IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA AND FISHERIES INVESTIGATIONS

Annual Progress Report
Fiscal Year 2010

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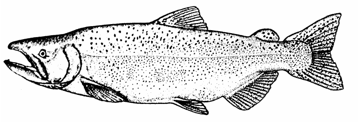

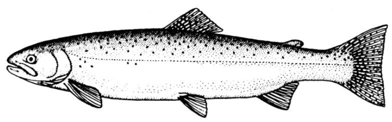

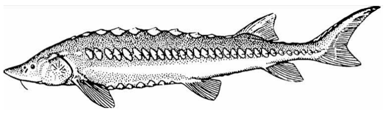

PREFACE

The following is the Ninth Annual Progress Report, Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California and Fisheries Investigations, prepared as part of the Central Valley Project Improvement Act (CVPIA) Instream Flow and Fisheries Investigations, an effort which began in October, 2001.[1] Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Game (CDFG). The purposes of this investigation are: 1) to provide scientific information to the Service's Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley streams and rivers; and 2) to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions.

The field work described herein was conducted by Ed Ballard, Mark Gard, Rick Williams, Nick Hindman, Dan Cox, Tricia Parker and Tricia Bratcher.

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[1] The scope of this program was broadened in FY 2009 to include fisheries investigations. This program is a continuation of a 7-year effort, titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. The last report for the Lower American River study was completed in February 2003, the final report for the Butte Creek study was completed in September 2003, and the last two reports for the Sacramento River were completed in December 2006. In 2004, Clear Creek was selected as an additional river for studies. In 2007, the Tuolumne River was selected for a minor project to quantify floodplain inundation area as a function of flow, with a final report completed in August 2008. In 2008, South Cow Creek was selected as an additional river for studies. In 2010, the Stanislaus River was selected to perform activities to assist the Bureau of Reclamation with conducting an instream flow study. In 2010, the following fisheries investigation tasks were selected for study: 1) Clear Creek Biovalidation – how well does IFIM compare to field observations; 2) American River gravel placement monitoring and design modeling; 3) American and Sacramento River and Clear Creek redd dewatering monitoring; 4) Stanislaus River floodplain area versus flow; and 5) Red Bluff Diversion Dam Interim Pumping Plant screen hydraulic evaluation.

The Yuba River study was planned to be a 4-year effort, beginning in September 2001. The goals of the study are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-runs) and steelhead/rainbow trout and to determine the relationship between streamflow and redd dewatering and juvenile stranding. Collection of spawning and juvenile rearing criteria data for fall- and spring-run Chinook salmon and steelhead/rainbow trout was completed by April 2004 and September 2005, respectively. Field work to determine the relationship between habitat availability for spawning and juvenile rearing and streamflow for spring-run and fall-run Chinook salmon and steelhead/rainbow trout was completed in, FY 2005 and FY 2007, respectively. A draft spawning report was completed in FY 2007 and draft rearing and redd dewatering/juvenile stranding reports were completed in FY 2008. In FY 2008, we completed the response-to-comments document for the peer review of the spawning study report and revisions to the draft spawning study report stemming from the peer review, and conducted a series of stakeholder meetings to discuss stakeholder comments[2] regarding the draft spawning report. In FY 2009, we

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[2] Stakeholder review for the Yuba reports was agreed upon during scoping meetings prior to commencement of the studies.

completed a sensitivity analysis to further respond to concerns raised at those meetings, completed a response-to-comments document for the stakeholder review of the spawning study report and revisions to the draft spawning report stemming from the stakeholder review, and conducted a stakeholder review and started a peer review of the juvenile rearing and redd dewatering/juvenile stranding reports. In FY 2010, we completed a second peer review of the spawning report and a peer review of the rearing and redd dewatering/juvenile stranding reports, and completed all three reports and response to comments documents. We plan to issue all three reports and response to comments documents in early FY 2011.

The Clear Creek study was planned to be a 5-year effort, beginning in October 2003. The goals of the study are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There are four phases to this study based on the life stages to be studied and the number of segments delineated for Clear Creek from downstream of Whiskeytown Reservoir to the confluence with the Sacramento River[3]. The four phases are: 1) spawning in the upper two segments; 2) fry and juvenile rearing in the upper two segments; 3) spawning in the lower segment; and 4) fry and juvenile rearing in the lower segment. Field work for the above four phases was completed in, FY 2005, FY 2007, FY 2008 and FY 2009, respectively. In FY 2007 the final report and the peer review response-to-comments document for spawning in the upper two segments was completed. A draft report on rearing in the upper two segments and the peer review of the draft report on spawning in the lower segment were completed in FY 2010. In FY 2010, we completed hydraulic modeling for one of the five lower segment rearing sites and are in the process of conducting the hydraulic modeling for an additional three sites. The remaining work on the Clear Creek reports will be completed in FY 2011.

The South Cow Creek study was planned to be a 5-year effort and began in October 2008 with habitat mapping and collection of spawning habitat suitability data for fall-run Chinook salmon. Fieldwork was completed on one site and started on an additional three sites to determine the relationship between stream flow and physical habitat availability for fry and juvenile rearing fall-run Chinook salmon in FY 2009. In FY 2010, we completed fieldwork on the three remaining juvenile sites, hydraulic modeling on two sites, redd mapping and an upstream passage assessment, and completed most of the final report. Due to funding cuts, the South Cow Creek study will be completed in early FY 2011 upon completion of hydraulic modeling of the two remaining sites and a final report on habitat quantity and quality in South Cow Creek.

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[3] There are three segments: the upper alluvial segment, the canyon segment, and the lower alluvial segment. Spring-run Chinook salmon spawn in the upper two segments, while fall-run Chinook salmon spawn in the lower segment and steelhead/rainbow trout spawn in all three segments.

The Stanislaus River study activities conducted by FWS began in FY 2010 with biological validation data collection for both spawning and rearing, and initial development of hydraulic and habitat models for four sites. The hydraulic and habitat modeling will be completed in FY 2011.

For the fisheries investigations tasks, work on the task "Clear Creek Biovalidation – how well does IFIM compare to field observations" was delayed until FY 2011 because we are still waiting on bed topography data on study site 3A from Graham Matthews and Associates. In FY 2010, with funding from the CVPIA b(13) program, we collected topographic data on the American River to use in designing a gravel restoration project, and modeled the amount of spawning habitat that would be created by four alternative designs for the gravel restoration project. In FY 2011, we plan to conduct post-restoration monitoring of this project and collect data to be used for the next American River gravel project. In FY 2010, we conducted redd dewatering monitoring on the Sacramento and American Rivers for the CVPIA b(2) program, and determined the effectiveness of the use of b(2) water on the Sacramento and American Rivers and Clear Creek in preventing redd dewatering. This activity will be continued in FY 2011. We were unable to conduct the Stanislaus River floodplain area versus flow task because of delays in a U.S. Bureau of Reclamation hydraulic model of the Stanislaus River. This task will be conducted in FY 2011 with funding from the Comprehensive Assessment and Monitoring Program. Following upon an initial hydraulic evaluation in FY 2009, we conducted an additional three hydraulic evaluations of the Red Bluff Interim Pumping Plant screens in FY 2010 at a range of Sacramento River flows and pumping levels.

The following sections summarize project activities between October 2009 and September 2010.

YUBA RIVER

Habitat Simulation

Chinook salmon and steelhead/rainbow trout spawning

A draft report and response to peer review comments document was completed in FY 2007. In FY 2007, we sent out the draft report to interested parties for review and comment prior to finalizing the report. This review by interested parties was in response to commitments made by the Service during the initial planning meetings with those interested parties. This is the first of the CVPIA instream flow reports to be reviewed in this manner. In FY 2008 and 2009, we conducted a series of meetings with stakeholders regarding the draft report. In response to comments received at these meetings, we completed in FY 2009 a habitat modeling and biological verification sensitivity analysis. The sensitivity analysis included different methods for developing criteria (density-based criteria), different methods of calculating habitat (geometric mean), and alternative criteria (specifically steelhead/rainbow trout spawning criteria that we developed on Clear Creek). In FY 2009, we completed a response-to-comments document for the stakeholder review of the spawning study report and revisions to the draft spawning report stemming from the stakeholder review. A second peer review and a final report on flow-habitat relationships for spawning and the response-to-comments document were completed in FY 2010 and the final report and response to comments document were issued on December 22, 2010.

Juvenile Chinook salmon and steelhead/rainbow trout rearing

Computation of spring/fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing habitat over a range of discharges was completed for all juvenile rearing sites in FY 2008. The draft report was completed in FY 2008. We sent this draft report out for concurrent stakeholder and peer review in FY 2009. Peer review, response-to-comments document and a final report on flow-habitat relationships for rearing were completed in FY 2010 and the final report and response to comments document were issued on December 22, 2010.

Chinook salmon and steelhead/rainbow trout juvenile stranding and redd dewatering

A draft report was completed in FY 2008. We sent this draft report out for concurrent stakeholder and peer review in FY 2009. The final report and response to comments document were completed in FY 2010 and were issued on December 22, 2010.

CLEAR CREEK

Hydraulic Model Construction and Calibration

Fall-run Chinook salmon and steelhead/rainbow trout rearing (Lower Alluvial Segment)

We completed hydraulic model construction for four of the five study sites (with the exception of 3B) in FY 2009. The hydraulic model construction for site 3B began in FY 2010, after we received additional bed topography data from Graham Matthews and Associates. We completed calibration for four of the five study sites and production runs for one of the study sites in FY 2010 after we received needed flow data from Graham Matthews and Associates. Production runs for three of the other study sites are in progress, and we intend to complete hydraulic model construction and calibration of Site 3B and production runs for all study sites in FY 2011.

Habitat Simulation

Juvenile spring-run Chinook salmon and steelhead/rainbow trout rearing (Upper Alluvial and Canyon Segments)

In FY 2010, spring-run Chinook salmon and steelhead/rainbow trout rearing habitat was computed over a range of discharges for the six spawning sites and six rearing sites in the Upper Alluvial and Canyon segments and a draft report was completed. We will complete draft and final reports on the 2-D modeling of the spring-run Chinook salmon and steelhead/rainbow trout rearing in the Upper Alluvial and Canyon segments in FY 2010. As requested by the Red Bluff Fish and Wildlife Office, we distributed a draft report in FY 2010 to interested parties for comment in addition to peer review, as is being done with the Yuba River Study reports. In FY 2011, we will complete the peer review of the draft report and issue a final report and response to comments document.

Fall-run Chinook salmon and steelhead/rainbow trout spawning (Lower Alluvial Segment)

We completed the hydraulic model production runs for all five study sites over the range of simulation discharges, computed fall-run Chinook salmon and steelhead/rainbow trout spawning habitat over a range of discharges for the five spawning sites and completed a draft report in FY 2009. A peer review of the draft report was completed in FY 2010. A final report and response to comments document will be completed in FY 2011.

Fall-run Chinook salmon and steelhead/rainbow trout rearing (Lower Alluvial Segment)

We will compute fall-run Chinook salmon and steelhead/rainbow trout rearing habitat over a range of discharges for the five spawning sites and five rearing sites and issue draft and final reports in FY 2011.

SOUTH COW CREEK

Redd Mapping

Fall-run Chinook salmon spawning

Redd mapping of the lower 5.25 miles of South Cow Creek was conducted October 27-30, 2008, November 24-26, 2008 and Nov 16-18, 2009 at flows of, respectively, 16.3, 22 and 17.9-20.7 cfs. Data for redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction (Gard 1998). Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. Measurements were taken with a wading rod and a Marsh-McBirney^R model 2000 velocity meter. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. The location of each redd was recorded with a Real Time Kinematic (RTK) Global Positioning System (GPS) unit, with the measurement taken at the center of the pit of the redd.

Upstream Passage Assessment

Fall-run Chinook salmon adult

An upstream passage assessment was conducted Nov 16-18, 2009 at flows of 17.9-20.7 cfs. The minimum thalweg depth was recorded for each riffle and cascade that was identified in the mesohabitat mapping for the lower 5.25 miles of South Cow Creek. The hydraulic models of the study sites were used to estimate the flow that would allow upstream passage of adult fall-run Chinook salmon by determining what flow would result in a minimum thalweg depth of 0.8 feet (Thompson 1972) for each of the riffles located in our study sites.

Hydraulic and Structural Data Collection

Juvenile fall-run Chinook salmon rearing

Hydraulic and structural data collection for the Poole, Jones, and Farrell study sites was completed in FY 2010. Two sets of high flow water surface elevations were collected for Poole, Jones, and Farrell sites. Due to lack of sufficient funds and time constraints, we were unable to collect data on the Sabanovich study site and eliminated it from the study.

We collected the data between the inflow and outflow transects by obtaining the bed elevation and horizontal location of individual points with a total station or survey-grade RTK GPS, while the substrate and cover (Tables 1 and 2) was visually assessed at each point. Bed topography data collection was completed for the Poole, Jones, and Farrell sites.

Hydraulic Model Construction and Calibration

Juvenile fall-run Chinook salmon rearing

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated. The PHABSIM transect at the outflow end of each site is calibrated to provide the water surface elevation (WSEL) at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by the PHABSIM transect at the inflow end

Table 1
Substrate Descriptors and Codes

Code	**Type**	**Particle Size (inches)**
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 – 1
1.2	Medium Gravel	1 – 2
1.3	Medium/Large Gravel	1 – 3
2.3	Large Gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small Cobble	3 – 4
3.5	Small Cobble	3 – 5
4.6	Medium Cobble	4 – 6
6.8	Large Cobble	6 – 8
8	Large Cobble	8 – 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10 – 12

of the site[4]. The River2D model is run at the flows at which the validation data set was collected, with the output used to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

All data for the four fall-run Chinook salmon rearing sites have been compiled and checked. PHABSIM calibration and construction and calibration of the 2-D hydraulic model have been completed for all four sites and running the production runs for the simulation flows has been completed for two of the four sites. The production run for the simulation flows for the remaining two sites will be completed in FY 2011.

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[4] This is the primary technique used to calibrate the River2D model.

Table 2
Cover Coding System

Cover Category	Cover Code
No cover	0
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

Habitat Suitability Criteria Development

Juvenile fall-run Chinook salmon rearing

We will be using habitat suitability criteria developed for the Lower Alluvial Segment of Clear Creek for fall-run fry and juvenile Chinook salmon rearing. These criteria were developed in FY 2010 for the Clear Creek study discussed above, using depth, velocity, adjacent velocity and cover data collected in FY 2007 on 495 occupied and 618 unoccupied locations. Criteria were developed using logistic regression for both fry (less than 60 mm SL) and juvenile (greater than 60 mm SL) fall-run Chinook salmon.

Habitat Simulation

Juvenile fall-run Chinook salmon rearing

Using the fall-run Chinook salmon fry and juvenile rearing HSC developed for the Lower Alluvial Segment of Clear Creek, fall-run Chinook salmon fry and juvenile rearing habitat will be computed over a range of discharges for the four rearing sites in South Cow Creek. Completion of this phase of the study will occur in FY 2011. We anticipate completing draft and final reports on the 2-D modeling of the fall-run Chinook salmon juvenile rearing in South Cow Creek in FY 2011.

STANISLAUS RIVER

Biological Verification Data Collection

Chinook salmon spawning

On December 7-10, 2009, we surveyed the entire extent of four IFIM sites (Two-mile Bar, Horseshoe, Valley Oak and McHenry) established by the Bureau of Reclamation for fall-run Chinook salmon redds. Data for redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction (Gard 1998). Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. Measurements were taken with a wading rod and a Marsh-McBirney^R model 2000 velocity meter. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. The location of each redd was recorded with a survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS) unit, with the measurement taken at the center of the pit of the redd. Our spawning biological verification data collection was largely unsuccessful, with a total of 12 redds found in the four sites. Two of the sites (Two-mile Bar and McHenry) did not have any redds.

Juvenile fall-run Chinook salmon rearing

The objective of this work was to collect data to verify the habitat modeling of the four IFIM sites established by the Bureau of Reclamation. On April 5-8, 2010, we conducted snorkel surveys of the banks of 650 feet of Two-mile Bar, 1,462 feet of Horseshoe, 1,617 feet of Valley Oak and 300 feet of McHenry for young-of-year (YOY) fall-run Chinook salmon and steelhead/rainbow trout. Depth, velocity, adjacent velocity[5] and cover data were collected both at locations with YOY salmonids and at locations which were not occupied by YOY fall-run Chinook salmon and steelhead/rainbow trout (unoccupied locations). Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator. One person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY spring-run Chinook salmon or steelhead/rainbow trout were observed. The snorkeler recorded the tag number, the species, the cover code[6] and the number of individuals observed in each 10-20 mm size class on a Poly Vinyl Chloride (PVC) wrist cuff. The average and maximum distance from the water's edge that was sampled, and the length of bank sampled (measured with a 300-foot-long tape) was also recorded.

A 300-foot-long tape was put out with one end at the location where the snorkeler finished and the other end where the snorkeler began. At every 40-foot interval along the tape, a the stadia rod was used to measure out the distance from the bank given in the data book. If there was a tag within 3 feet of the location, "tag within 3" was recorded on that line in the data book and the field crew proceeded to the next 20-foot mark on the tape, using the distance from the bank on the next line. If there was no tag within 3 feet of that location, the depth, velocity and adjacent velocity at that location was measured with a wading rod and velocity meter, and the cover at that location was noted. Depth was recorded to the nearest 0.1 foot and average water column velocity and adjacent velocity were recorded to the nearest 0.01 ft/s. For occupied locations, the tags were retrieved, the depth and mean water column velocity at the tag location were measured, the adjacent velocity for the location were measured, and the data was recorded for each tag number. Data taken by the snorkeler and the measurer were correlated at each tag location. The location of both occupied and unoccupied points was recorded with a survey-grade RTK GPS unit.

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[5] The adjacent velocity was measured within 2 feet on either side of the location where the velocity was the highest, consistent with the definition of adjacent velocity. Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon and steelhead/rainbow trout reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Stanislaus River is around 4 feet (i.e., 4 feet x ½ = 2 feet). This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth.

[6] If there was no cover elements (as defined in Table 2) within 1 foot horizontally of the fish location, the cover code was 0.1 (no cover).

Our rearing biological verification data collection was largely unsuccessful, with a total of 9 observations of YOY salmonids in the four sites. Two-thirds of the observations were at the Two-mile Bar site. One site (McHenry) did not have any YOY salmonids. Four of the observations were fall-run Chinook salmon, ranging in size from 35 to 50 mm TL, and five were steelhead/rainbow trout, ranging in size from 40 to 80 mm TL.

