Rocky Hill Water Situation. Section 5.

The Aeration System and Firm Capacity

Following the Rocky Hill Jan 25th 2021 Water System Special Meeting there were many questions about "firm capacity" and what it actually meant for the Rocky Hill water system.
Although it is not a real issue for the aeration system, it became apparent that many Rocky Hill residents do not have a complete idea of how the water system actually works and how it was designed and built in 1982 – and also what Firm Capacity actually means.
This Section 5 attempts to cover these issues.

As a result of previous communication on Capacity and Backup, it is apparent that water Capacity has nothing to do with adding more wells and pumps to the water system – but that water Capacity is synonymous with Storage.
The amount of water capacity in the system is determined by the storage tower, and the present water system (running duty cycle operation) is not even running more than half the time to maintain storage.
So, adding more wells and pipework and pumps going to the water plant is not only extremely expensive, it is totally unnecessary and would not accomplish anything.
To increase Capacity (if actually needed) one must increase Storage.
This is done all over the world by adding POU (point of use) storage – such as by the use of water storage tanks on city buildings or by adding distributed storage in large systems, such as regional reserve storage (reservoirs) and regional pumping stations supplying regional networks at standard line pressure.
This has all been described in **Section 3** under System design (page 4).

It seems now that reference was not apparently being made to needed extra water capacity, but to the "Firm Capacity" as being an urgently needed NJDEP requirement. This is something quite different, and will be explained below.

At the Rocky Hill Water System Special Meeting on Jan 25th, this question of firm capacity was presented as being a requirement by NJDEP that the water system have a backup system to supply enough water to meet peak daily demand in case the largest pumping or treatment unit is out of service and (because we only have a single well and pump) it was assumed that there was some implied need of another (second) well and main pump.
That is not a literal or correct understanding of the firm capacity requirement.

There was a cited reference link on this question;
www.state.nj.us?cgi-bin/dep/watersupply/pwsdetail.pl?id=1817001
This is entitled Public Water System Deficit/Surplus, and refers specifically to Rocky Hill Water Department, which has the identifying PWSID of 1817001.

Rocky Hill has an Allocation (permit) of 37.200 Million gallons of water per year. There is a stated calculated peak daily demand (based on using reported water pumping data) of 88,000 gallons per day (0.088 MGD).

This number is actually rather high, indicating continuous pumping at 61 gallons per minute all day long. The stated yearly 29.309 Million gallons per year is also high (vs. around 26 Million gallons per year actual).

There is then a vagueness in the definition of "peak daily demand" (to quantify the actual water needs of firm capacity) which is stated to mean the average daily demand in the peak month of the previous 5 years plus an estimation of summed residential and non-residential average daily demands according to certain residential and non-residential NJAC standards – summed together and multiplied by "a peaking factor of 3."

This is from the: **Firm Capacity and Water Allocation Analysis** document, which is an internal reference link in the above listed www.state.nj reference.

Regardless of all this, because Rocky Hill only uses one well, the Firm Capacity is then stated to be Zero and the Water Supply Firm Capacity of the Rocky Hill Facility is then stated to be minus 0.088 Million gallons per day - based on the assumed calculated peak daily demand.

Firm Capacity is stated to be … " a measure of the physical ability to provide treated water at adequate pressure when the largest pumping unit or treatment unit is out of service". … [a measure of the physical ability to provide…..]

Firm Capacity is elsewhere defined in more detail as:
… "adequate pumping equipment and or treatment capacity to meet peak daily demand … when the largest pumping station or treatment unit is out of service."

Firm Capacity therefore refers to the pumping and treatment backup capability that is available in a water plant to meet peak daily demand.

That is all that is stated about Firm Capacity, which basically relates to the backup capability of system hardware. There is nothing specified anywhere about requiring additional wells or pumping units.

