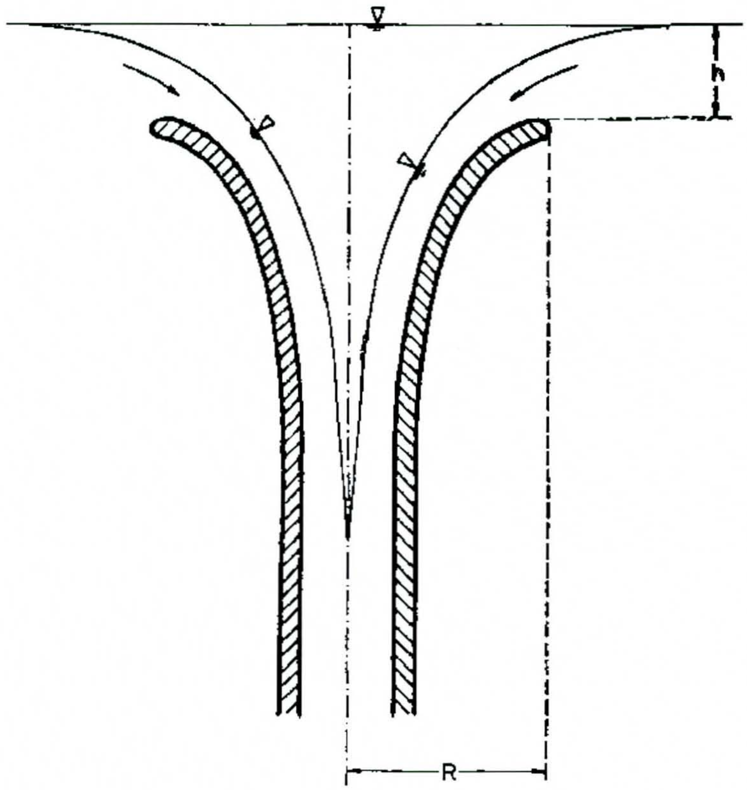
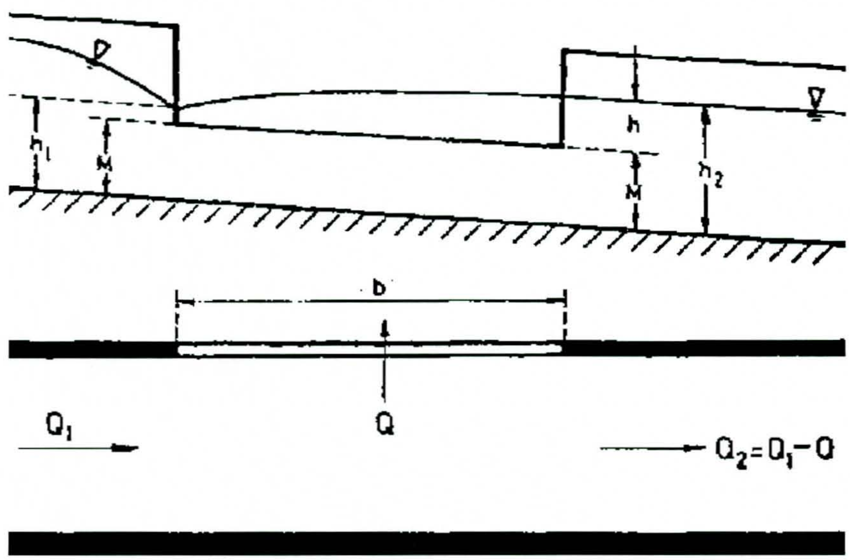
HEC-RAS SIDE WEIR CUSTOMIZATION for the FLOOD CONTROL DISTRICT OF MARICOPA COUNTY (FCDMC)

PLANNING ASSISTANCE TO STATES





US Army Corps of Engineers

Los Angeles District
South Pacific Division

November 2007

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

TO : Ph.D. Bing Zhao

FROM : Bryon Lake

SUBJECT : Three (3) Copies of the Planning Assistance to States Report.

DATE : 3/14/2008

Ph.D. Zhao, Hello and Good Afternoon Sir; I apologize for the delay in providing these copies of the report to you. I was waiting to hear if the Official Copy had been sent before providing these; as I have not heard I decided to provide these three (3) copies and let you know the Official Copy should arrive shortly, if it has not already.

Thank You Again for the opportunity to partner with you in this effort and I hope we are able to do so again in the future.

Thank You Again and Have a Great Day Sir,

Bryon L. Lake
Water Resources Plan Formulation
U.S. Army Corps of Engineers

CLERK OF THE BOARD

BASKET PICK UP

INTERGOVERNMENTAL AGREEMENT

FCD 2004A022

between the

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

and the

UNITED STATES ARMY CORPS OF ENGINEERS

for the

COST SHARING AGREEMENT

for

PLANNING ASSISTANCE

Approved by the
BOARD OF DIRECTORS
of the
Flood Control District of Maricopa County

Agenda Item No. C-69-05-075-2-00
Date 3/23/05

DO NOT REMOVE

THIS COVER IS PART OF THE OFFICIAL DOCUMENT

COST SHARING AGREEMENT
FOR
PLANNING ASSISTANCE BETWEEN
THE U.S. ARMY CORPS OF ENGINEERS
AND
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

THIS AGREEMENT, entered into this 22nd day of July, 2005, by and between the United States of America (hereinafter called the "Government"), represented by the District Engineer executing this Agreement, and the Flood Control District of Maricopa County (hereinafter called the "Sponsor"), represented by TIMOTHY PHILLIPS.

WITNESSETH, that

WHEREAS, the Congress has authorized the Corps of Engineers in Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251) as amended, to assist the States in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources; and whereas, Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640) authorized the government to collect from non-Federal entities fees for the purpose of recovering fifty (50) percent of the cost of the program; and,

WHEREAS, the Sponsor has reviewed the State's comprehensive water plans and identified the need for the planning assistance as described in a Scope of Studies; (HEC-RAS Side Weir Customization for the Flood Control District of Maricopa County, AZ.), incorporated into this agreement; and

WHEREAS, the Sponsor has the authority and capability to furnish the cooperation hereinafter set forth and is willing to participate in study cost-sharing and financing in accordance with the terms of this agreement; and

WHEREAS, Section 208(1) of WRDA of 1992, Public Law 102-580 (codified at 42 U.S.C. Section 1962d-16(b)(2)), authorizes the Sponsor to contribute up to one-half (½) of the non-Federal contribution for preparation of the Scope of Studies incorporated into this Agreement by the provision of services, materials, supplies or other in-kind services necessary to complete the Scope of Studies.

