IRRIGATION-CANAL-SIMULATION MODEL USAGE

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ABSTRACT: Unsteady canal-simulation model usage requires serious investments of time and personnel. The reasons for deciding to invest in a model, as well as reasons not to invest, are discussed. For most cases, it is better to invest in the improvement of an existing model than the writing of a new model. Many excellent models are available, although very few can be considered user-friendly for the average design engineer. Unsteady flow-simulation models are not recommended for real-time control, but are key tools for the study of various control scenarios. Canal models can simulate an actual canal, but the user must input the necessary canal gate-control algorithms in order to study the effects of various types of automation and control. The user must also understand the basics of the system to be modeled and have the time and capability to determine if model results are reasonable and sound.

INTRODUCTION

One of the tools frequently mentioned for an irrigation-project-modernization program is a good unsteady flow-simulation model for open channels (i.e., canals). The various models that exist are fairly similar in accuracy (barring any unknown mathematical errors that may exist). Their primary differences from the user's standpoint are: (1) User-friendliness and adequacy of documentation; (2) ability to handle a variety of boundary conditions such as combination weir/undershot gates, hydraulic gates, siphons, and pumps; and (3) hardware requirements (personal computers (PCs) versus mainframe).

Researchers and engineers have spent many years of work on various models. If there is an immediate need for simulation, one should probably not fund the development of a new unsteady flow model (i.e., do not reinvent the wheel), an easy trap to fall into because existing models will rarely fit one's exact needs. It is far better to invest time and money into modifying and documenting an existing model.

New models are sometimes developed unnecessarily if the engineers do not clearly understand the final use of an unsteady model. The result is generally a new model that is less complete than existing models, and that is never fully usable because funding runs out or because potential users lose confidence in the project due to their high expectations.

Existing simulation models have their positive and negative aspects. The good news is that: (1) There is a heightened interest in such models, as evidenced by good attendance at sessions on models at the 1991 I&D Specialty Conference in Hawaii; (2) model programs are becoming more widely available for use on PCs; and (3) some powerful modeling programs exist. The bad news is that these computer programs are not comparable to standard user-friendly PC software. If one has difficulties wading through the documentation for some of the off-the-shelf PC programs, unsteady canal

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models with virtually no documentation can provide a very frustrating experience. Canal models, as a rule, have insufficient documentation, require extensive knowledge of programming and hydraulics, are cumbersome to manipulate and operate, and have generally been developed for some special circumstance that differs from the new application in just enough ways to be troublesome. Documentation always comes last, and, in the rush to get the thing working, is rarely sufficiently completed to be useful.

RESOURCES NEEDED FOR USING FLOW MODEL

Unsteady flow models are not commonly used in small-to-medium-sized engineering firms, nor are they used in most U.S. irrigation districts, in spite of their potential importance as a tool. They are more often used in university research projects and water labs, in some water-oriented organizations with a large technical staff [e.g., United States Bureau of Reclamation (USBR)], and in a few very large engineering firms, which have some very specialized and highly trained staff. There is a simple explanation—the operation and manipulation of these programs generally require considerable and special staffing and time resources, if the program is used in development/design efforts. If the program is developed so that it can be used as a simple training tool using a few “canned” examples, or if it has been customized by the developer so the user can perform a few very simple “what if” operations, the user staff and time resources will be considerably smaller. The following discussion regarding resources will assume that some design and development work is done with the model.

Personnel

Rule number one, with unsteady flow models, is that the programmer/engineer who developed the computer program must be hired for a few days at the very minimum. More realistically, one should assume that the programmer will be needed for at least several weeks to get new users up to speed, and will have to be available from time to time afterwards. If one has access to a program, but not the programmer, it may be best not to use the program (even if it is free). These programs will most likely produce incorrect answers if they are not set up and used correctly; furthermore, getting up to speed by oneself is no trivial task. A “service contract” that provides for telephone or other programming support by the author should be considered.