Firm capacity relates to the required obligation of the water supplier to be able to provide peak daily customer demand if the main pumping station or treatment unit goes out of service. They (NJDEP) are pointing out exactly what that entails in terms of the water supply needs in a general case, and also in the case of Rocky Hill water needs in particular (0.088 MGD).

We know about that obligation. It is something that is accepted and appreciated. The Rocky Hill Water Facility is a Community owned Municipal water system and is not run by some Water Company or Independent Water Authority that could be adversarial to Rocky Hill community water needs.

In scientific parlance it could alternatively be stated and specified that the water system should involve maximum elements of functional redundancy in the event of major component or operational system failure to meet peak daily water demand. That is what the concept of "Firm Capacity" is all about.
If there is adequate functional system redundancy the treatment unit is not driven out of service and the concern of not being able to meet demand does not then exist.

The concept of system redundancy was of primary importance in the design of the Rocky Hill Water Treatment Facility, which is an aeration system. That is because it was designed to be an automatic system that functions without human operator control or intervention. Autonomous systems are generally complex systems.

With complex systems there is usually a performed analysis of component functionality and an assignment of redundancy priority. For instance in space projects there is even second order redundancy consideration given to primary power supplies and telemetry functions – without telemetry there is no communication, and without communication the mission is dead.
Every experimental package would therefore have its own telemetry and there would additionally be a redundant main telemetry buss architecture. A key element in such systems is always to have adequate diagnostics and control.
Of course a Water Facility is a far cry from being a space project, but some similar concepts can apply. There is a need to provide for redundancy of critical components and for detection of failure modes in the system operation.
This will all be briefly described below for the Rocky Hill system.

A failure and redundancy analysis was carried out by the task force that handled the Aeration System project. This consisted of Ivor Taylor, David Staph (Borough Engineer), Larry Merck (Water superintendent and employee of South Brunswick Water Authority), Raymond Whitlock (Rocky Hill council member and liaison to RHFD), and Albert Robotti (Rocky Hill mayor). Other members of the Rocky Hill community provided valuable input and assistance informally on a regular basis.

The first obvious failure point to consider was the main well pump. This was an old pumping unit with a large electrical motor driving a long shaft and impellor pumping system. Although proven very reliable in long-term practical use, this was not energy efficient and would also be quite difficult to replace or re-source or to repair in the event of a failure. It was decided it must be replaced.
It was replaced by a standard commercial submersible pump used extensively in modern water systems and as recommended by Larry Merck from personal experience. The key requirement was that it should be a commonly used (generic) component that would be readily available in the industry, and one that had multiple equivalent listed replacements.

To explain the basic operation of the aeration system in simple manner; the main well pump sends water up to the first stage aeration column below which is the first storage tank located 4ft above ground level and 4ft below ground level.
An inter-stage pump transfers this water from the first storage tank up to the second aeration column, which also has a similar storage tank. The water content of the second storage tank is then transferred up to the main storage tower of the Water Facility through a high lift booster pump. These pumps are all running at the same time when in an operational cycle.
For exactly the same reason as described for the main well pump, the auxiliary pumps are required to be selected standard commonly used (generic) components that are readily available in the industry, and with listed equivalent replacements. The pumps are installed with detachable couplings.

The air flow through the two aeration columns is generated by top mounted air extractor units, and air flow sensors are provided for each. Lack of air flow is a fault condition. It is important that air flow is maintained through the aeration columns. The air extractor units are of the type used industrially and commercially and are standard generic units readily available commercially.
The status of water levels in the storage tanks is monitored by ball float tilt switches as used extensively in water systems, and were recommended by Larry Merck.
The pumps are to be turned off at low level settings of the float sensors, and to be turned on (remaining on) at a higher level.
The float switch signals and the air flow switch signals are routed to a central control panel unit. Control signals are then electronically generated to power the air extractors and activate the pumping units from the control panel.
Air sensor fault conditions and illogical float sensor conditions are flagged and displayed as system faults. An air flow failure would initiate system shut-down.
An alarm notification system involving telephone message calling of designated people was also incorporated. This was the basis of the diagnostics for automatic operation and control of the Rocky Hill system.

