REPORT ON
REST AREA WATER SYSTEMS
For
Interstate Highways

To

Iowa State Highway Commission

By

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I hereby certify that this report was prepared by me or under my direct personal superivsion and that I am a duly Registered Professional Engineer under the laws of the State of Iowa.

Robert L. Johnson

Date: November 15, 1967 Reg. No. 4464

LETTER OF TRANSMITTAL

Mr. K. P. McLaughlin, P.E.
Chief Design Engineer
Iowa State Highway Commission
Ames, Iowa

Dear Mr. McLaughlin:

Two basic plans have been developed for the water systems in the rest area buildings along the Interstate Highways. These two plans or schemes are the basis for recommended extensions and improvements to the existing rest area facilities as well as several facilities presently under construction.

This study has been most challenging in view of the unique type of service provided by these rest area facilities. The completion of this study and report is, of course, equally rewarding to me personally and I hope that the recommendations of the report will be implemented.

If I can be of further assistance in interpretation of the report or implementation of the recommendations, please let me know.

Sincerely,

Robert L. Johnson

Robert L. Johnson, P.E.
Sanitary Engineering Consultant
Ames, Iowa

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INTRODUCTION

As part of the roadside development along the Interstate Highway System, the Iowa State Highway Commission has constructed eight pair of rest area facilities. Furthermore, two pair are presently under construction with an additional two pair proposed for letting in 1967. An additional nine and one-half pairs of rest areas are in the planning phase, a grand total of 45 rest area buildings.

The facilities existing were planned and designed in a relatively short period of time. The rest area facilities are unusual in terms of water use, water demand rates, and the fact that there are no applicable guidelines from previous installations. Such facilities are a pioneering effort to furnish a service which the travelling public desires and will use. The acceptance and current use of the existing facilities shows that the rest areas do provide a service the public will use and appreciate. The Iowa State Highway Commission is to be congratulated for this pioneering effort.

However there are problems, as should be expected when design of a new type of facility has no past operating experience to use as a guide. Another factor which enters is that a rest area facility is quite different and rather unrelated to engineering in the highway field of practice. Basically, the problems encountered can be resolved into several areas, namely 1) maintenance problems in equipment due to 2) insufficient capacity of several other elements of the water systems, and 3) no provisions for water quality control.

This study and report is supposed to essentially cover the review of the rest areas, either existing and under construction or letting. However, the approach used has been somewhat different. Several basic economically feasible water system schemes have been developed which are adaptable to the different well capacities and different water qualities encountered. These basic designs are used as a guide in recommending modifications to the existing rest area water systems, anticipating that the basic designs will be used for future facilities.

The magnitude of the problems involved is shown by the fact that the projected water use and demand variations of each rest area building is equivalent to the water supply for a community of about 100 people. The problems of proper operation and maintenance of an eventual thirty to forty-five such facilities are gigantic. For successful operation the rest area water systems must have a high degree of standardization and interchangability of all elements of the water systems, even if it means a limited degree of over-design in some rest area facilities.

WATER DEMANDS

The plumbing in the rest area buildings has been reviewed and is satisfactory. This item is discussed in more detail in Appendix I.

A. Peak Instantaneous Water Demand Rate

If all fixtures installed in a single rest area building were used simultaneously, the total water demand rate would be 570 gallons per minute (gpm). Obviously, this will never happen. Numerous studies of plumbing installations, using both probability analysis and field tests, have been conducted by the National Bureau of Standards and the Federal Housing Authority. The results of this work have been incorporated into the National Plumbing Code and a variety of other building and plumbing codes used throughout the country.

These studies have shown that with the fixtures installed, the probable <u>peak instantaneous water demand rate would be 60 gpm</u>. <u>In any water system using pumping as the basic supply element, the pumping rate should be equal to this peak instantaneous demand rate</u>. This includes the hydro-pneumatic tank systems in the present designs. This particular aspect of the water system is based on considerable past operational experience and thus can be established as a sound design basis.

B. <u>Maximum Hour Water Use Rate</u>

From this point in the analysis, there is essentially no past experience to provide a design basis. In an attempt to provide a rational design basis, several studies were conducted by the Iowa State Highway Commission personnel, including hourly water use readings and traffic counts into the rest area. On the basis of experience, and other criteria such as the Federal Housing Authority guidelines for rural community water systems, the ratio of the peak instantaneous demand rate to the maximum hour water use rate should be about two. <u>This yields a maximum hour water use rate of 30 gpm</u>.

The studies conducted by the Iowa State Highway Commission, in general, confirms the validity of this figure. For example, by actual count there has been 2067 people per 16 hour day enter a single rest area.

This is an average of 130 people per hour and on the basis of a great many traffic counts the peak hour is about three times the average. The studies also have shown that about 70 per cent of the people use the rest room facilities.

The above data means that about 295 people use the facilities during the maximum hour. At approximately 5 gallons of water used per person, this yields a present maximum hour of about 25 gpm. This is quite close to the above figure of 30 gpm maximum hour use from other criteria.

C. Maximum Day Water Use Rate

Likewise, the maximum day use rate for a single rest area building should be about 15 gpm. It would appear that the limiting factor in water use at the existing rest areas is the number of parking spaces provided. Careful consideration should be given to any plan to provide additional parking spaces, without a comparable addition to the water system. Several additional years of operating experience should be obtained to more fully define the situation at each rest area.

D. Summary of Water Demands

The annual average daily water use will be considerably lower, probably about one-fourth to one-fifth of the maximum day water use. Two particular aspects dictate that the design basis should be the maximum day water use rate. First, the peak instantaneous water demand rate could occur on any day of the year, even the lowest water use day. Secondly, the maximum day water use rate or just slightly below probably will occur for extended periods during the summer "vacation travel period".

To summarize, the following design criteria per rest area building have been adopted for this study:

1.	Peak Instantaneous Water Demand Rate	60 gpm
2.	Maximum Hourly Water Use Rate	30 gpm
3.	Maximum Daily Water Use Rate	15 gpm 21,600 gpd
4.	Annual Average Daily Water Use Rate	4 gpm 5,760 gpd

WATER QUALITY

The water quality available is an important design parameter as it will affect several other elements of the water system. It is a parameter that should be considered very early in the planning stage, preferably before exploratory work is done on wells and in fact it should be considered in the site selection. The public acceptance and use of the facilities will be directly related to the quality of the service provided.