NOW THEREFORE, the parties agree as follows:

1. The Government, using funds contributed by the Sponsor and appropriated by the Congress, shall expeditiously prosecute and complete the Study, estimated to be completed within eight (8) months, substantially in compliance with the Scope of Studies attached as Appendix A and in conformity with applicable Federal laws and regulations and mutually acceptable standards of engineering practice.
2. The Government shall contribute in cash fifty (50) percent and the Sponsor shall contribute in cash $50,000 and in services $7,550 respectively, of all study costs, the total cost of which is currently estimated to be $115,100, as specified in the cost estimate attached as Appendix B. At this time the Sponsor agrees to provide a cashier or certified check in the amount of $50,000 which shall be made payable to FOA, USACE, (Los Angeles District), prior to any work being performed under this agreement.
3. No Federal funds may be used to meet the local Sponsor share of study costs under this Agreement unless the expenditure of such funds is expressly authorized by statute as verified by the granting agency.
4. Before any Party to the Agreement may bring suit in any court concerning any issue relating to this Agreement, such Party must first seek in good faith to resolve the issue through negotiation or another form of nonbinding alternate dispute resolution mutually acceptable to the Parties.
5. In the event that any one or more of the provisions of this Agreement is found to be invalid, illegal, or unenforceable, by a court of competent jurisdiction, the validity of the remaining provisions shall not in any way be affected or impaired and shall continue in effect until the Agreement is completed.
6. This Agreement shall become effective upon the signature of both Parties.

For the Sponsor:

By: [signature]

Timothy, S. Phillips, P.E.,
Acting Chief Engineer and General Manager
Flood Control District of Maricopa County

Date: 14FEB05

For the Corps:

By: [signature]

Alex C. Dornstauder
Colonel, US Army
District Engineer

Date: 22 July 2005

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
A Municipal Corporation

Recommended by:

14Feb2005

Timothy S. Phillips, P.E. Date
Acting Chief Engineer and General Manager

Approved and Accepted:

By: 3/23/05
Chairman, Board of Directors Date

Attest:

By: 3/23/05
Clerk of the Board Date

The foregoing Intergovernmental Agreement FCD 2004A022 has been reviewed pursuant to ARS § 11-952, as amended, by the undersigned General Counsel, who has determined that it is in proper form and within the powers and authority granted to the DISTRICT under the laws of the State of Arizona.

Julie M. Lemmon 2/10/05
General Counsel Date

CERTIFICATION REGARDING LOBBYING

The undersigned certifies, to the best of his or her knowledge and belief that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement or planning assistance agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, cooperative agreement, or planning assistance agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this planning assistance agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under this planning assistance agreement) and that all subrecipients shall certify and disclose accordingly.
This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

David A. Brozovsky
David A. Brozovsky, CPM
Flood Control District Administrator
DATE: July 5, 2005

CERTIFICATE OF AUTHORITY

I, Julie M. Lemmon, do hereby certify that I am the principal legal officer of the Flood Control District of Maricopa County, that the Flood Control District of Maricopa County is a legally constituted public body with full authority and legal capability to perform the terms of the Agreement between the Department of the Army and the Flood Control District of Maricopa County in connection with the HEC-RAS Side Weir Customization for the Flood Control District of Maricopa County, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of the failure to perform, and that the persons who have executed this Agreement on behalf of the Flood Control District of Maricopa County have acted within their statutory authority.

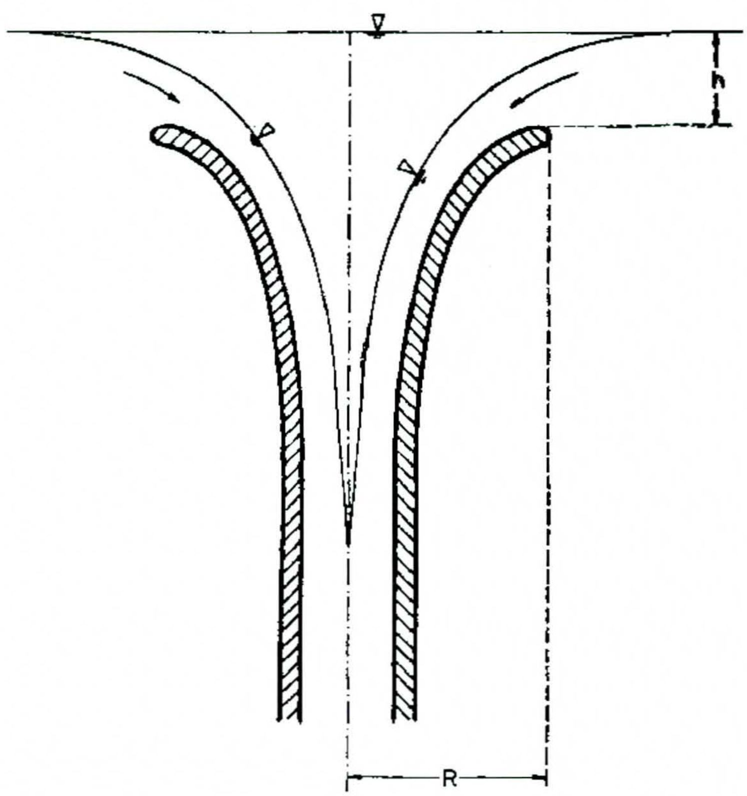
IN WITNESS WHEREOF, I have made and executed this certification this 30th day of June 2005.

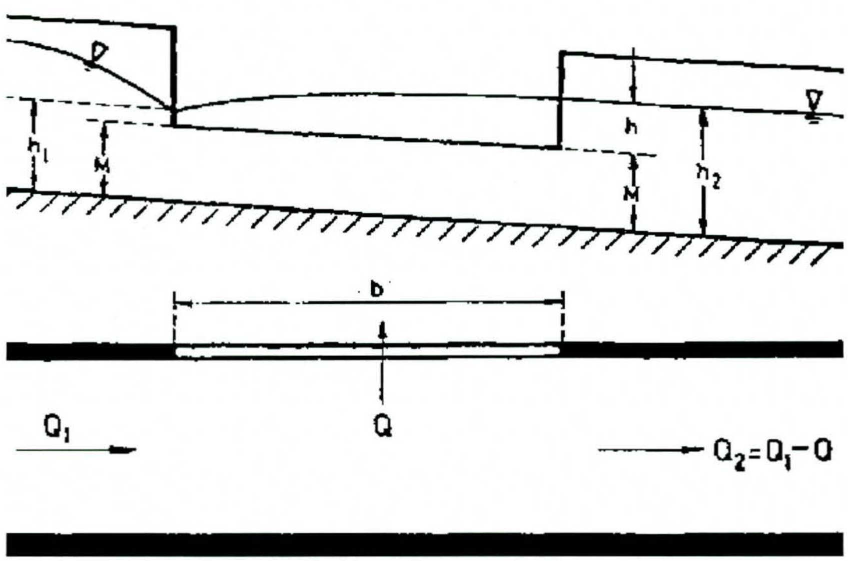
Julie M. Lemmon

Julie M. Lemmon
General Counsel
Flood Control District of Maricopa County

HEC-RAS SIDE WEIR CUSTOMIZATION for the FLOOD CONTROL DISTRICT OF MARICOPA COUNTY (FCDMC)

PLANNING ASSISTANCE TO STATES





US Army Corps of Engineers

Los Angeles District
South Pacific Division

November 2007

Scope of Study
HEC-RAS Side Weir Customization
for
Flood Control District of Maricopa County (FCDMC)
Section 22, Planning Assistance to States

November 2007

I. Background

HEC-RAS was developed by the US Army Corps of Engineers Hydrologic Engineering Center (HEC). It is the most widely used one-dimensional hydraulic modeling software package. It computes the flow depth and floodplains in a river system for given flow rates or discharge hydrographs. Although the executable files are public domain software, the source code is solely owned by US Army Corps of Engineers HEC, and it is not distributed.

