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PORTUGAL UNIVERSITY INSTITUTES DEVELOPMENT PROJECT

(Contract AID/NE-C-1701)

REPORT ON
SHORT-TERM STAFF ASSIGNMENT

Submitted by
DR. DAY L. BASSETT
Department of Agricultural Engineering
Washington State University
Pullman, Washington

July 14 - August 25, 1983

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REPORT ON

SHORT-TERM STAFF ASSIGNMENT

AT THE

INSTITUTO UNIVERSITARIO DE TRAS-OS-MONTES E ALTO DOURO (IUTAD)

VILA REAL, PORTUGAL

Submitted by

DR. DAY L. BASSETT
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ACKNOWLEDGEMENTS

I express my grateful appreciation to a number of persons whose support and cooperation made this opportunity possible. I consider it a privilege and pleasure to participate in the further development of the Instituto Universitário de Tras-os Montes e Alto Douro (IUTAD).

The administrative support and guidance of Prof. Doutor Fernando Nunes Ferreira Real, Reitor of IUTAD, was most useful in creating an environment in which this assignment could be completed. Dr. Jose Torres Pereira was helpful in making living, financial and travel arrangements and for defining the assignment initially. The suggestions of Mr. Charles Buchanan and Mr. Michael Lukowski, USAID/Lisbon were appropriate and greatly appreciated, as was the effort of Ms. Vivian Rider at Purdue in making the administrative arrangements so thoroughly. It was a privilege to share the inspiration of Prof. Doutor Zozimo Castro Rego, who has contributed so greatly to education in Portugal.

Sincere thanks is also expressed to personnel of the MAFA Regional Services at Chaves and Mirandela whose full and active cooperation was essential to my becoming familiar with the region and to our conducting irrigation field trials at Chaves. Their understanding of the region and its needs was most helpful in this planning effort and will remain essential to research which should follow.

Appreciation is expressed to members of the IUTAD clerical staff for their help and attention to important detail, as well as to the shop staff for preparing irrigation equipment on short notice.

Finally, my special thanks to Eng.[a] Maria de Lurdes Fernandez for her selfless dedication to our mutual assignment during this period, and to Eng. Francisco Rego for his patience, generosity and active help during

this strenuous period. Their complete support made possible the satisfactory completion of this assignment.

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INTRODUCTION

The Instutito Universitário de Trás-os-Montes e Alto Douro (IUTAD) was founded in 1973 and activated in 1975 to promote short university level courses, applied research and extension activities related to the needs of its implementation area in northeastern Portugal. The region is mountainous, has a population of about 500,000, is the economically poorest region in Portugal and the illiteracy rate is high. Agriculture is substantial, mainly on small farms, and employs as much as 60 to 70 percent of the labor force. Due in part to an out-migration of young people the average age of the population is high and the educational level tends to be low. IUTAD is expected to develop in cooperation with other institutions, including the Ministry of Agriculture (MAFA), programs that will help the people in economic and other ways.

A small but important portion of the tillable land in the region is irrigated, largely by old and traditional methods. These methods are designed and operated largely on the basis of experience, are very labor-intensive and tend to use water sub-optimally. One of the objectives of IUTAD is the evaluation and possible improvement of irrigation practices and water use.

Under the USAID-funded Portugal University Institutes Development Project a short term expatriate advisor was provided to assist IUTAD to prepare for this irrigation assignment. This report sumarizes the activities and the recommendations of the author who was priviledged to serve in this advisory role.

The geographic area of assignment centered at IUTAD in Vila Real, and comprised the more heavily irrigated areas to the north, including Montalegre, Chaves and Mirandela. The subject matter mentioned in various

communications included hydraulics, irrigation and erosion. In reality, issues of interest in the region proved to be largely irrigation, with hydraulics being an important supporting discipline, and erosion a significant constraint to be considered in irrigation development. During this study period emphasis was therefore placed on irrigation.

The objectives addressed by the advisor were mainly those defined initially:

1. to advise in programming the studies and field trials,
2. to help in the implementation of a first trial in order to advise on practical problems that always arise in that phase, and
3. to evaluate the needs of the Rural Engineering Department in the areas of teaching and research in hydraulics (and in irrigation).

The advisor's Portugese counterpart was Eng.[a] Maria de Lurdes Miranda Fernandez, Assistant-in-Stage, in the Department of Rural Engineering (Departmento de Fitotecnia e Engenharia Rural) at IUTAD, who is just completing her first year of service in this position.

To accomplish the above objective the schedule suggested by Dr. Jose Pereira was followed as much as possible. The work began with visits with several IUTAD administrators and faculty, as well as MAFA personnel. Irrigated areas were visited, as well as sites where improvement work on water delivery systems by MOF and MAFA Regional Services personnel is underway. Field trials in both furrow and sprinkler irrigation were planned, conducted and analyzed to provide experience in such activity for Eng.[a] Fernandez. The proposed IUTAD irrigation research contribution to the Tras-os-Montes Rural Development Project was reviewed, and advice on implementation offered, considering possible cooperation and resources of MAFA Regional Services. Irrigation in the region was examined

for areas of possible improvement. The hydraulics and irrigation (H&I) capability of IUTAD was reviewed, including courses, and recommendations prepared for improvement. The role of H & I extension at IUTAD was considered generally. Over half the advisor's time at station was devoted to field trials and research planning. Significant daily activities are summarized in Appendix A.

Accomplishment of planned activities was constrained and somewhat delayed by several factors, some of which were unpredictable. These included the extended vacations of IUTAD and MAFA personnel, a distance of 65 km to the main site selected for field trials, and the need to borrow or improvise necessary equipment for the trials. Unusually cool weather and rain reduced the need for irrigation and the opportunities for conducting evaluation trials. Fortunately, no housing, health or other personal problems arose to impede the work. The language barrier proved inconvenient but not insurmountable.

The following parts of this report summarize the author's assessment of the general nature of irrigation as practiced in the region, the potential of IUTAD to evaluate and perhaps help to improve this irrigation, and recommendations intended to help IUTAD become better able to accomplish its hydraulics and irrigation objectives on campus and throughout the region.

ASSESSMENT OF IRRIGATION IN THE REGION

Irrigation in the region has been widely described as "traditional", with some notable variations. Most frequently encountered are very small parcels located in mountainous or hilly areas with uneven topography and often steep slopes unless modified by contour tillage or terracing. Irrigation streams of water are generally very small, perhaps serving only one or two furrows at a time. This water may originate in small mountain streams or springs, be collected in small holding tanks and delivered to the land parcels in unlined earth ditches. On-farm application is almost entirely by furrows for row crops or by controlled flooding for close-growing crops, mainly pasture. As practiced here, these methods involve almost no water control or distribution equipment, but are instead very labor intensive. The water delivery systems tend to be village oriented, serving adjacent areas of about 50 to 200 ha.

Significant variations are found mainly in the more heavily irrigated valleys served by established irrigation projects, the Chaves valley being one example. Here the fields may be slightly larger, have less slope and more uniform topography. More commercial production is evident. Stream sizes tend to be larger than in the village systems, though still relatively small. On-farm application methods remain furrows or controlled flooding. Exceptions include a few small sprinkler systems and even fewer drip systems, largely experimental. Relative absence of these more modern systems seems in part due to system cost, lack of power on farms, the cost of that power, a very small commercial sector in irrigation, absence of extension activity in irrigation, and established tradition.

Another factor seeming to contribute to retention of old methods is the water delivery system. In the villages especially, water rights are

connected with the land, the owner having by tradition the right to an amount of water. There may be no official association of water users, but everyone in the village knows the list of users and the rules to be followed, which are handed down verbally to the next generation. Water delivery is on a rotation basis, with perhaps 3 or 4 hours of water use scheduled each week per user. Opening and closing of individual turnouts is the responsibility of each user. Occasional repairs are decided upon by a village administrative council and accomplished by user work contributions. Small streams available almost require the rotation system be used if growers are to have sufficient water with which to work. The rotation system, however, effectively prevents adoption of more modern systems because such systems require water for longer periods of time. Rotation also discourages the use of promising methods of scheduling irrigation, since water may not be available when needed.

Significantly, there is one irrigation project in the region which differs in many ways from the more traditional ones described above. This is a new project in the Valley of Vilarica. Water is supplied from the Burga dam to lower lands under gravity pressure for sprinkling and drip irrigation, though some furrow irrigation is being practiced. Now in its third year of operation, this project (about 200 ha) is still in the development period. Operating procedures and costs are still to be determined, but delivery will be on a demand basis, permitting use of the newer methods based on crop demand for water. The area contained little irrigation before project implementation. Local tradition in matters of water use had not become established, which may explain in part why the acceptance of sprinkling by growers has proceeded so rapidly. On-farm sprinkler equipment was originally supplied by the government. There is

little commercial activity in equipment sales in the area. Little extension activity dealing with irrigation is underway. While some very modern irrigation and cultural practices are being tried, such as cool weather production of strawberries under plastic tunnels, abuse of water is evident even with sprinkler irrigation. The project is being watched with interest locally, and assuming these early problems are resolved may well become the pattern for others now being planned. This very progressive project concept provides a marked contrast to traditional practices in the region, and as such can be very important in the IUTAD teaching, research and extension programs.

Soils in the region, while differing between locations, tend to have relatively high infiltration rates, permitting irrigation set times to be as short as an hour or even less. The soils seem quite resistent to erosion, especially under vegetative cover. Drainage and salinity problems are not evident in the hilly areas. There are isolated drainage problems in the Chaves Valley, but these are not yet of major regional significance.

Brief examination suggests certain generalities exist within the region regarding the effectiveness of irrigation, again recognizing exceptions. Water is generally regarded as valuable and deserving of care. With little water control equipment available, labor is substituted, causing irrigation to be labor-intensive. While commonly accepted, this condition is not desired by growers since the out-migration places a burden on those that remain, often women. Labor saving methods would apparently be welcome if acceptable economically and otherwise.

Since water is considered valuable and labor is invested generously to control it, run-off losses seem small. The short application times and small fields suggest that deep percolation losses are not great.

It follows that the application efficiency, E_a, should be relatively high. The uniformity with which water is distributed over the field, E_d, may also be fairly high on small fields with much labor present. On larger fields it can probably be improved substantially by better land surface preparation and the use of more satisfactory water control equipment. Observation suggests that storage efficiency, E_s, a measure of how fully the irrigation replaced depleted soil moisture, could also be improved if crop water use was monitored more closely, water was measured to each field, and could be obtained when needed instead of on rotation.

Other factors in the region which affect irrigation practice were also noted. Electric power is quite widely available in the region, but not at most farms. Its cost is sufficiently high to discourage but not entirely prevent its use in irrigation. Petroleum fuels are very expensive, which with the cost of engines and maintenance, strongly discourages adoptation of systems that require internal combustion power. A strong commercial sector to sell and service the more sophisticated systems is notably absent. Extension activities to educate growers on irrigation matters appear to be very modest, as does the supply of educational material. People with irrigation training are relatively few, and those actively working in technical irrigation are fewer yet. The low education level of many growers complicates the introduction and acceptance of new technology. Current very high interest rates tend to discourage borrowing to buy expensive equipment. Small land holdings cause irrigation development costs per unit of land to increase. These and other factors existing in the region, while generally discouraging to irrigation change, to not prevent it. They must, however, be included in the planning for irrigation improvement.

