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UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Washington, D. C. 20250

Vittetoe Report

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TO: R. M. Davis, Administrator, Soil Conservation Service, Washington, D. C.

RE: A Letter Report - Temporary Duty, Gene C. Vittetoe with USAID, Afghanistan - Helmand Valley Drainage Work

During the period July 23 to September 12, 1975, I carried out a temporary duty assignment in Afghanistan with the U. S. Agency for International Development. During this TDY period I spent three days at the start, three days near the middle, and three days at the end, in Kabul. The balance of the period I was at Lashkar Gah, in the Helmand Valley.

At the outset, I want to acknowledge the accommodating and helpful response of the people with whom I worked. Mr. Vincent Brown, Mission Director, was very cordial and informative. Mr. Fred Sligh, Dr. Frank Denton, Mr. Ernest Barbour, Mr. Don Reilly, Mr. Brent Gatch, Mr. Marty Kumorek, Mr. Richard Scott, and Miss Lois Johannes were all very helpful and willingly assisted me. At Lashkar Gah, Mr. Zack Tyson and Miss Jean Rosar were most helpful and daily aided my work. The people of the Helmand-Arghandab Valley Authority (HAVA) were equally cordial and accommodating. Mr. Formali was very interested in my work and enlightening with his background in the area. Mr. Wardak worked diligently and most cooperatively with me. Governor Sherzai was very kind and courteous, and expressly interested in the work.

My main purpose was to work on the initial phase of the USAID-HAVA drainage project in the Helmand Valley. For a short TDY period, it seemed to me as though I should concentrate upon limited, but major, things that could be accomplished in the period. Accordingly, I decided that I should work toward establishing a tentative criteria for the drainage, help to the degree I could on getting an early start of a construction segment underway, and try to determine what work supplies the oncoming team should consider in addition to those now available.

The preliminary physical aspects of the drainage problem and my work are reported in the following order:

1. A brief description of the area and the drainage need.

2. A discussion of the preliminary criteria for drainage.

3. A discussion of preliminary standards for construction drawings and construction specifications.

4. A discussion of the activity connected with the early construction start.

5. A discussion of work items for the following team.

6. Closing remarks.

7. Appendix to the report.

Description of the area and drainage need

At the start I made some field trips to get an image of the area and collect some observations. I also began to peruse the various reports of the past to lift out pertinent items that would be helpful. Although these reports are enlightening, they do not contain an abundance of readily recoverable and hard data that can be quickly adapted to the future and outlying scope of drainage now needed. Understandably, they are mostly feasibility or implementation reports for the scope of irrigation and drainage works heretofore established. However, with these reports and some observations a general description can be rather forthrightly made.

There are four distinct areas in the project area. They are known as the Nad-i-Ali area, the Marja area, the Shamalan, and the Darweshan. The farms are small in the relative sense. The Nad-i-Ali and Marja areas are situated to the west of the river and are upland desert soils. The Shamalan area is on the west side of the river and is bottomland. The Darweshan, farther down river, is on the river's east side and is bottomland. In the areas west of the river, the water table gradient generally trends from the northwest to southeast, which is the general land relief. The components of the ground water tilt therefore are to the river and down river, as one would expect. In the Darweshan, the same components are in force and the water table trends to the south and west.

The Nad-i-Ali and Marja areas are dominated by an underlying conglomerate. The top of this conglomerate perhaps varies in depth from the ground surface $1\frac{1}{2}$ to $3\frac{1}{2}$ meters, with a prevalent amount likely being at the 2 - $2\frac{1}{2}$ meter range. The conglomerate consists of tightly cemented well-rounded gravel aggregates of varying size. It is extraordinarily hard and virtually impermeable to water.

The presence and makeup of this conglomerate invites some curiosity as to its geologic form. I found no written geological interpretation on this subject. Since

I have no geologic credentials, I can offer no emphatic interpretation. One might suspect that this conglomerate has it genius as the outwash of the Uplift period. The aggregates obviously are greatly translated, all being highly rounded. It seems likely the following surface evaporation from the then water-loaded condition left residing near the surface an evaporative precipitate of lime that produced a high cementation. The area appears to have been subsequently overlain with soil, probably wind blown, thereby preserving the conglomerate. The overlying soil exhibits a rather distinct loess-like structure. The thickness of this overlain conglomerate is not known in great detail, but one would suspect that the thickness is relatively uniform. Desert areas surrounding the Nad-i-Ali and Marja areas display on the surface aggregates altogether similar to the aggregates of the conglomerate. If the surface in these surrounding parts were indeed conglomerated, it seems plausible that the absence of the preserving overburden and weathering exposure has dissipated the cementation.

The areal extent of the conglomerate (that is, the discontinuity) is difficult to discern. The most precise discontinuity is likely at the fringes of the river valley influence. The surface features seem to indicate that. There is a mild, though vivid, surface escarpment that marks the edge of the river's influence and the desert soils. One would expect that the historical regime of the river has suppressed the formation or preservation of any near-surface conglomerate or cementation in its area of influence. On the other hand, the expectation would be that the valley area under consolidation pressures is underlain at deeper depths with sandstone. Deep logs are not abundantly available. However, the Bureau of Reclamation made a few deep logs in the Shamalan area, and these indicate the presence of some sandstone at depths of 33 to 39 feet.

Although there are four separate areas for drainage, there are two distinct physiographic makeups in respect to the approach for the drainage. The Marja and Nad-i-Ali areas have practically no natural deep drainage at all, and the conglomerate acts as a barrier and becomes a paramount feature in the performance of artificial drainage to be installed. The Shamalan and Darweshan areas have some, but varied, natural drainage. The presence of any influencing barriers in these two areas will be in the form of clay strata, which may likely be quite varied.

Therefore, the need for drainage to support an enduring irrigation agriculture becomes rather apparent from the physiographic makeup alone. Additionally, however, the prior irrigated agriculture in the areas has created some very vivid land salting and this quickly affirms the drainage need. My expectation is that most, if not all, of the salted land is saline, by definition. There does not appear to be salty lands of the saline-alkali character. However, by definition this distinction is determinable by the exchangeable sodium percentage, and I would not declare that no saline-alkali conditions exist. Nevertheless, one expects that the calcium cation is very predominant.

The quality of the irrigation water used in the Helmand project areas is, in the relative sense, very good. The average total soluable salts in the water is 215 PPM. This is equivalent to an electrical conductivity of about 336 micromhos per centimeter, utilizing the commonplace conversion of 1 PPM = 0.64 micromhos. At first one wonders how so noticeable land salting has occured with such good water quality. To reconstruct the actual period and progress of salting would be difficult to do. The amount of cropping has changed with the settling of the areas. However, by manipulating a few numbers one can generate some indicators of the reality of the salt buildup periods, even with this relative good irrigation water. The concentration of salts in the soil results principally from the extraction of moisture by plant roots and surface evaporation. The consumptive water use in this climate province is extremely high. One would expect that without natural or artificial subsurface drainage, noticeable salt buildup (say in the 8 millimho range) would occur in about three years when cropped with heavy water using crops as cotton or alfalfa. For the intermediate water users, as corn and wheat, the period would be on the order of 6 to 7 years. The lesser water using crops would take about 11 to 12 years for such a buildup. salting rates

Preliminary Criteria for Drainage

With the foregoing preface, I set about to develop some preliminary criteria for the drainage work. Drainage criteria must necessarily be fitted to the specific areas being drained. Customarily, drainage criteria for an arid area is evolved from experience in the area with evaluations of the soil and subsurface materials, the salinity character, the irrigation practice, and an assortment of related factors.

The first element of any subsurface drainage criteria is a criterion or basis for selecting the quantity of water to be drained. It is convenient to express this element as a drainage coefficient in inches per hour (or the equivalent centimeters per hour). The drainage coefficient therefore is independent of area, and thusly is a coefficient to be applied in product with varied or selected drainage areas to yield a discharge rate (volume per unit of time). One normally expects that the devising of a drainage coefficient would involve (1) estimates of the leaching requirements, (2) estimates of the irrigation efficiency (including the water conveyance efficiency), and (3) estimates of the direct surface runoff from rainfall. From this, the dominating elements produce the coefficient.