The basic criterion for water quality evaluation is the Drinking Water Standards of the U. S. Public Health Service. These standards are the criteria used by most government agencies and the standards are obligatory for water supplies furnishing water to interstate carriers. If not legally bound, the Iowa State Highway Commission should certainly feel morally obligated to meet these standards for drinking water along Interstate Rest Areas.

The first and most important criteria is to provide a bacteriologically safe drinking water. The common sources used at the rest areas, well supplies, are generally quite safe in this respect. Periodic testing, as currently being done, should provide an adequate safeguard on this aspect of the drinking water. The second area of the standards to be considered is the limits of various chemical constituents in the drinking water. The pertinent items are listed below along with their maximum allowable concentrations and the effect of each constituent.

A. <u>Iron and Manganese - 0.3 mg/l</u>

The presence of these minerals will lead to staining of plumbing fixtures, some coating in pipes and hot water heaters as well as some taste problems, in addition to the red or yellowish red coloring of the water. Almost all well water in Iowa contains these minerals in excess of the above limits.

B. <u>Hardness</u>

Hard water is caused by calcium and magnesium and although there is no limit on hardness per se, the magnesium level should be below 125 mg/l. This will be discussed below with sulphates. The calcium and magnesium salts in hard water will cause deposits in pipes and particularly in hot water heaters. These deposits can greatly reduce the hydraulic capacity of pipes. The extent of such coatings was well demonstrated in the Jasper County Rest Area where a $1\frac{1}{2}$" drain pipe connected to a urinal had been clogged to a point where the inside diameter of the pipe was about the size of a pencil. This occurred with only about a year of operation. The possible problems in 15 to 20 years is apparent.

The need for treatment to soften the water is obvious in order to prolong the life of the installation. The cost of iron removal and softening will be less than the expense of the hexachlorphene chemical.

presently being used at the existing facilities to prevent iron and hard water staining.

C. Nitrates - 45 mg/l

The presence of nitrates near the 45 mg/l level can cause nitrate-cyanosis in infants (blue babies). Most uncontaminated well supplies in Iowa are considerably below this limit, but it is an important item to consider in evaluating water quality.

D. Chlorides - 250 mg/l

Above this level, particularly with high sodium concentrations, drinking waters may have a salty taste to some people. Some people may experience a certain degree of laxative effect from this type of water. None of the existing wells thus far has a water exceeding this concentration of chlorides.

E. Sulfates - 250 mg/l

Drinking waters with high sulfate concentration will produce a very definate laxative effect on most people, particularly if the sulfate is combined with high magnesium concentrations (Epsom Salts!). The presence of high total dissolved solids will also promote this laxative effect.

Many towns in Iowa have water which exceeds these sulphate concentration limits and the inhabitants become acclimated to the water. The acclimation process can be discomforting under normal domestic conditions. The traveling public does not have the time to become acclimated and the laxative effect on a traveling family could be completely disasterous. Rest areas could not be spaced close enough.

Magnesium is removed by the softening process. Unfortunately sulphates are not so easily removed. About the only practical method available is complete de-mineralization of the water, together with blending of a portion of the untreated water to provide some taste since de-mineralized water is quite unpalatable. The only water use requiring such treatment would be the supply to the drinking water fountains, thus the quantities involved are small.

The de-mineralization process is expensive and requires periodic regeneration of resin beds with strong acids and strong caustics. It is not a simple process to consider. This will be discussed later in the report.

All of the well supplies for the rest areas from Iowa County west to Pottawattomie County have water which exceeds the sulphate level of 250 mg/l by a factor of two to almost ten times the recommended maximum. This water quality factor alone, shows the vital importance of considering water quality very early in the planning stage for the rest areas.

TREATMENT REQUIRED

A. Iron and Manganese

With relatively few exceptions, iron and manganese removal at the existing rest area buildings is needed and should be provided. No one treatment method is satisfactory for all iron and manganese bearing waters. The basic iron and manganese removal process recommended is pressure aeration for oxidation of the iron and manganese followed by pressure filtration. With the exception of the wells along I-29 in Woodbury

County with high levels of free carbon dioxide, this basic process should be satisfactory. The higher levels of manganese in Iowa and Adair Counties may require supplemental chlorination or pH adjustment for adequate oxidation of the iron and manganese. However, the basic process and equipment required would be unchanged.

B. Softening

The maintenance problems in the Jasper County Rest Area already encountered with only about a year of operation show the desirability of providing softening of the well supplies. With the exception of the wells in Iowa, Jasper, Adair and Polk Counties, the hardness of the well supplies is below 500 mg/l (29 grains per gallon) and in most cases less than 400 mg/l (23 grains per gallon) all expressed as calcium carbonate. The softening required for all these rest areas can be accomplished quite economically and simply by using common commercial softening units.

The water supplies in Iowa, Jasper, Adair and Polk Counties will require larger units for softening due to the higher hardness present. These are the rest areas where softening is most urgently needed and even here, where softening will be more expensive, the softening cost will be less than the cost of the chemicals presently being used to prevent iron, manganese and hard water stains.

As might be assumed from the above, the process recommended for softening is the cation exchange process operating on the sodium cycle (zeolite softening). These softening units would follow the iron and manganese removal filters.

The economic value of softening is shown by the fact that the chemical costs involved will be less than 7.5¢/1000 gallons for the great majority of the rest areas and even the water with the highest hardness will have chemical costs of only 25¢/1000 gallons. The reduced maintenance cost and increased life of the facilities will pay for the softening costs several times over during the life of the installation.

C. Sulphate Removal

The type of treatment required for sulphate removal is de-mineralization as previously mentioned. This should be avoided if at all possible. The rest areas where the limit of 250 mg/l is exceeded are in Iowa, Jasper, Polk, Dallas and Adair Counties. In the case of Iowa County and Polk County, I-80, rest areas, the sulphate level on one side is considerably lower than the other, 701 mg/l versus 1230 mg/l and 414 mg/l versus 1120 mg/l respectively. The Dallas County rest area has 570 mg/l sulphate.

It is the writer's opinion that if the magnesium removal is provided by softening and the better quality (lower sulphate) of the rest area supplies in each pair is used for drinking water, the problem will be greatly alleviated even with the sulphate concentration above that in the U.S. Public Health Service Drinking Water Standards.

In the case of Jasper and Adair Counties it is so high on both sides as to force provision of sulphate removal or two alternatives as follows: 1) provide a tank for drinking water only which is filled by hauling the drinking water or 2) post a sign at the drinking fountains in these rest areas to warn the public of the problem due to highly mineralized water.