Hydraulic Model Construction and Calibration

Fall-run Chinook salmon and steelhead/rainbow trout spawning and rearing

The topographic data used for the four sites included total station data collected by the Bureau of Reclamation, as well as previously collected Light Detection And Ranging (LIDAR) and Sound Navigation And Ranging (SONAR) data. The LIDAR and SONAR data was also used to develop the topography for a two to four-channel-width upstream extension for the Horseshoe, Valley Oak and McHenry sites. Since SONAR data was not available for the Two-mile Bar site, an artificial one-channel-width upstream extension was used, based on the cross-sectional profile at the upstream end of the site. The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The PHABSIM transect at the outflow end of each site is calibrated to provide the WSEL at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by the PHABSIM transect at the inflow end of the site[7]. The River2D model is run at the flows at which the validation data set was collected, with the output used to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.
All data for the four sites have been compiled and checked. The bed files and computational meshes for two of the four sites were completed in FY 2010. The remaining hydraulic model construction and calibration will be completed in FY 2011.

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[7] This is the primary technique used to calibrate the River2D model.

FISHERIES INVESTIGATIONS

Clear Creek Biovalidation

Methods

This task had the following six subtasks: 1) compare 2008 juvenile habitat use to juvenile Combined Suitability Index (CSI); 2) compare 2005 juvenile habitat use to juvenile CSI; 3) compare 2007 Spawning Area Mapping (SAM) to adult CSI; 4) compare 2008 SAM to adult CSI; 5) after building fall-run Chinook salmon adult criteria from unoccupieds in model, rerun earlier analysis comparing SAM and CSI; and 6) review statistical approach for these. The juvenile habitat use and spawning area mapping data was supplied by the Red Bluff Fish and Wildlife Office. Discussions during FY 2009 narrowed the scope of this work to examining data from restoration sites 3A and 3B. CSI values for site 3B will be computed from the River2D model developed for the Clear Creek IFIM study. CSI values for site 3A will be computed from a River2D model that will be developed using: 1) bed topography data previously collected by Graham Matthews and Associates; 2) substrate and cover polygon mapping that the Energy Planning and Instream Flow Branch conducted in FY 2009; and 3) transect data collected by the Energy Planning and Instream Flow Branch in FY 2009.

Results

Transect and substrate and cover polygon data were completed in FY 2009. The substrate and cover polygon data will allow us to assign substrate, cover and bed roughness values to each of the bed topography data points previously collected by Graham Matthews and Associates. We plan to conduct hydraulic modeling construction and calibration and habitat simulation for the 3A study site in FY 2011 once we have obtained the bed topography data previously collected by Graham Matthews and Associates. After we have completed the hydraulic modeling construction and calibration and habitat simulation for the 3A and 3B study sites, we will be able to complete the first five subtasks. The sixth subtask was completed in FY 2009 by Western Ecosystems Technology, Inc. under a Cooperative Agreement funded by the Energy Planning and Instream Flow Branch. We plan to complete this entire task in FY 2011.

American River Gravel Placement Monitoring and Design Modeling

Methods

The purpose of this task was to collect topography data to be used in the design for gravel placement in the American River and to model the amount of fall-run Chinook salmon and steelhead spawning habitat, over a range of flows, that would be created by four different alternative designs for the gravel placement. We had previously collected topography data for a portion of this site (located upstream of Sunrise Bridge), as well as downstream of the site, in 1998 (U.S. Fish and Wildlife Service 2003). High flows in 2006 resulted in downcutting of the main stream river channel at the upstream end of an island downstream of the site. As a result, a side channel that used to flow at a total American River flow of 800 cfs no longer had flow until the total American River flow reached an estimated 3,200 cfs. The gravel placement design consisted of both placement of spawning-sized material near the upstream end of our 1998 site to create spawning habitat, and placement of larger material in the downcut main channel location to raise the water surface at this location, so that the side channel would once again flow at lower American River flows.

We collected the following data to assist in the design of the gravel placement: 1) topographic surveys at both locations where material was to be placed; 2) measurement of the WSEL at the location of one of our 1998 transects, located upstream of the island, to determine how much the WSEL had dropped as a result of the channel downcutting; 3) resurveying the cross-sectional bed profile at two of our 1998 transects that were located in the side channel; 4) surveying the thalweg profile of the side channel. The topographic surveys at the placement locations were performed using survey-grade RTK GPS units for the dry and shallow portions of the locations, and with a combination of an Acoustic Doppler Current Profiler (ADCP) and a survey-grade RTK GPS unit for the deeper portions. For each traverse with the ADCP, the RTK GPS was used to record the horizontal location and WSEL at the starting and ending location of each traverse, while the ADCP provided depths and distances across the traverse. The WSEL of each ADCP traverse is then used together with the depths from the ACDP to determine the bed elevation of each point along the traverse. For the location where the spawning-sized material was to be placed, we also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit, and mapped in substrate and cover polygons for the areas sampled with the ADCP; the vertices of these polygons were recorded with the survey-grade RTK GPS unit. The RTK GPS data had an accuracy of 0.1 foot horizontally and vertically. The measurement of the WSEL at the location of one of our 1998 transects and the survey of the thalweg profile of the side channel were performed with the survey-grade RTK GPS unit, while the re-survey of the side channel transects were performed with an autolevel and stadia rod.

We developed hydraulic and habitat models for the upstream gravel location by combining the following topographic data sources: 1) the topographic data we collected in 2010 for the gravel placement area; 2) our 1998 topographic data for a downstream extension from the downstream extent of our 2010 data collection to the 1998 transect location upstream of the island; 3) coarse-scale topographic data from upstream of our 2010 data collection supplied by the Bureau of Reclamation; and 4) topographic data for the gravel to be placed, for four different designs, supplied by cbec, inc. eco engineering. The first three data sources were used for all four designs. The topographic data for the 2-D model (contained in bed files) was first processed using the R2D_Bed software, where breaklines were added to produce a smooth bed topography. The resulting data set was then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh was used in River2D to simulate depths and velocities at the flows that were simulated (1,000 to 5,000 cfs by 1,000 cfs increments). The 1998 stage-discharge relationship for our transect upstream of the island was used as the downstream boundary condition for the hydraulic models of the four designs. The hydraulic models were used with fall-run Chinook salmon and steelhead spawning criteria that we previously developed on the American River (U.S. Fish and Wildlife Service 2000) and channel index files, using the substate data we collected in 2010 and an assumed substrate of 1-3 inches for the gravel to be placed, to generate the amount of fall-run Chinook salmon and steelhead spawning habitat, for flows of 1,000 to 5000 cfs, for the four designs.

Results

The measurement of the WSEL at the 1998 transect upstream of the island indicated that the WSEL at that location had dropped 1.29 feet as a result of the downcutting of the main channel at the upstream end of the island. The data collected from the side channel did not indicate any significant change in the topography of the side channel since 1998. Figures 1 and 2 show the predicted spawning habitat (i.e., weighted usable area) that would result from the four designs.

Discusssion

The modeling of the designs was valuable both to quantify the relative benefits of the designs with regards to spawning habitat, and to enable agency staff to visualize the habitat that would result from the designs. Evaluation of the four designs was complicated by the varying amounts of gravel used in the different designs. We recommend that the alternative designs for the 2011 gravel addition all be based on the same volume of gravel to be added.

Sacramento and American River and Clear Creek Redd Dewatering Monitoring

Methods

The purpose of this task was to quantify the benefits of using water dedicated to fish and wildlife benefits under Section b(2) of the CVPIA to reduce dewatering of fall-run Chinook salmon and steelhead/rainbow trout redds in the Sacramento and American Rivers and Clear Creek. On October 26-29, 2009, we surveyed the shallow portions of eight two-dimensional hydraulic and habitat modeling sites on the Sacramento River between Keswick Dam and Battle Creek, that we had developed using hydraulic and structural data that we collected in 1997 to 1999, for fall-run Chinook salmon redds. In addition, we relocated transect pins and vertical benchmarks for these sites, to be able to convert the redd locations from real-world Universal Transverse Mercator (UTM) horizontal coordinates into the local coordinate systems that we had used for these sites. Data for redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction (Gard 1998). Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. Measurements were taken with a wading rod and a Marsh-McBirney^R model 2000 velocity meter. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the

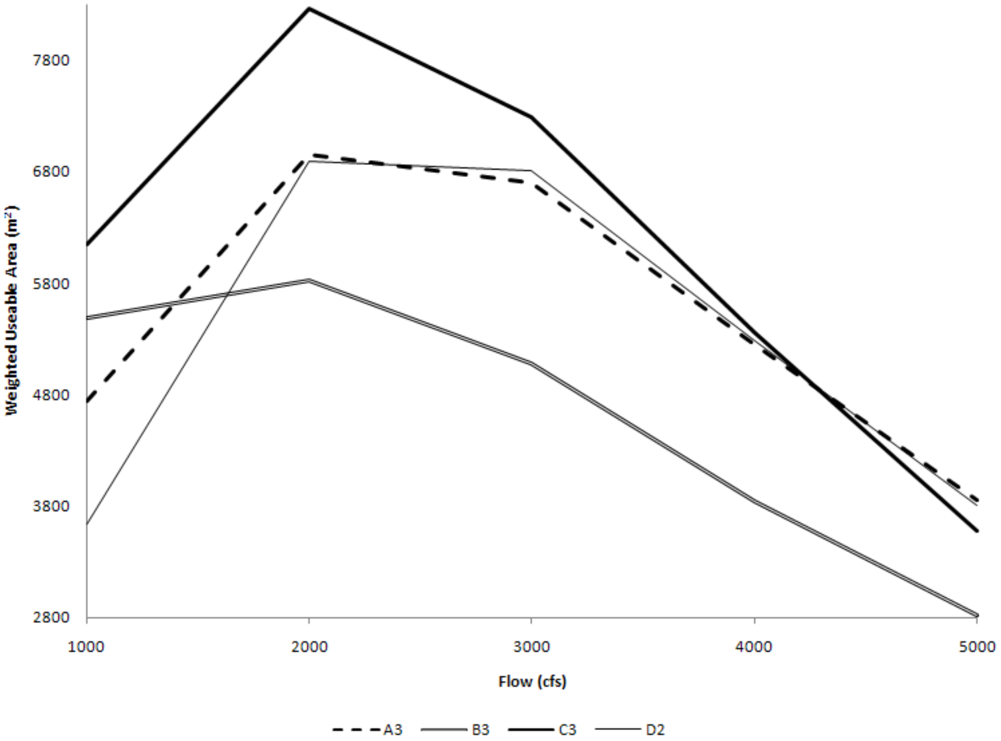

Figure 1
WUA for Fall-run Chinook Salmon Spawning for four designs

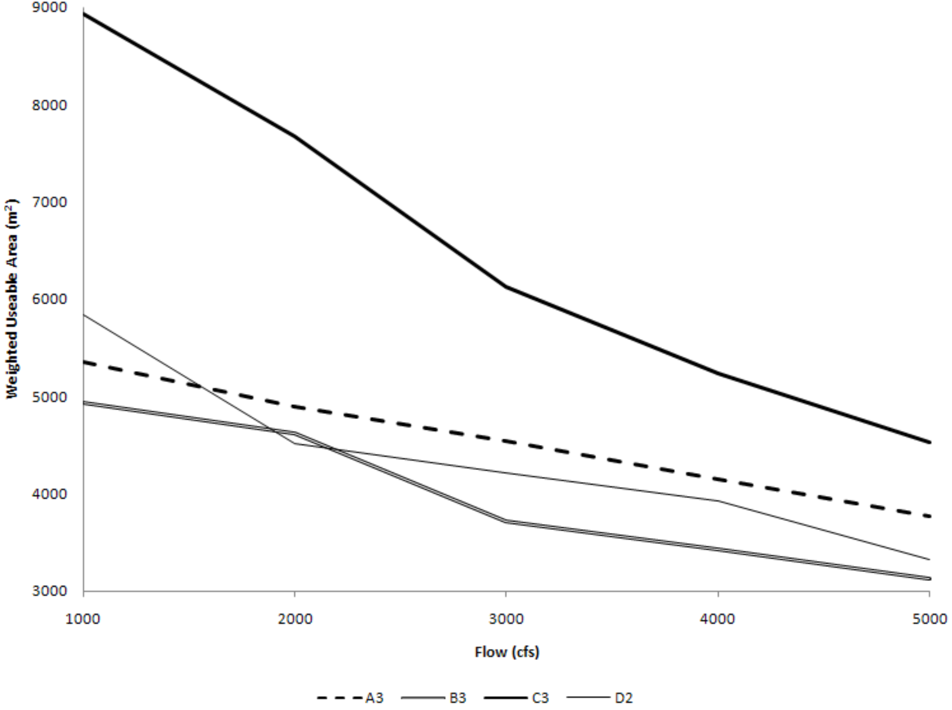

Figure 2
WUA for Steelhead Spawning for four designs

pit; and 3) in the tailspill. The location of each redd was recorded with a survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS) unit, with the measurement taken at the center of the pit of the redd. On November 23-25, 2009, we collected the same data for five sites on the American River that we had developed using hydraulic and structural data that we collected in 1997 to 1998, for shallow fall-run Chinook salmon redds. On February 16-18, 2010, we collected the same data for steelhead/rainbow trout redds in our five American River sites.

For Clear Creek, the Red Bluff Fish and Wildlife Office supplied us with spawning area mapping polygons for fall-run Chinook salmon and locations for steelhead/rainbow redds. From this data, we used the redds located in five two-dimensional hydraulic and habitat modeling sites on the lower alluvial segment of Clear Creek, that we had developed using hydraulic and structural data that we collected in 2006 to 2007. Since we had established these sites based on UTM coordinates, we were able to convert the redd locations to local coordinates by just subtracting given numbers from the UTM coordinates. For the spawning area mapping, we determined how many redds were in each mapped polygon by dividing the area of the polygon by 211 ft^2/redd[8] and then equally spaced points for that many redds in each polygon, using GIS.

We ran the hydraulic models for all of the study sites in all three streams at the lowest flow that would have been present if b(2) water had not been used, and plugged in the surveyed redd locations to determine what the depth and velocity would have been at each redd location at that flow. Using the criteria in Table 3[9], we then determined how many of the redd locations would have been dewatered if b(2) water had not been used.

Results

For the Sacramento River, we found a total of 44 shallow fall-run Chinook salmon redds in our eight study sites. For the American River, we found a total of 231 shallow fall-run Chinook salmon redds and 35 shallow steelhead or late-fall-run Chinook salmon redds in our five study sites. Likely a large portion of the American River steelhead redds were actually late-fall-run Chinook salmon redds, which spawn at the same time as steelhead. The only redds we were able to positively identify were those with fish on them; of these, four had late-fall-run Chinook salmon on them and three had steelhead on them. For all of the Sacramento and American River sites, we were able to locate enough transect pins or vertical benchmarks in each site to enable us

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[8] This was the average area of single-redd fall-run Chinook salmon polygons in 2003 on Clear Creek.

[9] A redd was considered dewatered if the depth was less than the depth in Table 3 or the velocity was less than the velocity in Table 3. The depth criteria were based on the assumption that redds would be dewatered if the tailspills were exposed, while the velocity criteria were based on the assumption that there would be unsufficient intragravel flow through the redd if the velocity was less than the lowest velocity at which we found a redd. See U.S. Fish and Wildlife Service (2006).

Table 3
Dewatering Criteria

Stream	Species/Race	Depth (ft)	Velocity (ft/s)
Sacramento	Fall-run	0.5	0.32
American	Fall-run	0.5	0.10
American	Steelhead[10]	0.2	0.30
Clear	Fall-run	0.5	0.10
Clear	Steelhead	0.2	0.61

to convert the redd locations from real-world Universal Transverse Mercator (UTM) horizontal coordinates into the local coordinate systems that we had used for these sites. For Clear Creek, there were a total of 526 fall-run Chinook salmon redds and 84 steelhead redds in our five study sites.

Figures 3 through 5 show what the Sacramento and American River and Clear Creek flows were from initiation of spawning through emergence of fry and what the flows would have been if b(2) water had not been used. No b(2) water was used on the Sacramento River in FY 2010; accordingly, no redds would have been dewatered if b(2) water had not been used. Use of b(2) water potentially prevented dewatering of 102 (19%) fall-run Chinook salmon redds and 50 (60%) steelhead redds on Clear Creek. For the American River, use of b(2) water potentially prevented dewatering of 84 (36%) shallow fall-run Chinook salmon redds and 14 (40%) shallow steelhead redds.

Discusssion

The redd dewatering monitoring proved to be an effective method to quantify the benefits of using b(2) water for reducing redd dewatering. However, the relative benefits of using b(2) water for redd dewatering, as compared to other uses of b(2) water, is difficult to estimate. Questions that still remain to be answered included how to extrapolate the monitoring results to the entire stream in question, and if the sites have changed to the extent that the results are no

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[10] These criteria were developed for steelhead, but were applied to both steelhead and late-fall-run Chinook salmon redds, as we were unable to determine which species created most of the redds.