The leaching requirement is relatively small. The relationship of the depth of drainage water (leaching) required to the depth of irrigation water consumptively used is proportional to the relationship of the irrigation water salinity and the permissible salinity at the drainage face. If one considers a leaching need to satisfy a 4 millimho drainage level, then with the irrigation water quality being used the leaching requirement would be only 8.4% of the evapo-transpiration water use. Even for ultra-sensitive crops (as certain vegetables), the leaching requirement would be only about 17 percent. Therefore, the real leaching requirement does not dominate to depict the coefficient of drainage.

The rainfall is so meager that it, too, fails to dominate. The present mode and efficiency of the irrigation (and conveyance) produces the coefficient. To quantify this requires some generalized estimates at this stage of the project. The resulting drainage coefficient for a broadly cropped area is preliminarily established at 0.01 inches per hour (See Appendix I).

Prior studies have not depicted the field irrigation efficiencies. The water application appears to be rather low, and perhaps widely varied. The conveyance losses, at best, are nebulous and are not well known. A 1953 Morrison-Knudsen study on a segment of the main diversion canal reports a loss of 0.8 cubic feet per second per square foot per day, which is 3.45 acre-feet per kilometer of canal per day. This, however, was a study in a highly gyp reach. I believe about the only way to improve upon the preliminary drainage coefficient is by generating some new data on field efficiencies and conveyance losses. If this is done, I recommend the conveyance losses for catagories of canal size be translated to a parameter in terms of canal density (linear miles per square miles, or linear kilometers per square kilometer), in order to stay with a coefficient approach.

The drain-out period (that is, the peaking of the collective drainage water) will change as the drainage network is intensified. The Shamalan report by the Bureau of Reclamation (1968) observes that the drain-out was in November and again in April, and accounts for this by saying the high evapo-transpiration in the summer makes lesser the summer drain-out. I graciously would tend to discredit this thought as one commences to change and intensify the arteries of drainage. One must guard against the use and application of transitory data. The quantity of water to be drained is best depicted by mass balances (water input = abstraction + drainage) for the peak period of input, which will be July.

Concerning farther elements of criteria, and second to the drainage coefficient, is the criterion or basis for determining drain depth and spacing. For subsurface drainage it is convenient tothink of a drain as a horizontally oriented bore (well) that accepts flow by partial or complete convergence of the flow to the drain. Basically, the subsurface flow to drains conforms to a horizontal flow theory, being dominantly a top-side convergence, or a radial theory, being a more complete convergence. The relative position of the underlying barrier governs the behavior.

In the project areas, there will be sites with pronounced barriers and those without. The Marja and Nad-i-Ali areas have a very definite drainage barrier. The Shamlan and Darweshan have varied conditions in respect to drainage barriers. Therefore, it is necessary to establish an expression for drain depth and spacing for both conditions. As a preliminary criterion the Ellipse equation and the Modified Ellipse equation have been selected (See Appendix II). The ellipse equation is applicable to those conditions where the depth of the barrier below gound surface is at or less than twice the depth of the drain. The Modified equation is applicable where the barrier is deeper.

Drain Spacing

The hydraulic conductivity of the drainage media is a principal term of the equations and should be determined for the field sites to be drained. The random data of the past on hydraulic conductivity are not in sufficient detail to predetermine depth and spacing. However, the probable ranges of spacing merit some speculation at this point. In the less favorable parts of the Marja and Nad-i-Ali, the drain spacing for totally effective drainage might be on the order of 40 to 45 meters. In the more favorable conditions, the spacing may be 80 - 90 meters. In the Shamalan and Darweshan, the less favorable conditions may yield spacing of about 60 to 120 meters, and in the most favorable situations the spacing may range upward to about 300 meters. However, this can be only highly speculative at this time, and serves only to illustrate the paramount influence of hydraulic conductivity and underlying barriers upon the spacing of drains.

The third element of the preliminary criteria is the side slopes for open drains. I had no data on the engineering properties of the soils, and therefore established a preliminary criterion upon some rather general observations. Typically, the soils into which banks will be excavated are medium strength soils. The upper parts of the banks will be prevalently dry. The soils bake well, the desiccative cycle is infrequent, and shrinkage upon drying is relatively low. Areas of high pore pressure and quickening are not vividly present. The wetted area of the flowing channels is rather constant and quick drawdown is of minimal concern. On the generalizations, the preliminary criterion for side slopes of the main drains is established in the range of 1:1 to $1\frac{1}{2}$:1, varying with depth (See Appendix III). These slopes should be sufficient. The criterion addresses the preponderant condition. Should an area be encountered that would require flatter slopes it likely would be an isolated area in the Shamalan or Darweshan where a particular alluvial lensing has presented an abnormally weak condition.

The fourth element of the preliminary criteria deals with the maximum allowable velocity for main drains. Again, widely gathered and precise data are not available for a rigorous look at the probably limiting velocities. However, there are some indicator data and some flowing channels for observation by which a basic criterion can be established. The basic limiting velocity is preliminarily set at 3 feet per second (See Appendix IV). There are wide areas, notably in the Marja and Nad-i-Ali, where sizeable gravels on the flow boundry will permit higher velocities. However, the basic 3 FPS limit will be rather adaptable to most of the drainage channels.

The fifth element of the preliminary criteria has to do with the hydraulic roughness for open flow. The two main factors that bear upon this determination are the surface condition left by the mode of excavation and the vegetation growth. Other factors, as varying cross section, sinuosity, silting and scouring, and debris are insignificant. The vegetation in the channels is primarily reedgrass and a few cattails. Based upon a reasonable recurrence of maintenance, the preliminary criterion for hydraulic roughness (Manning's n), for capacity design, is set at the minimum of 0.03 (See Appendix V).

The foregoing elements are the primary criteria for this stage. Obviously, adjustment and extension of these preliminary criteria will need to be made as the project phases unfold. However, I believe these preliminary aspects are quite suitable for now. One notices that I have dealt altogether with open drains, and have not addressed elements of criteria for buried (conduit) drains. For good reasons, HAVA and USAID have decided that the field drains (initially, at least) will be open drains. Certainly, open field drains when properly sized and spaced will collapse the water table and produce a functional drainage.

Open Drains

However, I would be technically remiss not to mention buried field drains and place some emphasis upon their technical adaptability to the area. I purposefully avoid calling them tile drains, for such connotes a drain of clay or concrete tile. I would not strongly recommend clay or concrete tile drains for wide-spread original installations in the area. On the other hand, I would unreservedly recommend buried field drains of perforated, flexible corrugated plastic tubing. There has been in the area the prior and older installation of a few tile drains, and their performance has been less than desirable in some instances. One should cautiously guard against using altogether these prior experiences as a basis for determining the functional acceptance of buried drains, for to do so would not give full recognition to the technological advances that have intervened.

Modern-day high speed (ladder type) trenchers, equipped with shore boxes and automatic tube feeders, can install the flexible corrugated polyethylene plastic tubing very quickly. The cost of drains, thusly installed, would be competitive with the hand or machine excavated open drains, if not indeed cheaper. One would speculate that both sand-gravel and fiberglass filters would be used. In the Marja and Nad-i-Ali areas, where many of the drains would be placed into the gravelly fringe of the conglomerate, it would be difficult to use a shaping shoe at the bottom of the trenching. Therefore, a sand-gravel envelope likely would be the choice bedding and filtering arrangement for the drain tubing. In areas where the position of the drain is in moldable soil (where a shaping shoe will work) the fiberglass filter would be a good choice. In either case, the trenchers are readily adaptable to automatically feed the filter material into position with the tubing. One would expect that a modern-day machine could install the tube drains complete with filter and backfill at the rate of about 500 feet per hour. The cost of such a machine, fully equipped and with laser grade control, is about $105,000.

For the project area, I have no misgivings about the technical acceptability and choice of a perforated plastic tubing for the original installation of buried drains. However, when considering the conversion of installed open field drains to buried drains, I suspect that clay or concrete tile (hand installed) would be more adaptable. One point is worth mentioning. It is likely that intially installed open field drains will be positioned at the edge of fields where there may be a tree row or other untilled outage. Any type of buried drain requires that the overlying surface be free of trees or deep-rooting shrubs in order to preclude the infiltration of roots to the drain. This, however, is about the only maintenance element involved for properly installed, modern, buried drains. By far, the historical problems and maintenance difficulties of buried drains (in the U. S. and elsewheres) has been due to improper design and installation. Only in rare locations have chemical complexes (such as crustaceous magnesium oxide) been a problem and I certainly foresee no difficulty on this point in the Helmand areas.