HEC-RAS is the major tool for hydraulic modeling at Flood Control District of Maricopa County (FCDMC). It is used by FCMDC's staff and FCDMC's external consultants on a daily basis.

Recently, side weir use in Maricopa County has increased. Side weirs, also known as lateral spillways, are used as key structures in many flood control projects. Side weirs are usually installed along the side of the main channel to divert water into another hydraulic structure when the flow surface in the main channel rises above the side weir crest. Figure 1 shows a side view of a channel with a side weir.

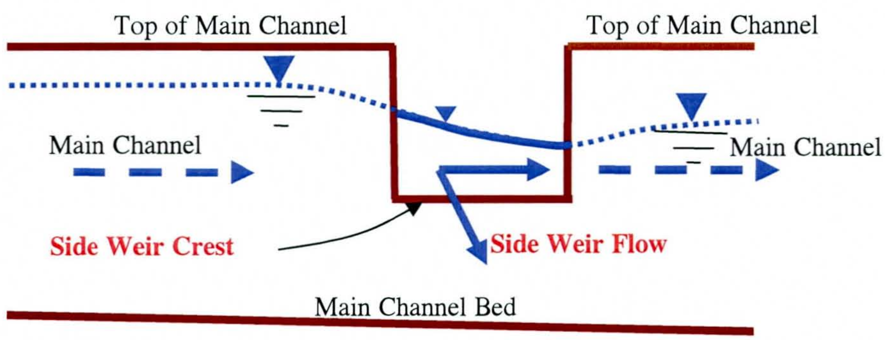


Figure 1. Side View of Main Channel with Side

One of the useful features in HEC-RAS version 3.1 is the side weir and off-line detention basin modeling. However, since the FCDMC's procedure involves the iterative use of HEC-RAS and an empirical equation, it takes a significant amount of time for side weir modeling and design. The modification of the software requested in this Section 22, Planning Assistance to States Study will save a tremendous amount of modeling time with the empirical equation directly incorporated into HEC-RAS for both steady state and unsteady state modeling. The empirical equation used in Maricopa County is based on Hager (1987).

II. Purpose

The purpose of this project/study was to modify HEC-RAS by incorporating Hager's side weir discharge coefficient into HEC-RAS for both steady state and unsteady state modeling conditions.

III. Authority
Section 22 of the Water Resources Development Act of 1974, as amended, provides authority for the Corps of Engineers to assist States, Local Governments, and other Non-Federal entities in the preparation of comprehensive plans for development, utilization, and conservation of water and related land resources.

IV. Schedule
The study was expected to take six (6) to eight (8) months to complete with optimal funding and the availability of technical experts, (labor). The initial study schedule and duration of activities began on November 1st, 2005 with an anticipated duration of six (6) to eight (8) months, concluding by 05/27/05 or 07/17/05 given optimal funding resources, and labor. As a result of Federal Funding constraints and the schedule and work-load for the Hydrological Engineering Center (HEC) staff; resulting from technical support work for Hurricanes Katrina and Rita impacts caused a two (2) year slip in the delivery of the final products and the training session for the sponsor. The following is the initial basic outline of the schedule as it appeared in the Project Management Plan:

1. Initiate the study	10/01/05
2. Completion of the customization of the (HEC-RAS Model)	01/25/06 **or** 02/04/06
3. Draft Report completed	03/04/06 **or** 04/14/06
4. Internal & external reviews completed	04/12/06 **or** 05/13/06
5. Submittal and coordination of final report	05/27/06 **or** 07/17/06

The study and deliverable products were completed September 28th, 2007. The Sponsor and the Hydrological Engineering Center (HEC) scheduled the training session of the software modification and completed the delivery of final products and the training session November 2007. This coordination report will accompany the Transmittal Letter of completion following the conclusion of the above mentioned activities.

The description of the tasks and the corresponding duration of accomplishment are described in the following sections.

VI. TASKS

1.0 Study Initiation

This effort included the initial coordination meetings between the Corps and Sponsor. These initial meetings via the telephone further identified mutual study needs, data availability, refinement of the scope of work, and identified the specific details of analyses and content of the Final Plan and products desired.

2.0 Major Tasks performed by the Hydrologic Engineering Center, (HEC).

The **first task** was the review of Hager's equations and methodology. Hager has written several papers on this subject. These papers, along with materials provided by FCDMC were reviewed.

The **second task** defined how the side weir methodology would be incorporated into HEC-RAS for steady flow and unsteady flow computations. Algorithms were designed for inputting data, computations, and graphical and tabular output.

The **third task** incorporated Hager's side weir discharge coefficient equation into HEC-RAS steady state algorithm. This consisted of the development of interface code, and computational algorithms.

The **fourth task** incorporated Hager's side weir discharge coefficient equation into HEC-RAS unsteady state finite difference algorithm. This also required the development of interface code, and computational algorithms.

The **fifth task** was to perform a series of tests with HEC-RAS to ensure the new side weir feature is working. In order to perform this task, FCDMC provided data sets for testing and comparison of results. These data sets consisted of HEC-RAS projects in which the iterative method of applying Hager's equations to HEC-RAS side weirs had been applied.

The **sixth task** documented the new features in the HEC-RAS User's manual, Hydraulic Reference Manual, and the Applications Guide.

The **seventh and final task** was providing the on-site training session at FCDMC about HEC-RAS unsteady state modeling and side weir modeling. A 3 ½ day training class was provided on site at the FCDMC Facility November 2007. The Hydrologic Engineering Center provided the "hands-on", on-site training session.

The details of the Hager's equation are provided in Appendix A.

The testing results Excel spread sheets are provided as Appendix B.

1. Environment and Computer Language

The software modification was developed and tested to perform calculations and be utilized in the Window 2000 and XP environment on Personal Computers; in order to match the environment and computer language utilized by the Flood Control District of Maricopa County. The original computing language used to develop the current version of HEC-RAS was used in the development and testing of this modification for the deliverable products of this project.