In view of the operating and regeneration problems for de-mineralizing equipment, the latter alternative of posting a warning sign is recommended for these two rest area pairs. Consideration should also be given to removing the outside drinking fountain at those rest areas where the sulphate level is so high, thus reducing the availability of the problem water.

PROPOSED WATER SYSTEM SCHEMES

A. Provision for Water Pressure

There are three general methods of providing the required water pressure for operation of the rest facilities.

The first to consider would be elevated storage, either tank or standpipe type. This system has the advantage of easily providing water for the variable and peak type water demands which exist in the rest area facilities. The primary disadvantage is the initial cost where relatively flat terrain is encountered. Freezing problems may occur during the low demand periods in the winter months. The freezing problems can be handled by judicious operating procedures such as using only a portion of the storage volume available during low demand periods to ensure adequate turnover of the stored water to prevent freezing. The cost problem in flat terrain still remains. However, where the terrain is favorable, i.e. a hill forty to fifty feet or more above the rest area buildings, this type of system is recommended over all others, particularly when the rest area buildings in a pair can be combined into one water system. This combination of rest area buildings into one system has a number of advantages in the treatment aspect also since the size of units becomes more economical. There are a number of design possibilities for the elevated storage such as architectural treatment for aesthetics and incorporation into use as a look-out tower. The writer feels that this is an area where some very original and creative design is possible. Whenever possible, the provision of elevated storage should be considered as the first alternative to provide water pressure. In fact, this could and should be incorporated into the planning process.

The second possibility is the use of several booster pumps to provide the water pressure required with only nominal storage for a pump suction purposes. This type of system is well suited to a fairly uniform water demand with only occassional periods of high usage. This is not the type of water demand experienced at the rest areas and thus this type of direct booster pumping system has not been considered as applicable.

The third possibility is a hydro-pneumatic tank system, which is the system presently used in the existing rest area facilities. Although not as well suited to widely varying demand rates as elevated storage, a properly designed hydro-pneumatic system will function very satisfactorily. A common misconception about the hydro-pneumatic system is that it provides water storage. It does not. The primary purpose of a hydro-pneumatic tank is to provide water pressure between certain limits, 40 to 60 pounds per square inch (psi) at the existing facilities. The ability of a hydro-pneumatic system to meet the water demands is dependent solely upon the capacity of the pump supplying the hydro-pneumatic tank which should be equal to the peak instantaneous demand rate. The tank volume is determined by the number of pump cycles that can be tolerated during the maximum hour water use period. The maximum number of pump cycles per hour recommended varies from 2 per hour to 10 per hour depending on the guidelines used and the degree of reliability required. Ten cycles per hour is the most common recommendation for the normal 1800 rpm pump motor, with the number of cycles per hour reduced as the horsepower and/or the speed of the electric motor increases.

The water demand rate for the period from about 10 A.M. to 2 P.M. is sustained at or only slightly below the maximum hourly demand rate as shown by the studies conducted by the Iowa State Highway Commission. The submersible well pumps and motors used at the existing facilities are generally run at 3600 rpm. In view of this, it is recommended that when the well pumps supply the hydro-pneumatic tank directly, the number of pump cycles per hour be limited to 5 per hour. However, when booster pumps, operating at 1800 rpm supply the hydro-pneumatic tank, the number of pump cycles per hour can be increased to 10 per hour.

On this basis, the pump supplying the pneumatic tank should be capable of meeting the peak instantaneous demand of 60 gpm previously determined. Likewise, for a maximum hour demand rate of 30 gpm previously determined, the volume of the hydro-pneumatic tank should be 360 gallons for the 1800 rpm booster pump and 720 gallons for the 3600 rpm well pump.

It can be shown by the calculus that the maximum possible amount of the hydro-pneumatic tank volume used per cycle when operating at the 40-60 psi condition is 27% of the tank when the tank at the 60 psi level is 27% full and empty at the 40 psi level. This is not particularly satisfactory in practice and generally the hydro-pneumatic tank should be operated so the tank is 30% full of water at the 60 psi level and 5% full at the 40 psi level.

<u>In order for the hydro-pneumatic system to function properly,</u>

controls should be provided to add air or vent air and maintain the proper air-water ratio. The controls should be of the type specified for the Polk and Story County rest areas on I-35. These controls are vital to the operation of the systems.

The following schemes are based on use of the hydro-pneumatic system, but can readily be adapted to use of elevated storage where the topography is such that this is economically feasible.

B. Proposed Water System Schemes

The possible arrangements of the water systems is quite varied, depending upon 1) well capacity available, 2) treatment required, i.e., softening only or iron removal plus softening, and 3) whether or not the water systems of the rest area building pairs can be combined. The following schemes take into account the wide variation possible in each of the three variables above.

1. Scheme A-1 - This scheme fits the following situation.

   a. Well capacity is 60 gpm or more.

   b. Softening is the only treatment required.

   c. Each building water system is separate.

In this scheme the well pump discharges through the softening unit into two 360 gallon hydro-pneumatic tanks, very similar to the present type of operation. This is the most simple and inexpensive system. However, it fits a situation which will be found relatively infrequently in Iowa as most well waters will require iron removal.

2. Scheme A-2 - The following situation is applicable for this scheme:

   a. Well capacity is about 30 gpm.

   b. Softening is the only treatment needed.

   c. Each building water system is separate.

This system arrangement has the well pump discharging through the softening unit into an intermediate storage of 1,000 gallons capacity. A 60 gpm booster pump will take suction from the intermediate storage and discharge into one 360 gallon pneumatic tank. As can be seen, this system is quite similar to Scheme A-1.

3. Scheme A-3 - This scheme is identical to Scheme A-1 except the well capacity is now about 15 gpm and the intermediate storage required is 3,600 gallons.

4. Scheme A-4 - This scheme is identical to Scheme A-1, except the well capacity is 60 gpm and two 60 gpm booster pumps, one for each building, take suction from the 1,000 gallon intermediate storage. In other words, the two building water systems are combined.

5. Scheme A-5 - In this scheme the two building water systems are again combined with a well capacity of 30 gpm and 7,200 gallons intermediate storage provided. The scheme is identical to Scheme A-4 except for the size of the intermediate storage.

The A-series of schemes can be further compressed by using intermediate storage of 7,200 gallons minimum whenever intermediate storage is required. This will then allow development of only two basic plans.

6. Plan A

   a. Well capacity is 60 gpm.

   b. Softening is the only treatment.

   c. Each building water system is separate.

   d. The well pump discharges through the softening unit into two 360 gallon pneumatic tanks.