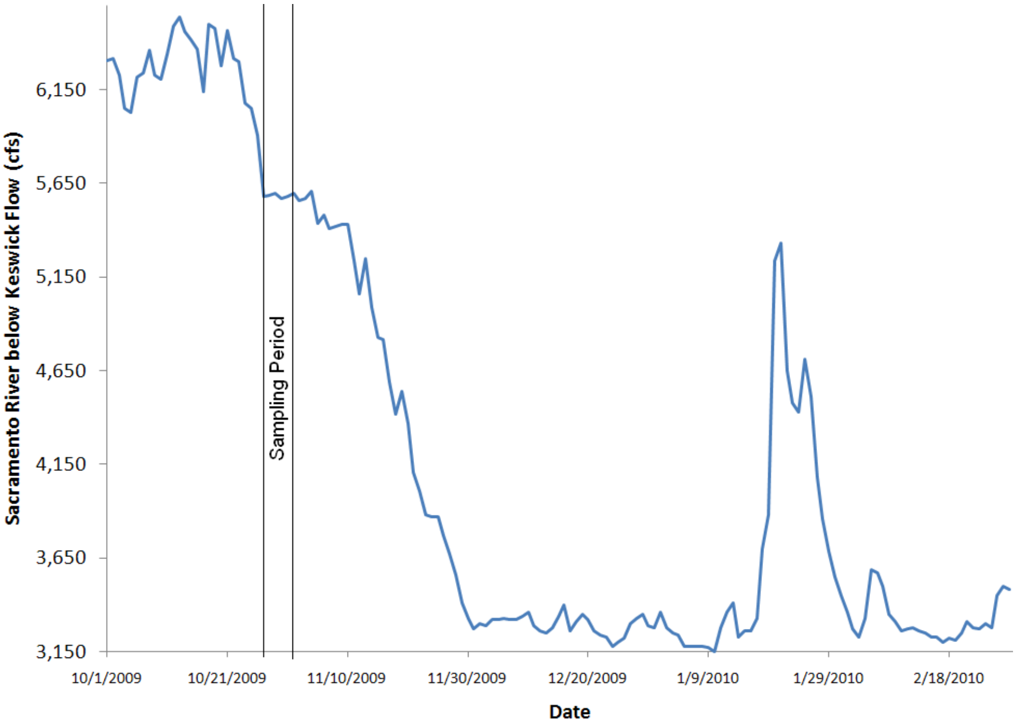

Figure 3
Sacramento River flows for FY 2010 b(2) redd dewatering montoring

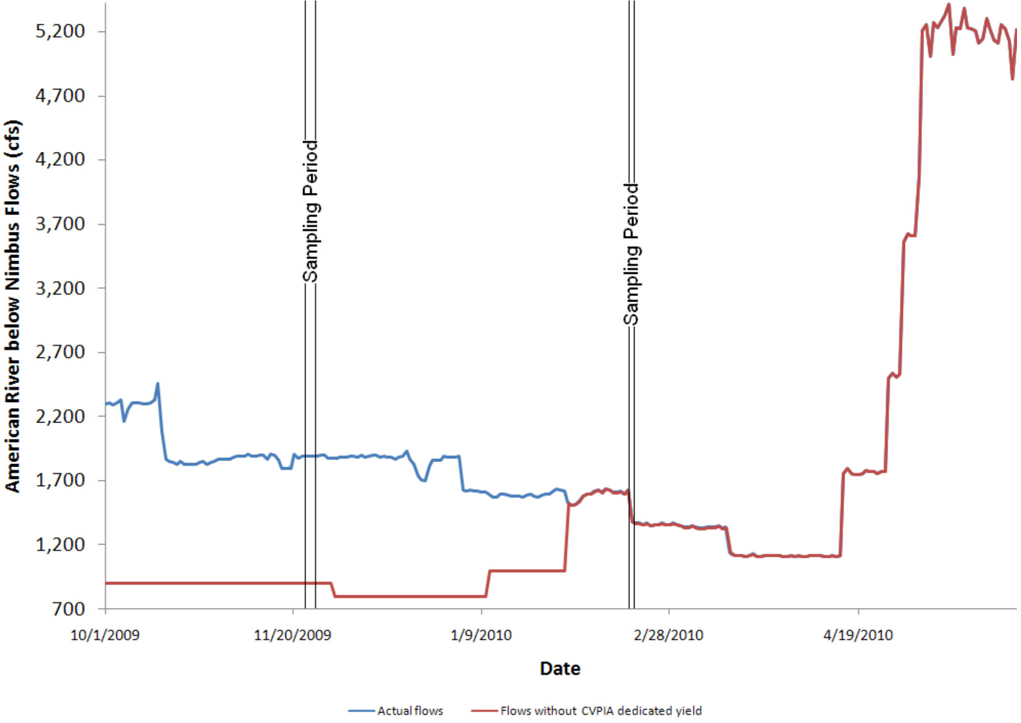

Figure 4
American River flows for FY 2010 b(2) redd dewatering montoring

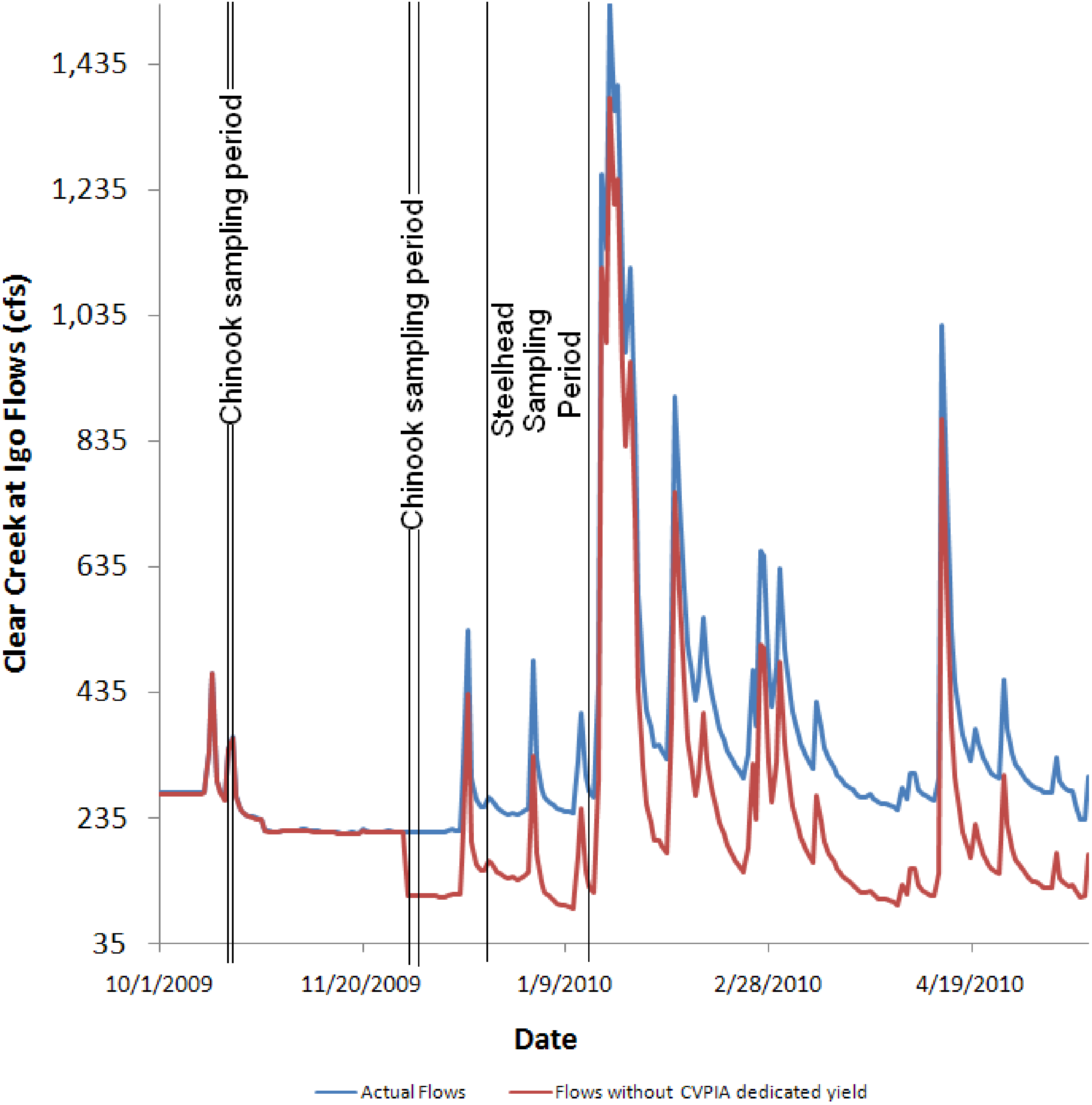

Figure 5
Clear Creek flows for FY 2010 b(2) redd dewatering montoring

longer valid. On a qualitative level, the Sacramento River sites have not appeared to change, while several of the American River sites (Sunrise and Above Sunrise) have changed due to restoration projects and river downcutting. We plan to perform a quantitative evaluation of this question in FY 2011 using the measured depths and velocities at the redd locations, by comparing them to simulated depths and velocities at the flow present during data collection. In addition, we plan to use a current hydraulic and habitat model of the lower portion of the Sunrise site, developed by NMFS Santa Cruz staff, and the hydraulic and habitat model we will be developing of the restored Above Sunrise site in FY 2011, as part of the American River gravel placement monitoring, to evaluate the benefits of b(2) water for these two sites in FY 2011. A source of uncertainty in the American River results is the relative benefit of b(2) water for steelhead versus late-fall-run Chinook salmon; regardless, the monitoring demonstrates benefits overall to anadromous salmonids. For Clear Creek, most of the fall-run Chinook salmon redds were dewatered as a result of the depth dewatering criteria, while most of the steelhead redds were dewatered as a result of the velocity dewatering criteria, indicating that there may be different mechanisms causing egg and pre-emergent fry mortality from redd dewatering for different species.

Red Bluff Interim Pumping Plant Screens Hydraulic Evaluation

Methods

On May 10 through September 2, 2009, the Service measured near-screen velocities on the 10 cone screens located on the intake for the Red Bluff Interim Pumping Plant (Appendix A). Two sets of measurements were made while the pumps were operating, while one set was made when the pumps were off. Approach and sweeping velocities were measured with a SonTek 16 Mhz Acoustic Doppler Velocimeter (ADV) provided by the CVPIA Anadromous Fish Screen Program. The ADV measured near-screen velocities 3 inches from the screen face. Velocities were measured at 48 locations, in an array of 6 depths and 8 positions around each screen. For the upstream-most screen, velocities were measured at 96 locations. Velocity measurements were recorded at a rate of 25 HZ for a minimum of 60 seconds.

Results

Approach velocities on Screens 8 – 10 did not exceed 0.45 ft/s, but none of these screens consistently had approach velocities well distributed over all screen areas. Flow distribution on screen numbers 1 – 5 were heavily influenced by river current. Approach velocities in areas receiving direct impact of the current far exceeded the design target value of 0.35 ft/s. Data collected when the pumps were not operating indicated that the high approach velocities were due to a combination of river current and pumping. Approach velocities exceeded 0.33 ft/s for at least one location for all screens except Screen 10 when the pumps were not operating.

Discussion

Overall, the results of this testing confirm that the use of conical screens in areas where there is a dominant current in the water body is problematic, and that the use of conical screens should be restricted to the areas where they were developed to operate (tidal and back water areas where water depths are shallow and there is no dominant current in the water body) to reduce the probability for impingement of fish onto the screen face. Based on the high approach velocities we measured when the pumps were not operating, we recommend that the screens and associated facilities be removed after 2011. When selecting where to reuse these screens, the screens should be used in tidal and back water areas where water depths are shallow and there is no dominant current in the water body. For 2011, the probability of impingement of fish onto the screen faces would be reduced by selectively using the downstream-most screens and minimizing pumping from the interim pumping plant, both in terms of pumping rates and length of time that the interim pumping plant is operated. While additional hydraulic monitoring of the interim pump screens is not warranted, we strongly recommend that hydraulic monitoring be performed for the flat-plate screens for the Red Bluff permanent pumping plant after the plant is operational, currently scheduled for 2012.

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APPENDIX A

Red Bluff Interim Pumping Plant Screens Hydraulic Evaluation

Results From Hydraulic Evaluation Of Cone Screens At Tehama Colusa Canal Authority's Interim Pumping Plant, May 10 – September 2, 2010, Red Bluff, California

Team of evaluation participants:

- Mark Gard, Ph.D., U.S. Fish and Wildlife Service (USFWS)
- Ed Ballard, USFWS
- Rick Williams, USFWS

Background

Reclamation built the interim pumping plant as a stopgap measure in early 2009 to divert water from the Sacramento River to the Tehama Colusa (TC) Canal during annual "gates out" periods for the three years of construction of a long-term pumping plant. Designed in response to a December 2008 mandate for delaying "gates in" operation of the Red Bluff Diversion Dam (RBDD) until June annually, beginning in 2009, the plant uses the most readily available "off-the-shelf" technology.

The interim pumping plant has ten vertical pumps each with a design capacity of 50 cfs (Figure 1). Pumps 1 through 5 and 10 are 300 Horsepower (HP), while Pump 6 is 350 HP and Pumps 7 through 9 are 400 HP. Pumps are paired to feed five, 36 inch conveyance pipes that lead to the settling basin at the head of the TC Canal. Each pump is screened with a 14 ft diameter conical fish screen manufactured by Intake Screens, Inc (ISI). Each screen has a total surface area of approximately 180 square feet and has a rotating brush cleaning system for debris removal that operates on a programmable timer. Conical screens were developed to operate in tidal and back water areas where water depths are shallow and there is no dominant current in the water body. They were chosen for this project based on the shallow water conditions at the proposed site even though it was doubtful that approach and sweeping velocity criteria could be met with this screen design[1]. A condition of accepting the proposed design was that velocities would be measured across the surface of each screen and the results provided to DFG and NMFS to assure they meet state and federal fish screening criteria[2]. An initial hydraulic evaluation of the cone screens was made on June 1-10, 2009 by an interagency team (U.S. Fish and Wildlife Service 2010).

Goal of Hydraulic Evaluation

Goals of fish screen hydraulic evaluations are typically 1) to measure near screen water velocities under a near worst case scenario of diversion rate and river flows expected to be encountered throughout the life of the facility; and 2) to adjust flow control baffles to distribute flow uniformly over the entire screen surface. Given the atypical use of the cone screen

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[1] NMFS fish screen criteria document, *Fish Screening Criteria for Anadromous Salmonids* (1997) states, "screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity." The CDFG document, *Fish Screening Criteria* (June, 2000) states, "[t]he design of the screen shall distribute the approach velocity uniformly across the face of the screen."

[2] Refer to conditions 6.4 and 6.7 of Incidental Take Permit No. 2081-2009-006-01 issued by the California Department of Fish and Game.

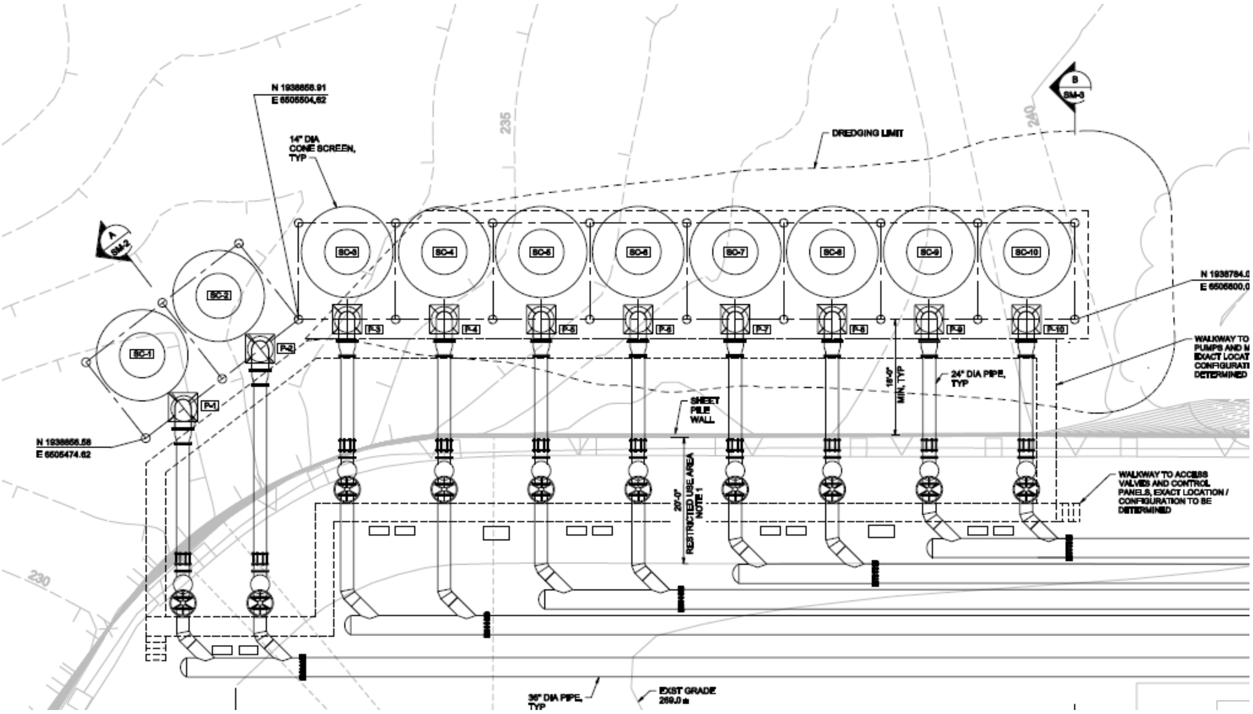

Figure 1. Layout of pumps and screens at the interim pumping plant. Screens and pumps were numbered 1 through 10, left to right.

technology at the interim pumping plant, there was a third goal to this evaluation: to determine whether or not the cone screens could be operated in conformance with the State and federal fish screening criteria. The goal of the 2010 testing was to evaluate the hydraulic performance of the cone screens under a range of river flows and pump operating conditions. An additional goal was to determine if potential impingement would occur at the screens even if the pumps were not operating. The null hypotheses for the above goals were: 1) that the cone screens, under a range of river flows and pump operating conditions, would meet State and federal fish screening criteria; and 2) that potential impingement would not occur at the screens even if the pumps were not operating.

Methods

A SonTek 16 MHz Acoustic Doppler Velocimeter (ADV) was used to measure near-screen velocities in three dimensions: X, Y, and Z. The ADV was positioned such that approach velocity was measured directly by the X component of the probe. Sweeping velocities were calculated as the resultant of Y and Z measured values. Raw data for each location were stored in separate files and processed with WinADV, a program developed by the U.S. Bureau of Reclamation. Point-average velocities were processed with Microsoft Excel to produce charts and graphs. Total discharge for each screen was calculated based on screen area and approach velocities as a quality control procedure. The formula to calculate the total discharge was as follows:

$$\text{Total Discharge} = \sum \text{screen area}_{\text{depth position } i} \text{ x average approach velocity}_{\text{ depth position } i}$$

Data were collected on three occasions between May 10 and September 2 as shown in Table 1. Pumps were operating on May 10-13 and August 31- September 2 but were not operating on June 7-10. Pump 10 was out of commission on August 31- September 2. A shallow draft, aluminum boat owned and operated by USFWS was used to provide safe access to the screens. The boat was tied up to structural piles typically within four feet of the top of each screen unit. This distance was thought to provide sufficient buffer against interference with screen velocities.

Screen area was divided into forty eight zones in an array of six depths and eight positions (bearings) around each screen unit for pumps 2 through 10 (Figures 2 and 3) and into ninety six zones in an array of six depths and sixteen bearings for pump 1. Velocity measurements were taken at or near the center of each zone. Positions for each measurement along each bearing and screen area for each zone are shown in Figure 4. ISI manufactured a jig to position the probe that attached to the screens' cleaning systems (Figure 4, Photo 1). By operating the cleaning system and adjusting the jig the ADV could measure near-screen velocities three inches from the screen face at nearly any point on the screen. The probe size prevented measuring velocities within the top two feet on each screen (Photo 2). Velocity measurements were recorded at a rate of 25Hz for a minimum of 60 seconds.

Results and Analysis

Plots of approach velocity and sweeping velocity data are shown in Appendices A and B, respectively. The plots show the distribution of velocities around the screen, with different lines for each position vertically on the screen. For the approach velocities, velocities that fall within the red polygon are negative approach velocities, where flow was coming out of the screen. Approach velocities on Screens 8 – 10 did not exceed 0.45 fps, but none of these screens consistently had approach velocities well distributed over all screen areas. Approach velocity distribution on screen numbers 1 – 5 were heavily influenced by the river current. Approach velocities in areas receiving direct impact of the current (i.e. the upstream surface of the screens) far exceeded the design target value. Velocity data indicate water will pass through the porous cones, entering the upstream side and exiting the downstream side. All screens showed water exiting the screen, indicated by negative approach velocities in the plots in Appendix A, for at least one location during at least one sampling period, although this effect was most pronounced for Screen 1.