The original program developer will more than likely expect that someone on staff has expertise in computer hydraulic programs, engineering, and unsteady flow. That person will then become the “expert,” since no one else on staff will probably ever really understand how the program works. It takes an average of several (two to six) person-months for such a qualified person to become comfortable with the typical programs that are available. What this means is that the other staff or engineers in an irrigation district or a consulting firm may never really understand how to completely set up and use the unsteady flow model—they simply will not have the time to learn the program details. Instead, they will have to rely upon a specialized engineer on staff who is trained in this area. This does not mean that senior personnel should not be closely involved. In fact, they must be involved. Their experience is essential in evaluating results—what may be thought to be good data by a programmer or inexperienced engineer may often be recognized as nonsense by someone who knows what to look for and what to expect in results.

Hardware

The hardware requirements are considerably easier to meet than was the case just a few years ago. Until recently, these models needed a mainframe computer. Now, many can be run on PCs. Generally, a math coprocessor is helpful. A hard disk is virtually always necessary, and a 386-based IBM-compatible machine is almost a minimum requirement. The specific requirements can be found from the authors of the various programs.

Data

The unsteady flow models are mathematical models that simulate actual canal operations. Therefore, the simulations are only as accurate as the input data. Canal roughness values, bottom slopes, side slopes, widths, elevations, pool lengths, transitions, and structures must all be defined properly. Some values may be relatively easy to obtain, such as the canal slopes and cross sections for a lined canal. Roughness values may not be known, or they may change during the year. Gate-discharge coefficients are particularly difficult to estimate accurately. The importance of estimating roughness values and gate-discharge coefficients accurately depends upon the ultimate use of the program. For real-time control, those values can be critical. For development of some gate-control algorithms (assuming there is a feedback loop in the gate-control algorithm), the precision is not as essential. However, for some proportional/integral (PI) controller development, it is quite important to know the exact gate-discharge equations.

The magnitude of the data-collection job should not be underestimated. As an example, when the ASCE Irrigation and Drainage task committee on unsteady flow modeling looked for sets of complete actual field data to run in various models, there was virtually none available.

Calibration

The old rule of "garbage in, garbage out" still applies. The output from any model must always be compared to reality. It should be noted that these are unsteady flow models. However, they must be able to accurately calculate steady flow conditions, as a bare minimum. Comparison with steady flow results also provides a means of checking predictions.

However, steady flow rarely exists in a real canal. To define the instantaneous unsteady condition at a single moment, all gate positions, flow rates, and water levels throughout the system need to be known. Gate positions and some water levels may be remotely monitored or recorded with relative ease in some modern projects. Flow rates, however, are very difficult (if not impossible) to accurately monitor or measure at all points throughout a real canal network.

KNOWLEDGE NEEDED BEFORE STARTING

Perhaps the most commonly stated, yet least understood reason for showing interest in a model is "to study the operation and automation of a specific canal." It is true that a good model can be a valuable asset for such a purpose. However, before a model is purchased for that purpose, the following items need to be defined for the canal reach that is to be studied:

1. The degree of flexibility desired.
2. How that particular canal reach can and will interact with upstream and downstream reaches. For instance, will the studied canal reaches be

operated on “demand” yet the downstream reaches be operated on an “arranged” basis?

3. The location of the command decisions, i.e., local control versus remote control.

4. The classification of control desired (scheduled versus responsive).

5. The adequacy of the present/proposed canal design for the particular control logic that will be selected/studied. For example, a study of a level-top-downstream control-gate algorithm will be futile unless sufficient wedge storage has been built into the canal design.

6. The specific gate-control algorithms to be used in studying the canal. This may be the least understood item of canal modeling. Even when an excellent unsteady flow model is purchased, studied, and calibrated, and all that work (taking many months or years) has been done, the user is probably not yet ready to begin using the model. A model does not automatically come with the necessary control algorithms. A model can only be used to study a particular gate-control algorithm or control logic. A “study of the operation” of a canal implies that there is some logic to the operation, and that gates are moved for some reason. One must supply the control subroutines to put into the unsteady model for computing the proper gate changes. That’s where the fun and the challenge really just begins. All of the preparation work of learning the model, collecting data, and calibration is just necessary to get ready to use the model. It just takes so much time and effort that some users mistakenly believe that once the model finally runs and is calibrated, the work is finished.