2. Schedule

The Flood Control District's contract lasts one year from the time when the contract starts. The Hydrologic Engineering Center developed a tentative schedule for the tasks and provided it to the Flood Control District of Maricopa County. The schedule and completion of the project was delayed for nearly a year as the Hydrologic Engineering Center was tasked with a multitude of support for modeling and analyses a result of Hurricanes Katrina and Rita and the impacts to the gulf coast. During this period the federal funding was impacted and was less than optimal. The Cost Share Agreement addresses the potential of both of these unforeseen delays. The schedule provided opportunities for the technical experts to work on the software modification and the development of products between specific task assignments associated with the hurricane support activities

3. Acceptance Testing

The Flood Control District of Maricopa County was provided the testing reports for review and provided the opportunity to perform acceptance testing; this acceptance testing was not as extensive as the testing performed by the Hydrologic Engineering Center. The Hydrologic Engineering Center was able to review the Flood Control District of Maricopa County tests and performed additional testing when necessary and applicable, as a result of the Flood Control District's input. Any errors uncovered during this phase were corrected by the Hydrologic Engineering Center for the final product.

4. Deliverables

The Hydrologic Engineering Center provided the final version of executable files for HEC-RAS, which includes Hager's discharge coefficient equation incorporated for side weir calculations.

The Hydrologic Engineering Center prepared and provided the final version of user's manual, hydraulic reference Manual, and Applications Guide which were provided with the executable files at the completion of the training session for the Flood Control District of Maricopa County.

Additionally the Hydrologic Engineering Center prepared a final report which provided a statement of work and describes how each task was accomplished.

A meeting was held at the Flood Control District of Maricopa County, Head Quarters facility to deliver the final products. At the time of this meeting the Hydrologic Engineering Center also provided the onsite training of the use of this software product.

The following is a breakdown of the cost estimate and associated tasks that were provided as part of the scope of work, project management plan and cost share agreement.

5. Cost Estimate for completion of the Hydrologic Engineering Center's Tasks.

Task	Time (days)	Cost
Task 1 – Review of Hager's work	5	$ 4, 000.00
Task 2 – Design Software	5	$ 4, 000.00
Task 3 – Develop Software for Steady Flow	15	$12, 000.00
Task 4 – Develop Software for Unsteady Flow	15	$12, 000.00
Task 5 – Software Testing	12	$ 9, 600.00
Task 6 – Documentation	10	$ 8, 000.00
Task 7 – Meeting and Training Class - preparation and two people performing training	15	$12, 000.00
Follow-up testing and review from FCDMC comments	5	$ 4, 000.00
Travel expenses (2 people – air fare, hotel, rental car, etc…)		$ 3, 000.00
Training Materials (software, training manuals, etc..)		$ 1, 000.00
Hydrologic Engineering Center Total Cost		**$69, 600.00**

3.0 PLAN FORMULATION AND STUDY COORDINATION

The following activities were provided by the Corps of Engineers Planning Section:

1. Study and Schedule Management:

Includes all study, project, and program activities, in accordance with current guidelines outlined in ER 1105-2-100, ER 5-7-1, EC 5-1-48, EC 1105-2-206 and EC 1105-2-208 providing detailed information for the work done for others, coordination with Project Management on technical requirements of Engineering Division, established study milestones, developed networks to include work activities, task schedules, critical path networks and funding schedules, directed, monitored, and modified assigned work items as required and agreed upon by the Sponsor, reviewed results and reports provided by the technical support staff, correspondence, report preparation and review, and inter-organization coordination. To provided coordination with the Project Manager involving periodic meetings with Sponsors to report on technical issues and the status of the study, in-kind services and credits. Study Team meetings will be held as they are necessary.

Study management ensured all required tasks and coordination was performed, resulting in production of a report document. Technical coordination and inter-disciplinary planning were provided by the Study Manager. Study management monitored the scope and progress of activities of the study to ensure the study remained as on track as possible, considering the external factors such as funding and technical resource availability, that the study remain within budget and on schedule as much as possible considering HEC's Hurricane Response "Tasker" for Support, and provided a work-through of the potential impacts on scope, schedule, and cost to ensure they are fully coordinated and resolved.

2. Coordination and Oversight:

The Study Manager served as coordinator among the various engineering functions to provide quality assurance, appropriate technical representation and participation in study team meetings, resolved technical issues, and insure products were delivered in a timely manner, managed the budgets and schedules, and reported on study status.

3. Liaison:

The Study Manager provided coordination, oversight, and liaison functions between the technical support team, the Corps, the Hydrologic Engineering Center and the Sponsor.

4. Meetings, Coordination and Document preparation:

Conducted and prepared briefings, schedules and attend meetings and issue resolution and response to comments received during the study.

5. Final Report coordination and documentation:

The Study Manager provided coordination and documentation through the process and provided this final report as a brief summary of the coordination, activities and actions to complete this Section 22 Planning Assistance to States Study

The following is the estimate of the tasks, man-days and costs associated with the Plan Formulation and Evaluation functions which was provided in the scope of work and project management plan.

SUBACCOUNT/TASK	DAYS	COST
1 Lead Report Prep	8	
1 Technical Coordination/Oversight	4	
2 Engineering Liaison	2	
3 Corps/Sponsors Liaison	2	
1 Manage Study and Schedule	4	
2 Coordinate Tech Team	2	
4 Meetings and Coordination	1	
5 Final Report documentation and Coordination	3	
Coordination from Project Management		
Sub Total	25-Days	$25,000.00
Contingency		$ 3,800.00
Travel (Final Coordination Report)		700.00.
		$29,500.00

PLAN FORMULATION AND EVALUATION TOTAL $29,500.00

HEC-RAS Side Weir Customization
for
Flood Control District of Maricopa County (FCDMC)

Task Number	Task	Cost
1	Study Initiation	
	Coordination and Meetings including Site Visit(s)	
2	Hydrologic Engineering Center Customization of HEC-RAS	$69,600.00
3	Plan Formulation and Coordination	
	Lead Report Preparation	$ 8,000.00
	Technical coordination and oversight	$ 3,000.00
	Engineering Liaison	$ 2,000.00
	Corps / Sponsor Liaison	$ 2,000.00
	Manage Study and Schedule	$ 4,000.00
	Coordinate Technical Team	$ 2,000.00
	Meetings	$ 1,000.00
	Final Report documentation and coordination	$ 3,000.00
	Travel	$ 500.00
	Overhead and Supervision Support and Review	$ 5,000.00
	Total	$30,500.00
4	Address comments & incorporate responses	
5	File project document and material	
	Sub-Total	$100,100.00
6	Project Contingency (15%)	$ 15,000.00
	Total Cost	$115,100.00

Task Number	Task	Federal $	Sponsor $	Sponsor In-Kind	Total $
1	Study Initiation	-	-	-	
2	HEC-RAS Customization	$34,800.00	$34,800.00		$69,600.00
3	Plan Formulation & Coordination	$15,250.00	$15,250.00	?	$30,500.00
4	Address comments			?	
5	File Project Documents			-	
6	Project Contingency (15%)	$ 7,500.00	$ 7,500.00	-	$15,000.00
	TOTAL	$57,550.00	$57,550.00		$115,100.00

APPENDIX A

Hager's Equation

Appendix A -- Hager's Equation

1. Hager's side weir discharge coefficient equation (Hager, 1987) will be integrated into the most current version of HEC-RAS for both steady state model and unsteady state model. Hager's equation deals with three types of side weirs: sharp-crested weir, broad-crested weir, and round-crested weir. Figures 2-4 show the side view of these three types of weirs. In Figures 2-4, water in the main channel flows perpendicularly to the paper.