Although the steel plate on the upstream side of Screen 1 successfully reduced flow through what would likely otherwise had been the hottest spot[3] on all screens, there were still high approach velocities on either side of the steel plate. Approach velocity measurements at bearing 270 degrees were taken directly over the solid plate and ranged from 0.17 to 0.56 fps when pump 1 was operating, despite having a solid barrier three inches away. Approach velocities to either side of the barrier plate at bearings 247.5 and 292.5 ranged from 0.41 to 1.28 and 0.82 to 1.41 fps, respectively, when pump 1 was operating. It is unknown what effect the plate had on approach velocities elsewhere on the screen. On a mass balance basis, the elimination of flow intake from the portion of the screen covered with the steel plate will increase approach velocities elsewhere on the screen. However, the plate accelerates flow parallel to the screen face immediately to the edge of the plate, possibly drawing water out of the screen due to the

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[3] The hottest spot refers to the location on the screen with the highest approach velocity.

Table 1. Pumping plant and river data.

Screen #/ Pump Pair	Date Tested	Recorded Paired Pumping Rate (cfs)	Measured Paired Pumping Rate (cfs)	River Flow at Bend Bridge (cfs)
7 & 8	5/10/10	47-76.6[4]	38.1, 24.3[5]	9,930
9 & 10	5/11/10	81.3 – 81.9	97.7	10,400
5 & 6	5/11/10	90.6 – 90.7	94.3	10,400
1 & 2	5/12/10	90.4 – 91.3	97.5	9,770
3 & 4	5/12-13/10	91.6 – 91.8	94.6	9,510 - 9,770
1	5/13/10	0[6]	5.6[7]	9,510
4 & 5	6/7/10	0	9.4, 1.9	17,500
6 - 9	6/8/10	0	-2.4, 2.2, 0.3, 3.7	16,800
2 – 3 & 10	6/9/10	0	4.2, 17.6, 1.4	14,600
7 & 8	8/31/10	74.5 – 75.4	61.8	8,950
5 & 6	8/31/10	89 - 90	76.7	8,950
3 & 4	9/1/10	90.8 – 91.4	92.8	9,100
1 & 2	9/1/10	90.3 – 90.4	92.0	9,100
9	9/2/10	50.9	42.3	8,960

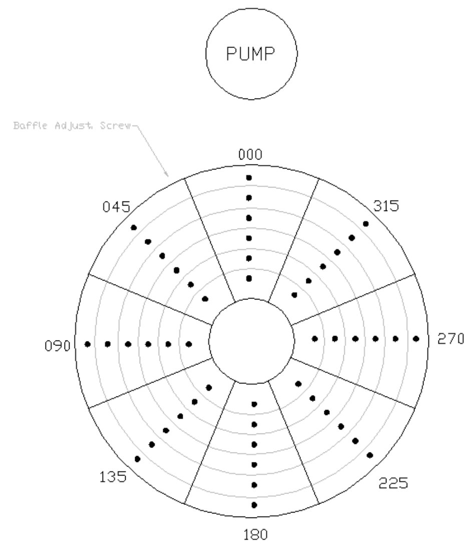

Figure 2. Plan view of locations for velocity measurements on each cone screen: six positions along each of eight bearing angles for a total of 48 measurement locations. The point naming convention used included the bearing angle (with "0" being closest to the pump column), and distance from the toe of the screen (0.5, 1, 2, 3, 4, 5) as shown in Figure 4.

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[4] The recorded flow for Pump Pair 7 & 8 was 47 cfs during testing of Screen 8 and was 76.6 cfs during testing of Screen 7.

[5] The first flow was the individual pumping rate for Pump 7, the second flow was the individual pumping rate for Pump 8 excluding two outliers at bearing 135 (-0.75 fps at height 4 and -1.19 fps at height 5).

[6] The flow rates of zero are the nominal flow since the pumps were off. On 5/13/10 with pumps 1 and 2 off, the recorded flow for this pump pair was negative 7 cfs.

[7] Calculated excluding velocities measured at 270 degrees (directly over the metal plate).

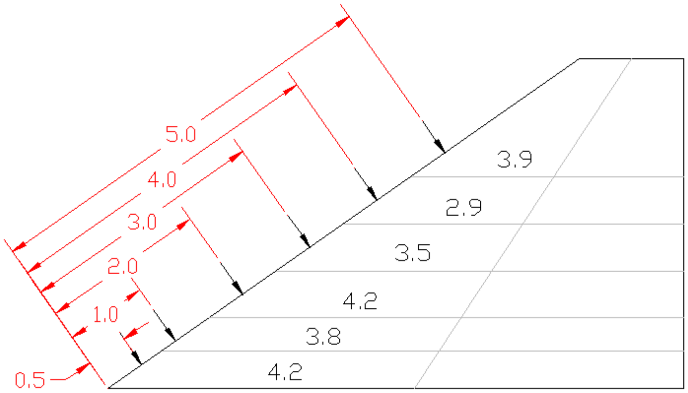

Figure 3. Partial section of a cone screen showing locations where water velocities were measured (arrows, distance values in feet) and the screen zone area associated with those measurements (square feet of screen area per zone). (Zones not shown to scale.)

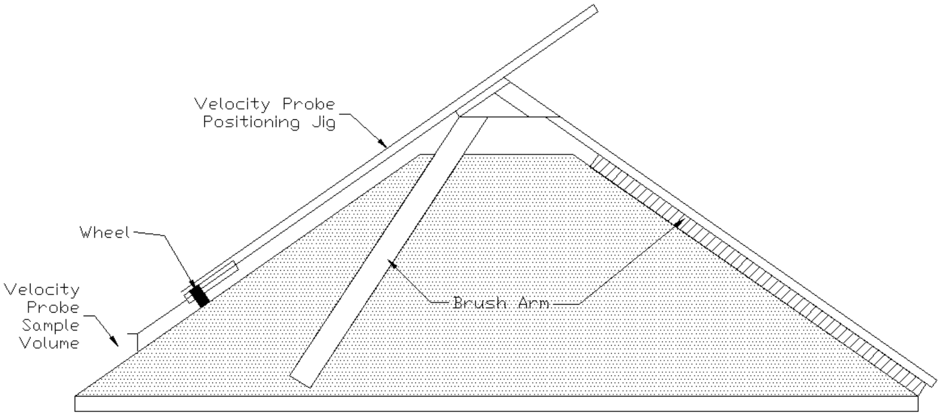

Figure 4. Diagram of equipment used for measuring velocities on cone screens. The jig arm could be raised or lowered to the appropriate elevation on the screen. The jig was attached to the rotating brush system for positioning the velocity probe around the circumference of the screen.

Photo 1. Mounting the velocity probe and positioning jig to the screen's cleaning system.

Photo 2. ADV probe in its highest position on the screen measured velocities two feet below the top of the screen panel.

Bernoulli effect (S. Thomas, personal communication). In any case, we recommend keeping the plate installed on Screen 1 to reduce approach velocities at what would have been the hottest spot on all screens.

Data collected when the pumps were not operating indicated that the high approach velocities were due to a combination of river current and pumping. Approach velocities exceeded 0.33 fps for at least one location for all screens except Screen 10 when the pumps were not operating. While the patterns of approach velocities were generally similar for the two sampling periods when the pumps were operating, there were some significant differences in some cases. For example, the approach velocities for Screen 8 were generally evenly distributed on May 10, but were not evenly distributed on August 31. This pattern indicates the importance of sampling under different conditions to fully evaluate the hydraulic conditions present around fish screens.

Sweeping velocities varied over a wide range depending on location. On Screen 1, sweeping velocities were 2 – 3 fps on the leading edge, 4 – 6 fps on either side, and approaching 0 fps on the downstream side. Sweeping velocity patterns were similar on Screens 2 and 3, but to a lesser magnitude. All screens had at least one point where the sweeping velocity was essentially zero.

Conclusions

Screens located in the main river current (Screens 1 – 3) had hot spots exceeding 1.0 fps, speeds that could present a serious hazard to juvenile salmonids and sturgeon, as well as other fish. Screens 4 - 6 also had hot spots in patterns similar to those on Screens 1 – 3, although to a lesser magnitude.

In 2009, with only 48 measurements, the overall average approach velocity on Screen 1 was less than zero, indicating more water was exiting the screen than entering it, which is erroneous since with the pump operating more water would be entering the screen than exiting it. The doubling of the number of measurement points on Screen 1 in 2010 substantially improved the diversion rate estimates, resulting in calculated diversion rates of 41.4 – 43.4 cfs. Accurate measurements of approach velocities when pumps are not in operation would likely require a similar level of effort, since with 48 measurements, differences between water entering and exiting the screen were as much as 17.6 cfs.

Comparisons of recorded and measured pumping rates (Table 1) indicate probable errors in both values. These data imply inaccuracies in the in line flow meters and errors in measurements of the approach velocities. If the actual diversion rate was less than what was measured, approach velocities will be greater and flow distribution may not be as uniform at the full diversion rate than they were when measured during this evaluation. There was no apparent pattern in recorded versus measured pumping rates, with recorded flows lower during the May sampling period but generally higher during the August to September sampling period. For a cone screen, theoretically diversion rates should be calculated by multiplying zone approach velocity by zone area where zone area is not actual screen areas but the area of a cone with a base diameter six inches greater than that of the screen (S. Thomas, personal communication). This would increase all calculated diversion rates and, theoretically, take into account water changing direction within the three inch area between the probe and screen. The accuracy of the measured pumping rates is limited due to the finite number of measurement points practical for taking measurements and the turbulence in the system, so inaccuracies associated with the calculated pumping rates needs to be considered in evaluating this data.

Based on measurements, calculated from approach velocity measurements, when the pumps were off, the measured discharges typically overestimate the flow[8] entering the screens, but the overestimate can range from 0.3 to 17.6 cfs. Errors in measured approach velocities are also suggested by two outliers on Screen 8 on May 10; while all of the other approach velocities were greater than zero in this case, the two outliers had measured approach velocities of -0.75 and -1.19 fps. Estimates of measured pumping rates likely could have been improved by measuring more velocities per screen. The measurements on pump 1 with the pump off suggest another possible source of error in the approach velocities, namely due to the velocities being measured three inches off the screen. The approach velocities of around 3 fps measured over the steel plate when pump 1 was off indicate that in some cases the current switches from approaching the screen to sweeping the screen at a distance closer than 3 inches from the screen.

Adjusting the flow control baffles on Screens 6 – 10 may be appropriate to increase the uniformity of flow distribution over the entire screen surface of those screens. Adjusting the existing baffles will not likely have much effect on water passing directly through screen units 1 – 5. A completely different baffle system which compartmentalizes screen sections, preventing flow from passing in one side and out the other, would greatly improve approach velocity distribution on screens located in an active current (i.e. Screens 1 – 5).

Sweeping velocity criteria were not always met, especially in the backwater area of Screens 6 – 10. When sweeping velocities are very low screen hot spots accumulate debris and present a greater hazard of impingement than a screen with greater sweeping velocities. In areas where sweeping velocities are very low manual debris removal is important to maintain satisfactory hydraulic conditions. Screen 7 appeared to have the biggest debris problem. Screen 10 had a one and a half foot by two foot sign that was adhering to the screen due to approach velocities on May 11, 2010; we removed the sign before starting velocity measurements. This observation suggests that manual inspection of the screens is needed on a regular basis to ensure that the screens are free of debris.

For most measurement locations, sweeping velocities exceeded approach velocities, in many cases by an order of magnitude or more. At those locations, fish coming in contact with the screen face will likely have sufficient velocity to be deflected off the screen and continue with the prevailing current. In areas where sweeping velocity is low, a screen with hot spots may lead to fish impingement (injury and/or mortality). Turbulence in the vicinity of Screens 1 – 4 may disorient juvenile fish allowing predator species to lie in wait in calmer waters for feeding opportunities.

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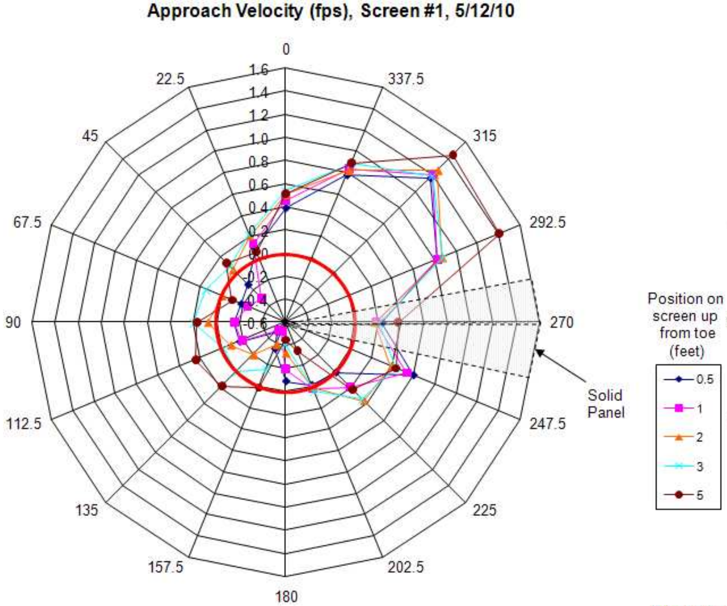
[8] Overestimate means any measured flow greater than zero since with the pumps off there should be no net flow entering the screens.

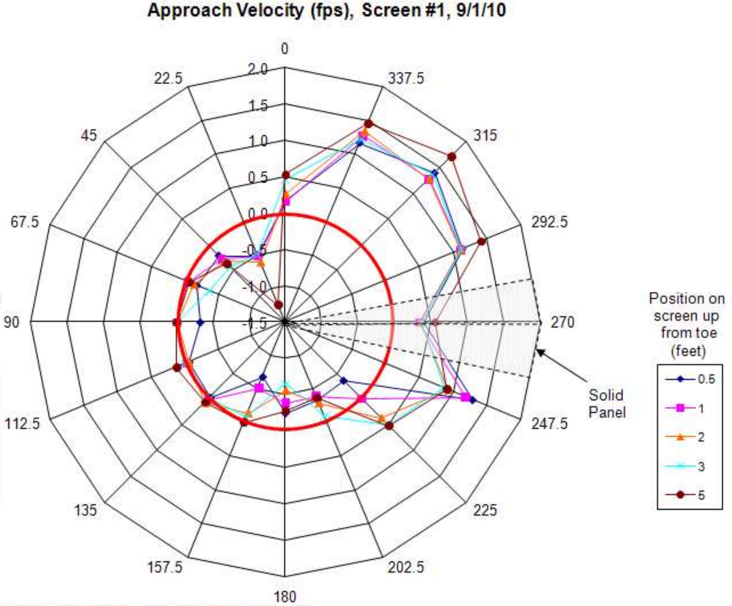
Reclamation’s interim pumping plant at Red Bluff was designed and constructed in early 2009, using “off-the-shelf” technology. The technology was recognized as being problematic for use in flowing waters, but was the best option available in the time allowed. This monitoring study confirms that use of these conical screens is problematic in the face of a strong, dominant current. The 8 conical screens are best suited for the shallow tidal and backwater environments for which they were designed. In the presence of strong flows, problems consistently occur with hot spots and failures to meet approach criteria. It is recommended that the screens be removed following the 2011 irrigation season. When selecting where to reuse these screens, the screens should be used in tidal and back water areas where water depths are shallow and there is no dominant current in the water body. For 2011, the probability of impingement of fish onto the screen faces would be reduced by selectively using the downstream-most screens and minimizing pumping from the interim pumping plant, both in terms of pumping rates and length of time that the interim pumping plant is operated.

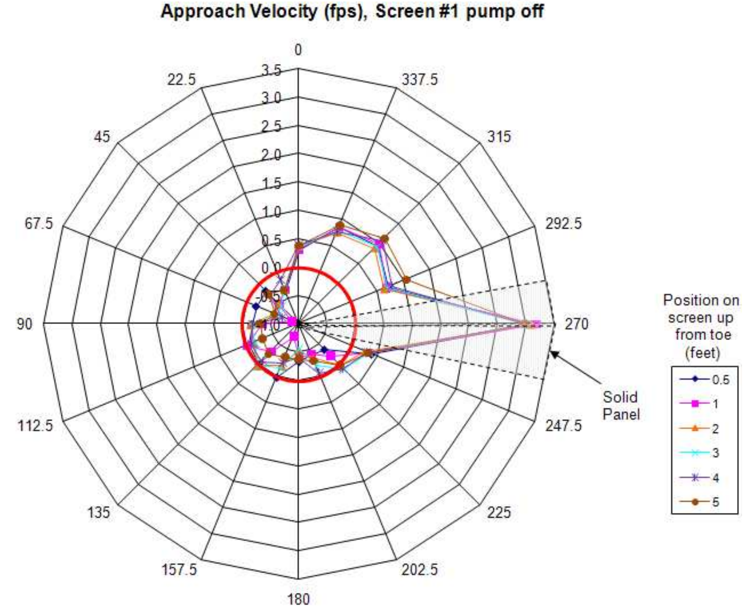
References

U.S. Fish and Wildlife Service. 2010. Identification of the instream flow requirements for anadromous fish in the streams within the central valley of California and fisheries investigations. U.S. Fish and Wildlife Service: Sacramento, CA.