WHY ONE MIGHT OR MIGHT NOT WANT TO USE MODEL

Several uses of models are now highlighted:

1. Real time control. This use of an unsteady flow model is highly discouraged. There are no successful programs of this type in operation that the writers are aware of. Canal unsteady flow-simulation programs are cumbersome, and better suited to simulations for control-algorithm development. A simulation program should not be used for real-time control when the actual canal is already providing the correct, actual data and the simulation program can never exactly predict the flows or water levels because the input data is always imprecise.

2. Development of control algorithms and operational strategies. This is where these models can excel. It is simply impossible to run hundreds of trials on a real canal and have access to all the desired data, but with a simulation model those trials can be done quickly and safely, with full access to all data. The safety aspect should not be minimized; early algorithm development generally has errors. Errors in a microprocessor algorithm on a real canal can cause serious damage to canals, fields, and towns.

3. Canal design. Unsteady models may not be what is needed. Often the canal design only solves for dimensions at maximum (steady) flow rates. In that case, a more simple, inexpensive steady flow model may suffice. However, if the canal design is completed in conjunction with a study of various advanced gate-control logics, the use of an unsteady model can pinpoint the needs for extra pool storage and freeboard.

4. Studies of when to release water from a dam to a canal with upstream

control. Unsteady models can show how a flow rate and water-level changes will pass through a canal system, with static or dynamic control structures. This type of “arranged yet unresponsive” type of canal control may be the greatest initial potential use of the future generation of “user-friendly” models.

5. Studies of buffer reservoir operation in canal networks, or studies related to buffer reservoir design. This may be another good potential use for the future generation of models. Currently, buffer reservoir operation is hit or miss in most U.S. districts.

LOOK FOR WAYS TO SIMPLIFY PROBLEM

Most irrigation projects are not composed of a simple series of canal pools. Instead, there are multiple layers of canal branches. Some simulation models handle branching systems while others only handle a single series of pools. The question for the user with a branching system is: Is it important to have a model that can analyze the entire system at once? In most cases, the answer is “no.” For example, if a lateral canal has a dead end and is operated with upstream control, the flow rate into that lateral is always known. Therefore, the flow of the outlet of the supplying canal (which supplies the lateral) is also known. It is not necessary to dynamically link the two together in a program in order to study the effects of a particular control strategy/algorithm in the supply canal.

RULES FOR USING MODEL

1. Check your work (input, data, dimensional units, channel connections, output).
2. Double-check your work. Then have someone else do it, too.
3. When you review results, try to figure out what is going on and why. A model is a tool for understanding a system. Try to answer: What is going on and why? Is it physically reasonable? Would I have guessed it would behave this way?
4. Make a radical change in the input. Does the model still work? Stressing a model helps determine the limitations.
5. When trying to prove a point with a model, try also to prove the opposite with the same data. Do not let your bias interfere with your interpretation of the results.
6. When the model tells you what you expect, be suspicious. Your own bias may be blinding you to a subtle error. (When it gives an unusual or unwanted result, you automatically search for a problem; do the same thing with expected results.)
7. Look at results removed from the focus of the study. Are they reasonable?
8. Repeat step 1.
9. Document everything and save it.

SUMMARY

Unsteady canal flow-simulation models can be valuable aids in development/design, but they require a firm and considerable commitment of time and personnel. Most are not yet considered to be user-friendly for the

average engineer. Before investing in a model, one should have a clear idea of what the model will provide, and what is desired from the model. Many questions may not require the use of an unsteady model to obtain an answer. Be cautious and use common sense in using any model (from simple equations to complex numerical models).