Therefore, I technically would urge that HAVA and USAID be very attentive to the circumstances or phase whereupon some buried field drains could be installed in addition to the open field drains presently envisioned. For the very long term outlook, there is much to be said in favor of buried field drains, which leave the land unoccupied and surface unimpeding to changes in field partition and farming method, and at the same time require the least maintenance effort when properly installed.

Preliminary Standards for Construction Drawings and Specifications

As projects are initiated, it becomes desirable that a standard and format be established for preparing drawings and writing specifications. For drawings, the thought is not that there is but a single or best way to prepare them. Conversely, there are many ways and for this reason a standard should be set. Otherwise, first one and then another devises his own drawing and scaling scheme. Some would have the water flow exhibited to run from left to right on the sheet, while others would have the opposite. Such random makeups begin to interfere with expeditious checking and review procedures. Therefore, a concise standard for preparing drawings is needed to set forth and address such matters as survey orientation, scales, sheet sizes, and related items. I have prepared a tentative standard for drafting and plotting (See Appendix VI). This, of course, can be changed and improved upon, but that now written seems adequate to serve the interim period.

The written specifications for the drainage work should be prepared for the principal work items. This approach seems preferable over one continuous narrative of specifications. Probably about five titled specifications will fulfill the recurring situation for the main drain construction. They likely will be Excavation, Concrete Pipe Conduits for Culverts, Clearing and Grubbing, Loose Rock Riprap, and Concreting (See Appendix VII). For the drainage work the procurable materials needed will be rather definite and uncomplicated. Therefore, I recommend that the material requirements be written directly into the construction specifications rather than be specified as separately written material specifications.

There have been prior generations of construction specifications in the area; those generated by M-K, the Bureau of Reclamation, and others. The construction unit is accustomed to construction specifications. Therefore the specification writer can be quite explicit without misgivings that his coverage will be too detailed for the construction unit. On the other hand, and as a result of only one bidder being involved, the writer will be able to deal with some matters of specificity in an abridged manner.

One might expect that someone from the construction unit will wonder why the older generations of specifications are not used for the outlying work ahead. That might even be suggested by some. I see little reason, purpose or merit in trying to adapt an older set of specifications to the work.

The present work is a different scope of work from the canal and drain construction of the past. The specifications therefore should be developed and expressed for the present work and set forth the construction requirements for the function and conditions now existing.

The Early Construction Start

When I arrived in Lashkar Gah the HAVA people were engaged in making field surveys for an early construction start. This survey work was in the Nad-i-Ali area and it continued for several days after my arrival. At that time consideration was being given to constructing a new outlet channel (6.43 kilometers) for Drains No. 2 and 3 in this area. The Nad-i-Ali area presently has three major drains (Nos. 1, 2, and 3). The three come together near the south side of the area and are served by one outlet channel leading to the Nad-i-Ali wasteway. The option for a new outlet for Drains 2 and 3 required some cost comparison with the option to deepen and widen the existing outlet channel. The HAVA group reduced the surveys to plottings and made comparative excavation estimates based upon tentative channel sizes. The new channel outlet became the choice option, and this 6.43 kilometers of channel was selected as the first construction segment.

I worked with the HAVA group to refine the hydraulic design and requirements for the segment. They set about to prepare the drawings and I began to prepare the draft specifications for the work (See Appendix VIII). Jointly we progressively worked on the design of the appurtenant road crossings. By August 24, the drawings for the channel segment and specifications were complete and USAID had presented HAVA a draft agreement for this first construction. Preliminary quotations from the construction unit were received August 30, and at the end of my TDY the joint approvals and final agreement by HAVA and USAID were being readied for construction to start.

This first segment produces a very suitable makeup for a construction start. It is a good design and affords a very favorable condition for the progressive and subsequent deepening of Drains 2 and 3 in the Nad-i-Ali area. The new outlet will accommodate a subsurface drainage discharge of 140 cfs, leaving a discharge of 120 cfs required of old outlet route. I am well pleased with the design. The HAVA group worked diligently and enthusiastically to complete it.

Work Items for the Following Team

The scope of work for the following team is presented concisely on page 67 of the Project Paper. The expressed scope anticipates that field work will be needed to develop information on: (1) soil chemistry, including salinity and other characteristics, (2) the water table, including the amount of flows and hydraulic conductivity, (3) drainage barriers, and (4) cropping patterns, parcel sizes, and ownership. It seems to me that some data gathering on items (2) and (3) will be the first and most pressing need. With this in mind, I discussed the availability of field tools. HAVA is rather well equipped in this respect. About the only additional item is a temporary perforated casing sleeve for hydraulic conductivity tests. Many of the test holes will stand up on the walls of the hole without casing, but a temporary casing should be available for those that do not. I left with USAID at LashkarGah a sketch for the making of a temporary test hole casing.

During the TDY period I tried to observe and determine what small work supplies the team should arrange for themselves before leaving the States. Most notably, is the supply of calculators. The office is not well equipped in this respect. I recommend that each of the two engineers on the team be supplied with a small electronic calculator, something on the order of the Hewlett-Packard HP-35 or the Texas Instruments SR-50. The other two members may want the same, but at least each should have a calculating instrument equal to the Texas Instruments SR-11.

The drainage engineer will want to supply himself with the SCS forms for drainage work. Additionally, each engineer should have a set of the SCS National Engineering Handbooks and a selection of the Technical Releases. The Soil Scientist, likewise, will need his work references.

Closing Remarks

I believe that now is a very appropriate time for SCS to enter with HAVA-USAID into the drainage picture in the Helmand area. Much work has been done in the area in the past by the Bureau of Reclamation and engineering firms, and most of this work is very good. The prior works have dealt with the broad layout of project development, forwhich the participants were well suited. The present and continuing drainage work deals with an intensification of the drainage network and salinity management on the land. The SCS, with its realm of experience in this field, should be particularly suited to assist ably in this future work. As to my own TDY, I suppose like many temporary assignments the tangible results are difficult to assess immediately. At any rate, I feel good about the assignment and the work done, and that perhaps is the best measurement at this point.

I recommend that you direct a copy of my report to Mr. Vincent Brown, the Mission Director at Kabul, and Dr. Stanley Krause, USDA-ERS. Also, it should be benefitting for each of the team members to have a copy. I am enclosing six copies for your use. I will give a copy to my immediate supervisor, Mr. E. E. Thomas.

Finally, I enjoyed the assignment. It was an interesting work venture, and I appreciate your willingness and decision to entrust the work to me.

Gene C. Vittetoe

APPENDIX I

Criterion for Drainage Discharge

The preliminary criterion for the quantity of flow from drains is established by synthesizing a value from estimated irrigation water inputs. The logic construction for the synthesis is:

1. Estimates of the leaching requirements for salinity balance in the drained soil profile.

2. Estimates of the magnitude of irrigation efficiency as presently practiced, and thus development of a representation of irrigation water losses reaching the drainage interface through percolation or direct irrigation runoff.

3. Estimates of the direct surface runoff from rainfall.

The magnitude of the irrigation water losses predominates for the drainage discharge requirements, and negates the influence of minimum leaching demands or rainfall runoff upon the dimensionlizing of the drainage.

The drainage discharge requirement is best depicted by the drainage coefficient, q, expressed in inches per hour or the equivalent centimeters per hour. The drainage coefficient therefore is expressed independently of area, and thusly is a coefficient to be applied in product with varied or selected drainage areas.

With the irrigation water losses predominating to depict the drainage discharge requirements, the peak irrigation water inputs thereby become the controlling element for estimating and computing the drainage coefficient criterion. The following tabulations are computed values of consumptive use of water by crops (evapo-transpiration). The values are developed after the procedures of SCS Technical Release 21 - Irrigation Water Requirements, which is a modification of the Blaney-Criddle procedure.