ASSESSMENT OF HYDRAULICS AND IRRIGATION AT IUTAD

In the IUTAD curriculum the instructional offering in hydraulics and irrigation is contained in two courses: an introductory course in hydraulics taken as a prerequisite for an introductory course in irrigation. They are taken in the third and fifth years of study, respectively. Students are agriculturally oriented, with some preparation in mathematics and physics. The hydraulics course is taken largely from introductory texts in fluid mechanics and hydraulics, which are readily available for this mature subject. Students are not required to buy a text, however, but are provided hand-out materials. Instruction is almost entirely on theory and problem solution, with essentially no laboratory or hands-on learning opportunities. Only one instructor is available to teach the course, which is offered in the fall semester annually. Content appears appropriate and sufficient for the intended purpose except for the laboratory instruction discussed below.

The irrigation course is also taught in the fall semester annually. It too is almost entirely theoretical, providing no laboratory or field experience. Significantly, this subject is less standardized world-wide than hydraulics and more subject to change with time and location. Effective instruction is therefore even more dependent upon practice to augment theory and to introduce local conditions than is hydraulics. Again, texts were not currently required, and only one person is available to teach the course. Content appears appropriate but not entirely sufficient for the purposes intended.

Eng.[a] Maria Fernandez teaches both courses, but has little experience in either subject beyond that gained in similar courses in her own training. She is the third person to hold this position in as many years.

Being the only instructor, she has little opportunity to discuss course material or bring in other experiences. It is also difficult for her to arrange extended study periods away from campus to gain the experience she needs. Her time available for off-campus research is limited, which accordingly limits the IUTAD involvement in such work since she is the only faculty member. No technician help has been assigned to her.

The teaching budget for H & I seems both small and uncertain, considering the needs for development. Each fund request is considered separately as presented. The more conventional annual budget system is not widely used.

Audio-visual equipment is available for instructional purposes. Slide files and other teaching resources appear very limited. Library references in H & I are quite inadequate for effective instruction, both in extent and availability to students.

Equipment fabrication is done in the IUTAD shops. Personnel are most helpful and prepared to handle common tasks. Capability in electronics and instrumentation is not evident. Computing equipment for H & I uses seems limited to hand calculators and one small desk-top computer shared across campus. Student use of the computer and programming ability are not stressed.

To date, H & I activities have been devoted largely to teaching with some time spent on research planning and none on extension. This is understandable considering the resources and committments already made. With the implementation of the proposed Rural Development Project much more time will be required for research, which suggests that additional people and operating funds must be made available.

Most faculty business seems to be conducted between the member and the central administration, with only moderate involvement of the Department Chairperson.

RECOMMENDATIONS AND COMMENTS

Earlier sections of this report have summarized certain characteristics of irrigation in the region, and IUTAD's capabilities to assist in the improvement of these and practices. The present section contains recommendations the author feels are necessary or desirable to help the IUTAD H & I faculty become as effective as possible in the discharge of duties that will surely increase in complexity and scope as research work begins. Considering financial and other constraints, the goals have been kept modest and short or intermediate term in nature.

Where priorities are involved, the comments will so indicate, in terms of immediate, early or delayed implementation. Any budget references should be regarded as approximate only, since constraints of time and vacations have prevented the making of a number of important administrative decisions upon which H & I plans depend. Some recommendations are therefore general in nature now, awaiting those key decisions.

Recommendations are listed under the three main program headings in which H & I will likely become involved - instruction, research and extension - and one that crosses program lines, other. In reality, the programs are greatly interdependent and should be considered parts of an integrated H & I activity.

A. Instruction

1. Should resources become too limited to conduct all IUTAD programs, funds should be used to maintain instruction. The forthcoming activity in research, however attractive, should not be carried on at the expense of a strong teaching program.
2. Further development of the teaching program in H & I in the near term should be confined to the improvement of the two present courses, rather than the introduction of new ones.

3. Efforts to improve the hydraulics course should concentrate on the development of laboratory and "hands-on" learning opportunities. Suggestions have been left with Eng[a]. Fernandez regarding subject matter additions. Later recommendations deal with laboratory development.

5. Consideration should be given to requiring each student to buy a copy of the text used in each of the courses.

   The technical nature of the material in both courses makes the transfer of knowledge verbally and by notes in class very difficult. Class time used this way is not used as effectively as it should be, and could be. Preparation of substitute hand-out materials can be costly. A good personal library is an inducement to continued learning. The faculty should do all it can to encourage learning. Economies in core courses made in this way may be false.

6. Greater use of english language references is recommended in the irrigation course.

   Many of the reports of irrigation research seem to appear in english language sources. The student should be made familiar with those sources and prepared to use then while in school.

7. Laboratory spaces, equipment and exercises should be made available for both courses as soon as possible. Allocation of spaces and funds should be given immediate priority. Details of this recommendation are contained in Appendix C.

8. The budget for these two courses should be increased substantially during each of the next several years to fund the needed improvements.

9. When the laboratories are operational, the student contact hours, especially in irrigation, should be increased from 4 to 6 hours per week to take full advantage of the new resources.

B. Research

Research in some form is common in schools teaching hydraulics and irrigation. Done appropriately, research can enrich the instruction program, contribute to extension activities and stimulate faculty members. This should be true at IUTAD as well, providing existing constraints are recognized as research is undertaken. The Tras-os-Montes Regional Develop Project (RDP) is an appropriate way to begin H & I research, again recognizing constraints. The following recommendations are intended to expedite this introduction into research.

1. The work plan to be followed in H & I should follow that described in Appendix B, which is modified slightly from the original RDP proposal.

   This plan is based on the need to determine first the characteristics of irrigation in the region, and then to explore possible ways to make improvements. It recognizes that resources at IUTAD are limited, that additional persons and support will be needed and assumes that project funds will in fact be adequate to do the work. The plan considers the prior committment of the faculty to teaching. It also considers the special needs of Eng.[a] Fernandez for additional training and for faculty examination in about 3 years.

2. Procedures to be used in the evaluation trials during the first two years should follow those outlined in Appendix B, with modifications made as experience accumulates.

   As requested, the author reviewed with Eng.[a] Fernandez several documented procedures for evaluating furrow irrigation systems and practices. The procedure proposed by the American Society of Agricultural Engineers, June, 1983, was selected as a base. This was demonstrated as far as possible in a field trial on the MAFA experimental station at Chaves. A similar procedure from USDA Handbook 82 which permits additional recommendations to be made was reviewed and demonstrated in a second field trial at Vila Real, in preparation for demonstration work later in the project. In both trials it was found that the limit on personnel expected to be available to conduct the field trials requires the test procedure to be simplified. Accordingly, the procedure in Appendix B includes the simplifications. A third evaluation trial was conducted to demonstrate procedures for evaluating sprinkler system performance, again following USDA Handbook 82. This was done to permit sprinklers to be included in the testing program, if desired, especially in the demonstrations later in the project and in course exercises.

3. It is recommended, and indeed is essential, that at least one additional person be made available to help conduct the furrow irrigation evaluate trials planned for the first two years of the Regional Development Project. This person must be male.

   The nature of these studies, even though simplified, requires that at least two persons be available to gather data.

Pre-trial and post-trial work, including scheduling with growers also requires more than one person to handle tasks in different places at the same time. Much of the work is physically heavy and difficult. Eng.[a] Fernandez, while most conscientious and willing, is physically not able to do this heavy work on a sustained basis. The second person engaged for the work must therefore be able to do the physical labor and hence should be a man.

4. Preliminary discussions with the MAFA Regional Services personnel on their possible assistance in the proposed research should be finalized and firm plans made for their participation.

   Regional Services has indicated general support for the IUTAD study of on-farm irrigation practices, and that under certain conditions may be able to provide a man and car for the study. Such a person will be highly valuable, especially for organizational work with growers. His availability should be assured as soon as possible since this may influence other personnel planning for the coming summer. A second regional service person would greatly facilitate the testing and should be requested for service during the summer.

5. It is recommended that H & I research, including the proposed Regional Development Project, be funded on a project and on an annual basis to permit effective planning for the use of funds.

6. It is recommended that the budget level for the H & I activities on the RDP be increased to permit the work to proceed efficiently.

   The proposed budget seems low in several catagories, including travel. The proposed evaluation studies will be quite costly

in terms of personnel and travel. Close cost estimates will depend on the farms selected and on the number of people ultimately involved. If too little money is available to do quality work and do so efficiently the project results may be questionable and the reaction among cooperating growers could be negative. This would be harmful to the public image of IUTAD at a time when a good image is important.

7. It is recommended that H & I personnel cooperate with MAFA Regional Services in assembling information that may eventually become an irrigation guide for design and operation of irrigation systems in the region.

   An irrigation guide for the region will do much to improve over time the effectiveness of irrigation in the region. While the responsibility for preparing such a guide should rest with MAFA, it is very appropriate and useful that IUTAD participate in its preparation. The author has provided MAFA and H & I personnel with an example guide and with a set of instructions on the preparation of those guides. The example, while not for regional conditions directly, may be useful in preparation of a local guide by displaying trends, etc. that will expediate the preparation.

C. Extension

1. Modest activity in extension type activities by H & I personnel is recommended.

   It is not necessary that extension activity be based entirely on completed research, though this is a valuable source of

information. It is quite possible to prepare useful educational materials from general information already available, modified as needed to accomodate local conditions. Such activity is relatively easy and inexpensive to carry out, and could be initiated on a limited basis yet this year. This work could stimulate the faculty and bring needed visibility to the institute.

2. It is recommended that administrative arrangements between IUTAD and MAFA Regional Services Extension, defining the nature and extent of H & I activities in extension, be made clear.

   Where Ministries of Agriculture have jurisdication in extension the role of a participating University is often unclear. Uncertainty impedes useful involvement. The evidently good relations between these agencies in the Tras-os-Montes region should be protected and used. This can be encouraged by clarifying the roles of each and by offering assistance to each other. In this instance, H & I personnel at IUTAD can serve as a valuable source of information in irrigation and could assist MAFA with its dissemination.

3. As a means of accomplishing 1 and 2 above, it is recommended that H & I personnel take the initiative to prepare the draft of a simple document in extension for submission to MFAF for their possible use.

   Several possibilities have been discussed with Eng.[a] Fernandez, including example publications. The author is available to assist with the preparation of such a document.

D. Other

1. The computing capability at IUTAD should be increased by the addition of at least two more desk-top computers, with

word-processing software. This should be given immediate priority.