A fundamental advantage of systems that are not space launched is obviously that they can be attended to and quickly fixed if necessary on the ground. The level of system redundancy (or backup) is therefore always to be weighed and evaluated against quick repair, and well designed systems are based on deliberately avoiding the addition of unnecessary features that could themselves lead to extra failure or other complications. This was the approach taken in the design of the Rocky Hill system.

One such situation involving addition of complex system features (with this type of aeration system being described) relates directly to the simultaneous use of several pumping stages, and the important requirement to balance water flow rates across the stages to avoid possible flooding conditions in the storage tanks.

In some systems this problem is solved by introducing electric motor controlled valves that are servo loop controlled electronically to regulate water flow across the

stages at a designated flow rate. This was the method used in an aeration system project being designed and developed by IBM Dayton N.J. in the same time period. In the use of such electronic control loop operations any possible stabilizing failures can have quite serious consequences (system flooding) and is something that is not easily solved by simple introduction of component redundancy.
One common method of balancing pumping flow rates in the water supply industry is to empirically trim the pump impellers. This approach however does not exactly solve the problem (especially for long term unattended operation) and it was rejected for the Rocky Hill system.

The method actually used in the Rocky Hill Water Facility is one that would have been used by the Romans, and is based on gravity. Very simply the first storage tank has an overflow port located near the top of the tank that overflows back down to the well. The second stage storage tank has an overflow port at a higher level that overflows to the first storage tank. So, second stage (ultrapure) water overflows back to the first stage (pure) water storage tank, which in turn overflows back down the well. Gravity determines the direction of overflow. Gravity does not need any redundancy backup.
In this design the actual pumping speed of the pumps is largely irrelevant, there will not be any system overflow flooding. The difficult problem of precisely balancing water flow rates across the aeration stages is therefore eliminated. This is a key element of the system design.

As an extra control, the mid-stage pump (pumping water from the first storage tank up to the second aeration column) is equipped with a bypass pipe and manual valve that returns some of the pump output back into the input water (thereby reducing the pumping rate of the mid-stage pump - if required). This in practice can enable both storage tanks to be set to be approximately equally filled when in the middle of an operation cycle, with an adjustment that essentially also modifies the amount of overflow.

A second basic item that was considered was specifically the redundancy of the well itself. The Rocky Hill well #2 is not particularly deep (around 160 feet) but has always been a prolific source of high quality water. There was nothing recorded that indicated any problems with water output from the well since its construction in the 1936 time period, under the FDR works program. The aquifer seemed to be quite plentiful. At the present time the Rocky Hill Water Treatment plant pumps around 26 million gallons per year.
As part of the remediation program of the EPA, administered by NJDEP, on the Rocky Hill aquifer (in response to the TCE contamination detected in the early 1980’s) there has been Superfund remediation activity for many years, with issued reports every 5 years by the U.S. EPA Region 2, New York, NY.
In the 2016 report it is stated that (to that date) over 300 million gallons of water had been pumped from the Rocky Hill aquifer and dumped to the Montgomery Township storm drains and that the “pump and dump” operation is ongoing at 44 gallons per minute. This equates to pumping 23.7 million gallons per year, ongoing.

So, by all accounts, the aquifer is providing a lot of water. There is not any indicated requirement for well redundancy (backup). We don't need more wells.

The water pressure in the aeration stages is low, with open storage tanks, and there were no redundancy (backup) concerns in the use of PVC pipework related to water pressure.
It has already been described above that there are no functional redundancy concerns with the aeration stages (there are no issues about balancing water flow rates between stages) and therefore the only redundancy items of the water system concern the three (3) pumps and the two (2) air extractors, which are the only basic hardware components of the aeration system.