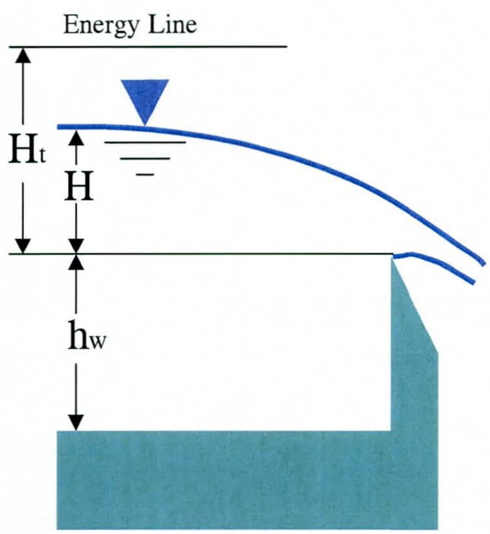


Figure 2. Sharp-Crested weir

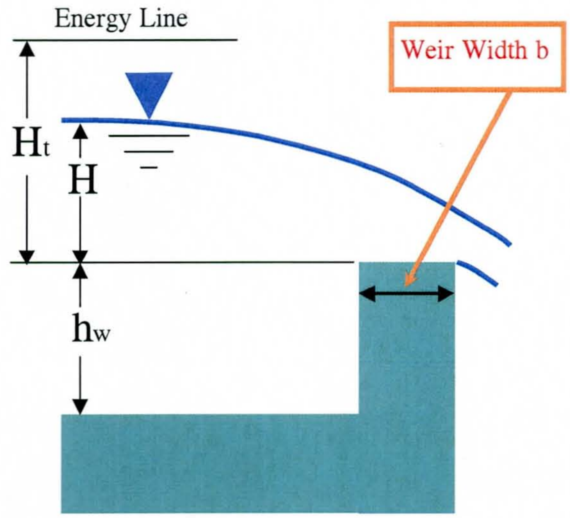


Figure 3. Broad-Crested weir

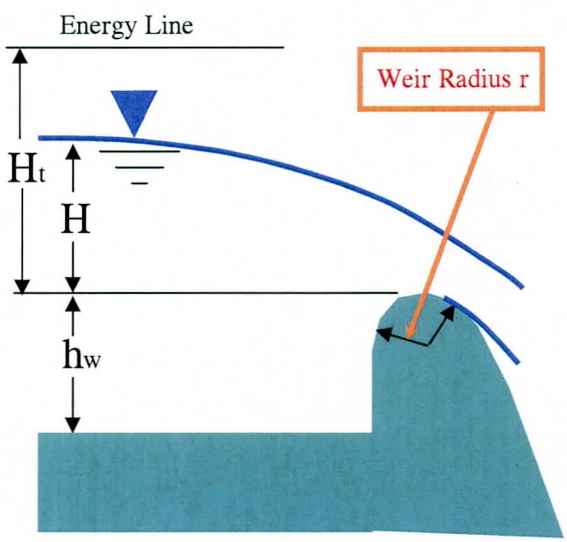


Figure 4. Round-Crested weir

The flow equation for the side weir can be expressed in the conventional weir equation as follows:

$$Q_w = CLH^{1.5} \qquad \textbf{(1)}$$

where

L is the side weir length (along the main channel flow direction);

H = the head measured from the top of the weir crest (excluding the velocity); and

$$C = \frac{3}{5} m C_0 \sqrt{g} \left[\frac{1-W}{3-2y-W} \right]^{0.5} \left\{ 1 - (\beta + S_0) \left[\frac{3(1-y)}{y-W} \right]^{0.5} \right\} \qquad \textbf{(2)}$$

where

m = the number of side weirs (1 or 2);

$$W = \frac{h_w}{H_t + h_w} \qquad \textbf{(3)}$$

$$y = \frac{H + h_w}{H_t + h_w} \qquad \textbf{(4)}$$

where

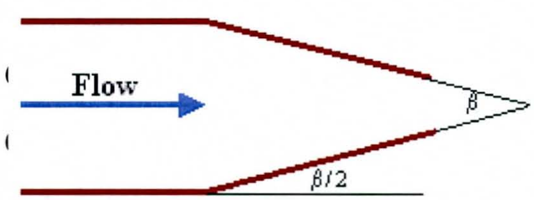
H_t = the total head measured from the top of the weir crest;

h_w = the weir height;

g = the specific gravity;

S_0 = main channel bed slope;

β= the main channel contraction angle in radians;



$$C_0 = 1 - \frac{2}{9\left[1 + \left(\frac{H_t}{b}\right)^4\right]} \text{ for broad-crested weir (b is weir width, Figure3)} \quad \textbf{(5)}$$

$$C_0 = \frac{\sqrt{3}}{2}\left[1 + \frac{\frac{22}{81}\left(\frac{H_t}{r}\right)^2}{1 + \frac{1}{2}\left(\frac{H_t}{r}\right)^2}\right] \textit{for round-crested weir (r is weir radius, } \text{Figure 4}\textit{)} \quad (6)$$

<u>Appendix A (II)</u>

Reference

Hager, W. (1987). “Lateral Outflow Over Side Weirs,” Journal of Hydraulic Engineering, 113(4), ASCE, New York, New York.

APPENDIX B

The following pages contain the results from the Rectangular Channel Test for:
Broad Crest
Sharp Crest
Ogee Crest
Zero Crest Height, and
Unsteady Flow Runs

RECTANGULAR CHANNEL TEST RESULTS

BROAD CRESTED

Rect. Channel, Side Weir, S=2ft/mi	4,000 cfs	5000 cfs	6000 cfs	7000 cfs	8000 cfs	9000 cfs	10000 cfs	11000 cfs	12000 cfs	13000 cfs
ave weir top elevation	10.21	10.21	10.21	10.21	10.21	10.21	10.21	10.21	10.21	10.21
total head elevation	11.22	12.27	13.19	14	14.75	15.5	16.14	16.77	17.38	17.93
water head elevation	11.01	12.03	12.9	13.67	14.38	15.08	15.68	16.26	16.83	17.34
channel bottom elevation at midpoint	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
w	10	10	10	10	10	10	10	10	10	10
H	11.01	12.06	12.98	13.79	14.54	15.29	15.93	16.56	17.17	17.72
h	10.8	11.82	12.69	13.46	14.17	14.87	15.47	16.05	16.62	17.13
W	0.908265	0.829187	0.770416	0.725163	0.687758	0.654022	0.627746	0.603865	0.582411	0.564334
y	0.980926	0.9801	0.977658	0.97607	0.974553	0.972531	0.971124	0.969203	0.967967	0.966704
s0	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038
b	10	10	10	10	10	10	10	10	10	10
cstar	0.777801	0.778177	0.779517	0.78227	0.786834	0.793916	0.802233	0.812501	0.824231	0.836022
c	2.225	2.385	2.428	2.457	2.484	2.511	2.541	2.573	2.612	2.651
HEC-RAS Computed c	2.232	2.379	2.428	2.456	2.481	2.512	2.541	2.573	2.613	2.650