Computer modeling has proved to be a highly useful instructional aid on both hydraulics and irrigation. Computer capability at IUTAD at present is inadequate to support emphasis by the faculty on this approach. When the additional machines are on hand the faculty should begin to encourage their use in course work. Recent advances in word processing on these machines makes them very useful to both faculty and students in the preparation of written documents. This increased productivity in written material can greatly aid the faculty with their assignments in teaching, research and extension. The estimated cost to the Institute of 1 million Escudos for two or three machines is justified in terms of preparing students for work in today's technical activities. Service for the machines must be available.

2. Library resources in H & I should be strengthened substantially and with immediate priority. This expansion should be done in accordance with procedures of the proposed Teaching/Learning Resource Center.

   Library reference on hydraulics and irrigation are inadequate in scope and number, and in both texts and journals. Effective instruction and productive research both require ready access to related information. Eng.[a] Fernandez has been provided with a partial list of books and journals to be considered for early procurement and subscription. Others will be suggested by the author as they become evident.

3. The H & I faculty should be encouraged to seek membership in at least one professional society providing access to current research and development. The American Society of Agricultural Engineers is one such society. Eng[a]. Fernandez has been provided with the address for application purposes.

4. Development of an instrument shop at IUTAD should receive consideration soon under early priority.

   Instruction and research in H & I both use instrumentation frequently. There is need for certain pieces of equipment to be readily available, for a center where special equipment can be built, and where repair and maintenance can be done. Lack of appropriate and operational equipment is a serious handicap for an educational institution.

5. The H & I faculty at IUTAD should be increased to two persons as soon as possible. This is considered to have early priority in spite of acknowledged budget constraints.

   One person is at a great disadvantage in conducting teaching, research and extension activities in irrigation, for they often require representation in two places at once. Opportunity for professional dialog and for personal growth are restricted or eliminated. Energy is often spread so thin as to be ineffective. Resulting discontent can adversely effect even the students, and can cause resignations which are costly in many ways. Since the two previous persons to hold the one H & I faculty position have not seen fit to stay and have interrupted the programs by leaving, it is highly desirable that stability be restored. Addition of a second person, with

care given to the division of responsibilities, would do much to generate enthusiasm. Until this can be done, dividing one position to provide half-time assistance would help.

6. It is recommended that Eng.[a] Fernandez be allowed a short period of training abroad in an irrigated area as soon as possible to increase her practical abilities in both teaching and research. Preparation of requests for approval and support should be given immediate priority.

   Eng.[a] Fernandez has little experience in teaching and almost none in research. It is urgent that she be given some first hand contact with on-going work in these areas. She is quite capable of learning from even a brief experience, and is anxious to have the opportunity to do so. Her husband is preparing plans to undertake a PhD program in 1984 at the University of Idaho in the USA. The author highly recommends that she be permitted to accompany her husband during part of his study period to participate in both course work and applied research. Further, it is suggested that this be done with the author at Washington State University, only 10 km from the Univ. of Idaho where her husband will study. Advanced degree work would not be undertaken at this time, but is contemplated when time permits at a later date.

7. It is recommended that the association between the author and Eng.[a] Fernandez be continued by mail and otherwise as opportunity permits in order to provide as much support as possible as she becomes involved with additional aspects of the IUTAD assignment.

SUMMARY

This report has described briefly the objectives and procedures of this short term assignment (Hydraulics and Soil Erosion Advisor) with IUTAD. These are followed by the authors assessment of irrigation in the region and the potential of hydraulics and irrigation personnel at IUTAD to work with and perhaps to improve that irrigation. Recommendations of the author on actions IUTAD many take to better prepare itself to assist this improvement effort are then presented, listed under the headings of instruction, research, extension and other.

Speaking broadly, the author is enthused about the progress made to date at IUTAD, and about the potential of the Institute to assist economic and other development in the region. The mission of the Institute, while somewhat unique in its regional emphasis, is appropriate. Much good work has been done to prepare the Institute to accomplish this mission, considering the short time since its establishment. The central administration is encouraged to continue and even expand its efforts to assemble resources needed to train the young faculty and to support efficiently the growing programs of teaching, research and extension.

The hydraulics and irrigation program is no exception. A good start has been made, mainly in teaching, but much remains to be done. Much administrative and financial support will be needed to develop this activity to the point where it can effectively assist and even lead in certain aspects of the movement toward more effective irrigation. In the opinion of the author, improvement in irrigation in the region is possible, and in fact is already underway in certain areas. The introduction of pressurized water delivery under a demand system for use in sprinkling in the Vilarica valley is a good example. The role of IUTAD H & I personnel

can be very important in the orderly introduction of these new methods, as well as in the improvement of traditional methods. Education of young people to use the new technologies and to assist in their application is the foundation upon which the other developments depend. To carry out this role, the addition of laboratory facilities is urgent. With little research in irrigation being done by others in the region, the applied research by H & I personnel at IUTAD can become very important in adapting new developments to meet regional conditions. Applied research by H & I personnel in irrigation should therefore be introduced as soon as support is adequate, following the general recommendations prepared during this short-term assignment. IUTAD can become an important source of irrigation information to support the MAFA extension activity, which at this time has little underway in irrigation.

The author considers it significant that while the objective of this short-term assignment dealt largely with improvement of traditional irrigation (furrows), an equally urgent need for H & I involvement seems to be with the introduction of new technologies such as sprinkler and drip irrigation. These newer concepts are one way of improving water use on lands now served by traditional methods. On old or new lands, it is imperative that the new systems be adapted to local conditions and be designed and used properly at the time of introduction. Where this has been done in others areas, grower acceptance has been encouraging. Where it is not done, production under the new systems can be lower and more costly than under traditional methods, causing acceptance of new ideas by growers to be set back for many years. IUTAD H & I persons are in a uniquely important position to aid and guide the introduction of these new ideas. This does not mean that new systems should dominate the H & I work

programs, for improvement of traditional methods by other means remains important. It does mean, however, that the H & I work program should include all systems if IUTAD is to become a reliable and impartial source of information for use on old as well as new land.

Recognizing the unique opportunity to assist in regional development, the author emphasizes again the need for additional support for the H & I activities. It is not possible for one person, however dedicated, to do all that should be done by IUTAD under existing conditions in the region. Funds are known to be limited, and demands are also great in other subjects as well. It remains true, however, that inadequate preparation of its faculty can cause public distrust of IUTAD. Inadequate guidance of new developments can greatly reduce or delay the benefits to the region that good water use can bring.

In view of the importance of the contribution IUTAD H & I personnel can make in the region, the author would consider it a privilege to remain involved in these activities as a resource person on a continuing correspondence basis, and perhaps on a more active basis if and when this becomes mutually desirable. Appreciation is again expressed to those who helped make this initial assignment possible.

APPENDICES

A. Summary of Itinerary

B. Research Recommendations

C. Laboratory Recommendations

APPENDIX A

Summary of Itinerary

D. L. Bassett

Hydraulics and Soil Erosion Advisor

IUTAD, Vila Real, Portugal

July and August, 1983

Date	Activity
July 14	Enroute Pullman to Seattle
15	Enroute Seattle to Lisbon
16	Week end. Arrived Lisbon. Met Eng[a]. Fernandez
17	Week end. Visited Lisbon area
18	Visited USAID/Portugal (Charles Buchanan and Michael Lukowski). Toured rice exp. station. Met Dr. Zozimo Rego, University of Portugal, Lisbon
19	Visited Institute at Evora, R. Sierrelhierro and A. Santes
20	Enroute to Vila Real with Eng[a]. Fernandez by auto
21	Met Dr. Jose Torres Pereira and other local personnel. Familiarization. Officed
22	Housed. Visited campus irrigation site. Planned activity schedule
23	Week end. Planned local irrigation equipment modifications
24	Week end. Reviewed H & I research plan and course outlines

	25	Visited irrigated areas and small water development projects near Chaves, as well as the Ministry of Agriculture experiment station there
	26	Visited irrigated areas and small water development projects near Montelegra, as well as the Ministry of Agriculture experiment station there. Advised on fabrication of irrigation equipment
	27	Office work, planning field trials, preparing forms
	28	Office work, planning field trials, arranging for equipment
	29	Prepared Vila Real corn plot for field trials
	30	Week end
	31	Week end. Reviewed work plans
August	1	Office. Finished corn plot preparations
	2	Office. Addressed problems that arose of getting water to the plot and maintaining adequate control of water
	3	Prepared the Chaves potato plot for field trials
	4	Continued preparation of Chaves potato plot with installation of equipment
	5	Conducted furrow irrigation trials on the Chaves potato plot
	6	Week end. Reassembled equipment following the Chaves test
	7	Week end. Took post-trial soil moisture samples on the Chaves plot
	8	Processed Chaves soil samples. Office work and data analysis
	9	Planning for IUTAD laboratories. Met with Rector Real. Met also with Eng. Afonso, climatologist from Braganca to discuss possible coordination of research

10 Continued review of teaching programs and analysis of field data

11 Ran furrow irrigation field trials on Vila Real corn plot

12 Met with Regional Services personnel at Chaves to plan for cooperation on proposed IUTAD H & I research on on-farm use of irrigation water. Planned sprinkler performance trial at the experiment station at Chaves

13 Week end. Began report

14 Week end. Visited grape-growing regions in and near the Douro River Valley

15 Local holiday. Continued preparation of report

16 Planning laboratory space requirements. Met with Reitor Real on space requirements for H & I, and on possible visit of Eng[a]. Fernandez to USA

17 Prepared and conducted a sprinkler performance trial on the experiment station at Chaves

18 Analysis of data. Further planning of proposed H & I research

19 Planning space requirements. Continued preparation of report

20 Week end. Visited Northwest Portugal

21 Week end. Visited Northwest Portugal

22 Visited irrigated areas near Mirandella, particularly the Vilarica Valley project. Discussed with local government personnel the possibility of conducting IUTAD on-farm water use studies on the project and on the experiment station at Mirandella

23 Discussed with Eng[a]. Fernandez possible changes in proposed H & I research plan to include new systems on the Vilarica

project. Also discussed report recommendations for IUTAD teaching, research and extension

24 Final technical discussions with Eng[a]. Fernandez. Explained references being left with her. Cleared office. Final discussion with Dr. Jose Torres Pereira of the report, recommendations and future plans. Concluding contacts with shop and other personnel supporting the H & I activity.

25 Departed Vila Real with Eng[a]. Fernandez by auto to Porto, concluding discussions with her. Departed Porto via air for London enroute to USA.

APPENDIX B

Proposed Research Plan

IUTAD Hydraulics and Irrigation

Regional Development Project

The following material is respectively submitted as a minor modification and clarification of the research description in the original project document. The general plan was prepared cooperatively with Eng[a]. Fernandez, with details subsequently provided by the author.

Objectives:

Years 1 and 2: Determine the major characteristics of irrigation as now practiced in northern Portugal.

Year 3: Analyze data on irrigation characteristics taken in years 1 and 2. Select certain characteristics of irrigation as now practiced that could reasonable be improved. Prepare plans to demonstrate this improvement.