7. Plan AA

   a. Intermediate storage is 7,200 gallons capacity.

   b. Well capacity is 30 gpm and the sides are combined or the well capacity is 15 gpm and the sides are separate. Note that there is no advantage to having a well capacity greater than 30 gpm in this case.

   c. The well pump discharges through the softening unit into the intermediate storage.

   d. Booster pumps of 60 gpm capacity, either one or two, are provided.

   e. The booster pumps take suction from the intermediate storage and discharge into 360 gallon pneumatic tanks, one per side.

The following B-series of schemes can be organized into a similar pattern when iron and manganese removal is required in addition to softening. There is one additional restriction to be considered when iron and manganese removal is required. This additional limitation is that a minimum run length of about three hours is required to prevent the "flush-out" from the filters of the iron and manganese which has previously been removed. The flushing effect would occur under a frequent start-stop condition and thus there is no Scheme B-1 comparable to the Scheme A-1. Because of this limitation, the intermediate storage volume must be larger in comparison with parallel A-series schemes.

Since the B-series is similar in organization, they are simply listed below.

8. Scheme B-2

a. Well capacity is 30 gpm.

b. Iron, manganese and softening treatment.

c. Each building water system is separate.

d. Booster pump is 60 gpm capacity.

e. Intermediate storage is 7,200 gallons, dictated on minimum filter run length, assuming 3/4 of storage volume is used in the cycle.

f. The well pump discharges through the iron and manganese removal unit into the softening unit and in turn into the intermediate storage.

g. The booster pump takes suction from the intermediate storage and discharges into a 360 gallon pneumatic tank.

9. Scheme B-3 - This is identical to Scheme B-2 except the well capacity is 15 gpm and the intermediate storage volume of 7,200 gallons is dictated by the need to meet the water demands and not by the minimum filter run lengths. Thus there is no advantage to having the well capacity greater than 15 gpm if the building water systems are separate and iron and manganese removal is required.

10. Scheme B-4 - This is identical to Scheme B-2 except the well capacity is 60 gpm and the building water systems are combined. The volume of intermediate storage, 7,200 gallons, is again dictated by the need to have a minimum 3 hours of filter run.

11. Scheme B-5 - This is identical to Scheme B-2 except the building water systems are combined and the 7,200 gallon intermediate storage volume is dictated by the need to meet the water demand.

It is interesting and unusual that the B-series of schemes is essentially identical. As can be seen, there is no advantage to having the well capacity greater than 30 gpm if the building water systems are combined or greater than 15 gpm if separate. In fact, there is a disadvantage of larger capacity wells in that the treatment units would have to be larger and thus more expensive.

The B-series can thus be reduced to one plan which is very similar to Plan AA.

12. Plan B

a. Intermediate storage is 7,200 gallons.

b. Well capacity is 30 gpm and the water systems are combined or the well capacity is 15 gpm and the water systems are separate.

c. Booster pumps of 60 gpm capacity, either one or two, are provided.

d. The well pump discharges through the iron and manganese removal unit into the softening unit and into the intermediate storage.

e. The booster pumps take suction from the intermediate storage and discharges into 360 gallon pneumatic tanks, one per side.

At this point, there are really only two basic plans, Plan A and Plan B, since Plan AA is only a special case of Plan B where iron and manganese removal is not required. These two plans will cover quite a wide variety of possible well capacities and water qualities. The advantages and disadvantages of these plans are summarized below. The plans are shown schematically in Figure 1.

C. Advantages

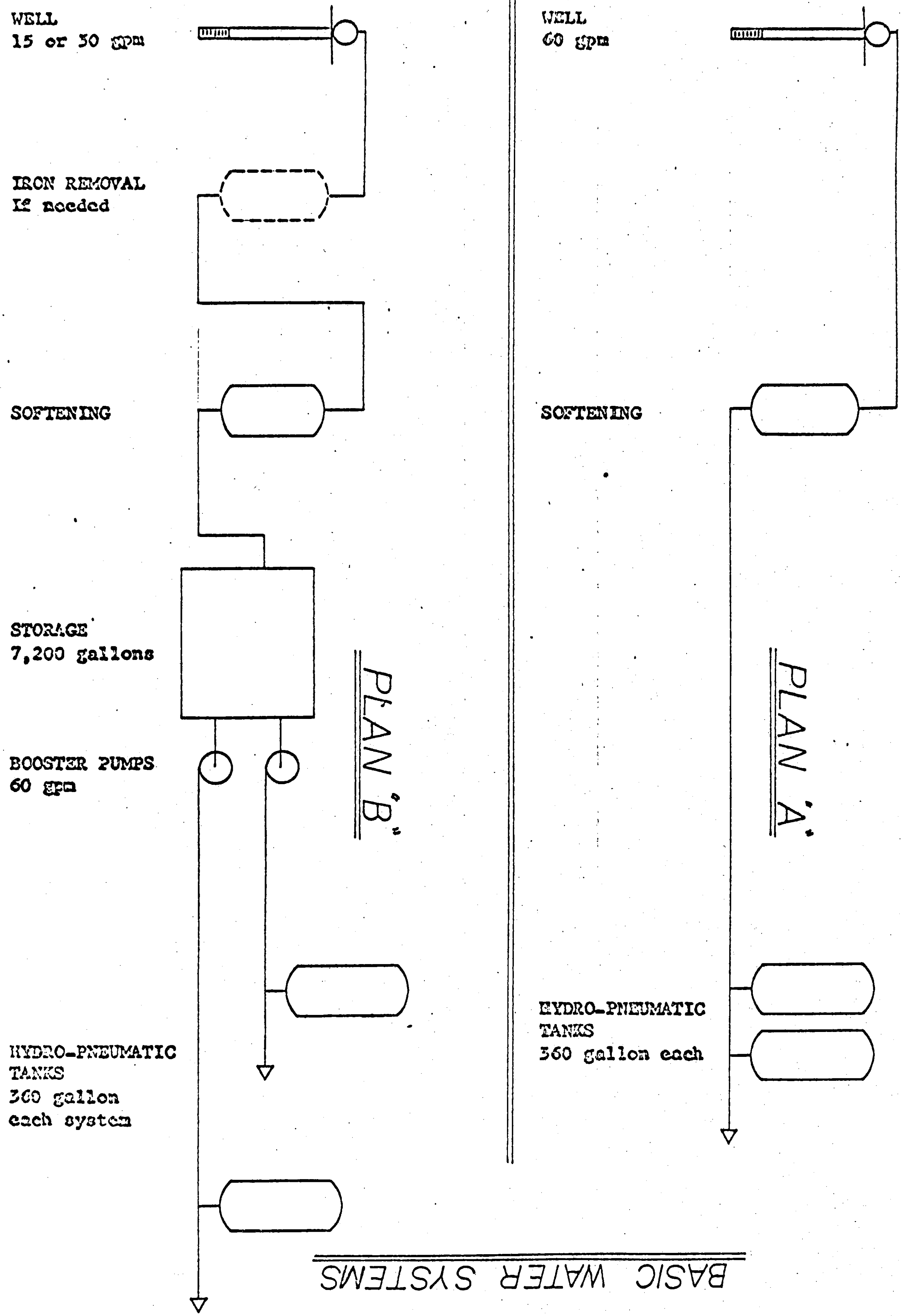
1. Well pumps are used in only three capacities, 60, 30 and 15 gpm of which the majority will fall into the 30 gpm category.
2. The intermediate storage of 7,200 gallons is identical in all cases.
3. The booster pumps of 60 gpm capacity used will all be identical.
4. The hydro-pneumatic tanks will all be the same size, 360 gallons, installed either singly or in pairs to meet the various situations.