Month	Wheat	X 0.40	Corn	X 0.30	Cotton	X 0.25	Alfalfa	X 0.15	Dry Beans	X 0.10	All Others	X 0.12	Sum of the weighted
January	1.90	.76											0.76
February	2.78	1.11					1.50	.23					1.34
March	5.18	2.07					3.37	.51					2.58
April	5.49	2.20			/.63	.16	5.25	.79			2.71	.33	3.48
May	3.30	1.32			3.00	.75	8.91	1.34			5.61	.67	4.08
June					8.18	2.04	11.55	1.73	.85	.09	9.78	1.17	5.03
July			6.12	1.80	11.44	2.86	12.42	1.86	1.32	.13	13.22	1.59	8.24
August			9.43	2.80	9.03	2.26	10.16	1.52	1.33	.13	11.93	1.43	8.14
September			6.61	1.99	5.26	1.32	6.48	.97	.82	.08	7.32	.88	5.24
October			2.28/	.68	2.72	.68	4.10	.62					1.98
November	/.49	.20					1.96	.29					0.49
December	1.33	.53											0.53

Computed consumptive use (in inches) by months, by crops

(Weighted by estimated percentage of total land planted to the specific crop)

Weight factors are based upon cropping pattern (estimated by HAVA)

Wheat	40%	Alfalfa	15%
Corn	30%	Beans	10%
Cotton	25%	Fruit, Melons, other	12% (all others)

Use rate for "all other" crops is based upon equivalent computed use for spring and summer sugar beets, which rate amply accounts for these varied water uses by assorted crops. Slash mark in tabulation above indicates computation for partial month.

Observe that the peak monthly use (of the weighted sums) occurs in July. Observe also that the total percentage of crops on land is 92% at this month. The predicted cropping pattern used produces a percentage total in excess of one hundred, at 132% which accounts for some split-season and double cropping.

The values tabulated (as inches per month) are purposefully dimensionless in respect to area, so that they may be utilized and made applicable as coefficients to varied spatial or area situations. The peak use of the weighted sums is 8.24 inches (July). This value, when divided by 0.92 (the cropping magntude), yields a figure of 8.96. This is the equivalent use rate (monthly, July) for a total (broad) area when the cropping outage is not recognized.

The efficiency with which the water is applied has not been measured or evaluated in quantifiable terms. However, by casual observations one realizes that the total water delivered for irrigation is probably on the order of twice that consumed by evapo-transpiration. This would mean that the field application efficiency is about 50%. Direct evaporative abstraction during the application and water intake time period can be quite noticeable during the hot months. Water surface daily evaporation during July will average about 0.55 inches. This means that the direct evaporation losses at the atmosphere interface may range as high as 9 to 13 percent for irrigation application depths varying from 6 to 4 inches. A 10% figure is conveniently taken. Other field losses, to the drainage interface, are taken at 40% of the water applications, which amounts to a 60% irrigation efficiency in respect to the net depths of water after evaporative abstraction during the application periods.

8.24 inches = peak monthly consumptive use, weighted sum.
8.24/0.60 = 13.73 inches = net intake (includes direct runoff).
13.73 - 8.24 = 5.49 inches = losses (or excesses) to the drainage face from irrigation applications.

8.24/0.50 = 16.48 = conveyance requirement.
Conveyance losses are taken at 12%.
(16.48) (0.12) = 1.98 inches = estimated conveyance losses to the drainage face.

5.49" + 1.98" = 7.47 inches = probable peak monthly water amount reaching the drainage face from broadly cropped irrigated areas and from the associated distribution network.

7.47 inches/30 days per month/24 hours per day = 0.0103, taken at 0.01 in/hr.

CRITERION

0.01 inches/hour = selected drainage coefficient for a broad mixed-crop area (all mains and submains). Equivalent units: 0.0254 cm/hour.

For field drains, the specific and predominating crop grown should be used to arrive at the drainage coefficient. The drainage coefficient for the heavier water using summertime crops, as cotton, may range as high as 0.014 inches per hour, and as low as 0.008 for the lighter water using winter crops as wheat. However, as a matter of preliminary criterion (and pending farther evaluation by the following team), one should be careful to avoid selecting a drainage coefficient for field drains drastically below the 0.01 value.

APPENDIX II

Criterion for Determining Drain Depth and Spacing

The control of the water table by artificial subsurface gravitational drainage, for a specified area, is primarily a function of the amount of water to be drained, the hydraulic conductivity of the soil media, the depth and spacing of drains, and the flow boundary conditions.

This CRITERION seeks to establish a preliminary basis for determining drain depth and spacing in respect to the dominating subterranean boundary condition. Analysis of flow patterns by flow net development is rarely practical, nor desirable, for the practitioner charged with designing and implementing drains for agricultural purposes. Such techniques typically are reserved for the investigator interested in other pursuits, devoid of the implementation objective, and centered upon technical study.

A drain, being a horizontally oriented bore or channel, accepts flow by partial or complete convergence to the drain. Basically, the subsurface flow to drains conforms to a horizontal flow theory (being dominantly a top-side convergence) or a radial flow theory (being a more complete convergence). The relative position of the underlying barrier (flow boundary) governs the behavior. Investigators of the past, out of theory and empirical development, have created various formulae suitably adaptable to the modeled conditions found in the field, and upon which drain depth and spacing can be designed.

CRITERION

Field Drains:

For the field condition where the soil is underlain by a horizontal barrier (conglomerate or other) at depths equal to or less than twice the depth of drain and the ground water flow is largely in a horizontal direction, the Ellipse equation (after Donnan, etal) shall be used to depict drain depth and spacing. The Ellipse equation is expressed as

$$S = \left[\frac{4K(m^2 + 2\,r\,m)}{q}\right]^{\frac{1}{2}}$$

Where: S = drain spacing in feet
K = average hydraulic conductivity, in./hr.

m = vertical distance, after drawdown, of water table above drain at midpoint between drain lines, in feet.
a = depth of barrier below drain, feet.
q = drainage coefficient, in./hr.
d = depth of drain, feet.
c = d-m = depth to water table desired, in feet

Units of K and q must be compatible for the above formula, as expressed. Refer to Figure 4-28, SCS National Engineering Handbook, Section 16, for graphical aids in the solution of the Ellipse equation.

For the field condition where the soils and subsoils are deep, reasonable homogeneous (devoid of pronounced stratigraphy), and underlying barriers, if present, are at depths in excess of twice the drain depth, the Modified Ellipse equation shall be used to depict drain depth and spacing. The Modified equation functionally introduces an "equivalent depth" to barrier, thereby making allowance for deeper return flow and convergence to the drain. Refer to Figure 4-29, SCS National Engineering Handbook, Section 16, for graphical aids in the solution of the Modified Ellipse equation.

One expects that the Ellipse equation will be widely and dominantly adaptable in the Nad-i-Ali and Marja areas, where the underlying conglomerate is pronounced. On the other hand, one expects that in the Shamalan and Darweshan areas the Modified equation may be selectively, but widely, adaptable. Normally, for companion hydraulic conductance and like drain depths, the Modified equation yields noticeably greater drain spacing.

Field drains shall be designed and installed at the greatest practical depth for the physical conditions and outlet conditions encountered. They shall be outletted for free flow (no exorbitant backwater from the base flow stage of the outletting main drain channel). Field drains normally should be at or deeper than 6 feet (1.8 meters), and rarely is it practical to place the depths greater than 9 feet (2.75 meters) except for some selected open ditch drains serving as field drains in very deep soils. For limiting depths controlled by the underlying barrier (such as conglomerate), the depth of field drains should reach to the top of the barrier, providing the outletting requirements are satisfied. Field drains need not penetrate cemented conglomerate barriers since such added penetration is non-enhancing to the flow convergence behavior and therefore ineffectual.

The depth from ground surface to the drained water table, the value "c", depicts the degree to which the water table is collapsed, and should desirably be taken at 5.0 feet (1.5 meters). The minimum acceptable value for this dimension is 3.3 feet (1.0 meter). At this higher watertable there is insufficient draining depth for accomplishing a sustained salinity balance in the soil profile, and this minimum value of "c" therefore is acceptable only for an interim drainage condition.

Main Drains: Main drain channels constructed to accept drainage from lateral field drains shall be hydraulically dimensioned so as to provide the lowest practical water stage for the collective flow from subsurface drainage. The depth of main drains shall be determined in respect to the depth and performance requirements of the field drains served by the channel. Main drains may appropriately penetrate conglomerate or other barriers to satisfy the desirable and functional depths required.

Main drains designed for collecting subsurface flow from contributing field drains should desirably be deep enough so that the collective base flow can be discharged at flow depths of 2.0 feet (65 cm) or less. Rarely, should base flow depths in excess of 3.0 feet (90cm) be accepted for design.