Rect. Channel, Side Weir, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.29	13.06	13.75	14.41	15.03	15.62	16.18	16.73	17.25	17.76
water head elevation	11.36	12.04	12.65	13.21	13.74	14.25	14.73	15.18	15.62	16.04
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.25	12.02	12.71	13.37	13.99	14.58	15.14	15.69	16.21	16.72
h	10.32	11	11.61	12.17	12.7	13.21	13.69	14.14	14.58	15
W	0.888889	0.831947	0.786782	0.747943	0.714796	0.685871	0.660502	0.637349	0.616903	0.598086
y	0.917333	0.915141	0.913454	0.910247	0.907791	0.906036	0.904227	0.901211	0.899445	0.897129
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
b	10	10	10	10	10	10	10	10	10	10
cstar	0.777832	0.778147	0.77897	0.780607	0.783271	0.787144	0.792277	0.798861	0.806548	0.815419
c	1.670	1.863	1.965	2.026	2.074	2.115	2.152	2.184	2.219	2.254
HEC-RAS Computed c	1.673	1.866	1.964	2.029	2.077	2.118	2.153	2.188	2.222	2.257

RECTANGULAR CHANNEL TEST RESULTS

Sharp Crest										
Rect. Channel, Sharp crest, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.28	13.03	13.69	14.32	14.9	15.46	16	16.51	17.04	17.54
water head elevation	11.36	12.01	12.58	13.11	13.6	14.07	14.52	14.95	15.39	15.8
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.24	11.99	12.65	13.28	13.86	14.42	14.96	15.47	16	16.5
h	10.32	10.97	11.54	12.07	12.56	13.03	13.48	13.91	14.35	14.76
W	0.889679715	0.834028	0.790514	0.753012	0.721501	0.693481	0.668449	0.646412	0.625	0.606061
y	0.918149466	0.914929	0.912253	0.908886	0.906205	0.903606	0.90107	0.89916	0.896875	0.894545
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
b	10	10	10	10	10	10	10	10	10	10
cstar for Sharp Crested Weir = 1.0	1	1	1	1	1	1	1	1	1	1
c	2.148	2.384	2.505	2.576	2.626	2.662	2.689	2.711	2.729	2.742
HEC-RAS Computed c	2.147	2.386	2.506	2.581	2.630	2.666	2.693	2.713	2.732	2.745

RECTANGULAR CHANNEL TEST RESULTS

Ogee Crest										
Rect. Channel, Ogee crest, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.29	13.03	13.69	14.32	14.9	15.46	16	16.51	17.04	17.54
water head elevation	11.36	12.01	12.58	13.11	13.6	14.07	14.52	14.95	15.39	15.8
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.25	11.99	12.65	13.28	13.86	14.42	14.96	15.47	16	16.5
h	10.32	10.97	11.54	12.07	12.56	13.03	13.48	13.91	14.35	14.76
W	0.88888889	0.834028	0.790514	0.753012	0.721501	0.693481	0.668449	0.646412	0.625	0.606061
y	0.91733333	0.914929	0.912253	0.908886	0.906205	0.903606	0.90107	0.89916	0.896875	0.894545
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
r	4	4	4	4	4	4	4	4	4	4
cstar for Ogee Crested Weir	0.88793222	0.91788	0.95078	0.984534	1.015666	1.044586	1.070763	1.093643	1.115408	1.134069
c	1.906	2.189	2.381	2.536	2.667	2.780	2.879	2.965	3.044	3.110
HEC-RAS Computed c	1.911	2.206	2.403	2.563	2.692	2.800	2.896	2.974	3.044	3.105

RECTANGULAR CHANNEL TEST RESULTS

Zero Crest Height										
Rect. Channel, Zero H Weir, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Average total head elevation	8.64	9.26	9.85	10.43	10.99	11.53	12.07	12.61	13.13	13.63
Average water head elevation	6.83	7.29	7.74	8.17	8.59	8.99	9.39	9.85	10.24	10.61
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	0	0	0	0	0	0	0	0	0	0
H	7.6	8.22	8.81	9.39	9.95	10.49	11.03	11.57	12.09	12.59
h	5.79	6.25	6.7	7.13	7.55	7.95	8.35	8.81	9.2	9.57
W	0	0	0	0	0	0	0	0	0	0
y	0.76184211	0.760341	0.760499	0.759318	0.758794	0.757865	0.757026	0.761452	0.760959	0.760127
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
b	10	10	10	10	10	10	10	10	10	10
cstar for Zero Height weir = 8/7	1.14285714	1.142857	1.142857	1.142857	1.142857	1.142857	1.142857	1.142857	1.142857	1.142857
c	3.197	3.193	3.194	3.191	3.190	3.188	3.186	3.196	3.195	3.193
HEC-RAS Computed c	3.211	3.205	3.201	3.198	3.196	3.193	3.191	3.205	3.204	3.202

RECTANGULAR CHANNEL TEST RESULTS

Unsteady Flow Runs										
Rect. Channel, Broad Crest, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.28	13	13.67	14.3	14.9	15.48	16.04	16.59	17.11	17.58
water head elevation	11.35	11.98	12.55	13.08	13.59	14.07	14.52	14.95	15.38	15.8
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.24	11.96	12.63	13.26	13.86	14.44	15	15.55	16.07	16.54
h	10.31	10.94	11.51	12.04	12.55	13.03	13.48	13.91	14.34	14.76
W	0.88968	0.83612	0.791766	0.754148	0.721501	0.692521	0.666667	0.643087	0.622278	0.604595
y	0.91726	0.914716	0.911322	0.907994	0.905483	0.902355	0.898667	0.894534	0.892346	0.892382
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
b	10	10	10	10	10	10	10	10	10	10
cstar	0.77783	0.778105	0.778836	0.78026	0.782604	0.786091	0.79085	0.797035	0.80434	0.812144
c	1.665	1.848	1.943	2.004	2.052	2.088	2.119	2.147	2.181	2.221
HEC-RAS Computed c	1.668	1.847	1.943	2.005	2.051	2.089	2.122	2.156	2.188	2.224
Rect. Channel, Sharp crest, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.27	12.96	13.67	14.3	14.9	15.47	16.03	16.57	17.09	17.6
water head elevation	11.34	11.93	12.54	13.07	13.57	14.05	14.5	14.94	15.37	15.78
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.23	11.92	12.63	13.26	13.86	14.43	14.99	15.53	16.05	16.56
h	10.3	10.89	11.5	12.03	12.53	13.01	13.46	13.9	14.33	14.74
W	0.890472	0.838926	0.791766	0.754148	0.721501	0.693001	0.667111	0.643915	0.623053	0.603865
y	0.917186	0.913591	0.91053	0.90724	0.90404	0.901594	0.897932	0.895042	0.892835	0.890097
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
b	10	10	10	10	10	10	10	10	10	10
cstar for Sharp Crested Weir = 1.0	1	1	1	1	1	1	1	1	1	1
c	2.136	2.356	2.490	2.564	2.613	2.652	2.675	2.695	2.713	2.725
HEC-RAS Computed c	2.140	2.360	2.495	2.570	2.620	2.657	2.683	2.704	2.720	2.733