5. A high degree of standardization can be achieved in well pumps, booster pumps, hydro-pneumatic tanks, treatment units and controls.
6. When the building water systems are combined, the piping can be easily arranged to serve both sides from one booster pump, thus increasing the reliability of the service.
7. Where the topography is favorable, the intermediate storage could be elevated storage, thus eliminating the booster pumps and the hydro-pneumatic tanks.
8. The use of intermediate storage provides a limited source of fire fighting water.

D. Disadvantages

1. In the case where no iron removal is needed, the intermediate storage is over sized to some extent. However, the number of cases where iron removal will not be needed in Iowa, will be in the minority and the relative cost of the over sized segments is quite low.
2. The existing rest area buildings will need to be enlarged or an additional building will be required to contain the equipment.
3. There may be occasions when chlorination could be required since the water will now be exposed to the atmosphere before use. The writer feels that this will be a rather rare occasion.

BASIC WATER SYSTEMS



BASIC DESIGN RECOMMENDATIONS

A. General and Future

1. Due to the expense involved in wells, treatment, etc., it would be desirable to use connections to municipal water supplies whenever possible.

2. In the interest of economics in the water system costs and increasing the process unit capacities to more desirable levels, the water systems of the rest area buildings should be combined whenever possible.

3. Whenever the topography is favorable elevated storage should be used to supply water pressure.

4. Since the rest area facilities are basically a water supply service to the public, the water supply capacity and water quality should be an important and early factor in planning the rest area. It is strongly urged that the water supply exploration be completed before final site selection is made.

5. The maintenance and operational problems involved with the existing and proposed 45 different water systems is staggering to contemplate. As discussed earlier in the report, a high degree of standardization of all elements is essential. This is often difficult to attain under the bid procedure limitations of public agencies, but the potential savings to the public far outweigh the bidding problems.

6. A second area of maintenance and operation to be considered is the personnel involved and management organization. The problems

will be quite different than those previously encountered by the Iowa State Highway Commission. The writer feels that a staff, within the existing organization or separate, who are trained and educated in this area of engineering will be needed to successfully operate and maintain the facilities. No reflection upon the fine efforts of the present personnel is intended.

B. Existing Rest Areas

The following recommendations are for the additions and modifications required to bring each rest area into one of the basic water system plans previously outlined.

1. Scott County - This rest area fits Plan A since no iron or manganese removal is required and the sites are separated too far to combine economically. Specifically, the following items are required at each site:

   a. Replace the existing 120 gallon hydro-pneumatic tanks with two 360 gallon tanks per side and required controls.

   b. Install a 350 KG total capacity duplex type softening unit at each site.

   c. The existing well pumps are rated at only 50 gpm. These will probably work satisfactorily and replacement with 60 gpm pumps can be delayed until such time as maintenance or repair of the pumps is required.

2. Cedar County - The recommendations for this rest area are the same as for Scott County. These two water systems could be

combined, but since no iron or manganese removal is required, and the wells are already existing, there is no particular economic advantage to combining them.

3. <u>Johnson County</u> - Iron and manganese removal will be required in addition to softening. It is recommended that Plan B be used and that the two water systems be combined with the treatment facilities located at the south site. Specifically the items required are:

   a. Replace the south well pump (55 gpm) with a 30 gpm pump and leave the north well pump as a standby unit.

   b. Construct the intermediate storage of 7,200 gallons capacity.

   c. Install iron and manganese removal equipment ahead of a 750 KG total capacity duplex type softening unit.

   d. Complete the installation with two 60 gpm booster pumps.

   e. Replace the existing 120 gallon hydro-pneumatic tanks with units of 360 gallon capacity on each side and required controls.

   f. Construct a 2" interconnecting pipe line between the buildings.

4. <u>Iowa County</u> - There have been considerable maintenance problems at this rest area pair already. The water quality is poor with both sulphates and hardness being quite high. In addition, the well on the south side rest area pumps sand when the discharge rate is above about 10 gpm. This is too low a rate to furnish

adequate water. The well on the north side has greater capacity, lower hardness and lower sulphate concentration.

It is recommended that the water systems be combined using Plan B, with the north side well as the supply, keeping the south well as standby only. There is some doubt as to the validity of the water analysis from these rest areas and these analyses should be done again before the following recommendations are implemented.

a. Replace the north well pump with a 30 gpm unit and place the south well on standby.

b. Construct the intermediate storage of 7,200 gallons capacity.

c. Install iron and manganese removal equipment ahead of a 1500 KG total capacity duplex type softening unit.

d. Install two 60 gpm booster pumps.

e. The existing 120 gallon hydro-pneumatic tanks are currently being replaced with 500 gallon tanks and controls which will be satisfactory for this system.

f. Construct a 2" interconnecting pipe line between the buildings.

5. Jasper County - The well capacities at this site are low and as a result Plan B with 15 gpm wells will be needed. The topography at this site is such that elevated storage would be quite feasible, but the well capacities are so low that the favorable topography cannot be used. The following recommendations apply to each site.

a. Replace the existing well pumps with 15 gpm units.

b. Construct the intermediate storage of 7,200 gallons.

c. Install iron and manganese removal units ahead of a 1500 KG total capacity duplex type softening unit.

d. Install a 60 gpm booster pump.

e. Remove one and modify the remaining three 120 gallon hydro-pneumatic tanks to accommodate the required air add, air vent controls.

f. Post a sign warning the public of the possible laxative effect of this water. The outside drinking fountain should be removed.