Main drains shall be spaced so as to provide an adequate collection system, in agreement with the land partition, roads, canals and other physical considerations. Normally, the amount, spacing and intensity of the main drain system should be such that (1) the length of any one field drain leading thereto is not more than one kilometer (3,280 feet), and (2) the necessary and aggregated discharge of a single field drain does not have to exceed approximately 0.20 cfs (90 gpm). When these limits are exceeded, full consideration shall be given to increasing the amount of main drains, as submains, in order to deminish the spacing thereof and curtail the reach required of contributing field drains.

Main drains beyond, and downslope of, the areas to be drained need not be purposefully deep nor designed to flow at shallow depths for the base flow. Conversely, such get-away reaches should be designed for minimum base flow depths of approximately 3.3 feet (1 meter) and preferably 4.0 feet minimum. Reedgrasses grow in water, from the wetted fringe to a tolerable depth that permits sufficient plant above water for survial. In order to isolate the abundant growth of reeds to the channel banks and to impede their dense growth across the channel bottom, and thereby deminish the maintenance effort, get-away channels should be consciously designed for noticeably increased depths of the base flow over that set forth for collective main drains.

APPENDIX III

Criterion for Side Slopes of Drains

Side slopes of excavated opened channels or trenches shall be designed to be stable when subjected to the active state of stress of the bank and surcharge loading, and to be stable against the attach of water flow on the banks. No data on the engineering properties of the soils are available to assist in determining the structural and hydraulic stability requirements for side slopes. However, field observations of the general character of the soil, and their expected properties, with the exhibit of existing banks and slopes, afford a suitable basis for setting forth a preliminary criterion for channel side slopes.

The general soils into which banks will be excavated are medium strength soils Functionally, the upper reaches of banks will be prevalently dry. The soil typically bakes well, the desicative cycle is infrequent, and shrinkage upon drying is relatively low. Areas of high pore pressures are non-existent or rare; no quickening is vividly present by limited observations made. The wetted areas of flowing channels are reasonably persistent and constant, and quick drawdown is of minimal concern. The seepage excape gradients are mild.

CRITERION

By generalization, the following criterion for side slopes of main drain ditches is preliminarily established:

Less than 1.5M depth (5 feet):	1:1
1.5M (5 feet) to 2.75M (9 feet):	$1\frac{1}{4}$:1
Greater than 2.75 M (9 feet) depth:	$1\frac{1}{2}$:1

The slope ratios expressed above are units horizontal to units vertical. One may reasonably expect that the aforementioned side slopes can accept surcharge loading (spoil banks) without designed setbacks to the following maxium heights:

	Surcharge
5' ditch depths:	2.5 feet (0.75M)
5' - 9' ditch depths:	3.3 feet (1.0M)
9' plus (not to exceed 12') ditch depths:	4.0 feet (1.2M)

Side slopes of excavated field drains (trenches) may be essentially vertical. The flowing depths are very shallow in respect to the total trench depths. Only a slight batter is required, on the order of 1/8 to 1, in the Marja and Nad-i-Ali areas. In other areas, of alluvial soils exhibiting layering, flatter slopes may be required. Spoil (excavated material) from trenched field drains should be presentably reposed on the ground surface near the trench edges. Spoil banks shall be fashioned so as to make complete bank closure along both sides and distal end of excavated field drains in order to preclude the entry of surface waters. Steeply incised field drains cannot accept land surface water breaks into them, and such must be prohibited.

APPENDIX IV

Criterion for Maximum Allowable Velocity in Main Drains

The limiting velocity for open earthen channel flow is best predicted for a specific site by logging and sampling the materials to be found on the flow boundary. Typically, measurements of grain size distribution and plasticity become prime indicators of stability for materials exhibiting fine grain and cohesive characteristics. Grain size distribution and in-place density become good indicators for larger grained, cohesionless materials. Precise data, widely gathered, are not presently and readily available for a rigorous look at the probably limiting velocities. However, with what data are available, coupled with some observations, one can set forth a generalized criterion.

CRITERION

The basic maximum allowable velocity for open channel flow is established at 3.0 feet per second (FPS). This limit is permissible as a preliminary criterion without undergoing qualifying tests, other than general site observations to rule out the likely presence of any unduly weak materials.

For the sustained base flows, the tractive force on the beds and lower banks of the channels generally will be less than 0.3 pounds per square foot. When noticeable amounts of gravel are present and interdispersed in the soil matrix, allowances for an increase in the basic 3 FPS may be considered as follows:

When, (1) 45% or more of the total fraction is greater in size than the No. 4 sieve, and

(2) 25% or more of the total fraction is greater than the 3/4" size,

Then, the limiting velocity may be increased to 3.7 FPS.

When, (1) 65% or more of the total fraction is greater in size than the No. 4 sieve, and

(2) 25% or more of the total fraction is greater than the $1\frac{1}{2}$" size,

Then, the limiting velocity may be increased to 4.3 FPS.

Additional liberties with allowable velocity should not be taken without rather detailed logging, sampling, testing, and evaluation of the stability characteristics on channel line, for the specific work site. SCS Technical Release #25, Chapter 6, is presented as a suitable reference for evaluating channel stability.

APPENDIX V

Criterion for Coefficient of Hydraulic Roughness

Channel flow is usually expressed by the mean velocity of the flow, which is a function of the roughness of the channel, the hydraulic radius, and the slope of the energy gradient. Manning's formula is one of the most widely used expressions. Of the three variable terms of velocity, the coefficient of roughness "n" is the most difficult one to determine reliably. The computed discharge for any given channel will be more reliable than the value of n used in making the computation. The selection of n therefore requires careful consideration.

The value of n is primarily influenced by (1) the physical roughness of the bottom and sides of the channel, (2) variations in size and shape of cross section, (3) channel alignment, (4) vegetation, (5) silting and scouring, and (6) obstructions from lodged debris. For the Helmand Valley drainage channels, the physical roughness and vegetation are the dominant factors. The other factors are relatively insignificant.

Manning's n for a newly constructed drainage channel should be on the order of 0.023 to 0.025. This considers a flow boundary of clean earth, regular in shape and on line, but with some surface roughness depicted by that formed with toothed excavators. One may reasonably expect that reedgrass (and other vegetation) will establish itself on the channel slopes as the channel ages. The roughness due to this vegetation in the side slope prism of the flow section may change to 0.045 to 0.055 for that part of the flow perimeter. The degree, mode and frequency of channel maintenance becomes a major element in discerning the aged roughness. With reasonable maintenance, one may expect that the composite n value for the aged channel will be on the order of 0.030 to 0.033, for drainage channels of the general size and configuration expected in the Helmand Valley.

The required capacity of the channels (for the selected design depths) should be determined using an aged n value. However, in respect to the limiting or allowable velocity from a channel erosion standpoint, the n value for this velocity examination should be taken at that condition expected of the newly constructed channel. The velocity of the newly constructed channel may be examined from the capacity design by using a ratio of the aged to new n values.

CRITERION

For capacity design, use an n value not less than 0.030. Rarely should the selected value range above 0.033 unless very deferred maintenance is foreseen.

For examining the velocity against the allowable velocity, use the velocity from the capacity design times the factor 1.2. This factor results from a n value of 0.030 divided by the value 0.025. A factor of 1.32 should be used when the higher n of 0.033 is used for capacity design.

The newly constructed velocity becomes less significant for certain collection and outletting channels when the selected capacity for design is based upon some future condition to be realized by a progressive extension of the upstream drainage network. Under such circumstances the full design flow is not immediately imposed upon the newly constructed downstream channel. However, the mode and recurrence of maintenance will restore the n value below that prescribed for capacity design. One therefore should give due consideration to this functional condition when examining the stability design.

APPENDIX VI

Standard

for

Drafting and Plotting

1. SURVEYS

Surveys for drainage typically should be run in the upstream direction. Most frequently, the outlet condition and position becomes a point of primary concern, and with rare exception surveys should be progressed from the outlet point. Cross sections taken on the survey route should be recorded and plotted with the orientation one has when facing the direction of the increasing stations on route. When, for reason of some rare field conditions, it becomes necessary or desirable to run a survey in the downstream direction, the surveyor should assume at the starting point a station number, amply large, and physically run the survey with decreasing station numbers to the outletting end.

