyatt	• Tributary flow estimates graphed prior to the decision date are obtained by subtracting the discharge at Penticton from the flows at Oliver. After the decision dates the numbers are all year averages. • This year early runoff exhausted the snow pack by late May so the all year averages for June are likely 10 – 15 cms high.
June 1 15:01	Hyatt	Alexander Symonds McKee	• Tributary flows are declining, low elevation snow pack is gone and high elevation snow pack is waning • The problems caused by rapid snow melt coupled with rain should be subsiding

Date Time	From	To	Message
June 7 8:35	McKee	Team	• I have reset the May 1 – July 31 inflow estimates to 450 M m^3.
June 21 12:34	Hyatt	Team	FWMT Update as of June 21st, 2006. • (1)Early May: Following sockeye emergence on May 3rd, water managers increased releases to 45 cms. This kept Ok. Lake. Down to the mid-June benchmark of 342.54 m • (2)Late May: Releases were scaled back from > 40 cms to < 25 cms as tributary inputs increased to 35 cms during 3rd week of May. Okanagan Lake levels rose to 342.40 m by June 2. • (3) Early June: Declines in tributary inputs, allowed increased releases at the Penticton Dam from < 25cms to 60 cms. This slowed Okanagan Lake level increases. • (4) Mid-June: Rainfall (June 8-16) melted the remaining snow-pack. Weekly net inflows to Ok Lake were about 40 % above average which triggered an amber flood-hazard warning. Releases of 60 cms at Penticton produced 78 cms in Oliver and triggered a red flood damage warning for the river at Penticton. Some flooding occurred on Mission Creek but flood damage was minor in Okanagan lakeside and Okanagan River locations. • (5) Late June: Increased discharge at the Penticton Dam to 67 cms on June 19th increased the rate of decline in Okanagan Lake levels. • (6) Outlook: Environment Canada forecasts a drying trend but total net inflows into Okanagan Lake will equal or exceed 650 million cubic meters this year which will require above average spill for some portion of the summer (see new Scenario 359).
July 5 @ 12:54	Symonds	Team	• FWMT really proved its worth this year • It greatly assisted in decision making and met the objectives of all parties
July 5 @ 14:47	Fast	Rosenberger	• FWMT is likely one of the best tools of its kind in North America if not the world • 2006 really demonstrated the benefits • it is one of the best examples of interagency cooperation I have seen in my 34 year career • it should be brought to the Ministers attention
END	**END**	**END**	**END**

Appendix 2. Letter sent (E-mail dated July 5, 2006 12:54) to the FWMT Operations Team from Brian Symonds, Director of Regional Operations, Water Stewardship Division, BC Ministry of Environment.

Everyone,

Although I was unable to participate in the meeting last week I do want to say that from my perspective FWMT was put to the test this year and really proved its worth through the improved flow and lake level management for fish. Everyone involved in both its development and implementation this year deserves congratulations on its success.

2006 was clearly a year with a number of management options, challenges and operational choices which continued to evolve and change throughout the freshet period. By using the tool we were able to anticipate the impact of a range of different release scenarios on the different interests and make informed and cooperative decisions, something which would have been far more difficult without FWMT. The real-time information on the development of both the kokanee and sockeye eggs and the timing of fry emergence enabled us to fine tune our operations to minimize the detrimental impacts on fish while at the same time providing clear windows of opportunity to safely increase discharges to minimize the impacts of high water around both Okanagan Lake and along Okanagan River. Overall I feel that the tool enabled the system to be managed in a transparent and cooperative manner, while at the same time balancing and meeting the objectives of all parties involved in fisheries management despite the challenges and twists which the spring weather presented. This is the kind of year that in the past might have lead to a significant amount of controversy around the operation of the system and where past operating practices may have resulted in greater negative impacts on the fisheries resources than occurred.