The extractor units are mounted on box sections molded onto the top of the fiberglass aeration columns, and can be detached for direct removal. The air extractor unit on the second aeration column was replaced around 5years ago because of a bearing failure. There are molded side boxes for electrical connections. The aeration columns each have a large detachable inspection plate for access to the central injector spray nozzles and to the top sections of the aeration column packing material.
We chose to use structured packing rather than random packing in the aeration column design. The impedance with structured packing is lower and, because the flow characteristics and break point distributions in the material (needed features to establish the required thin film water flow conditions) are better controlled, the computer calculations relating to extraction efficiency and to the aeration column parameters are more robust and reliable. To meet the design goal of non detectable (ND) under the existing contaminant conditions at that time it was necessary to obtain extraction efficiency of at least 95% or higher for each aeration stage.
The aeration columns are actually larger than they appear. They enter down into the aeration building above the storage tanks.

The fiberglass aeration columns and the storage tanks were manufactured locally in Trenton specifically for the project and the structured packing material for the aeration columns was obtained from a manufacturer of such material in Florida. The aeration column (Trenton) manufacturer installed the packing material (with provided instructions) before delivery of the aeration columns to the Rocky Hill site.

Considering (as a simple case) the redundancy of the mid-stage pump, it is certainly possible of course to parallel the mid-stage pump with another pump by adding extra shut-off valves and extra pipework. This is the usual generally accepted backup procedure. If the mid-stage pump fails the backup system could then take over. If this is done manually however there is little or no advantage over simply de-coupling the failed pump and just inserting a replacement unit.
The Rocky Hill system was intended to be an autonomous system and therefore, for an authentic redundant backup, the procedure should be automatic, not manual.

In an automatic redundancy (backup) procedure the initial pump failure would need to be detected. Since this could be mechanical failure, as well as electrical, the detection would necessarily involve detection of failed water flow by the required addition of a flow rate sensor. The sensor electrical signals would then go back to the control panel, and control signals would be issued to operate the four (4) needed electrically operated valves to disconnect the (failed) pump and to switch the pipework over to the backup pump, and then a command signal would be issued to start the backup pump. However, this is bordering on the ridiculous. This is all a ground based operation. This is not a space project.

These examples are presented to show that even in the simplest case of installing a backup pump in a normal working system, the manual switching of 4 valves and the installation of parallel pipework is hard to justify against a simple rapid pump replacement procedure.
When it becomes a question of requiring automatic backup in an operating autonomous system the complexity increases significantly, as described above, and becomes quite counterproductive. In cases like this it makes more sense to temporarily stop the process and quickly replace the pump unit manually.
This is often not fully appreciated. There is considerable water storage capacity in the system itself, and replacement operations can generally be arranged and implemented without functional disruption.

Redundancy backup of the main well pump unit is particularly problematic and troublesome because it is located at the bottom of the well, and it was already concluded that the well itself is not a redundancy candidate - only the pump.
To make things easier however there is a roof-mounted trapdoor located directly above the well head so the main pump can be lifted out and directly replaced.
This worst case situation occurred some years ago, and the Rocky Hill Water Facility was out of action for maximum only two or three days, and initiated the existing short term emergency water supply backup link implemented many years ago with Elizabethtown Water Company.

From all this it is seen that the best practical way to handle redundancy in such situations is by appropriate system design if possible, and then by making the system easily and quickly serviceable by using quick disconnect couplings (as an example) and by using readily available standard industrial replacement items.
Firm Capacity becomes the system's ability to effect rapid repair and re-establish normal operation.

The concern of NJDEP (always acting as Community advocate) is clearly that a water provider should have the capability (described as Firm Capacity) to provide the community with peak daily water demand as quickly as possible in the event of the treatment unit being out of operation, and that it should not be reliant on emergency alternative backup water supply sources as any long term solution.