Years 4 and 5: Demonstrate in selected areas of northern Portugal (1) that certain aspects of irrigation as observed in years 1 and 2 can be improved, and how this can be accomplished, (2) the potential contribution of recently developed irrigation systems, and (3) the services the Ministry Extension Service and IUTAD can offer to those wishing to improve irrigation practices.

Procedures:

Following final approval of the project plans the initial preparations for IUTAD participation will be made, including the establishment of funding procedures, completing plans for Ministry cooperation, procuring equipment, preparing work plans and arranging for necessary personnel.

Fields in northern Portugal will be selected for irrigation evaluation trials. These must be representative of those in the area, and the owners and managers must be willing to cooperate in the study. The traditional furrow method will be most widely studied, but newer and more modern systems will also be included for comparison. The field evaluation procedure will be that proposed by the American Society of Agricultural Engineers, modified and simplified to accomodate the small fields in the area. The procedure used to evaluate sprinklers will follow that set forth in USDA Handbook 82. Two trials will be done on each selected field during the irrigation season to observe any seasonal differences in operation and performance. Performance parameters will include water application efficiency, water storage efficiency, uniformity of distribution, labor required, and resulting crop yield and quality where possible. As many fields will be studied during each season as resources permit, preferably at least 2 each week.

The data on system performance taken in years 1 and 2 will be analyzed to identify general characteristics of the irrigations studied. Those characteristics that appear to be in need of improvement will be identified. From these, certain ones that might reasonably be improved will be selected, considering the financial, cultural or other constraints opposing change. Plans to demonstrate improvement of those characteristics selected will then be prepared. The selection and improvement planning

processes will involve many interested persons, including the growers. Plans must include provisions to pay for the modifications required, and to protect the interests of both the growers and the investigating organizations.

In the fourth and fifth years, these demonstration activities will be conducted, both on grower fields and on experiment stations, where adequate control can be provided. When results so justify, extension activities can be arranged to make findings available to all irrigators in the region. Publications and reports summarizing the entire study will finally be prepared, from which other extension publications can be prepared.

Personnel:

At least two and preferably three persons should be available to conduct the field trials in the first two years. During the actual tests, two persons must be present. Much of the work of the entire project will, however, be done at other times and places. An essential part of the study is over-all coordination, including funding, personnel management, interagency cooperation and public relations. This should be done by IUTAD personnel, presumably Eng[a]. Fernandez. Another essential function is communication and coordination with growers whose fields are considered and/or used in the study. This function should be performed by persons well acquainted in the study areas and who are respected by growers. MAFA personnel appear best prepared to perform this role. A third function involves pre-trial site preparation, post-trial data gathering, and data analysis. This can best be done by a technician assigned full time to the project. The fourth function is of course the testing itself. Since the public will be involved it is essential that the work be well organized and

be conducted efficiently. It is therefore preferable that three persons be available to discharge the first three functions mentioned, since they will be done concurrently but at different places. On test days, at least two of these persons will perform the test, while on other days the other three functions will be handled. Whether only two persons can handle all the work efficiently will depend on such factors as distances involved and other committments they have. It is also not clear whether one person can be found who is familiar with growers in the several areas studied, or whether a separate person will be required in each area.

It must be recognized by all concerned that this study cannot be conducted by one person, not matter how dedicated. Trying to conduct the work without sufficient trained personnel will jeopardize the necessary public support as well as the IUTAD and MAFA images among growers.

Supplies and Equipment:

Since this work will be done in fields not adjacent to the campus or a MAFA office it is imperative that field personnel have their own supplies, equipment and transportation. Each person must have an automobile available at all times. The test equipment to be identified by Eng[a]. Fernandez in detail later must include various flow measuring devices, soil moisture sampling equipment, surveying equipment and hand tools. An electric oven and precision balances for determining soil moisture of the samples taken must be readily available in the area of testing to avoid loss of accuracy due to delay in drying. These could be located temporarily at MAFA offices or experiment stations in the local areas.

It should be recognized that the availability of some of this equipment on campus at Vila Real may not be sufficient for this work. Borrowing equipment or traveling great distances to use existing facilities will be more costly in money and time than buying a separate set dedicated to this study.

Budget:

The project budget proposal as recently revised upward by Eng^{a}. Fernandez now appears reasonable, assuming MAFA participation as discussed.

APPENDIX C

Proposed Laboratory Facilities
IUTAD Hydraulics and Irrigation

The following comments are intended to assist IUTAD authorities in their efforts to provide laboratory facilities to increase learning in hydraulics and irrigation. Unfortunately, it is not possible at this stage of development of the University to define precisely what should be provided and what cost will be. The development process is instead sequential in nature. One of the very early steps in the development process is a committment by the central administration that laboratory facilities in some form will be provided. This must then be followed by allocation of certain resources, particularly land or space, and money. When this has been done, design of facilities and procurement of equipment can begin. The information presented here is intended to help administration appreciate the need for and the general nature of H & I laboratory facilities.

Justification.

Experience worldwide indicates that effective instruction in both hydraulics and irrigation requires that theory presented in lecture be augmented, supported and demonstrated by practical, "hands-on" learning opportunities. This is especially important for students who have little or no background in the physical sciences or with equipment. The disciplines of fluid mechanics and applied hydraulics are relatively mature and are well described theoretically. Many students can memorize the

theoretical expressions sufficient to pass academic tests, but may be poorly prepared to apply their knowledge in real situations. These persons often feel so insecure with applications that they avoid such assignments, thus causing their education to be less valuable to society than it could have been. To be assured by trial that the principles apply as learned, and to learn how the applications are made, gives these persons greater willingness to use their education, and greater competence in doing so.

Irrigation instruction also requires practical experience to reinforce learning, but for a slightly different reason. In addition to involving many theoretical expressions, modern irrigation requires a great deal of equipment. Persons unfamiliar with this equipment tend to be reluctant to use it and unprepared to design or operate it. Again, their theoretical education is not as effectively used as it could be if it were backed by practical experience with the equipment under controlled conditions created especially for learning. In the opinion of the author, improvement of irrigation in northern Portugal can be done most effectively and rapidly by persons familiar with both the theory involved and the equipment to put the theory to use. Since IUTAD is expected to train these persons, its administration should provide the practical experience that will permit its graduates to undertake field applications of new technology with enthusiasm and confidence.

It should also be noted that research in H & I frequently requires laboratory facilities for development, testing and calibration of equipment and concepts. Laboratories in these disciplines are therefore often designed for both research and teaching functions, and supported financially from both budgets.

It is also true that the differences between the disciplines of hydraulics and irrigation require that laboratory space be dedicated to each discipline separately. Coordination between the two labs, is however, quite possible and should be considered throughout the planning process to make full use of resources available. Information in the following sections addresses the needs of the two laboratories, and the possible coordination between them and with other campus units.

The Hydraulics Laboratory.

The hydraulics laboratory at IUTAD should serve two main functions: a learning center for students and a center for applied research in water related subjects.

To accomodate these functions the laboratory should be located on or near campus and be housed and maintained for year-round use. It should contain (1) a teaching area including space for demonstration and test equipment and an adjacent student work area equipped with tables, chairs and chalkboard, (2) a research area for uninterrupted development and testing of equipment and concepts, and (3) a tool and equipment storage area common to both the teaching and research functions. Wash and toilet facilities, as well as an office area are highly desirable.

The facility must be provided with a ready source of water and drainage for disposal of the water. The water must be under the control of the laboratory personnel for their use at any time. The stream size needs will depend on the equipment installed, but must be substantial or be augmented by sump storage in or near the building. Electric power must be available and adequate to run motors of up to 10 horsepower. The building must be structurally able to stand the weight of heavy equipment, the water

contained therein, and students in the immediate area. Accoustical treatment should be provided to avoid disturbance of other activities in or near the laboratory. Lighting of work and study areas should be good. Safety of students and workers should be considered.

The size and shape of the laboratory is not fixed but can instead be adapted within limits to fit existing conditions. For general planning, a rectangular space perhaps 12 by 24 meters may be acceptable if carefully designed. To permit use of equipment requiring water columns of substantial height the space should have a ceiling height of 4 or 5 meters, or have access to a second story over part of the area.

Instructional equipment for the laboratory may be either purchased or built locally. Many labs use both purchased and locally-fabricated equipment. Prefabricated units generally have the advantage of being carefully designed and constructed, reflect the benefit of much student experience elsewhere, are generally self-contained and can be placed in use promptly upon delivery. Possible disadvantages include relatively high cost, extended time for delivery, and frequent absense of company service. Locally constructed equipment can be built to meet specific needs and fit available space. Obviously, skilled design and construction personnel are required. Total cost may also be high, but may be met from different local budgets.

It is the author's recommendation that the IUTAD lab be equipped largely with purchased equipment, with smaller, simpler and more specific supporting units being fabricated locally. For the convenience of IUTAD planners, three suppliers of such equipment have been identified to date. Company identification and excerps from their catalogs are appended to this report as Attachment C-1. The Armfield Company has a representative in

Oporto, but declined to submit even tentative prices for planning pruposes. Prices shown in the other catalogs must be used only for general planning, for delivery and other factors are not included. Whether the other two companies have Portugese representatives could not be determined. Units the author considers appropriate for consideration in the IUTAD lab are indicated on the attached sheets. Actual selection of equipment should await decisions on space and funds available. Fortunately, purchases can be spread over time as funds become available.

Irrigation Laboratory

The irrigation laboratory at IUTAD should also serve two main functions: a learning center for students and a site for applied water management studies. The lab must comprise an agricultural land area whose size and shape will permit demonstration of the major irrigation systems (furrow, sprinkling and drip) on prototype scale. It must be equipped to permit demonstration of the typical or recommended irrigation equipment for such functions as water measurement, pumping, open channel and pipe conveyance, and distribution of water to fields. The site must be provided a water supply that is under the control of H & I personnel at all times, and with a surface drainage system to remove excess water.

The land area should be long enough to permit recommended lengths of either furrows or sprinkler laterals. It should be wide enough to permit conventional sprinkler heads to be used. A land plot approximately 35 meters wide and 150 meters long is therefore recommended. The plot should have a mild and uniform slope in the direction of irrigation, initially or after land grading. Cross-slope should be very small. The soil should be as uniform as possible throughout the plot, and typical of soils in the region.

The land area should be located close to campus for convenience of students and faculty. It should also be close to the hydraulics laboratory, since some tools and equipment can be used on both labs. The water supply could also be common. Multiple use of certain components of the two labs is encouraged to keep costs as low as possible.

Significantly, this land can be used for more than one purpose (i.e., irrigation and another use compatable with it). In fact, it is often desirable that the land not be allocated exclusively to irrigation since H & I personnel are usually not fully prepared to handle regular farming activities. The author recommends that at IUTAD the selected plot be allocated jointly to crop production and irrigation activities, permitting the irrigation facilities to be used to enhance crop production during the growing season and the land to be available for irrigation demonstrations and trials compatable with crop production and in non-cropped periods. Since land suitable for irrigation and irrigated crop-production near the campus is very limited it seems wise to make multiple use of that land where possible.