Rect. Channel, Ogee crest, S=10ft/mi	8,000 cfs	9,000 cfs	10,000 cfs	11,000 cfs	12,000 cfs	13,000 cfs	14,000 cfs	15,000 cfs	16,000 cfs	17,000 cfs
ave weir top elevation	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04
total head elevation	12.29	13.01	13.71	14.36	14.97	15.56	16.12	16.66	17.19	17.71
water head elevation	11.36	11.98	12.59	13.14	13.65	14.14	14.61	15.05	15.48	15.9
channel bottom elevation at midpoint	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
w	10	10	10	10	10	10	10	10	10	10
H	11.25	11.97	12.67	13.32	13.93	14.52	15.08	15.62	16.15	16.67
h	10.32	10.94	11.55	12.1	12.61	13.1	13.57	14.01	14.44	14.86
W	0.888889	0.835422	0.789266	0.750751	0.717875	0.688705	0.66313	0.640205	0.619195	0.59988
y	0.917333	0.913952	0.911602	0.908408	0.90524	0.902204	0.899867	0.896927	0.894118	0.891422
s0	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189	0.00189
r	4	4	4	4	4	4	4	4	4	4
cstar for Ogee Crested Weir	0.887932	0.916955	0.951831	0.986698	1.01936	1.049574	1.076314	1.100012	1.121195	1.140012
c	1.906	2.175	2.383	2.544	2.678	2.794	2.896	2.980	3.054	3.119
HEC-RAS Computed c	1.909	2.179	2.388	2.550	2.686	2.804	2.904	2.991	3.065	3.130

APPENDIX C

New Lateral Weir / Embankment Editor

Weir/Embankment Editor

The Embankment and Weir data are entered together, and are used to describe the embankment in which the outlets will be placed, as well as any uncontrolled weirs. To enter the weir and embankment data, press the **Weir/Embankment** button and the editor will appear as shown in Figure **Error! No text of specified style in document.**-1.

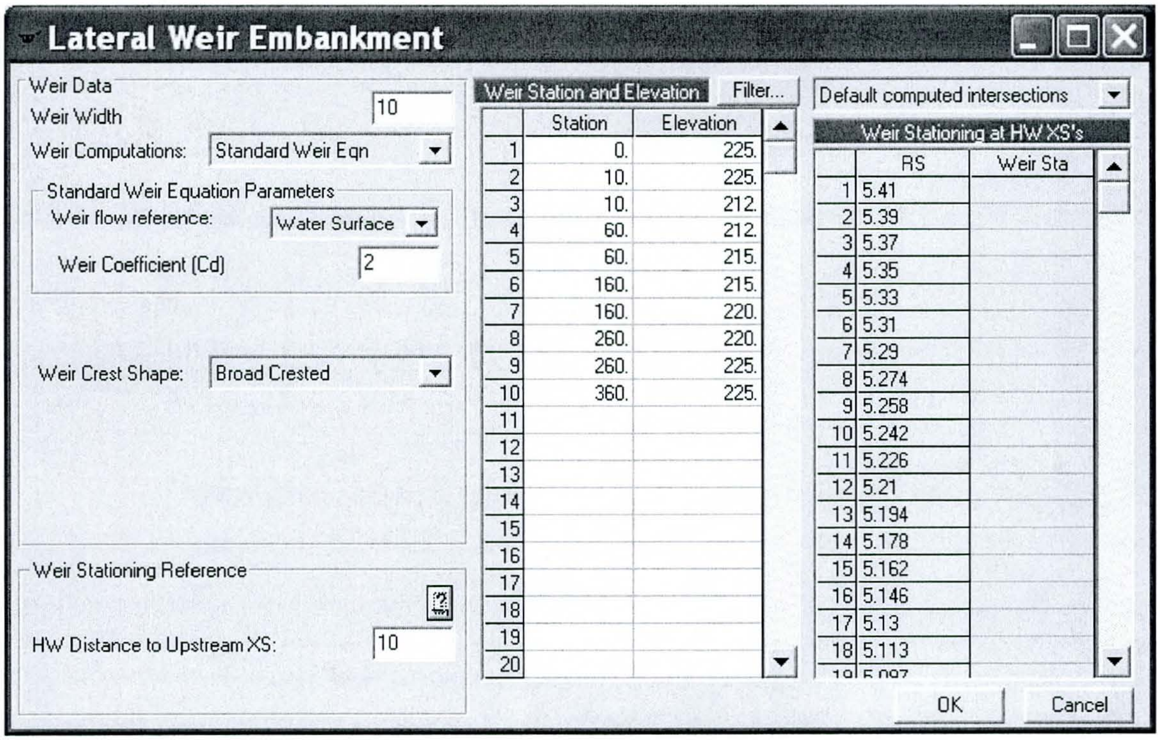


Figure ***Error! No text of specified style in document.****-1 Lateral Weir/Embankment Editor*

The Lateral Weir/Embankment Data editor is similar to the Deck/Roadway editor for bridges and culverts. The data on the Weir/Embankment editor is the following:

Weir Width - The width field is used to enter the width of the top of the embankment. This value will only be used for graphical plotting, and does not have any effect on the computations. The width of the embankment should be entered in feet (meters for metric).

Weir Computations – This field allows the user to select either the standard weir equation or Hager's lateral weir equation. When the standard weir equation is selected, the user will also need to enter a weir flow reference head, and a weir coefficient. If Hager's lateral weir equation is selected, the user must also enter: default weir coefficient; weir average height; an average bed slope, and a weir angle in degrees if it is anything other than parallel to the stream.

Weir flow reference - This value is used to select whether weir flow is computed by using the energy gradeline or the water surface from the cross sections. The default is to use the energy gradeline.

Weir Coefficient - Coefficient that will be used for weir flow over the embankment in the standard weir equation.