6. Polk County - I-80 - Since the sulphate level and hardness are lower in the water from the north well, it is recommended that the water systems be combined using the north well as the supply. The modification for this site are identical with the Iowa County modifications except new 360 gallon hydro-pneumatic tanks and controls are needed and the softening unit which follows the iron and manganese removal units should be of 750 KG capacity.

7. Adair County - These two sites have the poorest water quality of all the rest areas investigated with sulphate levels of 1500 and 2240 mg/l and hardness of 1390 and 1670 mg/l for the north and south side respectively. The two sites are too far separated to combine into one.

As a result, Plan B should be implemented at each site. The modifications required are identical to those recommended for the Jasper County rest area above. There is some doubt as to the validity of the available mineral analysis of these two well supplies and these should be checked because it may require a departure from the basic pressure aeration-pressure filtration iron and manganese removal process.

8. Woodbury County - The iron and manganese concentrations in these wells are quite high. This fact, coupled with the very high carbon dioxide concentration and low pH will require a departure in the basic iron and manganese removal unit used. At this location, the sides can and should be combined. The iron and manganese removal process will require forced draft aeration and detention with pH adjustment by feeding soda ash prior to filtration.

Since the water distribution system of Sioux City extends to the airport fairly close to these rest areas, the possibility of using the municipal supply should be investigated thoroughly before the following recommendations are implemented.

a. Combine the building water systems, using the west side well as the supply unit at 30 gpm and the east well should be placed on standby. This will necessitate replacement of the existing well pump.

b. Construct the 7,200 gallon intermediate storage.

c. Install iron and manganese removal equipment as outlined above together with a 750 KG total capacity duplex type softening unit.

d. Install two 60 gpm booster pumps.

e. Replace the existing 120 gallon hydro-pneumatic tanks with 360 gallon tanks and required controls.

f. Construct a 2" interconnecting line between the buildings.

9. Priority of Modifications - As a guide in planning the above recommendations, the following priority is established.

a. The replacement of the hydro-pneumatic tanks by the larger capacity tanks and adequate controls is by far the most critical item which should be completed at all rest areas before the next summer tourist travel period.

b. Where the recommendations call for replacement of a well pump with a smaller capacity unit, it will be satisfactory to use the existing well pumps and throttle the discharge valve to the capacity needed. However, when repair of these pumps is needed, it is recommended that properly sized units be installed.

c. The provision of iron and manganese removal units where needed should take preference over softening except in the Jasper and Adair County rest areas which need softening equipment as well as iron and manganese removal. These two rest areas should have preference over all others in putting treatment equipment into operation.

C. Rest Areas Under Construction

The construction plans for the rest area buildings under construction have been modified from those used in constructing the existing rest areas.

The revised plans call for 315 gallon hydro-pneumatic tanks and controls to maintain the proper air-water ratio in the tanks. These 315 gallon tanks are sufficiently close to the 360 gallon capacity used in this study to be acceptable, particularly since the nominal 315 gallon tank has a 348 gallon total capacity.

The specific recommendations for modification of these contracts are listed below.

1. Polk County - I-35 - The building water systems should be combined to fit Plan B as this water will require iron and manganese removal. The west side well should be used as the supply with the east well placed on standby. The items to implement the Plan B are:

   a. Delete the small iron filter and 60 KG softener from the contract.

   b. Change the well pump to a 30 gpm capacity unit.

   c. Construct the 7,200 gallon intermediate storage.

   d. Add an iron and manganese removal unit followed by a 750 KG total capacity duplex type softening unit.

   e. Add a 2" pipe line to combine the building water systems.

2. Story County - The sites are separated too far to be combined. The west side well has excellent capacity and water quality which will not require iron and manganese removal. The following items are recommended to bring the west side rest area into Plan A configuration.

   a. Delete the small iron filter and 60 KG softener from the contract.

b. Change the well pump to a unit with 60 gpm capacity.

c. Add a second 315 or 360 gallon hydro-pneumatic tank.

d. Add a 350 KG total capacity duplex type softening unit ahead of the hydro-pneumatic tanks.

e. Check the space available to be certain the equipment will fit into the mechanical room provided.

The east side well is of quite low capacity and this rest area facility should fit the Plan B configuration. Specific modifications required are:

a. Provide a well pump of 15 gpm capacity.

b. Construct the 7,200 gallon intermediate storage.

c. Provide a 60 gpm booster pump.

d. Provide one 360 gallon hydro-pneumatic tank, deleting the two 525 gallon hydro-pneumatic tanks from the contract.

e. Provide a 350 KG total capacity duplex type softening unit ahead of the intermediate storage.

f. Delete the small iron filter and 60 KG softener from this contract.

D. <u>Rest Areas Due for Letting</u>

These two facilities are presently scheduled for letting in December, 1967. It is strongly urged that this letting be delayed for about two months until the basic water Plans A and B can be developed into usable plans and specifications, and standardization programs can be formulated. This short delay in these projects could save a considerable amount of problems later on.

At the present time, however, the following recommendations can be made.

1. Dallas County - This facility must be combined since there is only one well and thus it should fit the Plan B configuration. The specific items are:

    a. Well pump should be 30 gpm capacity.

    b. Intermediate storage of 7,200 gallons is required.

    c. Two 60 gpm booster pumps are needed.

    d. A hydro-pneumatic tank of 360 gallon capacity with proper controls is needed for each building water system.

    e. Iron and manganese removal unit followed by a 750 KG total capacity duplex type softening unit.

    f. A 2" interconnecting pipe line between buildings should be provided.

2. Pottawattamie County - The well capacity and the water quality at this site is such that Plan A is adaptable here. Specifically the recommendations for this project for each building water system are:

    a. A well pump of 60 gpm capacity should be provided.

    b. Install two 360 gallon hydro-pneumatic tanks and necessary controls.

    c. Install a 350 KG duplex type softening unit.

    d. The space available in the building for the proposed equipment should be checked.

APPENDIX I

Review of Building Water Systems

The existing plumbing and water system was reviewed as requested to cover the following items.

A. Plumbing Fixtures

The fixtures specified for the rest area buildings are of the flush valve type, siphon jet or washout style. This style of fixture has proven to be very satisfactory and free from vandalism problems in public installations. The review of shop drawings and the inspection should be carefully done to insure that the style of unit specified is actually installed by the contractor. The main item of concern is to prevent the installation of any blow-out style fixtures which require larger quantities of water and also require higher operating pressures.