2. PLOTTINGS AND DRAWINGS

Profiles should be plotted with the water exhibited to be running from right to left of the sheet. Station numbers will run from left to right. Plan views should be projected at the left hand station (first station) on each sheet, and thereafter be untrue projections when the plan is other than a straight line. Where a plan view has only one curve (point of intersection) occuring on a single sheet, the true projection from the profile may then be made at that PI instead of the left hand end of the profile. Cross sections will be plotted in the orientation of the increasing stations on route.

Scales. Most, if not all, of the graph paper upon which plotting will be made will be graduated in inches, with multiples and subunits of the inch. Therefore, establishing scales on precise scale ratios for the metric system is not practical.

Horizontal scales for Profiles:

Minimum - 1" = 400'; 1" = 120M (Approximate ratio - 1:4800)
Maximum - 1" = 100'; 1" = 25M (Approximate ratio - 1:1200

1" = 50M should be commonly selected.

Vertical Scales for Profiles:

Minimum - 1" = 10'; 1" = 3M
Maximum - 1" = 2'; 1" = $\frac{1}{2}$M

1" = $\frac{1}{2}$M or 1" = 1M should be commonly selected.

Horizontal Scales for Cross Sections:

Minimum - 1" = 20'; 1" = 6M
Maximum - 1" = 10'; 1" = 2M

Vertical Scales for Cross Sections:

Minimum - 1" = 10'; 1" = 3M
Maximum - 1" = 4'; 1" = 1M

Scales for Structural Layout:

Not less than $\frac{1}{4}$" = 1'
Not less than $\frac{1}{4}$" = 25 cm

Scales for Structural and Reinforcement Details:

Not less than $\frac{1}{2}$" = 1'
Not less than $\frac{1}{2}$" = 25 cm

3. SHEET SIZES

Drafting sheets for contract drawings should be not less than 30" horizontal X 20" vertical nor greater than 36" horizontal X 24" vertical. All sheets in a set of drawings should be the same size, neatly trimmed, and contain a border line. Sheets for plotting surveys (not contract drawing) need not conform to the horizontal size, but may be rolled from longer sheets.

Each sheet of contract drawings except the title sheet should contain a title block in the lower right-hand corner. Th title block should be 5" horizontal X 3" vertical.

4. FIELD ORIENTATIONS

For channels, streams, and drains, the "left side" will be that side to the left when facing downstream or in the direction of flow. This is the field and conversation orientation that should be used, and makes the plotted cross section the mirror image of this conversation orientation.

The general directional descriptions should be as follows: The "West" side is that to the left of a line that ranges in bearing from SE-NW to SW-NE. The "East"is on the opposite. The "North" side is that to the left of a line that ranges in bearing from SW-NE to NW-SE. The "South" is on the opposite. Accordingly, directional descriptions are restrained to North, South, East and West, and the sub-cardinal directions such as Southwest, Northeast, and so forth are favorably avoided for descriptive and conversation use.

APPENDIX VII

Standard

for

Writing Construction Specifications

Each construction contract must contain a suitable set of drawings and construction specifications fitted to the scope of work to be done under the contract. Drawings illustrate and dimensionalize the work, although they may contain also brief notes that are specifying to the work. Specifying notes on drawings should be restrained to those notes intrinsic to an illustration of the drawings. Written specifications, on the other hand, set forth the construction results to be satisfied.

The specifications should be written for each major item of work, such as performing channel excavation, installing concrete pipe conduits for culverts, and so forth. What constitutes a major item of work, and therefore defines the scope of any one specification, is determined by the distinctiveness of the dominating construction operation and the particularity of the materials employed. Where construction involves a large or ranging amount of procurable materials, it is rather common practice to write the specifications as separate construction specifications and material specifications. However, for general drainage work, the amount and range of procurable materials required is not great and complicated. Therefore, the construction specifications for drainage work should contain within that writing, as a distinct section, the specifying requirements of all materials for that item of construction.

The specifications should be written in the general outline of (1) the scope of the specification, (2) materials, as applicable, (3) the body of the specification, setting forth the construction results or construction procedures to be satisfied, and (4) the method of measurement and payment for the items of work involved.

For the Helmand Valley drainage work the most frequently needed and recurring specifications for the main drains will be

Main Drain Excavation
Clearing and Grubbing
Concrete Pipe conduits for culverts
Concrete
Loose rock riprap

For each of the above specifications, the general outline of the elements to be addressed by the specification is as follows:

Main Drain Excavation

1. The Scope
2. Classification of the Excavation (definition of common excavation and rock excavation)
3. Markings (how the channel will be staked or marked)
4. Excavation (the requirements of the excavation process)

   a. The lines and finish required.
   b. Blasting stipulations (if required).
   c. The starting point and sequence required.
   d. Stipulations for handling wetness or water in the excavation area.
   e. Stipulations for removing sloughs and maintaining the channel during the contract period.
   f. Stiulations at bridges and crossings.
   g. Work stipulations at or near utilities.

5. Disposal of Excavated Materials

   a. Locations
   b. Shape and finish required.

6. Measurement and Payment

Clearing and Grubbing

1. Scope
2. Marking
3. Removal
4. Disposal
5. Measurement and Payment

Concrete Pipe Conduits for Culverts

1. Scope
2. Materials
3. Excavation (if special trenching or excavation distinct from other excavation in the contract)

4. Laying and Bedding
5. Joining Pipe
6. Backfill
7. Dewatering (if required)
8. Measurement and Payment

<u>Concrete</u>

1. Scope
2. Materials

   a. Portland cement
   b. Aggregates
   c. Water
   d. Admixtures
   e. Joint filler and waterstops

3. Class of concrete (compressive strength required)
4. Air content and consistency (air and slump)
5. Design of the concrete mix
6. Handling and measuring materials
7. Inspection and testing
8. Mixers and mixing
9. Forms
10. Preparation of Forms and subgrade
11. Conveying
12. Placing
13. Construction joints
14. Expansion and contraction joints
15. Removal of forms
16. Finishing formed surfaces
17. Finishing unformed surfaces
18. Curing
19. Concreting in cold weather
20. Concreting in hot weather
21. Measurement and payment

When concrete is reinforced concrete, add specification for reinforcement will be required and should address:

1. Steel reinforcement material
2. Bending

3. Splicing
4. Placing
5. Measurement and Payment

Loose Rock Riprap

1. Scope
2. Materials

    a. Quality
    b. Grading

3. Subgrade Preparation
4. Equipment-placed rock riprap
5. Hand-placed rock riprap
6. Measurement and Payment

APPENDIX VIII

Draft Specifications

for the

First Work Segment - Drainage

Outlet Channel, Nad-i-Ali Area

CONSTRUCTION SPECIFICATION

MAIN DRAIN EXCAVATION

1. SCOPE

The work shall consist of the excavation of all materials necessary for the construction of channels serving as main drains and the disposal of all excavated materials.

2. CLASSIFICATION

Excavation will be classified as common excavation or rock excavation in accordance with the following definitions:

> Common excavation shall be defined as the excavation of all materials that can be excavated, transported, cast or unloaded by means of excavators equipped with attachments (such as shovel, bucket, backhoe, dragline or clam shell) appropriate to the character of the materials and the site conditions.
>
> Rock excavation shall be defined as the excavation of all hard, compacted or cemented materials (bedded or conglomerated) the accomplishment of which requires blasting or the combined use of blasting and heavy ripping equipment with the operation of excavators in a process not defined for common excavation.

Excavation will be classified according to the above definitions by the Engineer, based on his judgement of the character of the materials and the site conditions. The presence of dispersed gravels, cobbles, isolated boulders or rock fragments will not in itself be sufficient cause to classify excavation as rock excavation, and the classification therefore is based upon the work effort and required excavation process as defined.

3. MARKING

The limits of the channels to be excavated will be marked by means of stakes, flags, or other suitable methods.

4. EXCAVATION

Channels shall be excavated as closely as practicable to the lines, grades, and cross sections shown on the drawings, considering the character of the material and the excavation methods employed. The excavated surfaces shall be reasonably smooth. In no case shall the excavated cross-sectional area of the channel be less than the specified area.

When blasting is required, the transportation, handling, storage and use of dynamite and other explosives shall be directed and supervised by a person of proven experience and ability in blasting operations. Blasting shall be done in such a way as to prevent damage to appurtenant works or unnecessary fracturing and blowout, and shall conform to rigid safety requirements which the contractor shall be obligated to set forth and implement.