The author recommends that the irrigation lab be developed on the land immediately north of the proposed reservoir site near the campus entrance, as shown schematically in Fig. C-1. Crop production on the land could be continued essentially as at present and need not be interupted greatly by irrigation activities. Instead, the irrigation facilities installed should aid the ongoing production. Water could be supplied from the proposed reservoir, since that water will be under control of the University. The adjacent stream provides a natural drain for excess water at modest cost. The size, shape and slope of the land are acceptable for irrigation. The location is convenient. Assuming the water will be delivered from the

reservoir to the lab in a closed pipe, the low elevation of the land will permit the water to be pressurized by gravity, thus reducing the cost of energy for certain uses such as sprinkling. If the hydraulics lab is also located below the proposed reservior as shown schematically in Fig. C-1, it too could benefit from the gravity pressure in the water supply, and the two labs could make joint use of some common facilities such as pumps, water measuring devices and tools.

Equipment for the irrigation lab would generally be that found on practical irrigation farms in the area or which has potential for use on those farms. This would include a small sprinkler system, surface and buried pipe water conveyance and delivery systems, water measurement devices, commonly used pumps, a drip irrigation system with its associated filters, and soil moisture measuring devices. One or more lysimeters for measuring crop water use could later be installed. Most of this equipment can be obtained from local irrigation dealers, sometimes on a loan or lease basis to the University.

Several of the systems to be installed must be designed specifically for the site selected. For this reason, it is not possible at this time to specify equipment or estimate closely the costs thereof. Important as this estimate is, it can only be made after decisions have been reached defining the site as well as the time and manner of construction. Suffice it here to suggest that the costs will probably be the equivalent of at least $15,000 US. These costs can be spread over an extended period of time, though this is not recommended.

It follows from the above comments that the early steps in development of the recommended laboratories involve a formal request for such space initiated by the H & I personnel, followed by administrative allocation of

land and resources for this purpose. Design and cost estimation can then proceed. It is recommended again that development of both labs be considered together in order to achieve the most usable facilities with the least cost through multiple use of components and equipment.

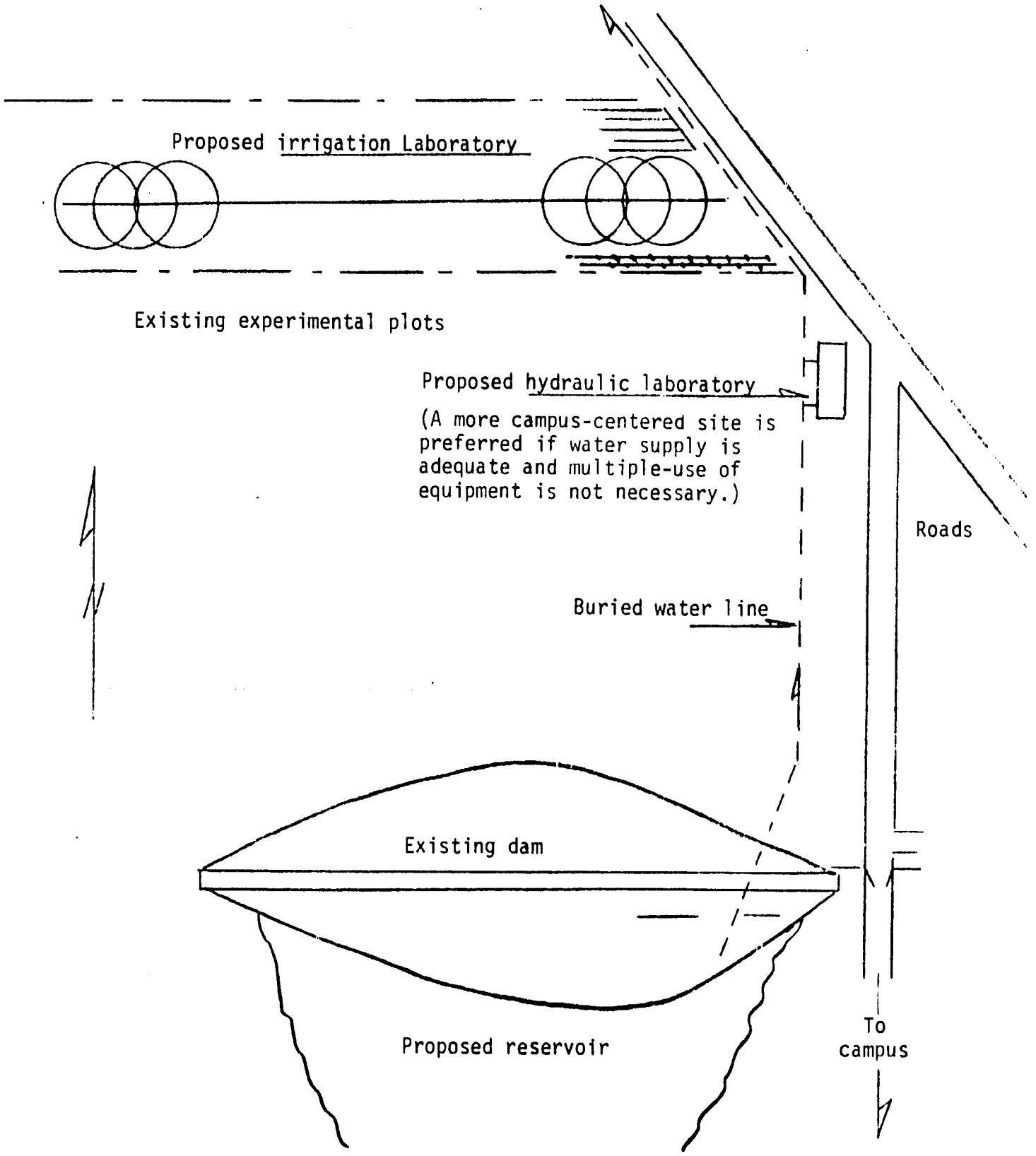

Fig. C-1. Recommended locations of proposed hydraulics and irrigation laboratories, IUTAD, Vila Real

ATTACHMENT C-1

Possible suppliers of hydraulic laboratory equipment.

1. Armfield Technical Education Co., Ltd.
   Bridge House, West Street, Ringwood, Hampshire, ENGLAND BHW41DY
   Tel : Ringwood (04254) 78781
   Telex: 417253 Armtec G

   Basic hydraulics bench
   - Hydrostatic pressure
   - Basic weirs
   - Bernoulli demonstration
   - Orifice and jet apparatus
   - Pipe friction apparatus
   - Flow visualization channel
   - Osborn Reynolds apparatus

   Properties of fluids bench
   Multi-pump test rig
   Multi-purpose teaching flume
   Glass-sided tilting flow channels
   Flowmeter demonstration apparatus
   Lysimeter
   Infiltration demonstration apparatus
   Surface irrigation model
   Sprinkler infiltrometer
   Sprinkler testing rig

   Note: Armfield Oporto declined to release prices.

2. Technovate, Inc.
   910 Southwest 12th Avenue
   Pomano Beach, Florida 33060 USA
   Tel : 305-946-4479
   Cable: Technov-

   See attached sheets

   Note: Technovate represents Armfield in the USA

3. Engineering Laboratory Design, Inc.
   PO Box 278
   So. Highway 61
   Lake City, Mn 55041 USA
   Tel : 612-345-4515

CATALOG
NUMBER 11

SOME OF THE

ENGINEERING & ENGINEERING TECHNOLOGY

LEARNING SYSTEMS

YOU CAN BUY FROM

TECHNOVATE INC.

[illegible] 12TH AVENUE POMPANO BEACH FL 33060 USA
CABLE: TECHNOVA TEL 305 946 4470

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46

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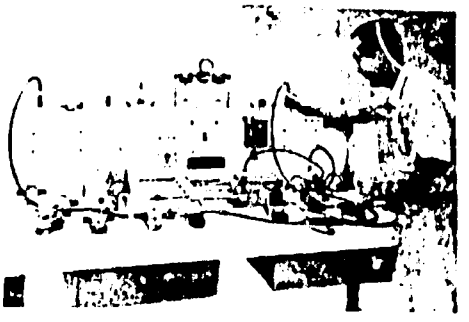
9088

FLUID POWER (PNEUMATIC)

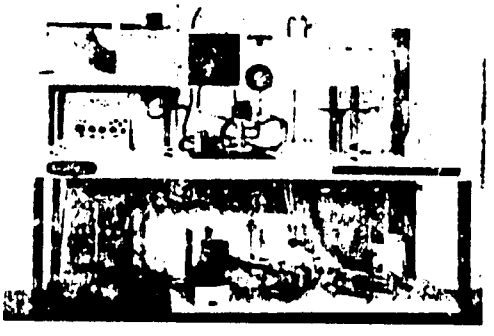


This is a fully operational pneumatic unit. It is designed for efficient learning of the principles of fluid power, automation and the functions and uses of different types of electrical relays, switches, circuits, controls, mechanical valving (automatic, pilot operated, manual), piping, pneumatic actuators and controls. Highly versatile, Model 9088 provides capabilities for a wide variety of experiments (both programmed and student-devised). Operating conditions can be made to vary over a broad range.

9092

PROPERTIES OF FLUIDS

(hydrostatics)

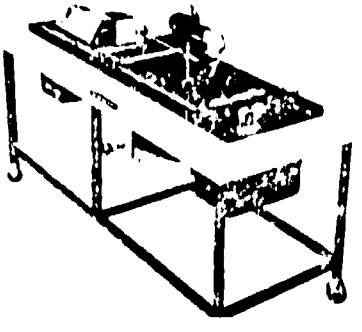


Teaches students in basics of fluids: densities, specific gravities, hydrostatic pressures and centers of pressures, metacentrics, Archimedes' and Pascal's laws, capillarity, viscosity, much more. Also function, use and calibration of hydrometers, barometers, manometers, Bourdon pressure gauges.

9093

HYDROKINETICS

includes hydrogen bubble generator

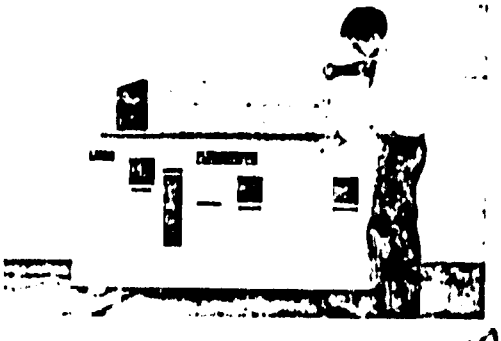


Covers basics of shallow channel flow: laminar and turbulent, Reynolds numbers, boundary layers; flow around airfoils, cylinders, etc.; nozzle geometrics, shock waves; Karman Street vortices; 3-D flow. Includes hydrogen bubble generator, light source.