It might be possible to reduce the water consumption to some degree by using tank type fixtures. However, the small savings in water used are more than offset by the increased problem of maintaining a clean facility since the tank type unit is not well adapted to the high rate of consumer use which is experienced at these rest area facilities. Essentially the same comments can be applied to the use of automatic flushing systems.

B. System Hydraulics

The pipe sizes, layout and operating pressures were also evaluated. The system is well designed and the 40 to 60 psi operating pressure is proper for these buildings.

C. Operating and Maintenance Problems

Essentially all of the operation and maintenance problems encountered stem from either inadequate well and hydro-pneumatic tank capacities or the incrustation of the pipes due to the hard waters. The provision of softening should eliminate the latter problem. The combination of inadequate hydro-pneumatic tanks and lack of control on the air-water ratio has led to excessive cycling of the well pumps. By actual count, the maintenance personnel have observed as high as 67 cycles per hour in contrast to the recommended 5 to 10 cycles per hour at a maximum. It is easy to see why electrical relays and contactors are failing frequently. The plans developed in the body of this report will eliminate the capacity problem.

However, control of the proper air-water ratio must also be included for a properly functioning system. These controls are included in the specifications of the two rest area pairs under construction and the two pair due for letting. This type of control system should be provided at all rest areas. Again the units used should be standardized.

Due to the insufficient well capacities in Iowa, Jasper and Polk Counties, the flush valves have been adjusted to drastically reduce the rate of water use. This should be considered as only a temporary solution. Such practice greatly increases the potential of plugging the drain lines and sewers. In addition the reduced water use means that the waste water strength entering the treatment lagoons is increased. This can lead to insufficient oxygen levels, subsequent septic conditions in the lagoons and result in odors. In plain words, the lagoons may start to stink.

D. Summary

From the hydro-pneumatic tank on, the system is well designed and should provide long satisfactory service. The main problems encountered have been due to insufficient capacity of wells or hydro-pneumatic tanks and the lack of proper controls.

The recommendations in the main report, coupled with the controls for maintaining the proper air-water ratio mentioned above will provide the adequacy through the balance of the water system.

A P P E N D I X I I

Well Pumps and Motors

A. Existing Equipment

The adequacy of the existing pumps with regard to capacity has been covered in the main report, as well as the recommended changes for each rest area site. The existing motor and wire sizes have also been reviewed at each site.

The motors are adequate at all rest area sites for the well pumps as installed, with the possible exception of the installation at the north side rest area in Adair County where the 5 horsepower motor used may be slightly overloaded.

From the data available to the writer, it appears that the wire sizes used are inadequate at Cedar, Johnson, Jasper and Adair Counties. These should be checked for any possible change orders that may have been made during construction of which the writer has no knowledge.

It should be remembered that when the changes recommended in the well pump sizes are made, the adequacy of the wire sizes may change also. In general, however, the recommended pumps will be smaller and thus the existing wire sizes will probably be adequate for the future installations. However, it should be confirmed in each case.

B. Standardization and Interchangeability

The basic water plans developed in the main report involve only three well pump capacities: 60, 30 and 15 gpm. However, the total head requirement at each well will be, in general, quite different. This presents a certain degree of difficulty in a standardization program. Nevertheless, standardization can be achieved as the following will show.

A well pump is composed of a series of "bowls" or "stages", each of which is a single pump capable of delivering a certain discharge at a certain head. The required total head from the well pump is achieved by placing in series the number of stages needed to reach the total head desired since the heads are additive for pumps placed in series.

Standardization can be thus achieved in the following manner.

1. Select a single particular "bowl" for each of the three capacities desired, 60, 30 and 15 gpm, each of which will have a particular head per stage.
2. The desired total head at each site can then be achieved by placing together the required number of stages. The only variables involved will thus be the pump shaft length and the motor size used.

A high degree of standardization of the pump motors is also possible. Under the proposed water plans in the main report, the required motor sizes will generally be 3, 5, or 7½ horsepower with the majority being 3 or 5 horsepower motors.

The following program for standardization of motors is recommended.

1. Install a minimum motor size of 3 horsepower.
2. Install a minimum motor starter of 5 horsepower capacity.
3. Install wire sizes capable of handling a minimum of 5 horsepower.
4. Retain on hand at all times a well pump rated at 30 gpm at a total head of 400 feet with a 5 horsepower motor.

This program will allow the installation of this standby unit at any rest area in case of failures. The pump will be adequate for all Plan B schemes since the 15 gpm rate can be achieved by throttling the discharge valve. It will be undersized at those rest areas where a $7\frac{1}{2}$ or 10 horsepower pump is installed. However, the unit will provide enough capacity that the rest area can remain in limited operation at worst. There is an added advantage in that this program also provides a high degree of standardization of the motor starters and the number of integral repair parts needed on hand will be limited.

C. Power Supply

Currently almost all rest area facilities are provided with 230 volt, single phase power. It is recommended that whenever possible, three phase power be used. This will be particularly important at those few rest areas where a 10 horsepower pump motor is needed as this is commonly the maximum size well pump motor available for single phase current application.

D. Maintenance Program

The following is suggested as a reasonable routine preventative maintenance. The following items should be determined at each pump installation about once or twice a year.

1. Resistance of cable to the submersible motor.
2. The starting and running voltage and amperage.
3. Pump discharge rate and total operating head.

Comparison of these determinations with the conditions existing at the time the units were installed will indicate when repair is likely to be needed and the majority of these repairs can be planned, instead of providing for emergencies.

The readings on the static water level and the well drawdown which are required for the Iowa Natural Water Resources will be sufficient to indicate when the well conditions may be changing. It would be advisable to include these two readings with the above items so that a single trip by the maintenance personnel will provide all the basic data needed in one maintenance report.

These determinations should be timed so that all rest areas are reviewed ahead of the heavy summer tourist traffic so that repairs can be made if needed.

APPENDIX III

Review of Wells

A. Exploration

The importance of completing the well exploration before or during the rest area site selection and initial planning has already been stated. It is re-emphasized here. The rest area facilities are primarily a water supply service to the public and it is only logical to determine the potential well capacity and the quality of the water supply first, since this will have such an important bearing on the design of the facilities provided.

Currently, the Iowa State Highway Commission is obtaining the hydrologic forecasts for potential water bearing formations from the Iowa Geological Survey. In addition, a survey is generally made of existing farm and municipal wells in the vicinity of the proposed rest area sites. There is often additional information available from the Iowa Natural Resources Council.