Unless otherwise approved, excavation shall start at the downstream end of the channel and proceed continuously upstream. All excavation operations shall be done as concurrently as practical on each side of the ditch or channel. In no case will the excavation on one side of any ditch be allowed to advance ahead of the completed ditch by a distance of more than one kilometer (3,280 feet), unless otherwise authorized by the Engineer.

Channel excavation in the wet (that is, excavation under water) is permitted, and complete dewatering for excavation is not required. However, the contractor shall conduct his operations so that the gravity drainage afforded by the downslope conditions is fully utilized and the impounding or upstaging of waters in the excavation area is therefore avoided.

It shall be the contractor's responsibility to remove all sloughs, slides, bars, and debris that may accumulate in downstream channel reaches theretofore considered complete. Such removal is applicable to that which restricts or reduces ditch capacity, or that is otherwise required to be removed in order to make the total of the channel work, as specified, acceptable at the close of the contract period.

At locations shown on the drawings where permanent bridges or culverts are to be constructed under the contract, the contractor shall phase his operations so that such bridges or culverts are installed, functional and operational in suitable sequence to the need for advancing the channel excavation upstream thereof.

At locations other than permanent crossings, the contractor at his option may install temporary earthfill crossings in previously excavated channel reaches in order to move equipment from one side of the channel to the other; provided, that when such option is employed the temporary crossing installed shall be removed and the areas thereabout cleaned up immediately after such crossing has served or fulfilled its purpose. Temporary crossings as facilities of the contractor shall be installed with underlying pipes, of suitable number and size, when the constructed channel is passing flow.

When channel excavation is to be accomplished under power or telephone lines, such excavation shall be made without damage to or interruption of service of such lines. Any damage or interruption of service due to the contractor's operations or negligence shall be his responsibility. At least two days in advance of work to be performed under or near a power or telephone line, the contractor shall notify the owners or maintenance agency of such line in order that such organization at their option may be present during construction operations at their facilities.

5. DISPOSAL OF EXCAVATED MATERIAL

Material excavated from channels shall be deposited in spoil banks along the side of the channels, as typified on the drawings. As far as is practical, excavated material shall be placed equally on both side of the channel, except when specifically and otherwise noted on the drawings.

The spoil banks shall be shaped and graded by bulldozer blade, motograder or similar blade equipment. The finished profile of the shaped spoil shall be reasonably uniform with no significant mounds or depressions. The finished surface shall be smooth enough that it can be easily traversed by wheel-type vehicles.

The shaping and grading operation upon the spoil banks shall be carried out in a manner so as to maximize the coverage and influence of the operating equipment upon compaction of the material. When the material deposited is of varying characteristic in respect to gravel content, the more gravelly material shall be placed at and near the crown of the spoil banks, to the degree practical, and thereby produce the better trafficking surface. Rock or conglomerate material shall be deposited on the backside of the spoil banks and, when specified, shall be over-covered during the spoil shaping and grading operation.

6. MEASUREMENT AND PAYMENT

For items of channel excavation established in the contract, the volume of excavation will be measured to the neat lines and grades shown on the drawings, and computed to the nearest cubic meter by the method of average cross-sectional end areas. When two classes of excavation, common and rock, are items of excavation in the contract, field survey measurements will be made during the excavation process to affirm the elevations and delineation between common and rock. Regardless of the quantities actually excavated, the total and combined measurement for payment will be made to the specified neat lines, and field measurements will be made only to depict the delineation between common and rock.

Payment for items of excavation will be made at the contract unit price. Such payment will constitute full compensation for all labor, materials, equipment, and all other items necessary and incidental to the performance of the work, as specified.

CONSTRUCTION SPECIFICATION

CLEARING AND GRUBBING

1. SCOPE

The work shall consist of the clearing and grubbing of designated areas by the removal and disposal of trees, snags, logs, stumps, shrubs, and rubbish.

2. MARKING

The limits of the areas to be cleared and grubbed will be displayed or noted on the drawings, from which the limits at the work site will be marked by means of stakes, flags, tree markings or other suitable methods. Trees to be left standing and uninjured, within a area otherwise inscribed for clearing and grubbing, will be designated by special markings placed on the trunks at a height of approximately 1.5 meters above the ground.

3. REMOVAL

All trees not marked for preservation and all snags, logs, brush, stumps, shrubs and rubbish shall be removed from within the limits of the marked areas. Unless otherwise specified, all stumps, roots and root clusters having a diameter of $2\frac{1}{2}$ centimeters or larger shall be grubbed out to a depth of atleast 0.90 meters below subgrade elevation for concrete structures or pipes and 0.30 meters below the ground surface at all other designated areas.

Removal of trees and the other specified matter shall be controlled to prevent damage to preserved trees and trees adjacent to the clearing limits. All trees, or other matter, felled into any existing ditches shall be removed from the ditches not later than the end of the work day in which they were felled.

Construction stakes for ditch excavation or the installation of other works will be set only after clearing and grubbing has progressed to the point that a reach of at least 600 meters in length (or the total of the clearing, if less) has been cleared and grubbed to allow efficient operation of the staking crew.

4. DISPOSAL

(Option 1) Unless otherwise specified, all materials removed from the cleared and grubbed areas shall be burned or buried at selected locations on the right-of-way. Locations to be occupied by excavations, structures and earthfills (excluding spoil banks) shall not be selected for burning or burying. When the contractor elects to bury cleared and grubbed materials, such woody materials shall be buried below the natural ground line deep enough for a minimum 45 centimeter of earth covering between the buried materials and the natural ground line.

(Option 2) When arranged by supplemental agreement between the contracting parties, merchantable timber and wood yielded from the clearing operation may be cut, trimed and salvaged for merchantable purposes. When such option is arranged and exercised, the value of the salvaged materials shall be considered at least equal to the added work and cost of salvaging and the option to salvage therefore shall be unimposing upon any third parties. When salvage is carried out, the contractor shall neatly trim the salvaged materials and orderly stack the materials at or near the work site in uninterferring locations. Trimings, slash, roots and root clusters, and other residues of the salvage operation shall thereafter be disposed of as specified for Option 1.

5. MEASUREMENT AND PAYMENT

Clearing and grubbing will not be measured for direct payment, but the area will be estimated to the nearest 0.25 hectare. Payment for clearing and grubbing shall be considered subsidiary to the items of excavation, and such subsidiary and indirect payment shall constitute full compensation for all labor, equipment, tools and all other items necessary and incidental to the completion of the work.

CONSTRUCTION SPECIFICATION

LOOSE ROCK RIPRAP

1. SCOPE

The work shall consist of the construction of loose rock riprap revetments and blankets as specified.

2. MATERIALS

Rock for loose rock riprap shall conform to the following requirements:

Quality Individual rock fragments shall be dense, sound and free from cracks, seams and other defects conducive to accelerated weathering. The rock fragments shall be angular to subrounded in shape. The least dimension of an individual rock fragment shall be not less than one-third the greatest dimension of the fragment.

Except as provided below, the rock shall have the following properties:

a. Bulk specific gravity (saturated surface-dry basis) not less than 2.5.

b. Absorption not more than 2 percent.

c. Soundness: Weight loss in 5 cycles not more than 10 percent when sodium sulfate is used or 15 percent when magnesium sulfate is used.

The bulk specific gravity and absorption shall be determined by ASTM Method C 127, or an equivalent method. The test for soundness shall be performed according to the procedures for ledge rock in (U. S.) Federal Specification SS-R-406c, Method 203.01, or a comparable equivalent.

Rock that fails to meet the requirements stated in a, b, and c above, may be accepted only if similar rock from the same source has been demonstrated to be sound after five years or more service under conditions of weather, wetting and drying, and erosive forces similar to those anticipated for the rock to be installed under this specification.

Grading The rock shall conform to the grading limits shown on the drawings, and shall be within these specified limits after it has been placed in the riprap.

3. SUBGRADE PREPARATION

The subgrade surfaces on which the riprap is to be placed shall be cut or filled and graded to the lines and grades shown on the drawings. When fill to restore subgrade lines is required, it shall consist of material similar to that on the cut surfaces and shall be thoroughly compacted. Riprap shall not be placed until the foundation preparation is completed and the subgrade surfaces have been inspected and approved by the Engineer.