Appendix A – Approach Velocities


Approach Velocity (fps), Screen #1, 5/12/10


Approach Velocity (fps), Screen #1, 9/1/10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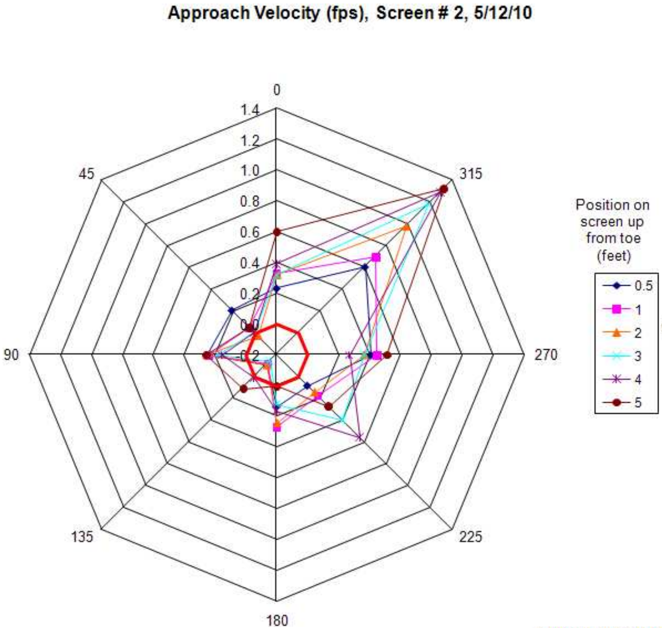
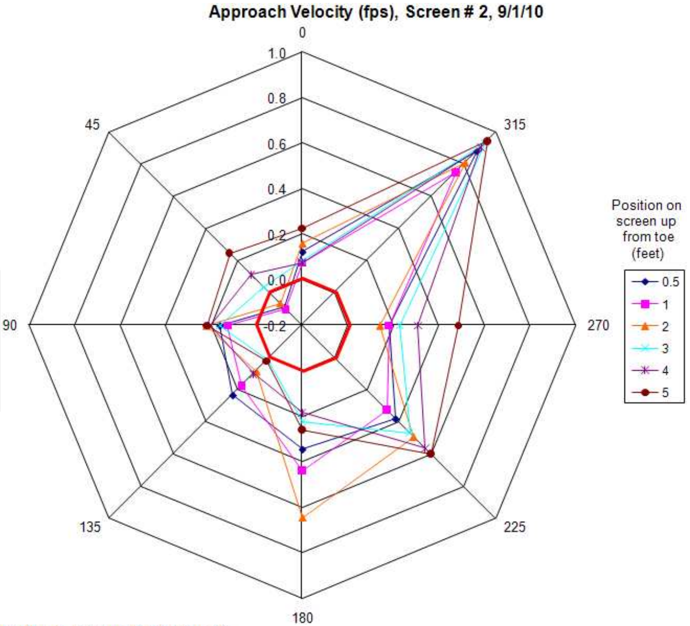
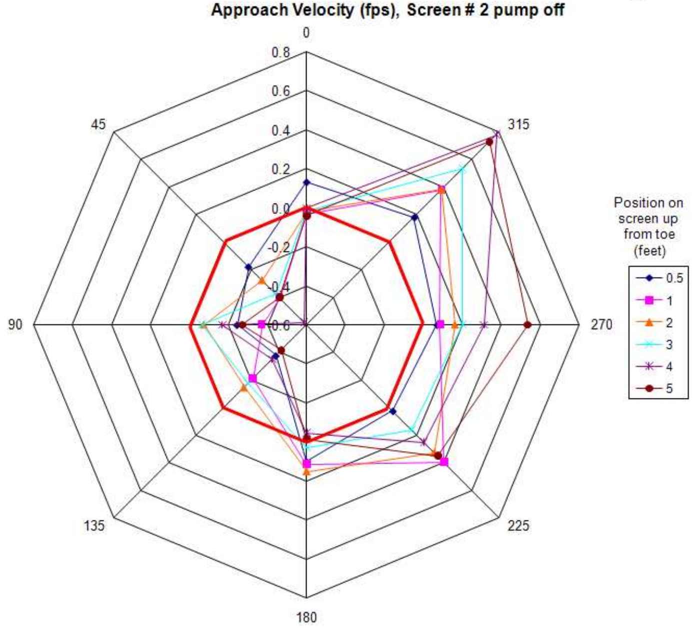
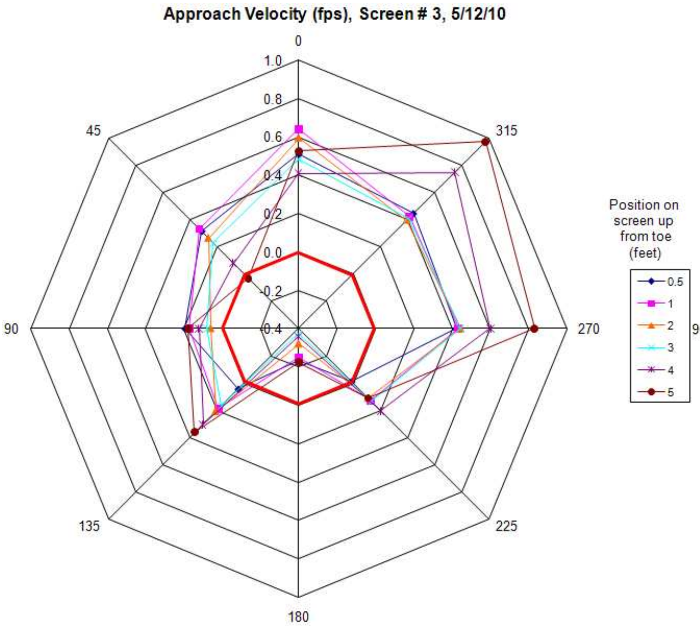
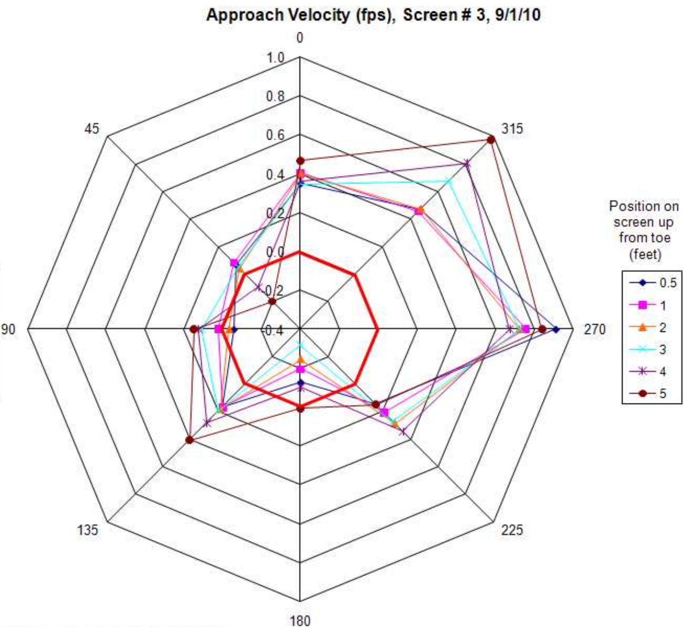
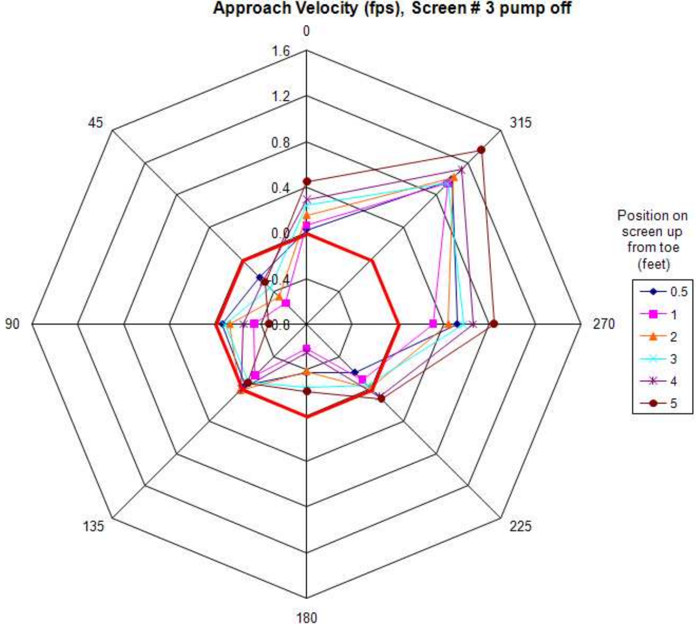

Approach Velocity (fps), Screen # 2, 5/12/10
0
315
270
225
180
135
90
45
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Position on screen up from toe (feet)
0.5
1
2
3
4
5

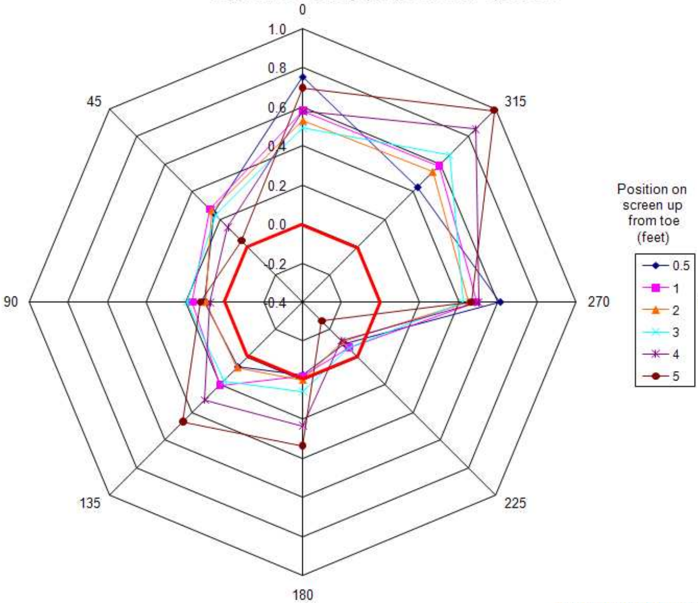

Approach Velocity (fps), Screen # 2, 9/1/10
0
315
270
225
180
135
90
45
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Position on screen up from toe (feet)
0.5
1
2
3
4
5


Approach Velocity (fps), Screen # 2 pump off
0
315
270
225
180
135
90
45
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Position on screen up from toe (feet)
0.5
1
2
3
4
5


Approach Velocity (fps), Screen # 3, 5/12/10


Approach Velocity (fps), Screen # 3, 9/1/10


Approach Velocity (fps), Screen # 3 pump off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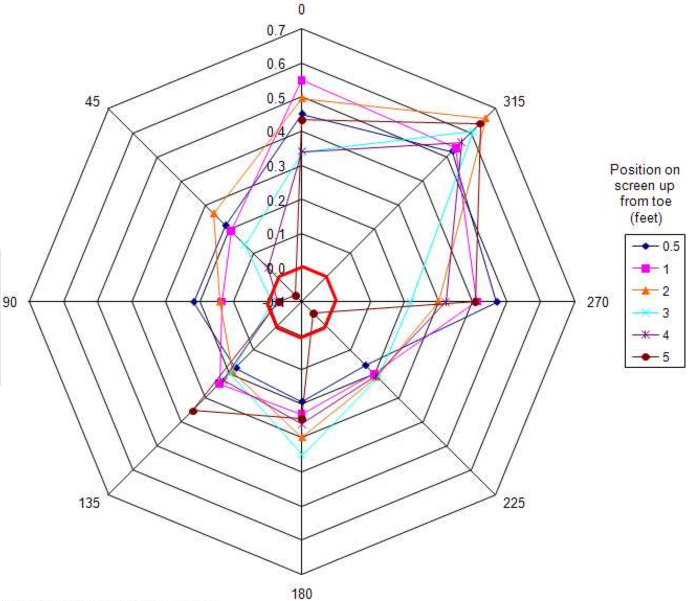
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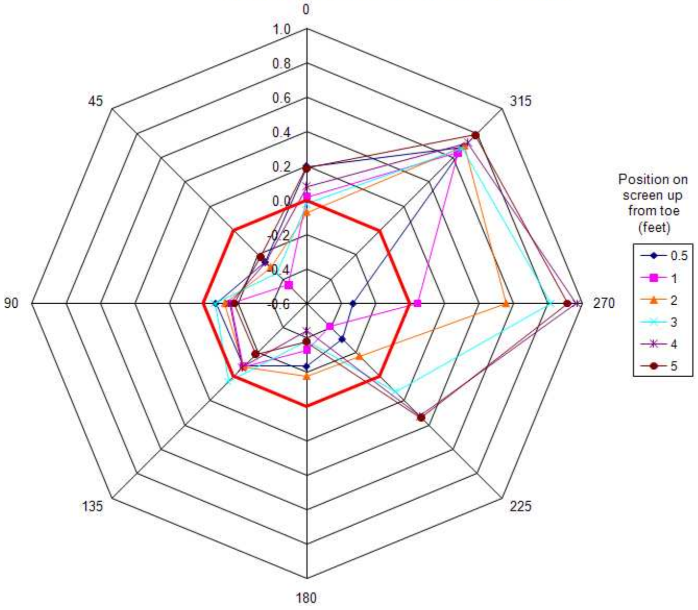
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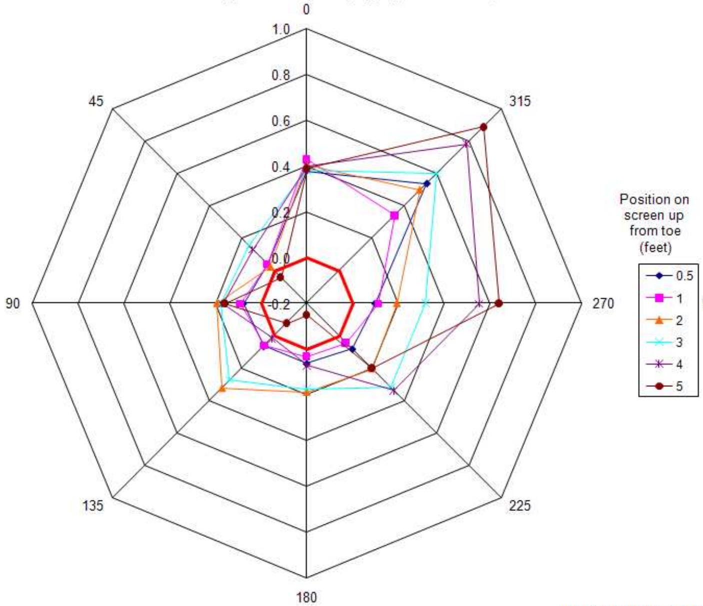
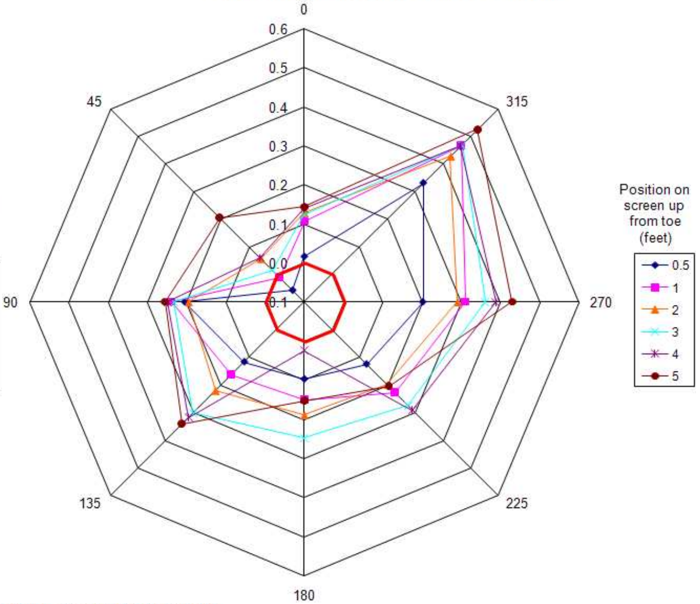
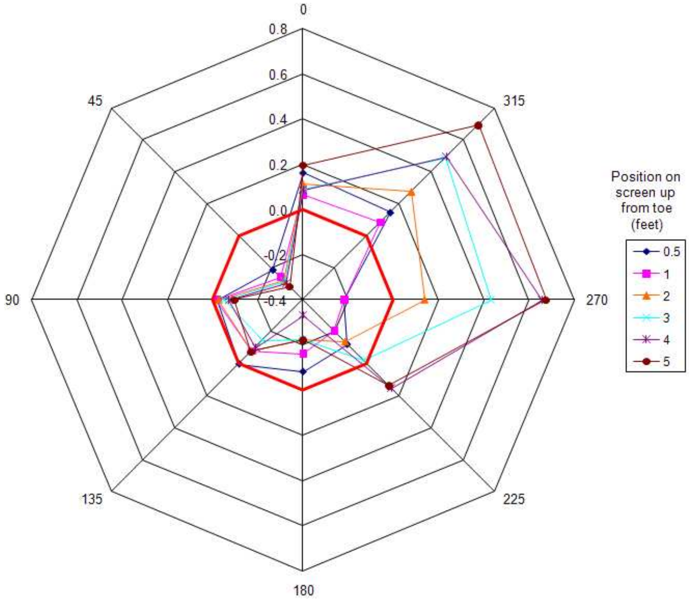
Approach Velocity (fps), Screen # 5, 5/11/10