9094

FLOW CHANNEL

(adjustable-bed)



Unique! Channel is Plexiglas tunnel whose bed geometry can be varied at will. Adjustable overshot outlet weir works against adjustable undershot sluice to manipulate flow. Students verify Bernoulli, create and measure hydraulic jumps, standing waves, much more.

TECHNOVATE

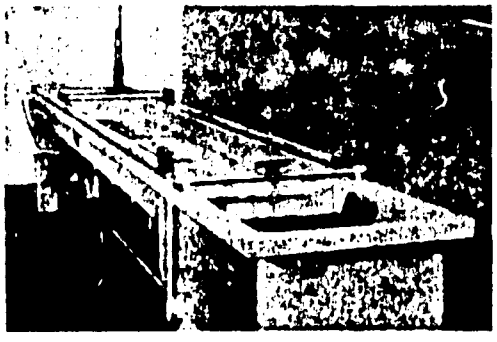
where you get the most out of your lab funding

9095

LANDSCAPE ARCHITECTURE

Accessories: movie screen

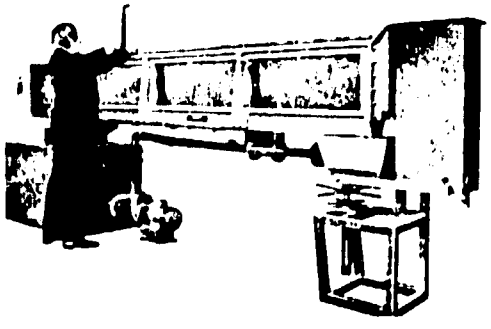
A system of four projecting overhead projectors allows manipulation of scenery through precise super imposition onto a single projection screen. (Also available as dynamic situation simulator with group dynamic audio)



9096

MOBILE BED/FLOW VISUALIZATION

Dual-purpose! Unit subjects coarse-sand bed inset with scale models of piers, pilings, etc., to controlled shallow-channel flow to develop measurable erosion, deposition patterns. Also used for 2-D flow visualization by Ahlborn dust (c 1902) and other techniques. Self-contained.

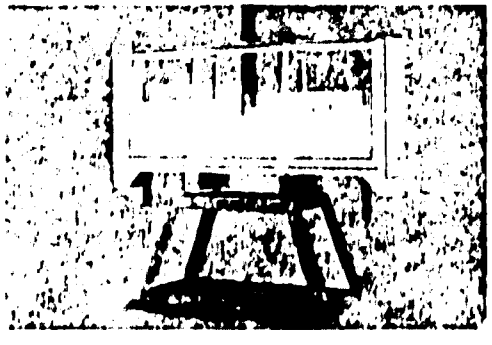


9097

TILTING FLUME

(glass-sided)

Positive- or negative-tilt, deep-channel, 2-D flow-visualization unit. Bed is a strong, rigid unit valved for six pressure-sampling points and one "disappearing" model holder. Sides are tempered, cantilever-supported glass. Self-contained.



9098

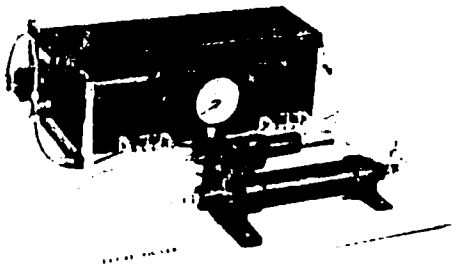
PERMEABILITY/SEEPAGE

How does a well affect ground water levels? What upward thrust does saturated earth exert against a buried gasoline tank? How much water will flow under (or through) an earth dam? And at what speed? This tank helps student verify theory, learn needed modifications

48.

9800

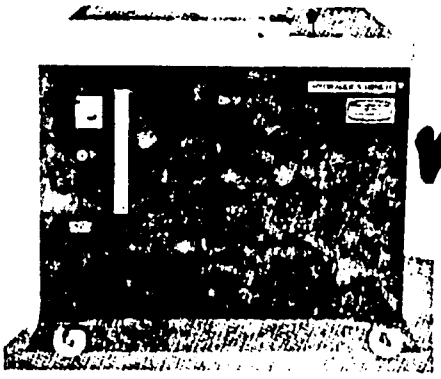
STRESS ANALYSIS
(thin cylinder, torqued)



The hoop and longitudinal stresses within the walls of a "thin cylinder" subjected to action of an internal pressure may be investigated. Calculations may be made involving the cylinder subjected to internal fluid pressure. Pure torque may also be applied, whereby modules of electricity and rigidity can be determined.

F1-10

HYDRAULIC BENCH
self-contained pressure gauge



Self-contained! Mobile, basin-topped bench stores, pressurizes and then delivers water through 3-way control valve to inlets of pressure gage calibrator accessory, F1-11, or experimental devices F1-12, -14, -16, -17, -18, -19, -20, -21, -22. Discharge is sent to pump directly or via flow-metering tank. **No weight handling!**

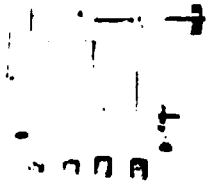
F1-11

F1-11 DEAD WEIGHT PRESSURE GAUGE CALIBRATION

This equipment functions upon the principle adopted in calibrating most industrial pressure gages. It consists of a precision-machined piston and cylinder assembly. The cylinder is supported upon levelling screws necessary for correct function of the equipment.

F1-12 HYDROSTATIC PRESSURE and center

Measures static thrusts of fluids on surfaces variously submerged and permits centers of pressure to be located by using calibrated weights to offset torques exerted on either of two pivoted, counter-balanced ring segments having different curvatures.



F1-12

F1-14

F1-14 METACENTRIC HEIGHT

Generates data and provides insight about factors that affect the stabilities of variously loaded floating bodies. Unit is open-decked, floating pontoon having adjustable-center-of-gravity mast with plumb bob and a scaled adjustable-list.

F1-15 BERNOULLI'S THEORUM

Where does Theorem apply? Unit supplies answers, shows static pressures at taps spaced along assymetrically converged and diverged test section as fluid is moved through at various rates. May be vertically oriented to compare piezometrics with manometrics.

F1-15

TECHNOVATE

always confronts them with
a fresh series of experiments

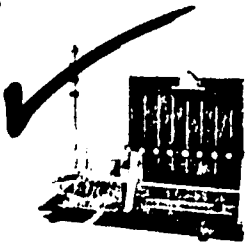
F1-16

F1-16 IMPACT OF JET

Measures force developed by jet of water impacting any of three typical targets (flat plate, 120 degree cone, hemisphere cup). To reduce variables, jet is vertical. Force is measured directly by placing weights on counterbalanced target holder subassembly.

F1-17 ORIFICE & WEIR CALIBRATOR

Orifices, nozzles and weir notches are easily calibrated with this channel. The water (from F1-10 or any supply) is fed through stilling section to weir. Special fittings accomodate orifices, nozzles. Jet trajectory is traced by included point gage.



F1-17

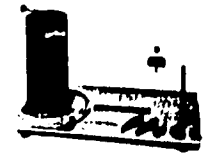
F1-18

F1-18 PIPE FRICTION

Permits recreation of the classic Reynolds/Frouds experiments on head losses in fluids flowing through pipes. Students determine critical points of transition from laminar to turbulent flow, formulate equations from observed data.

F1-19 FLOW VISUALIZATION CHANNEL

This apparatus introduces students to the characteristics of flow in an open channel at an elementary level. The channel consists of a transparent working section of large depth to width ratio incorporating undershot weirs at the inlet and discharge ends respectively. A dye injection system incorporated at the inlet to the channel permits flow visualization. Models supplied with the channel include broad and narrow crested weirs, large and small cylinders and symmetrical aerofoils.



F1-19

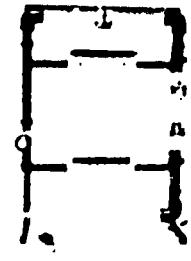
F1-20

F1-20 OSBORNE REYNOLDS' APPARATUS

This item or equipment is intended to reproduce some of the classic experiments conducted by Osborne Reynolds on laminar and turbulent flow

F1-21 FLOWMETER DEMONSTRATION APPARATUS

This accessory is designed to introduce students to the operating characteristics of three basic types of flowmeter. The equipment consists of a Venturi Meter, Variable Area Meter, and Orifice Plate, installed in a series configuration to permit direct comparison.



F1-21

F1-22

LOSSES IN BENDS APPARATUS

The following typical pipe fittings are incorporated for study: Mitre bend, 90° Elbow, Sweep bends, large and small bore and sudden contraction. All are instrumented with upstream and downstream pressure tappings. These tappings are connected to a bank of eight pressurized water manometer tubes.

NUMBER	DESCRIPTION	PRICE ($)
	Standard familiarization Plastic Flow Patterns	
93-05-002	Flat Plate w/round ends	
93-05-003	Flat Plate w/square ends	
93-05-004	Flat Plate w/asymmetric Sharp ends	
93-05-005	Flat Plate w/Asymmetric Sharp ends	
93-05-007	Rectangular Block	
93-05-009	3" Channel walls w/curved ends (pair)	
93-05-011	Airfoil	
93-05-012	3" Channel walls (pair)	
93-05-018	"S" Channel walls (pair)	
93-05-020	"S" Channel walls	
93-05-021	30" Channel walls (pair)	
93-05-023	9" Channel Walls (2 pair)	
93-05-024	Curved Channel wall	
93-05-028	Circular Cylinder 1/4" diameter	
93-05-029	Circular Cylinder 1/2" diameter	
93-05-030	Circular Cylinder 3/4" diameter	
93-05-031	Circular Cylinder 1" diameter	
93-05-032	Circular Cylinder Base	
	Optional Plastic Flow Patterns	
93-05-006	5" Curved block (pair)	77.00
93-05-014	2½" Spacer (pair)	32.00
93-05-016	1" Spacer (pair)	30.00
93-05-033	8" Curved block (pair)	106.00
93-05-034	Diamond shape	44.00
9094	**ADJUSTABLE BED FLOW CHANNEL SYSTEM**	19,800.00
9095	**VISUAL SIMULATORS**	
9095-1	Forward Projector (Single Head) (0-1000 watts) w/smoke & fire simulation	4,910.00
	E Models for Invironmental Impact Simulation	
9095-1E	Forward Projector (Single Head) (0-1000 watts)	4,610.00
9095-2E	Quadruple Forward Projector (Four Heads), portable unit	12,560.00
9095-2	Quadruple Forward Projector (Four Heads), portable unit, w/smoke & fire simulation without audio	13,160.00
9095-3	Quadruple Forward Projector (Four Heads), portable unit, w/audio, smoke & fire simulation	18,400.00
9095-3B	Audio system for portable unit	5,260.00
9095-4	Quadruple Forward Projector (Four Heads), Console unit, w/smoke & fire simulation only	14,735.00
9095-5	Quadruple Forward Projector (Four Heads) Console unit w/ audio, smoke & fire simulation	19,910.00
9095-5B	Audio system for Console unit	5,200.00
	Optional: re-usable shipping container	On request
9096	**MOBILE BED & FLOW VISUALIZATION TANK**	24,740.00
9097	**GLASS SIDED TILTING FLUME**	28,370.00
9098	**PERMEABILITY & SEEPAGE TANK**	8,595.00
9800	**STRESS ANALYSIS SYSTEM (Thin Cylinder, torqued)**	8,995.00