Weir Crest Shape - When submergence occurs over the weir/embankment there are two choices available to figure out how much the weir coefficient should be reduced due to the submergence. These two criteria are based on the shape of the weir. The first method is based on work that was done on a trapezoidal shaped broad crested weir (FHWA, 1978). The second criterion was developed for an Ogee spillway shape (COE, 1965). The user should pick the criterion that best matches their problem. If the user selects the Ogee Spillway shape, then some additional information is required. For an Ogee shaped weir the user must enter the "Spillway Approach Height" and the "Design Energy Head". The spillway approach height is equal to the elevation of the spillway crest minus the mean elevation of the ground just upstream of the spillway. The design energy head is equal to the energy grade line elevation (at the design discharge) minus the elevation of the spillway crest. In addition to these two parameters, the user has the option to have the program calculate the weir coefficient at the design discharge. This is accomplished by pressing the $\mathbf{C}_d$ button. Once this button is pressed, the program will compute a weir coefficient for the Ogee spillway based on the design head. During the weir calculations, this coefficient will fluctuate based on the actual head going over the spillway. The curves used for calculating the Ogee spillway coefficient at design head, and discharges other than design head, were taken from the Bureau of Reclamation publication "Design of Small Dams", Figures 249 and 250 on page 378 (Bureau of Reclamation, 1977).

HW Distance to Upstream XS - This field is used to enter the distance between the upstream end of the Weir/Embankment (based on where the user will start to enter the embankment data) and the cross section immediately upstream of the structure. This distance is entered in feet (or meters for metric).

Weir Station and Elevation - This table is used to define the geometry of the Weir and the Embankment. The information is entered from upstream to downstream in stationing. The user enters stations and elevations of the top of the embankment and weir. The stationing is relative, so it can be started at any number (i.e. 0, 100, etc...). The user enters stations and elevations from the upstream end to the downstream end of the lateral structure. Everything below these elevations will be filled in to the ground. By default, the lateral structure will be lined up with the river/reach by comparing the stationing entered with the reach lengths of the river/reach. If the lateral structure is connected to the right overbank of the reach, then the right overbank reach lengths are used. If the lateral structure is connected to the right or left bank station of the main channel, then the main channel reach lengths will be used. The **Filter** button allows the user to filter the station and elevation points in order to reduce the total number of points. This feature is often used when a lateral weir is used to represent a natural overflow area, and the data has come from a GIS.

Weir Stationing at HW XS's – This table will by default show the weir stationing that intersects with the cross sections in the river/reach that the structure is defined in. The software automatically aligns the weir with the cross sections in the reach based on the weir stationing and the reach lengths in the cross sections (either left overbank, main channel, or right overbank reach lengths). However, if the user does not like how the defined weir intersects with the cross sections in the reach, they can define their own intersection points by entering the desired weir stationing to intersect with each of the cross sections in the reach. Water surface elevations for the lateral structure will then be interpolated based on the user entered stationing.

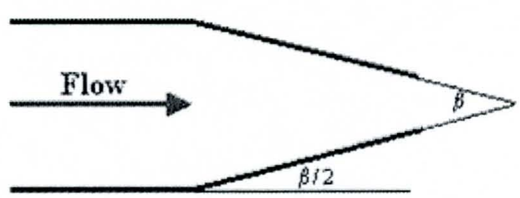
If Hager's Lateral weir equation is selected from the "Weir Computations" field, then the following additional fields will appear:

Default Weir Coefficient (Cd) – This weir coefficient will be used for the first iteration of trying the Hager lateral weir equation. The equation is iterative, and requires hydraulic results in order to make a weir coefficient calculation. The default weir coefficient is only used for the first guess at the hydraulic computations.

Weir Average Height – This field is used for entering the average height of the weir above the ground.

Average Bed Slope (Optional) – This field is used for entering the average slope of the stream bed in the reach of river that contains the lateral weir. If the use does not enter this field, the HEC-RAS program will compute the slope by estimating an average bed elevation for each cross section, then computing the slope of the average bed elevation. Average bed elevation of an irregular cross section is obtained by subtracting hydraulic depth from the water surface elevation.

Weir Angle in Degrees (Optional) – This field can be used to enter and angle for the weir. If the weir is parallel to the stream, the angle is assumed to be zero. If the weir is angled inwards towards the center of the river, an angle (beta) is required. This ise used for channels that have a contraction, and weir flow is allowed to go over the contracted section. A diagram showing the angle (beta) is shown below:



DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT CORPS OF ENGINEERS
P.O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

REPLY TO
ATTENTION OF

September 1, 2004

FLOOD CONTROL DISTRICT
RECEIVED
SEP 07 '04

CH & GM	FINANCE
PIO	LANDS
ADMIN	C & M
REG	P & PM
ENG	FILE
CONTRACTS	
ROUTING	

Office of the Chief
Hydrology and Hydraulics Branch

Mr. Timothy S. Phillips, P.E.
Acting Chief Engineer and General Manager
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

Dear Mr. Phillips:

We are in receipt of your letter dated August 9, 2004, requesting an engineering software customization of the Corps of Engineers' HEC-RAS hydraulic software package.

As you are aware, the development of the program resides with the Corps' Hydrologic Engineering Center (HEC), which is located in Davis, California. On your behalf, we will forward your letter to the lead developer of the program at HEC, Mr. Gary Brunner. Mr. Brunner will contact you or as noted in your letter, Mr. Bing Zhao, to further discuss your request.

We appreciate your interest in working with the Corps of Engineers to enhance a software tool that is widely used both by public entities and private industry throughout the nation.

Copies of this letter are being furnished to Mr. Gary Brunner, US Army Corps of Engineers, Hydrologic Engineer Center, 609 Second Street, Davis, CA 95616, and Mr. Bing Zhao, Application Development Branch Manger, Flood Control District of Maricopa County, 2801 West Durango Street, Phoenix, Arizona 85009. Questions regarding this subject may be directed to Mr. Rene Vermeeren of the Hydrology and Hydraulics Section at (213) 452-3547.

Sincerely,

David H. Turk

David H. Turk
Colonel, US Army
Acting District Engineer

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P. O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

February 3, 2006

REPLY TO
ATTENTION OF:
Planning Division

Mr. Bing Zhao
Engineering Application Development Branch Manager
Flood Control District of Maricopa County
2801 West Durango,
Phoenix, Arizona 85009

Dear Mr. Zhao:

Enclosed for your files is a signed copy of the Cost Sharing agreement pertaining to the HEC-RAS Side Weir Customization, Maricopa County Planning Assistance to States study.

As indicated in the Cost Sharing Agreement, the Sponsor, the Flood Control District of Maricopa County, shall contribute fifty (50) percent of the study costs (cash and in-kind services), with a cash contribution of $50,000.00. The Corps is requesting that you submit your non-federal cash contribution payment of $50,000.00. A check for this amount should be made payable to "FAO, USACE, Los Angeles District" with the project name of "PAS-AZ- HEC-RAS Side Weir Customization, Maricopa County PAS, the Flood Control District of Maricopa County, Arizona, CWIS#128230" and mailed to the following address as soon as practicable.

FAO, Los Angeles District
US Army Corps of Engineers
ATTN: CESPL-PD-W (Ed Demesa)
915 Wilshire Blvd. 14th Floor
Los Angeles, CA 90017

If you have any questions, please contact Bryon Lake, at (602) 640-2003 Extension 246 or Kim Gavigan, PAS Program Coordinator, at (602) 640-2003 ext. 251.

Sincerely,

for Michael Haltay

Daniel E. Sulzer
Acting Chief, Planning Division