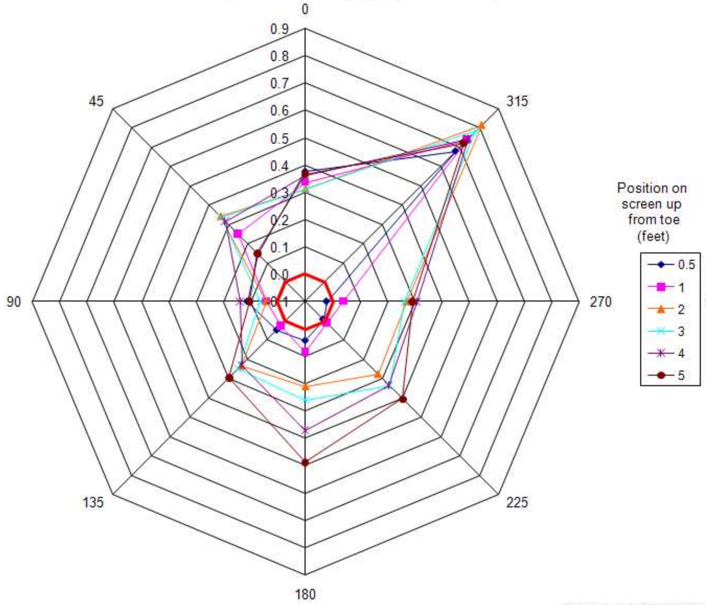


Approach Velocity (fps), Screen # 5, 8/31/10

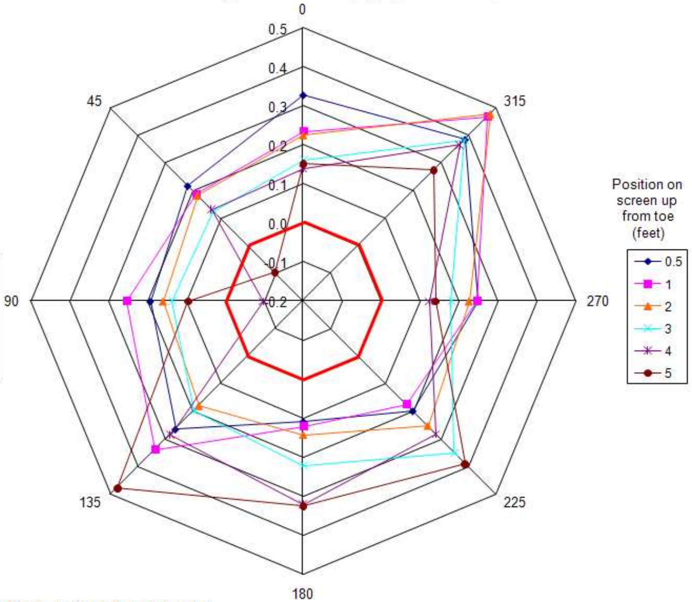


Approach Velocity (fps), Screen # 5 pump off

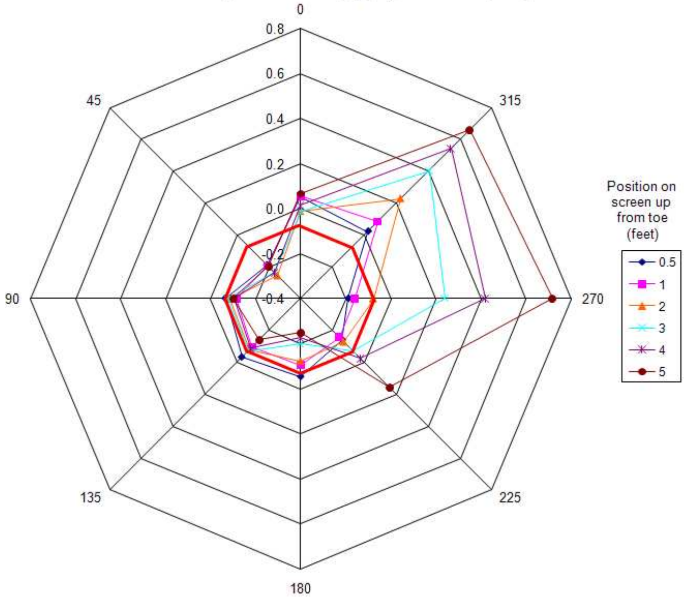




Approach Velocity (fps), Screen # 6, 5/11/10

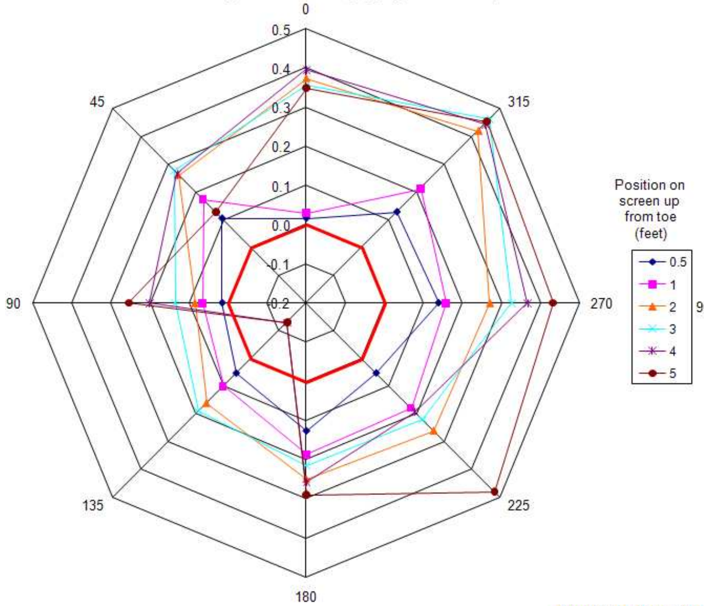


Approach Velocity (fps), Screen # 6, 8/31/10



Approach Velocity (fps), Screen # 6 pump off

Approach Velocity (fps), Screen # 7, 5/10/10



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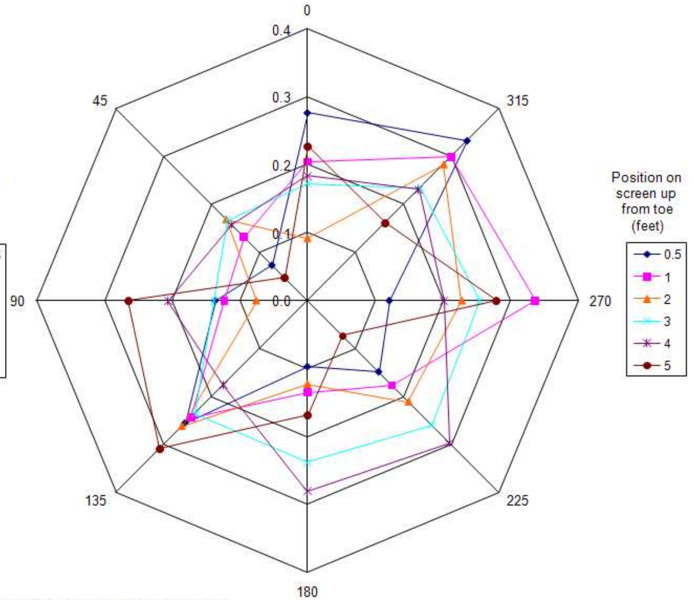

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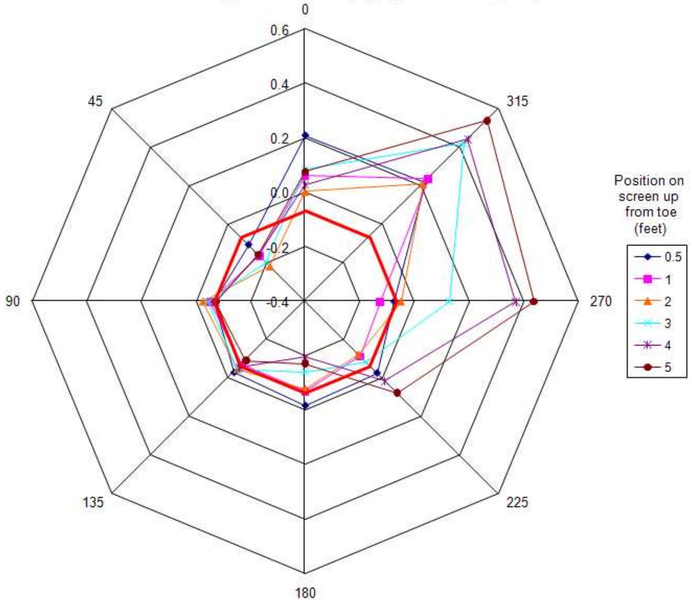

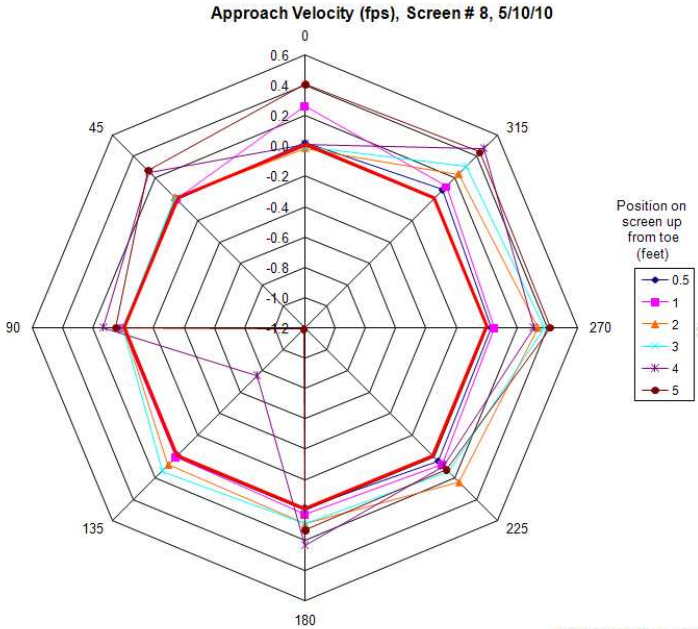

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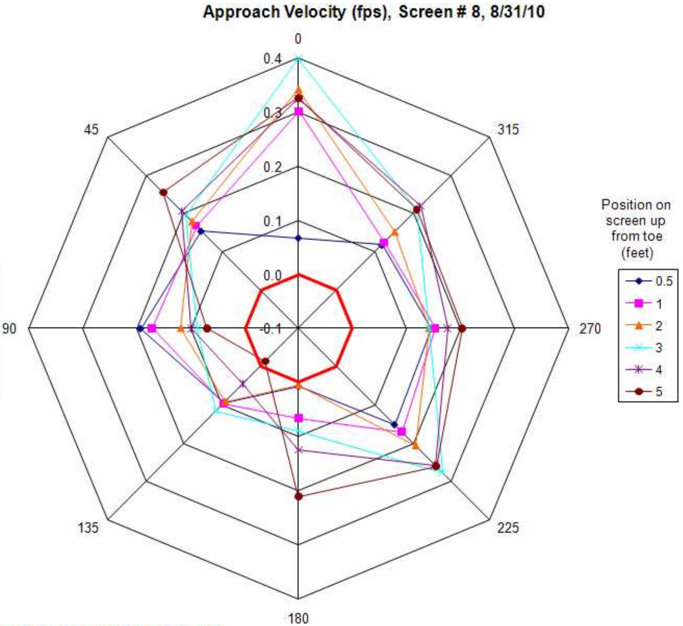

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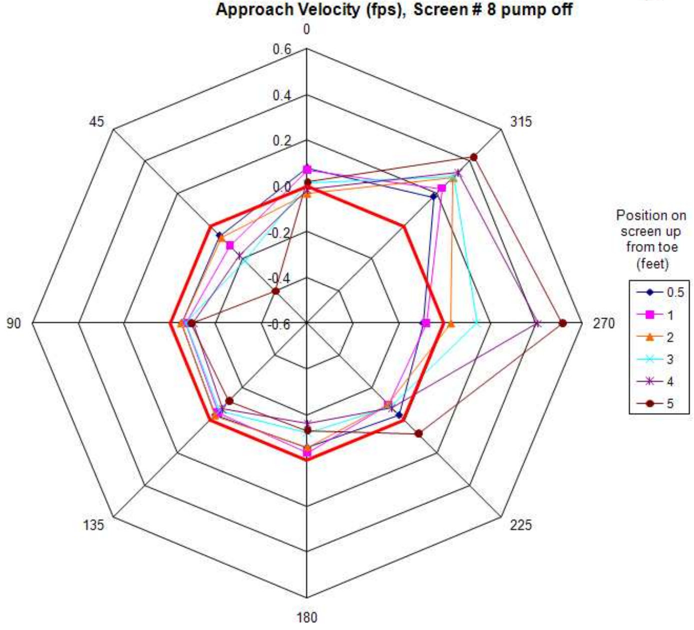

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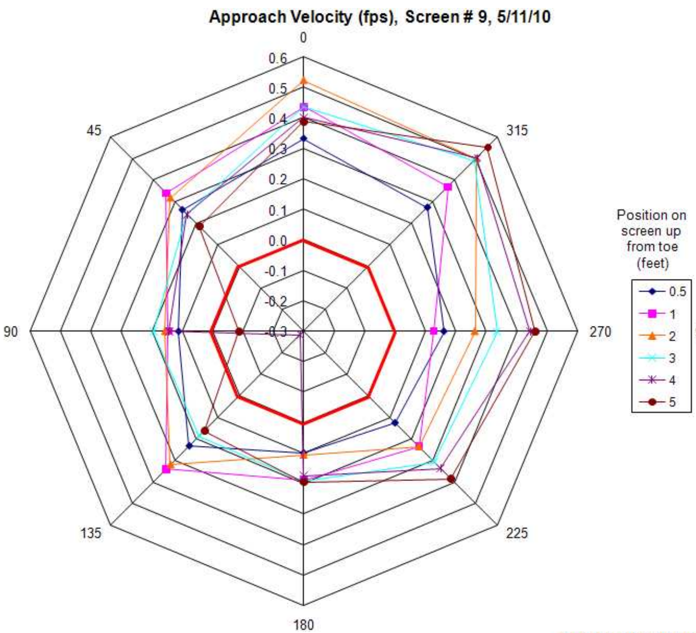
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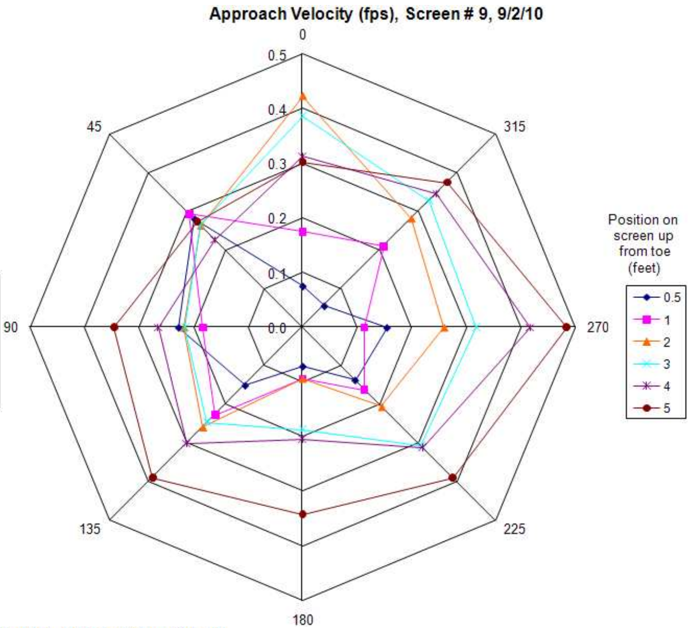
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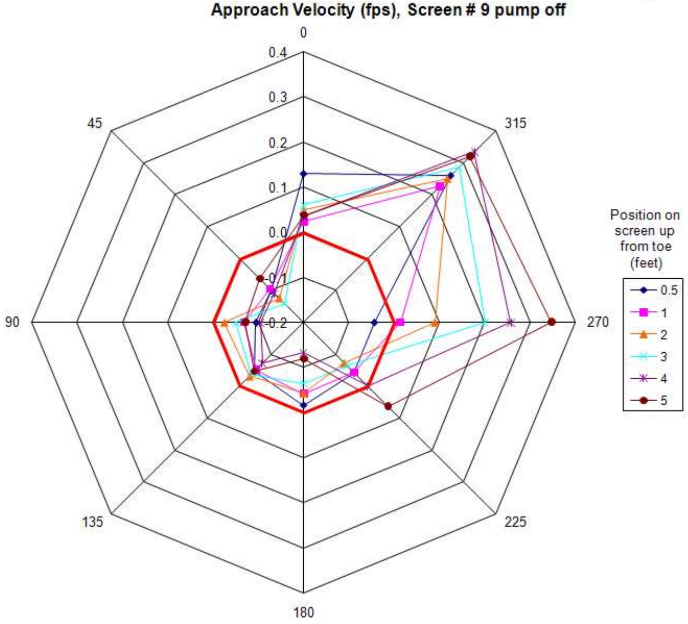
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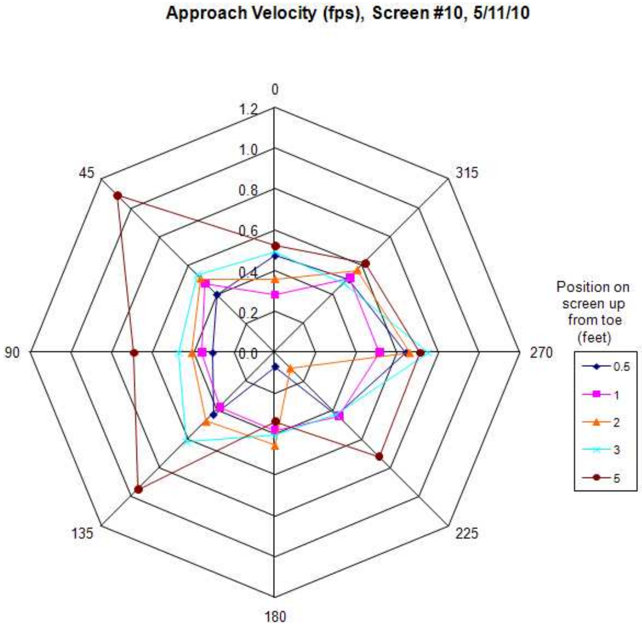
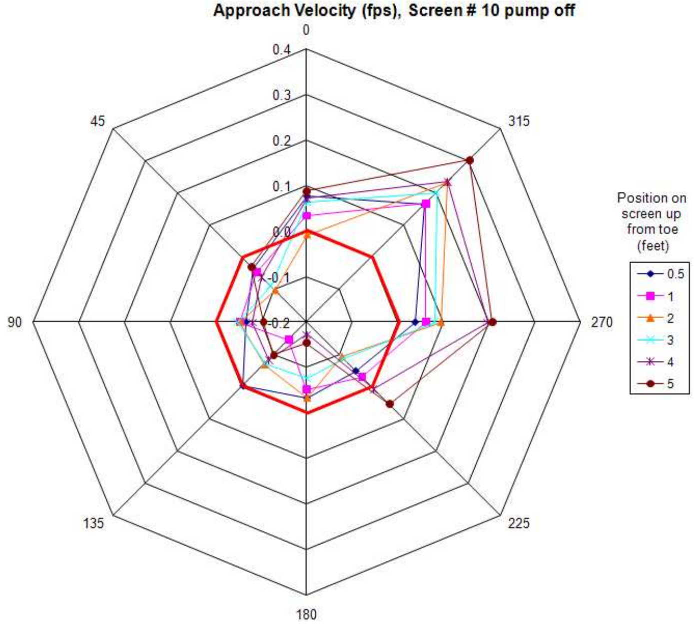
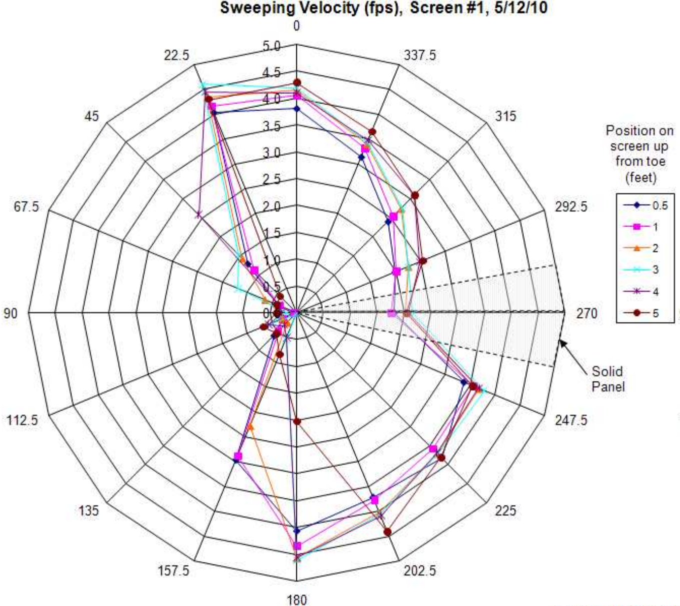
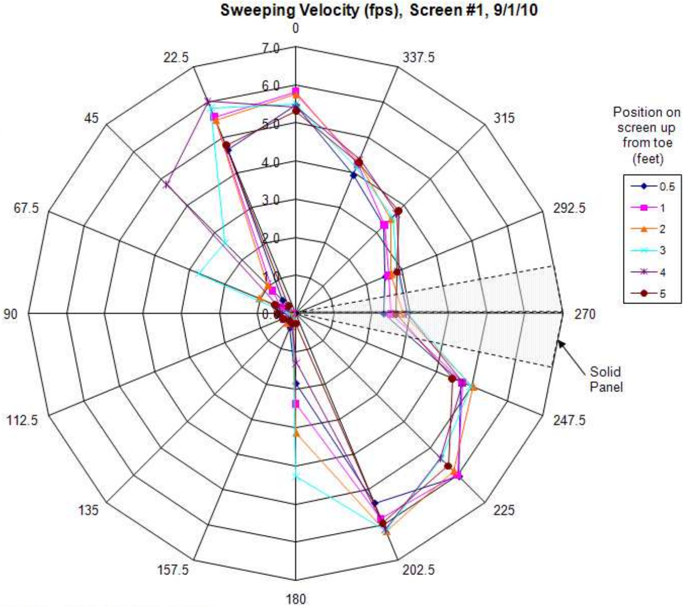