Overall, the approach used in the exploration process has been sound and logical as to obtaining wells of adequate capacity. The only factor which has not apparently been considered sufficiently is the water quality aspect. In most cases, it will be more economical to accept a well of good water quality, i.e. low iron, manganese, hardness and sulphates which produces perhaps only 15 gpm than to obtain a well of high capacity with poorer water quality.

It is strongly recommended that the role of water quality be considered more fully in the exploration and site selection.

B. Size of Wells

Contrary to common opinion, the diameter of a well is fixed by the physical characteristics of the pump to be used and not by the desired well capacity. For example, increasing a well from 6" to 12" diameter will only increase the available well yield by about 11% at the same drawdown. Thus there is no advantage to having a well larger in diameter than needed for the well pump. For the well capacities recommended in the various water plans (60, 30 or 15 gpm), the 6" diameter wells currently used should be completely satisfactory if this diameter is maintained to the bottom of the completed well.

The current practice using 6" diameter "rock wells" and 16" bore holes with a 6" screen for gravel-packed alluvial wells should be satisfactory in most cases. A review of each case should be made, however. In order to obtain the desired 6" diameter well to the bottom in the "rock wells", it may be necessary in some cases to use 8" or 10" holes for the upper portion of the well construction.

The circumstances which may cause deviation from the above diameters are: 1) the rock formations to be encountered are friable and subject to producing sand pumping wells or 2) the alluvial deposits encountered for the gravel pack well are very fine. In both cases, the well diameter should be increased to a degree which will need to be determined separately in each case.

C. Well Specifications Review

The well specifications have been reviewed as requested, particularly with reference to sand pumping problems and alignment.

1. Sand Pumping - This portion of the study evolved from the existing sand pumping problem in the south well at Iowa County. In a sense this particular problem will be solved by using the north well as recommended in the main report. It is fortunate in this case, but such problems will probably arise again. When considering the fact that only one out of 23 existing wells is a "sand pumper", the ratio is probably better than achieved in the state as a whole.

If it is known that the formation to be encountered have a "history" of sand pumping, the well construction should be modified. This will frequently be the case for wells developed in the Dakota Sandstone of northwest Iowa and the Jordan Sandstones in northeast Iowa and other formations. When sand pumping problems are anticipated, the following is suggested.

a. Use a 10" or 12" bore hole into the formation to reduce the entrance velocities.

b. Develop the well to sand-free condition if possible. If this is possible, the project is complete.

c. If sand pumping is still a problem and the well cannot be developed to be sand free, install a properly sized gravel pack and 6" screen. Properly designed, this should alleviate the problem and allow developing a sand-free well.

In general, sand pumping problems can be alleviated by adequate development and by operating the well at a reduced capacity for longer pumping cycles. The basic water plans of the main report allow nominal well rates and long well pumping times which should reduce the problems encountered. In no case should a sand pumping well be directly connected to the hydro-pneumatic tanks. The frequent cycling of 5 to 10 times per hour for this type of installation will simply aggravate the situation and make it much worse.

It is recommended that in addition to the 8 hour development time in the current specifications, a unit price bid be obtained for increasing or decreasing this development time. This will allow the well contractor to bid on a more realistic basis and will also result in a more realistic approach to the well development on the part of the contractor.

2. Alignment - It is recommended that the specifications include the following clause for well alignment.

> "The contractor shall use adequate care to ensure a completed well which is plumb and true to line. The contractor shall furnish all labor and materials needed to perform the following alignment test on the completed well. The contractor may perform the test at any stage of the construction at his own expense, but the final test for acceptance will be made on the completed well.
>
> Plumbness and alignment shall be tested by lowering into the well to a depth of (Anticipated Pump Setting) feet, a section of pipe 40 feet long. This section of pipe shall be no more than $\frac{1}{2}$ inch smaller in diameter than the diameter of casing or hole being tested.
>
> Should the pipe section fail to move freely to the depth specified or should the well vary from the vertical more than two-thirds the smallest inside diameter of that portion of the well being tested per 100 foot of depth, the plumbness and alignment of the well shall be corrected by the contractor at his own expense.

3. Test Pumping - The present provisions for test pumping of the wells produce such limited information as to be almost worthless for rational engineering design and selection of the well pumps.

The data taken during a test pumping should be of sufficient quantity and quality to allow analysis of the data by either the non-equilibrium method, the modified non-equilibrium method, or the equilibrium method if the well actually reaches equilibrium, which is doubtful in most cases. In addition to determining conditions for proper selection of the well pump unit, the analysis of data collected can also provide information about the presence and location of any major water recharging formations which may be encountered. Of more importance, formations preventing adequate recharge of the aquifer can also be disclosed.

The unfortunate thing about the present test pumping procedure is that with little or no extra total effort, all of the information needed could have been obtained.

A description of the details of the analysis is beyond the scope of this report, but several selected references are cited at the end of this appendix. Basically the data collection consists of determining the drawdown in the well at exact time intervals varying from about 1 - 2 minutes initially to about 30 - 60 minutes at the end of the test while pumping the well at a constant rate. The measurement of the drawdown should be to an accuracy of about 0.1 foot. It would be highly desirable to have Iowa State Highway Commission personnel collect this data, but these people should be familiar with the end use of the data so that proper collection is done.

The equipment needed by the Iowa State Highway Commission personnel would be one or two electric probe loggers and stopwatches, at a total cost of about $150. The specifications should provide for:

a. An 8 hour pumping test with a unit price bid for increasing or decreasing the time of test pumping where the contractor furnishes the pump, driver and flow measurement device. The pumping rate should be greater than 60 gpm if possible.

b. The Iowa State Highway Commission would provide two and in some cases four people to observe the time since pumping started and the drawdown in the well with the electric logger probe. The Iowa Geological Survey personnel are frequently interested enough to provide help during the test pumping and analysis.

D. Selected References on Well Hydraulics and Test Pumping

1. Bruin, Jack and Hudson, H. E., Jr., "Selected Methods for Pumping Test Analysis", 1955, Report of Investigation No. 25, Illinois State Water Survey Division.

2. ____________________, "Ground Water and Wells", 1966, Edward E. Johnson, Inc., St. Paul, Minnesota.

3. Ferris, J. G., D. B. Knowles, Brown, R. H. and Stallman, R. W., "Theory of Aquifer Tests", Geological Survey Water-Supply Paper 1536-E.

4. Rouse, Hunter (Editor), "Engineering Hydraulics, Proceedings of Fourth Hydraulics Conference, Iowa Institute of Hydraulic Research", Chapter V, "Flow of Ground Water", 1950, John Wiley and Sons, Inc., New York, New York.

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