Another observation is that FWMT served as a great educational tool for Don McKee and other WSD staff, who had limited previous experience with operating the system, and who were left to make management decision with limited input from myself as I was typically unavailable. When I think back on the challenges of operating the system in my first year, when I did not have the benefit of FWMT I am convinced that the releases decisions made by Don and others definitely benefited from the having access to FWMT. It is readily apparent to me that decisions made at critical times for fish were significantly influenced by the information provided by FWMT. Without this information being readily available in a timely manner there would likely have been different decisions made which may have resulted in greater negative impacts on the fisheries resources.

The use of the tool also provided an opportunity to identify some areas where further improvements could be made to help clarify some of the underlying assumptions used by FWMT and presentation of the results, particularly around the hydrologic outputs, to enhance its effectiveness for informing the decision making by "apprentice" water managers.

Thanks again to all who helped in the development of FWMT and its implementation during its first real test.

Brian Symonds, P. Eng.
Director, Regional Operations
Water Stewardship
Tel: (250) 490-8255 Fax: (250) 490-2231

Appendix 3. Letter sent (E-mail dated July 5, 2006 14:47) to Barry Rosenberger (Area Director, BC Interior Area, Fisheries and Oceans Canada, Kamloops, BC) from Elmer Fast (Area Chief, BC Interior Area, Fisheries and Oceans Canada, Kamloops, BC).

Brian's note (see Appendix 2) captures the feelings of all members of the Canadian Okanagan Basin Technical Working Group (COBTWG) who have been actively involved in the development and use of the Fish-Water Management Tool (FWMT) model in managing flows in the Okanagan River to address fisheries and non fisheries issues. The development of this tool was a cooperative venture undertaken by 3 levels of government within British Columbia [i.e. DFO (federal), MOE (provincial), Okanagan Nation Alliance (First Nation)] in conjunction with an international U.S. partner (Douglas County Public Utility District). Without the expertise, dedication and in-kind contribution of time of staff from these agencies and the tremendous funding support from our U.S. partner - Douglas County PUD, this accomplishment would not have happened.

Year 2006 was the first real test for implementation of this flow management model and use of the model was clearly a success in balancing the interests of fish against other issues affected by flow management. In summary … USE OF THE MODEL THIS SEASON TO DATE HAS REDUCED MORTALITY OF SALMON AND OTHER FISH SPECIES (E.G. KOKANEE) AT THEIR VARIOUS LIFE STAGES FROM LEVELS OF MORTALITY THAT OCCURRED PRIOR TO DEVELOPMENT OF THE FLOW MANAGEMENT MODEL. I think I can safely say that, based on assessment and use of this model to date, this group effort has resulted in the development of a flow management tool that is likely one of the best water management tools to be had anywhere in North America and perhaps the world. Long term use of this model and annual assessment over time will be the ultimate test in terms of ongoing benefits to the fishery resource. However, using this model in the 2006 spring season really demonstrated the benefits that can be derived from this tool.

I have spent nearly 34 years employed by Resource Management agencies at the federal, provincial, and territorial level and the cooperative effort displayed by the FWMT partners noted above is the best example of domestic / international inter-agency cooperation to achieve an important resource management objective that I have ever witnessed. With the right people, dedication and a common objective, bureaucratic barriers that we always seem to confront when dealing with resource management issues can be surmounted.

I think this is an example of an accomplishment that should be brought to the attention of the Minister and other senior DFO staff in Ottawa and DFO's regional director-general in Pacific Region. The Minister and senior Regional staff should be made aware of the tremendous contributions made by key people to bring this initiative to fruition:

1. Kim Hyatt - DFO (Federal)
2. Brian Symonds - MOE (Provincial)
3. Deana Machin / Howie Wright - ONA (First Nation)
4. Rick Klinge - Douglas County Public Utility District, Washington State

For your consideration.

Elmer Fast, Resource Management,
Fisheries and Oceans Canada
985 McGill Place, Kamloops, BC