Approach Velocity (fps), Screen #10, 5/11/10

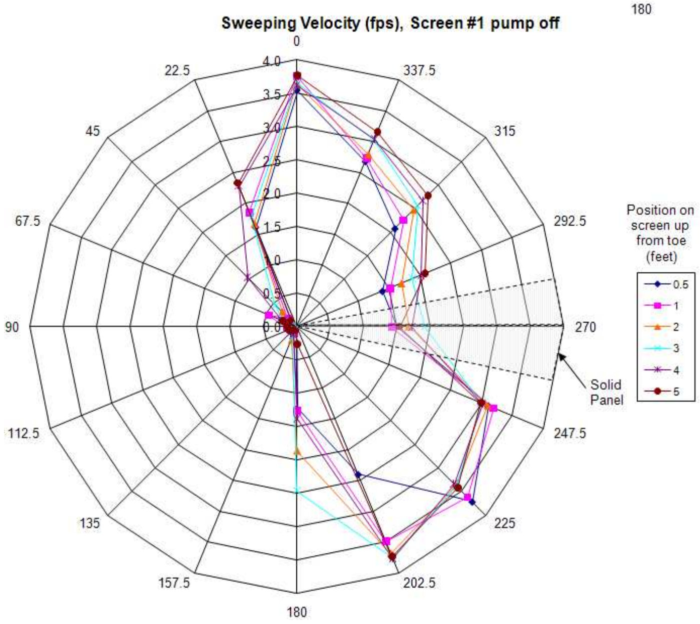
Pump 10 was out of commission on 8/31-9/2/10

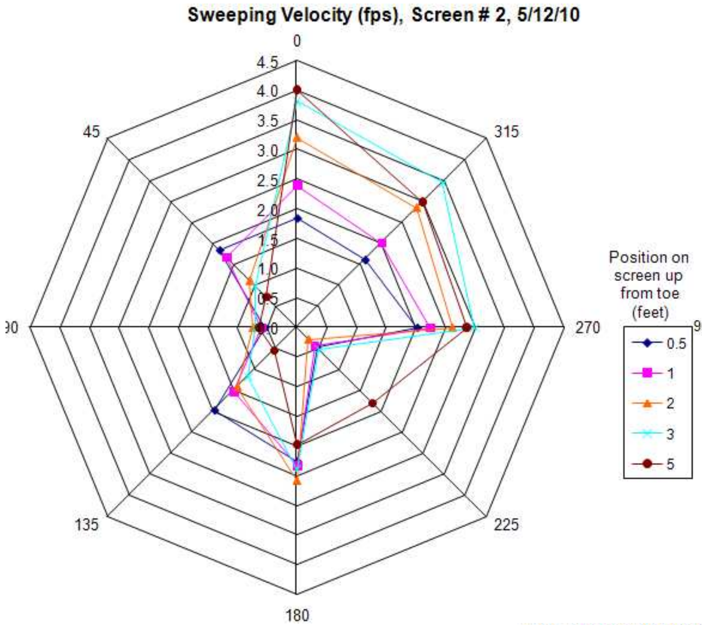

Approach Velocity (fps), Screen # 10 pump off

Appendix B – Sweeping Velocities

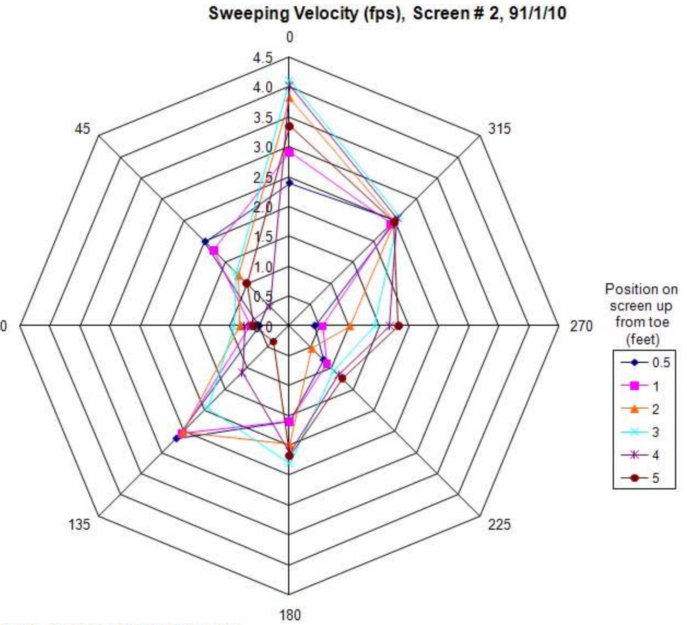

Sweeping Velocity (fps), Screen #1, 5/12/10


Sweeping Velocity (fps), Screen #1, 9/1/10

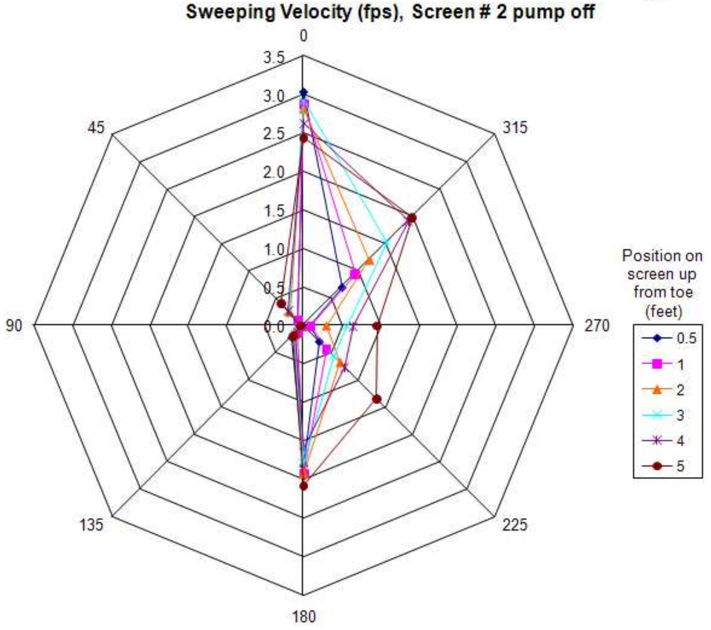

Sweeping Velocity (fps), Screen #1 pump off



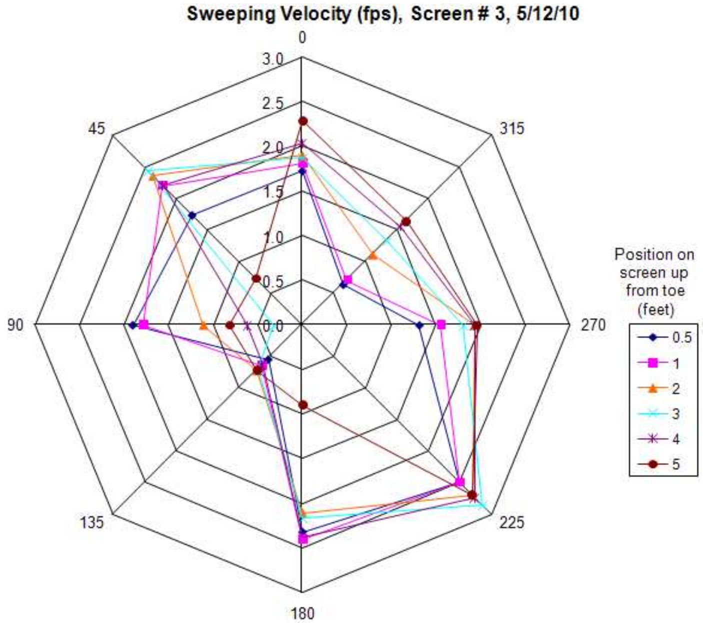
Sweeping Velocity (fps), Screen # 2, 5/12/10

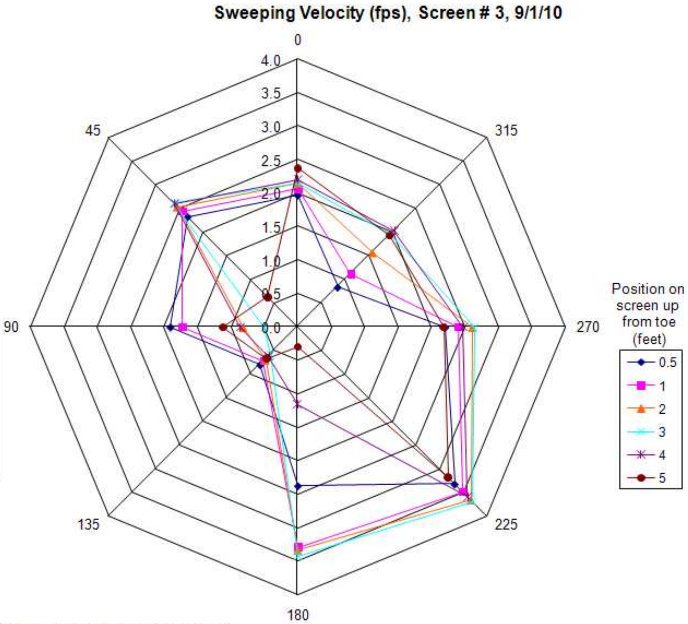


Sweeping Velocity (fps), Screen # 2, 91/1/10



Sweeping Velocity (fps), Screen # 2 pump off


Sweeping Velocity (fps), Screen # 3, 5/12/10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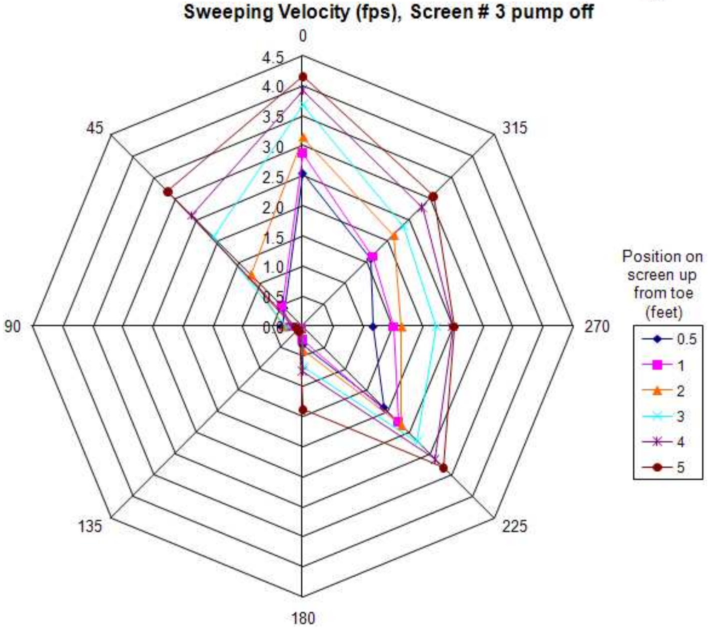
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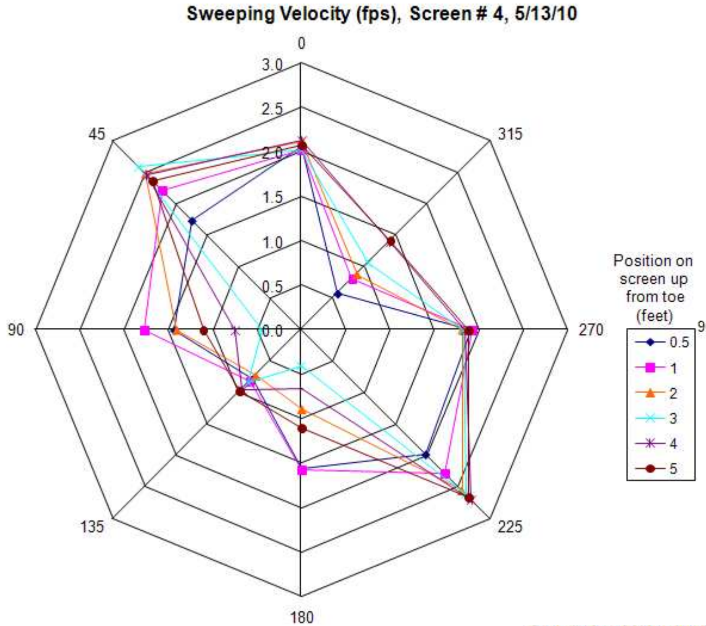
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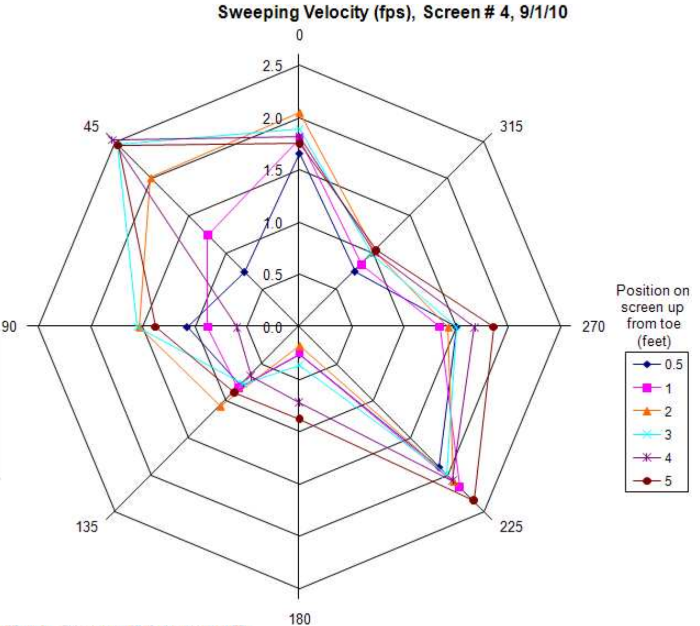
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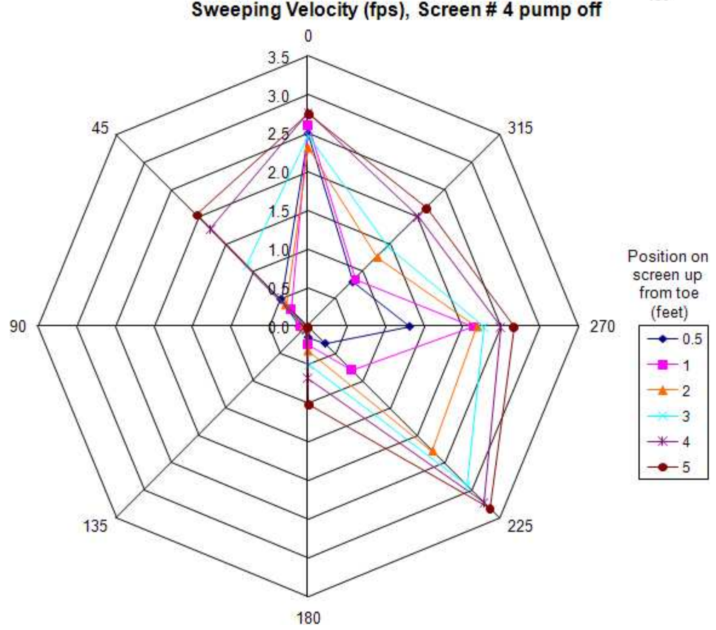
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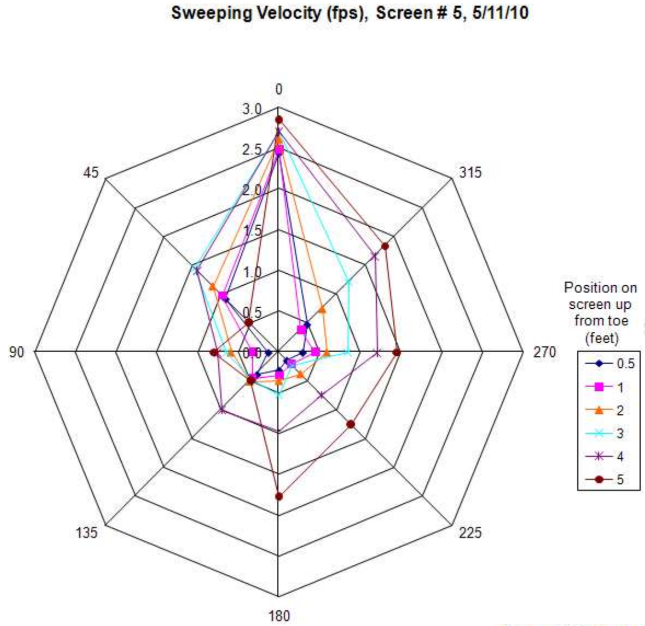
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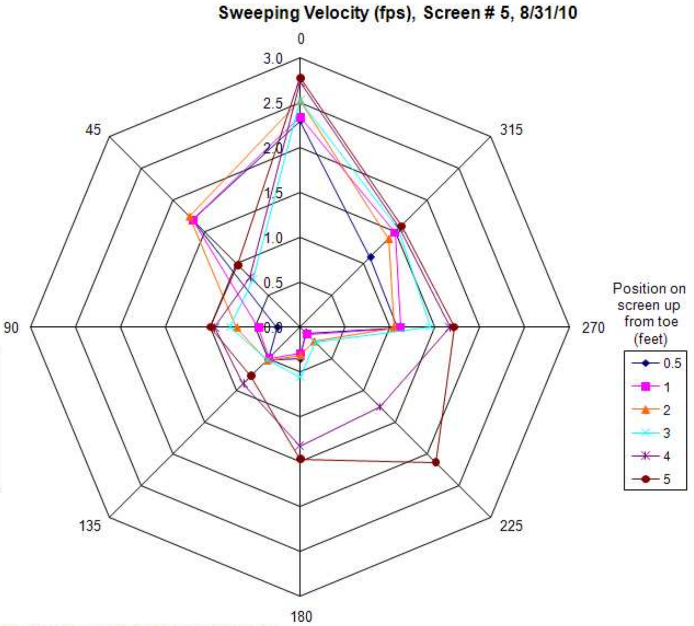
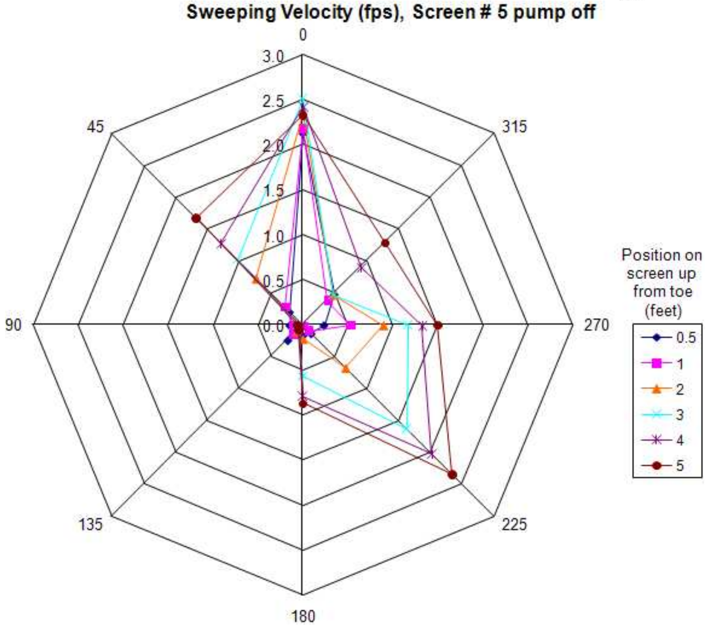
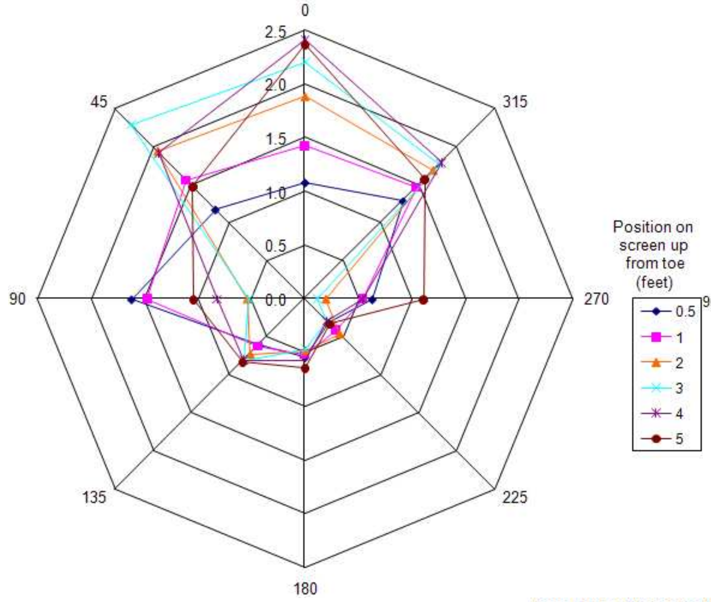