4. EQUIPMENT-PLACED ROCK RIPRAP

The rock shall be placed on the surfaces and to the depths specified, by equipment suited to the size, slopes and configuration of the area to be riprapped. The riprap shall be constructed to the full course thickness in one operation and in such a manner as to avoid serious displacement of the underlying material. The rock shall be delivered and placed in a manner that will insure that the riprap in place is reasonably homogeneous and firmly in contact one to another with the smaller rocks and spalls filling the voids between the larger rocks.

Riprap shall be placed in a manner to prevent damage to structures. Hand placing will be required to the extent necessary to prevent damage to the permanent works.

5. HAND-PLACED RIPRAP

The rock shall be placed by hand on the surfaces and to the depths specified. It shall be securely bedded with the larger rocks firmly in contact one to another. Spaces between the larger rocks shall be filled with smaller rocks and spalls. Smaller rocks shall not be grouped as a substitute for larger rock. Flat slab rock shall be laid on edge.

5. MEASUREMENT AND PAYMENT

For items of loose rock riprap established in the contract, the volume of each type of riprap will be measured to the neat lines and thicknesses shown on the drawings and computed to the nearest cubic meter by the method of average cross-sectional end areas. Payment will be made at the contract unit price per cubic meter, which payment will be full compensation for all labor, materials, equipment and other items necessary and incidental to the completion of the work as herein specified.

CONSTRUCTION SPECIFICATION

CONCRETE PIPE CONDUITS FOR CULVERTS

1. SCOPE

The work shall consist of furnishing and installing concrete pipe and the necessary fittings for the installation of culverts as shown on the drawings.

2. MATERIALS

Concrete culvert pipe shall be round reinforced pipe conforming to the requirements of ASTM Specifications C76 for the class of pipe and pipe diameter sizes shown on the drawings.

When rubber gasket joints are used, the joints and gaskets shall conform to the requirements of ASTM Specifications C443.

3. LAYING AND BEDDING

Pipe shall be laid to the line and grade shown on the drawings. The bell or groove shall be laid at the upstream end of each pipe section. Care shall be taken to avoid any undue trampling and disturbance of the prepared bedding surface.

The pipe shall be firmly and uniformly bedded throughout its entire length to the bedding depth and configuration specified on the drawings. The shaped earth bedding shall be neatly formed by use of templates so as to be fitted to the outside diameter of the pipe. The pipe shall be loaded sufficiently during backfilling around the sides to prevent its being lifted from the bedding.

When the earthen materials at grade are too gravelly and stony to strike and shape the bedding as specified, the grade shall be over-excavated to a subgrade approximately 15 centimeters (0.5 feet) below, after which earthfill shall be placed as specified for hand placed backfill to the pipe grade line and the pipe bedding thereafter shaped and prepared as specified above.

4. JOINING PIPE

Pipe joints may be Rubber Gasket Joint or Cement Mortar Sealed Joints. When rubber gasket jointed, the pipe joints shall be of the bell and spigot type. For cement mortar sealed joints, the pipe joints may be of either the bell and spigot type or the tongue and groove type.

Rubber Gasket Joint. Just before the joint is connected the connecting surfaces of the spigot and bell shall be thoroughly cleaned and dried, and the rubber gasket and inside surface of the bell shall be lubricated with a light film of soft vegetable soap compound (flax soap). The rubber gasket shall be stretched uniformly as it is placed in its groove or seat of the spigot to insure a uniform valume of rubber around the circumference of the pipe.

The joint shall be connected by means of a pulling or jacking force so applied to the pipe that the spigot enters squarely into the bell. The spigot shall be completely pulled into the bell, after which the section of pipe shall be adjusted to line and grade.

Cement Mortar Sealed Joint. Cement mortar for joints shall consist of one part by weight of portland cement and two parts by weight of fine sand with enough water added to produce a workable consistency. The mortar shall be batched and mixed in quantities consistent with the rate of use, and any mixed batch of mortar or portion thereof not used and placed within one hour from the time of wetting and mixing shall be forthrightly disposed of and not used for mortaring.

At the time of assembly and joint making the mating surfaces shall be clean and moist. The tongue end (spigot) of the pipe section being placed shall be covered with mortar and firmly pressed into the groove of the laid section in such a manner that the tongue fits snugly and truly in the groove (bell) and that mortar is squeezed out both on the interior and exterior of the joint. Care shall be taken that no mortar falls from the groove end during the abutting operation. Immediately after the pipe sections have been abutted, exposed external surface mortar shall be pressed into the joint and any excess mortar removed, after which the interior surface of the joint shall be carefully pointed and brushed smooth, and all surface mortar removed.

In following sequence, an external mortar band shall be placed around the joint. Such mortar band shall be approximately 20 centimeters in width and 2½ centimeters in thickness at its crown, and shall be neatly beveled to the edges. For belled pipe, the external mortar band shall be beveled from the crown of the bell at an angle of approximately 45° to a feathering edge at the exterior surface of the mated pipe section.

The external surfaces of mortar joints shall be cured by covering with moist earth, sand, canvas, burlap, kraft paper or other approved materials and shall be kept moist for 7 days or until the pipe is backfilled.

5. BACKFILL

All earthfill, as backfill, shall be obtained from required excavations or designated borrow areas. The selection, blending, routing and disposition of materials in the backfills shall be subject to approval by the

Engineer. Backfill materials shall contain no sod, brush, roots or other perishable materials. Rock particles larger than 4 centimeters (approximately $1\frac{1}{2}$ inches) shall be excluded from hand compacted backfill, and machine compacted backfill shall contain no particles larger than 10 centimeters (approximately 4 inches).

Backfill shall not be placed until the total of any one string of culvert pipe is complete in place. Backfill shall not be placed upon a frozen surface, nor shall snow, ice, or frozen materials be incorporated in the fill. Backfill shall be brought up uniformly on both sides of the pipe.

Backfill shall be placed in approximately horizontal layers. The thickness of each layer before compaction shall not exceed 10 centimeters (4 inches) for hand compacted fill, nor more than 25 centimeters (10 inches) for machine compacted fill. Materials placed by dumping in piles or windrows shall be spread uniformly to not more than the specified thickness before being compacted. The total of the backfill from the pipe bedding plane to a fill height not less than 60 centimeters (2 feet) above the crown of the pipes shall be hand placed and hand compacted backfill. Above this specified backfill height, the balance of the backfill as required may be machine placed and machine compacted. The passage of heavy hauling or compaction equipment will not be permitted until the backfill is completely and uniformly to the point at least 60 centimeters over the crown of the pipes.

During placement and compaction, the moisture content of the fill materials being placed shall be adjusted as needed, and maintained, so that the moisture range is not less than 2 percentage points below nor more than 3 percentage points above the optimum moisture for compaction as defined by ASTM Specification D 1556. Each layer of hand placed backfill shall be compacted by complete coverage with hand tampers, which may include manually directed power tampers. Each layer of machine placed backfill shall be compacted by not less than 4 complete passes upon the total of the layer by a tamping-type roller weighing not less than 1000 pounds per foot width of the roller, or an approved equivalent compaction utilizing the passing of other compactors or track-type or wheel-type equipment.

Backfill shall be placed to the lines and limits shown on the drawings or, when not specified on the drawings, to the natural ground or travelway surrounding the fill. The finished surfaces, crown and end-slopes, shall be smooth and true to line.

6. DEWATERING

When surface water or ground water is at or intruding to the work site of culvert installations, the Contractor shall provide means for the removal of such water. For diverting surface water, the Contractor shall build, maintain, and operate all coffers, channels, flumes, sumps, and other temporary diversion and protective works needed to divert the streamflow and other surface water through or around the construction site and away from the construction work while construction is in progress. For control and dewatering of intrusive ground water, the Contractor shall furnish, install, operate and maintain all drains, sumps, pumps, and other equipment needed to perform the dewatering.

The foundation for constructing the pipe bedding and the work area during pipe placement and backfilling shall be free of water and excessive muddy conditions as needed for the proper execution of the construction work as specified.

After the temporary works have served their purposes, the Contractor shall remove them and level and grade the area to the extent required to present a sightly appearance and to eliminate any interference with the operation of or access to the permanent works.

7. MEASUREMENT AND PAYMENT

For items of concrete pipe culverts established in the contract, the quantity of each size and class of pipe will be determined as the sum of the nominal laying lengths of the pipe sections used. Payment for each size and class of pipe will be made at the contract unit price per foot (or meter) of length. Such payment will constitute full compensation for furnishing, transporting and installing the pipe, including all necessary backfilling, dewatering, and other work and materials herein specified.