It is clear also that a major incident like main well pump failure could possibly be resolved a little quicker by having the replacement well pump unit in inventory on site, but probably not to any significant extent. Also, relatedly, there was only one such event in around 30 years.

The original Rocky Hill aeration system task force did not consider the question of carrying inventory items on site. There is no storeroom or maintenance workshop. Also, there were other pressing issues at that time.
The aftermath of the Vietnam war was a period of political and social unrest in the USA. There were extremes of vandalism, and graffiti covered the New York subway cars and building walls. In Rocky Hill, juvenile vandals climbed the Water Tower to repeatedly spray paint graffiti and comments. The Rocky Hill aeration system was being built at that time in the early 1980's and the well house was broken into several times, sometimes through breaking the door and windows.
There was a secondary well (referred to as Rocky Hill well#1) located behind the present Princeton Fitness Center which at that time was a supermarket location. This well #1 had never apparently been used, and was presumably considered to be the firm capacity (backup). The small brick building for well#1 was being used as a drug hangout in spite of locked door and posted notices.
There was very serious concern about unauthorized access to this well and the dumping of refuse and unknown items and materials down the well, thereby contaminating the Rocky Hill aquifer.
The well #1 was sealed and covered and the building was demolished.

Separate Rocky Hill community members at that time stepped in to rebuild and reinforce the perimeter chain link fencing to the well house, and to install a steel entrance door and door frame on the well house with double locks and to install steel bars over the windows and over the air intake filter for the aeration building. There are no windows in the aeration building, which also has a steel internal door to the well house that can be locked. The Rocky Hill water treatment plant is therefore a secure location with restricted access to the water supply.
There is still some residual concern today about the number and the security of test wells and unused remedial wells that are tapping into the aquifer, and even knowing where these wells are actually located.

Finally, the failure of most concern (for any system) is total electrical power failure. This has happened on a few occasions for the Rocky Hill Water Facility in the last 37 years. The system is designed to perform controlled shut down following individual pump failures, and with total power failure the process just stops with no related equipment damage.
Most power outages are relatively short-lived, one exception being Hurricane Irene in 2011 when power was lost in Rocky Hill for over a week.
An expensive industrial grade generator was installed recently that operates on natural gas, to provide electrical power backup for the Rocky Hill water facility.

It is located inside the perimeter enclosure. This provides a redundancy of the primary electrical power source, and is an essential component of any type of firm capacity.

It is seen from the above description that the Rocky Hill Water Treatment Facility was designed and built by the Community (at cost) and also paid for by the Rocky Hill community. There was no financial assistance of any sort provided by the State of New Jersey nor by any Federal authority. The cash flow needed during the construction phase was obtained through a loan from the local bank, and the loan was repaid within a year from the water billing revenues.
This was a system built by the Community, for the Community.

From consideration of the above brief descriptions of the Rocky Hill aeration system it is suggested that the blank statement that the Rocky Hill Water Treatment Facility has Zero firm capacity ability (simply because it only has one well) is actually quite incorrect and suggests there is (naturally) a lack of understanding of how the system is designed and how it operates. That information is not included in any NJDEP database.
When the treatment unit is normally running there is obviously no issue.
The Rocky Hill Water Treatment Facility has been running autonomously and serving Rocky Hill normally for more than 37 years, with minimal interruption.
Lack of "firm capacity" is therefore realistically not a system issue for the Rocky Hill community.

The real undeniable issue right now is the PFAS contamination of the Rocky Hill aquifer, and how the Water Facility can completely remove this unacceptable PFAS contamination from the drinking water.
Unfortunately the aeration system cannot by itself remove the PFAS chemicals because they do not have any significant vapor pressure, but they can all be totally removed with simple addition of ion exchange filter modules, at relatively low cost.

An addition to the aeration system to achieve this has already been designed and presented for Rocky Hill consideration (described in **Section 3**).

Ivor Taylor. Feb 18th 2021.