Sweeping Velocity (fps), Screen # 5, 8/31/10


Sweeping Velocity (fps), Screen # 5 pump off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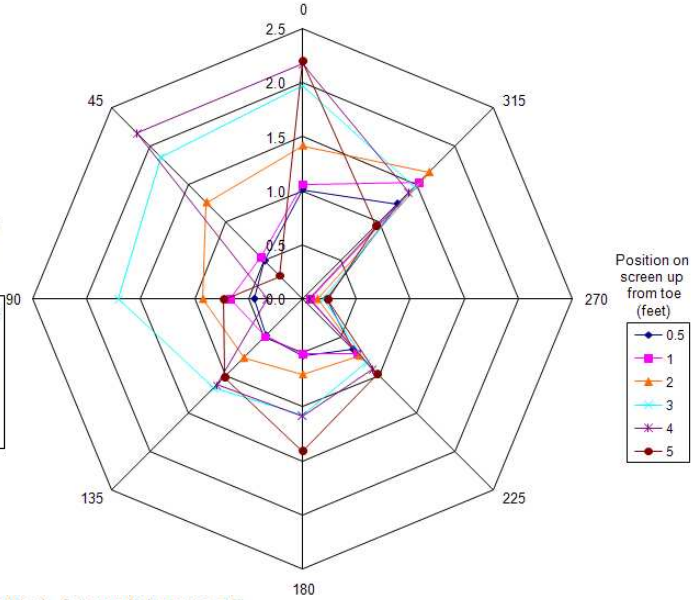
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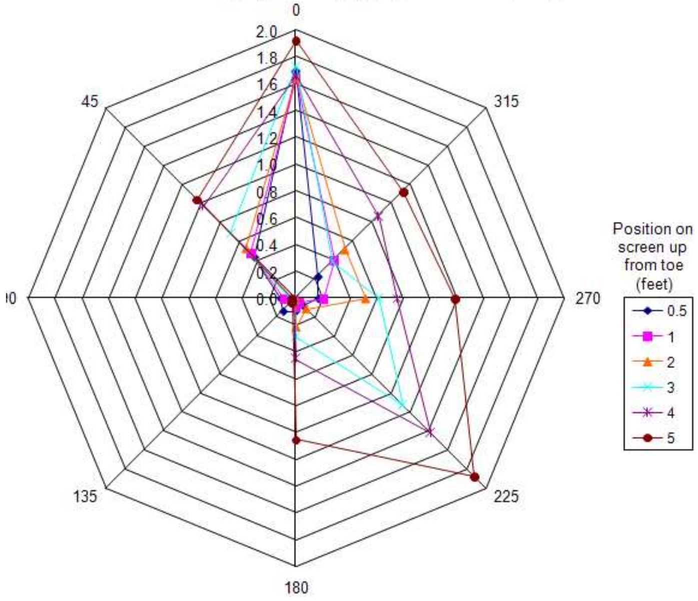
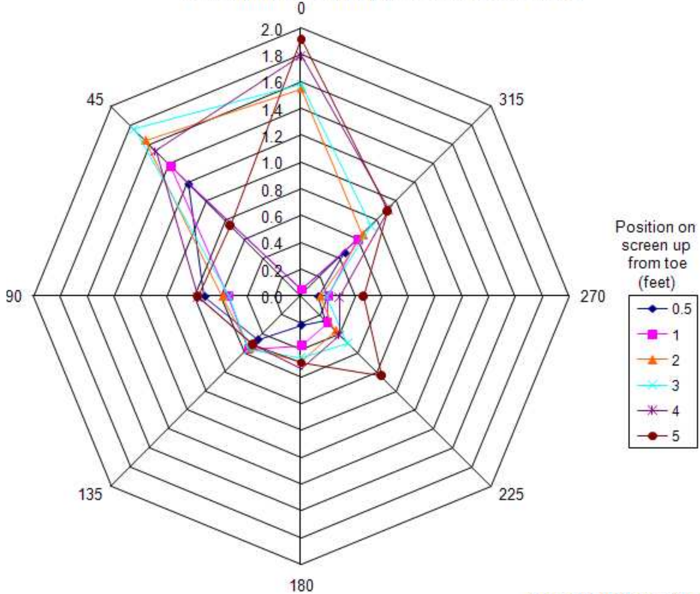
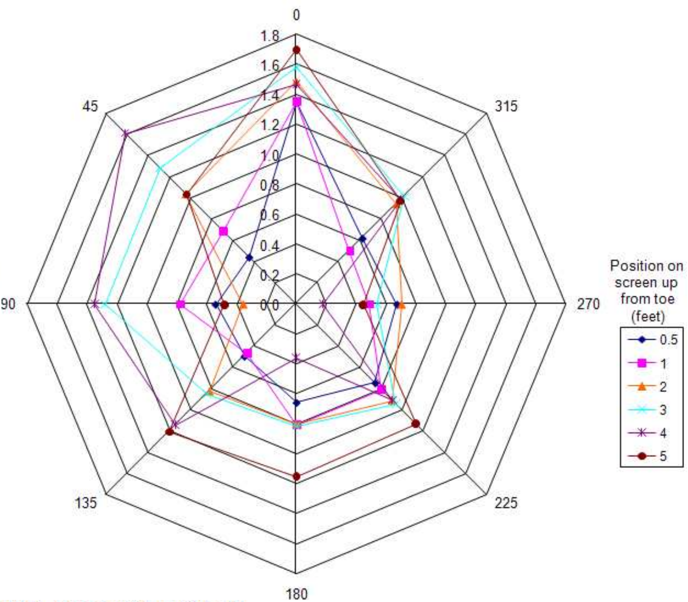

Sweeping Velocity (fps), Screen # 6 pump off



Sweeping Velocity (fps), Screen # 7, 5/10/10



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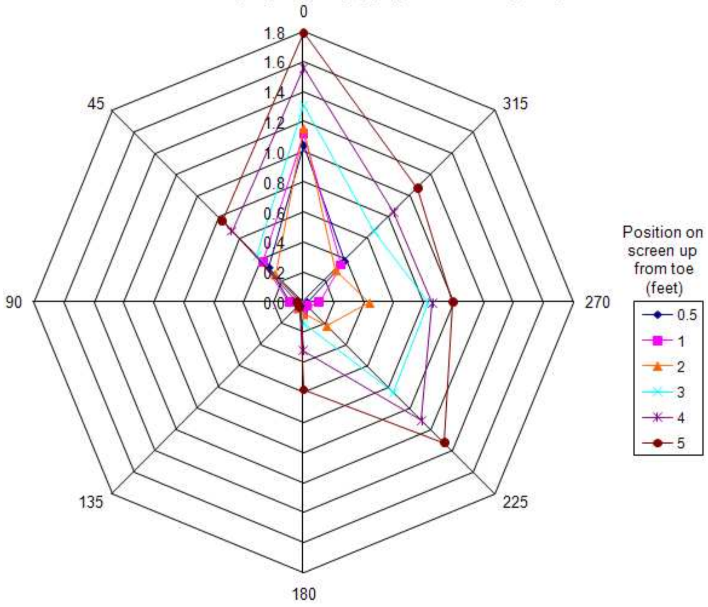
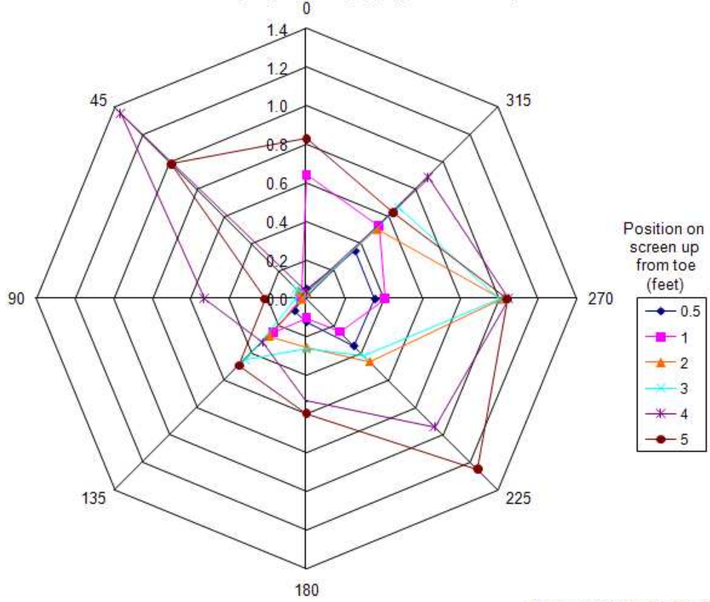
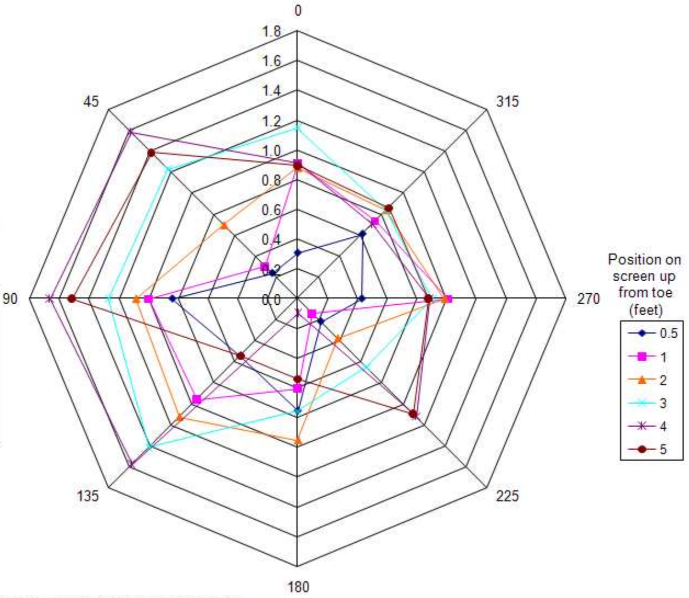


Sweeping Velocity (fps), Screen # 7 pump off

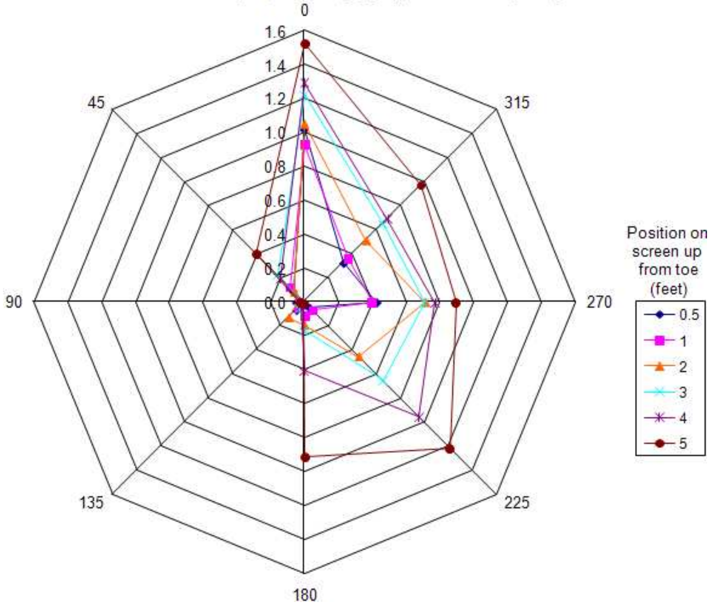
Sweeping Velocity (fps), Screen # 8, 5/10/10

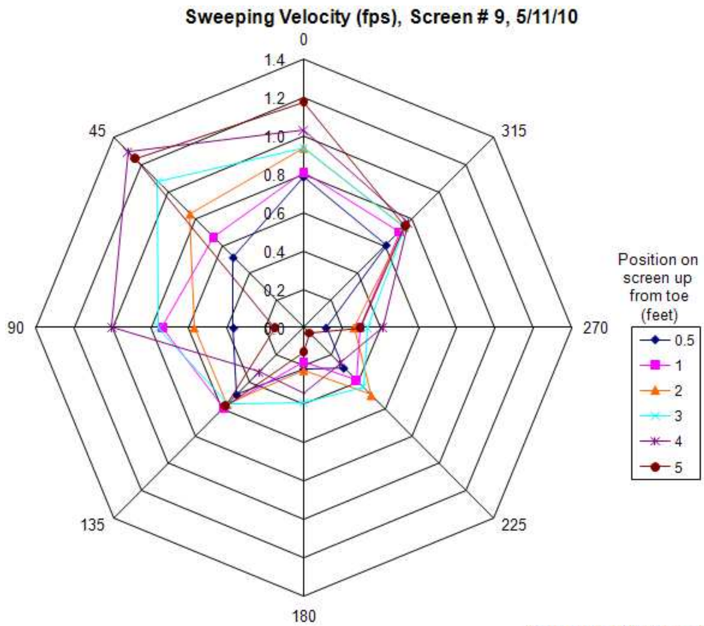


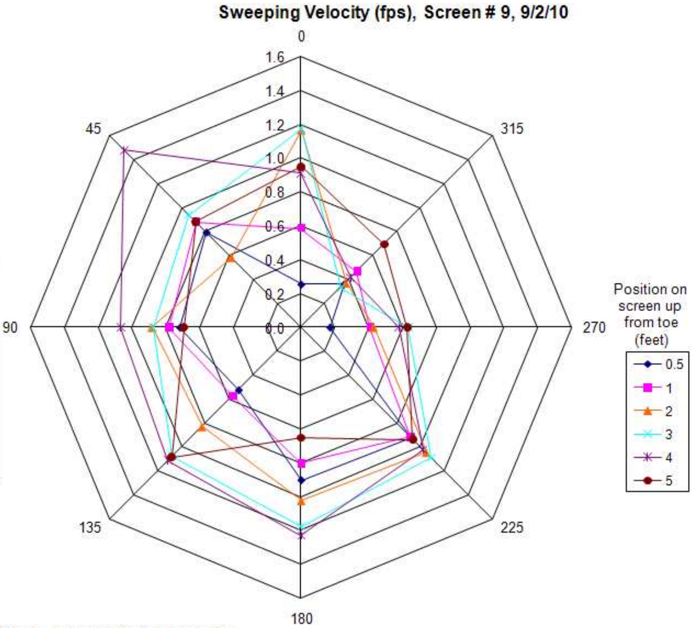
Sweeping Velocity (fps), Screen # 8, 8/31/10

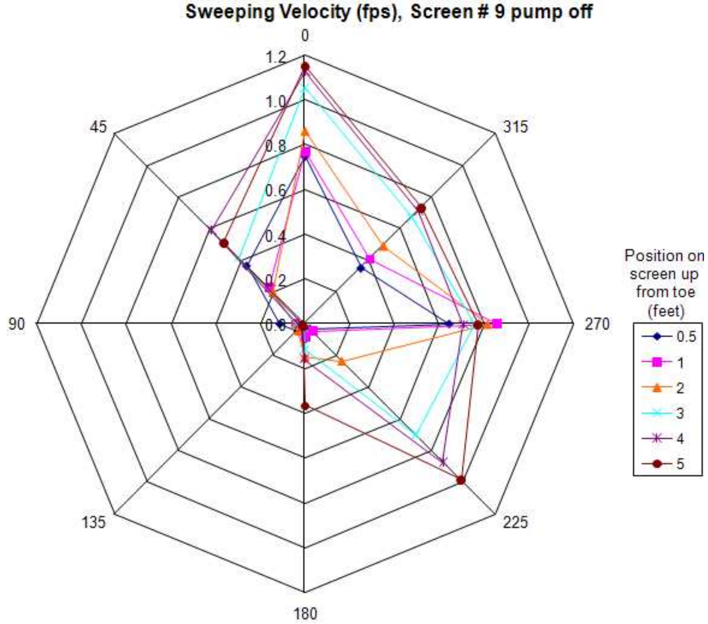


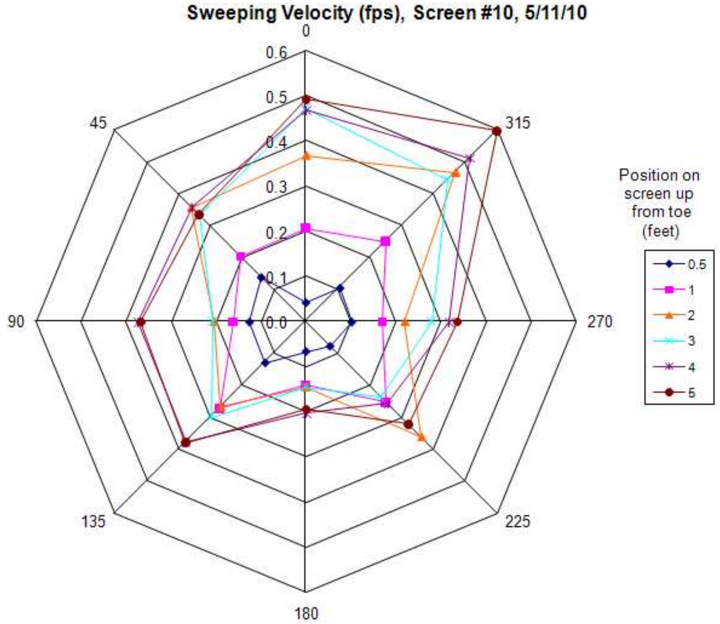
Sweeping Velocity (fps), Screen # 8 pump off




Sweeping Velocity (fps), Screen # 9, 5/11/10


Sweeping Velocity (fps), Screen # 9, 9/2/10


Sweeping Velocity (fps), Screen # 9 pump off



Pump 10 was out of commission on 8/31-9/2/10