Best Available Document

TECHNOVATE/ARMFIELD PRODUCTS

NUMBER	DESCRIPTION	PRICE ($)
F.1-10	**HYDRAULIC BENCH** (Basic Bench includes pressure gauge)	2,995.00
	Accessories	
F1-11	Dead Weight Pressure Gauge Calibrator	750.00
F1-12	Hydrostatic Pressure & Center of Pressure (P)	985.00
F1-14	Metacentric Height Apparatus (P)	690.00
F1-15	Bernoullis Theorem Demonstration (P)	1,330.00
F1-16	Impact of Jet Apparatus (P)	1,255.00
F1-17	Orifice & Weir Calibration	2,450.00
F1-18	Pipe Friction Apparatus (P)	1,385.00
F1-19	Flow Channel (P)	1,975.00
F1-20	Osborne Reynolds (Bench-Mounted) (P)	1,655.00
F1-21	Flow Meter Demonstration (P)	1,880.00
F1-22	Losses in Bends Apparatus (P)	1,295.00
F2	**FORCED VORTEX APPARATUS**	8,630.00
F4	**PRESSURE GAUGE CALIBRATOR**	4,965.00
F5	**OSBORNE REYNOLDS APPARATUS**	4,605.00
F10	**CAVITATION DEMONSTRATION APPARATUS**	1,950.00
F12	**DRAG COEFFICIENTS SYSTEM**	2,835.00
F20-11	1m Water Manometer	415.00
F20-12	1m Water Manometer (pressurized)	430.00
F20-13	1m Mercury Manometer	520.00
F20-16	500m Mercury Manometer	520.00
F20-17	Paraffin/Water Manometer 500 mm	520.00
F20-20	150mm Hook & Point Gauge	315.00
F20-21	300mm Hook & Point Gauge	355.00
F20-22	450mm Hook & Point Gauge	415.00
F20-30	Flow Monitoring System	7,345.00
C1-00	**COMPRESSIBLE FLOW BENCH, Complete**	15,780.00
C2-20	**SUBSONIC WIND TUNNEL** w/Balance & Air speed indicator, C2-10 & accessories, C2-12 through C2-20	29,090.00
C2-10	**WIND TUNNEL** w/Balance & Air Speed Indicator	15,740.00
	Accessories	
C2-12	Boundary Layer Flat Plate & Traversing Probe	1,390.00
C2-13	Multi-Tube Manometer	1,510.00
C2-14	Wing, Cylinder & Rake Only	2,760.00
C2-15	Slat & Flap Air Foil	1,550.00
C2-16	Pitot Static Tube	1,040.00
C2-17	Yaw Probe	495.00
C2-18	Drag Models	1,640.00
C2-19	Pressure Cylinder	1,420.00
C2-20	Flutter Wing	1,330.00

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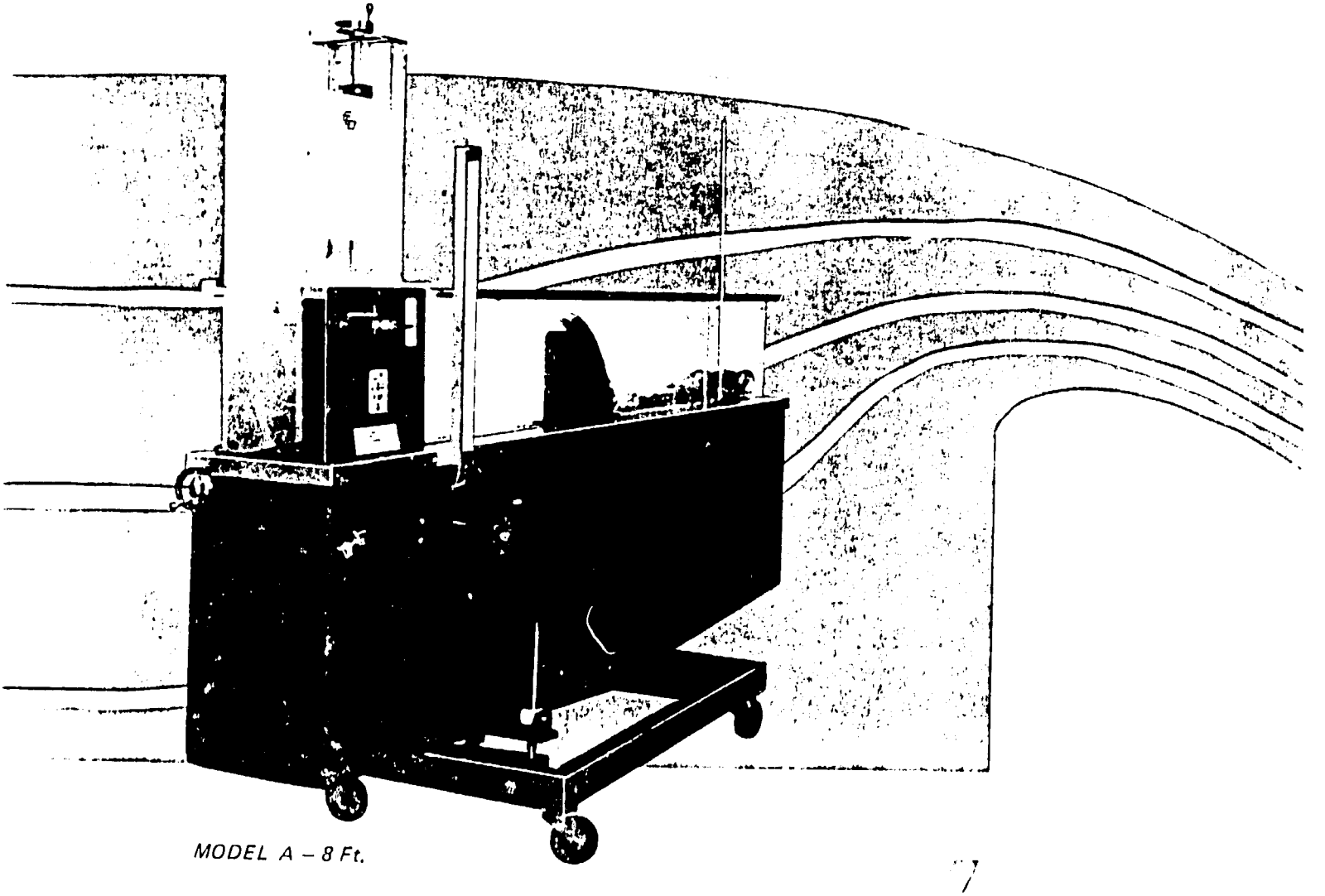
Fluid Flow



MODEL A – 8 Ft.

ENGINEERING LABORATORY DESIGN INC.

HYDRAULIC DEMONSTRATION CHANNEL

Best Available Document

MODEL B - 16 Ft.

GENERAL

The Hydraulic Demonstration Channel is a self-contained, portable unit which may be used in the classroom to support lectures and demonstrations or in the laboratory for specific studies by individual students or student groups. Fluid mechanics phenomena such as the hydraulic jump and variable flow in open channels can be clearly and rapidly presented. Models of many hydraulic structures and fluid meters may be easily installed and accurately demonstrated. All of the flow variables are operator controlled, including: flow rate, depth of flow, velocity and the slope of the channel bed. No external piping or water supply is needed. Electric service is the only utility required for operation. Complete operating instructions for the channel and the accessory models are provided with the channel.

CONSTRUCTION

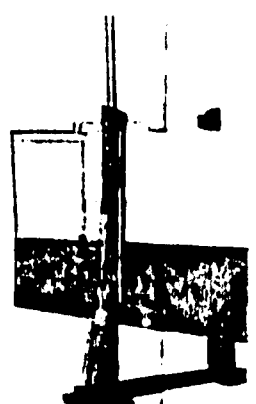
CHANNEL: The channel is constructed of ½" clear Plexiglas. All joints are solvent welded. Threaded metal inserts are provided in the channel floor for mounting models. The channel slope may be varied 4% negative to 12% positive by a motor driven jack screw.

RESERVOIR: The water reservoir serves as the base for the channel and is provided with swivel casters for ease of movement. The reservoir is fabricated of reinforced fiberglass. The volume of the reservoir is sufficient to completely fill the channel.

CONTROLS: All controls are conveniently located at the upstream end of the channel and include:

- Pump motor switch
- Slope motor switch
- Slope indicator
- Flow control valve
- Orifice meter and manometer
- Headgate and tailgate controls (Model A-manual/Model B-motor driven)
- Total head probes

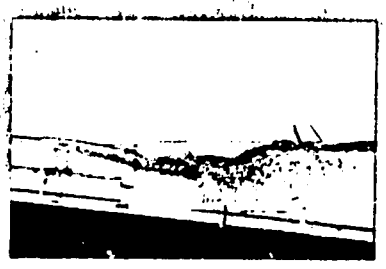
PUMP: The recirculating pumps are low pressure, high volume centrifugal units with a leak-proof mechanical seal and powered by 3/4 H.P. motors. Model A Channel has one pump, Model B Channel has two pumps.



STANDARD SPECIFICATIONS

	Model A	Model B
Channel Section	6" Wide x 12" Deep	12" Wide x 18" Deep
Channel Length	8 Ft. or 12 Ft.	12 Ft. or 16 Ft.

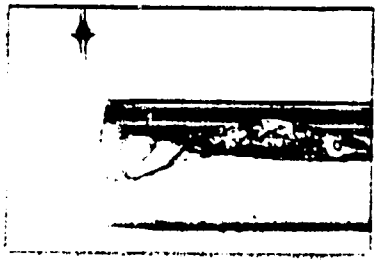
Power requirements: Standard wiring, 115V - 60 Hz - 1 Phase. Other voltage/frequency/phase can be furnished.



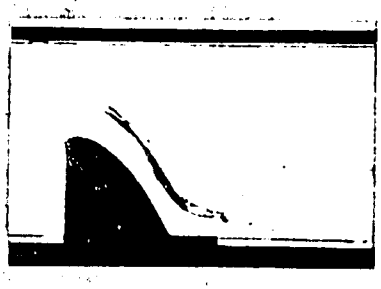
ENERGY DISSIPATOR

HYDRAULIC JUMP BASIN

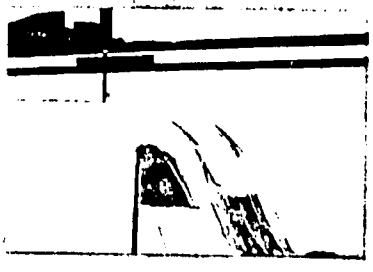
DROP-INLET STRUCTURE



PIPE ENTRANCES



OGEE SECTION



STRAIGHT WEIR

Basic Pipe Flow Model
Pipe Entrances
SAF Stilling Basin
Pipe Drop Inlet
Inclined Slope

Venturi Meter
Gauge Carriage
Pitot Tube
Reynolds # Apparatus
V-Notch Weir

Broad Crest Weir
Spillway Section
Straight Weir
Sudden Contraction & Expansion

Sluice Gate w/Pressure Tubes
Wave Generator (Model A only)
Flow Nozzle & Pipe Orifice
Hydraulic Jump Basin

SPECIAL DESIGNS

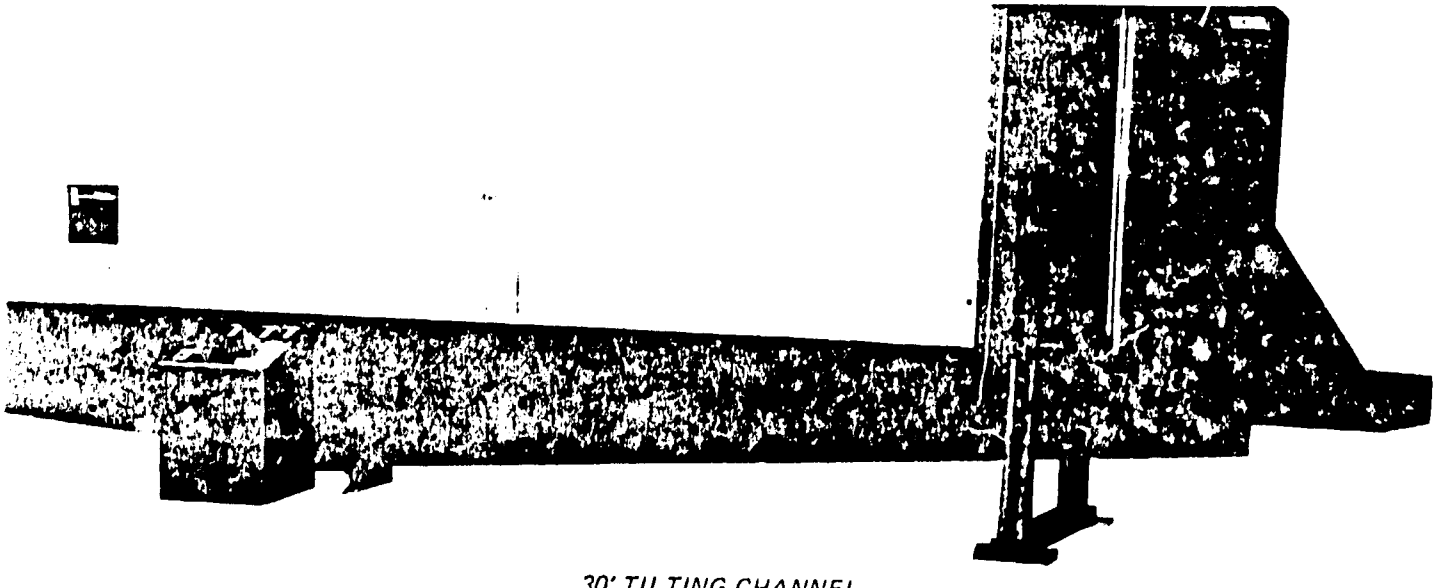
For those who require longer channel lengths and larger cross sections, Engineering Laboratory Design can construct units to any length required.

We have the design experience and manufacturing facilities to produce custom designs to suit any need. Channels can be designed to be completely self-contained with integral pump and reservoir or as basic units to be added to existing laboratory facilities.

Tilting channels are generally center pivoted using a hydraulic system to change the slope.

Power operated head gates and tailgates are normally supplied allowing control from a central control station.

The channel flow sections may be all clear plexiglas or combined with non-transparent sections fabricated of reinforced fiberglass. Supporting structural frame work is usually constructed of welded steel. Wave generating equipment can also be supplied to extend the usefulness of the unit.



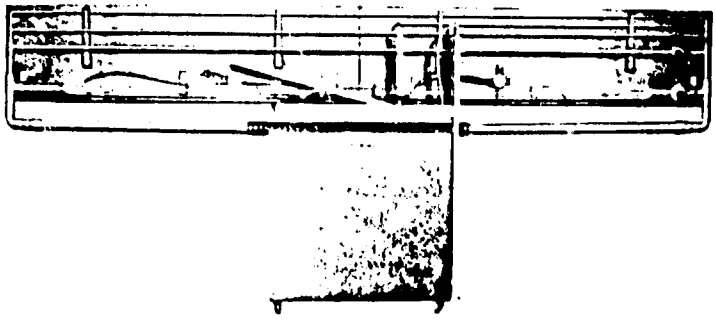
30' TILTING CHANNEL

FLOW IN CIRCULAR TUBES

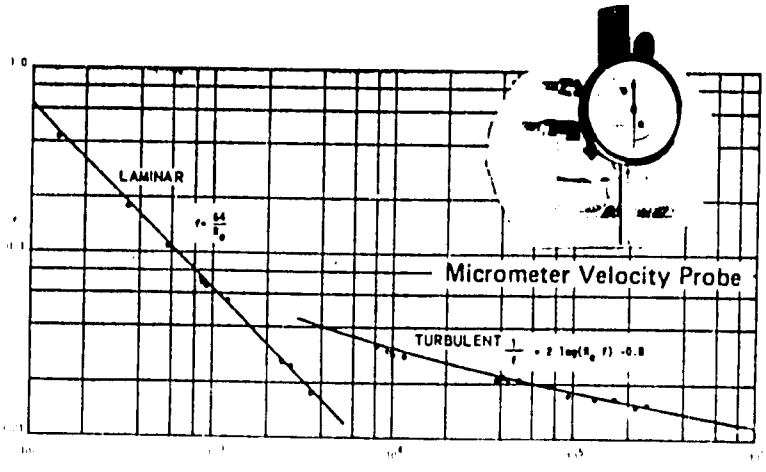
Measurement of velocity distributions and related rates of momentum transfer for water flowing turbulently in smooth tubes can be accurately determined with this equipment. Also, pressure-drops resulting from water flowing through tubes of different diameters can be measured and related to the well-known "friction factor." All parts of the equipment in contact with water are of noncorrosive materials. Bench, back panel and reservoir are constructed of fiberglass.

SPECIFICATIONS

1. PUMP – 1½HP bronze pump. Capacity – 136 GPM @ 20 ft. head to 20 GPM @ 65 ft. head.
2. TEST PIPES – Two lines are of hard drawn copper with nominal diameters of 1/2" and 1". A third line of smooth brass with a 1/8" inside diameter Laminar flow characteristics.
3. PRESSURE MEASUREMENTS – Head loss or pressure drop is measured by two differential manometers using either an air-water combination or mercury as indicating fluids.
4. FLOW MEASUREMENT – Measurement of the Turbulent flow rates is by Orifice Meters sized to cover the complete range of flow expected. Laminar flow rates of flow are determined volumetrically.
5. VELOCITY PROFILES – Measurement of the local velocities in the Plexiglas tube is made by means of a total-head impact-tube which permits radial traverses to be made with micrometer precision.



MODEL 202 – FLOW IN CIRCULAR TUBES

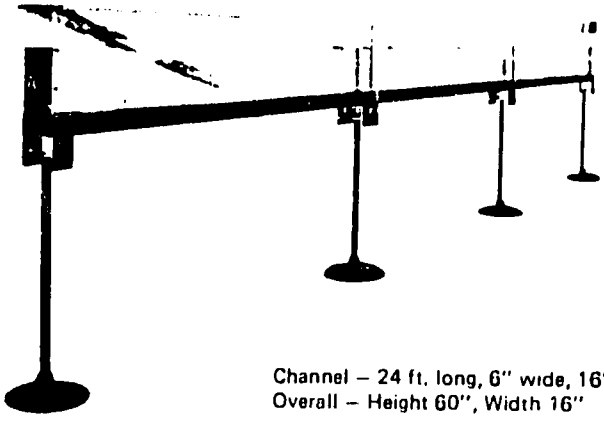


REYNOLDS NUMBER

Note: Above data is actual student laboratory data.

WAVE CHANNEL

A compact facility for demonstration and study of wave phenomena. The length of this unit is sufficient for a good quality wave form to develop. The amplitude and period of the wave can be varied to show a wide range of wave shapes. With the porous metal wave attenuator the wave form can be maintained without distortion due to reflections. The solid end slope allows study of breaking of waves on a hard beach. Calming by pneumatic or mechanical wave arrestors can be visually demonstrated. Breakwater studies can be effected by constructing model sections of crushed rock. Simple electronic components are available to measure wave height and period for chart recording.



Channel – 24 ft. long, 6" wide, 16" deep
Overall – Height 60", Width 16"

ENGINEERING LABORATORY DESIGN INC.

PO Box 278
So. Highway 61
Lake City, Mn 55041
612/345-4515

ENGINEERING LABORATORY DESIGN, INC.

BOX 278 • LAKE CITY, MINNESOTA 55041 • TELEPHONE 612-345-4515

PRICE LIST

HYDRAULIC DEMONSTRATION CHANNEL
(As covered by specifications)

No.		Price F.O.B. Lake City, Mn. 115V 60 Hz 1Ph	220V 50 Hz 1PH
11	Basic Channel Unit - Model A - 8 ft.	$ 5,240.00	$ 5,600.00
12	Basic Channel Unit - Model A -12 ft.	5,850.00	6,620.00
13	Basic Channel Unit - Model B -12 ft.	9,550.00	9,330.00
14	Basic Channel Unit - Model B -16 ft.	10,775.00	11,140.00
15	Wave Channel - Model W - 24 ft..	4,460.00	4,460.00

Models for above units: (Not included in basic price)

		Model A	Model B
1M	Pipe Flow Models (Required to operate Nos. 2, 3,4, 12, 13, 14, 18)	148.00	230.00
2M	SAF Stilling Basin	84.00	147.00
3M	Pipe Drop Inlec	97.00	157.00
4M	Hydraulic Jump Basin	73.00	147.00
5M	Sluice Gate with Pressure Tubes	232.00	341.00
6M	Straight Weir	30.00	40.00
7M	V-Notch Weir	37.00	58.00
8M	Wave Generator	340.00	390.00
9M	Broad Crest Weir	68.00	115.00
10M	Spillway Section	68.00	115.00
11M	Inclined Slope	75.00	125.00
12M	Flow Nozzle and Pipe Orifice	95.00	95.00
13M	Venturi Meter	250.00	250.00
14M	Sudden Contraction and Expansion	100.00	100.00
15M	Gauge Carriage	89.00	89.00
16M	Pitot Tube	65.00	65.00
17M	Differential Manometer (for use with Pitot, Venturi Meter, etc., 24" or 48" long)	63.00	80.00
18M	Reynolds Experiment Apparatus	120.00	130.00

Demonstration and special purpose channels to 100 ft. are available.

Effective January 1, 1983.