

OHIO DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINERAL RESOURCES MANAGEMENT

****PROCEDURE DIRECTIVE****

REGULATORY 2013-01

(This procedure directive replaces TECHNICAL 06-1)

- Subject:** Replacement of Water Supplies Affected by Coal Mining Operations
- Effective:** December 1, 2013
- Purpose:** To establish guidelines for 1) replacing water supplies that have been contaminated, diminished or interrupted by coal mining operations; 2) providing and/or reimbursing for the reasonable costs of temporary water supplies and operation and maintenance costs of the replacement water supply, and 3) clarifying the roles and responsibilities of the Division, the permittee and the water supply owner.

Regulatory requirements and Order by the Chief:

OAC 1501:13-9-04 (P) states, in part, that:

- (1) Any person who conducts coal mining operations shall:
 - (a) Replace the water supply of an owner of interest in real property who obtains all or part of his or her supply of water for domestic, agricultural, industrial, or other legitimate use from an underground or surface source, where the water supply has been affected by contamination, diminution, or interruption proximately resulting from the coal mining operations; and
 - (b) Reimburse the owner for the reasonable cost of obtaining a water supply from the time of the contamination, diminution or interruption by the operation until the water supply is replaced.

When the Chief determines that a water supply for a domestic, agricultural, industrial, or other legitimate use has been contaminated, diminished or interrupted by a coal mining operation, the Chief may provide a subsidence damage notice or order the permittee to replace the affected water supply. In enforcing such orders, the Division will assure water supply replacement or restoration is comparable in terms of quality and quantity to the premining water supply as required by Ohio law and rules. No final performance security release on disturbed lands within the permit area may occur until satisfactory water supply replacement or restoration has been achieved and temporary water supply costs, operation and maintenance costs, and landowner-initiated permanent replacement costs, if any, have been reimbursed, and the Chief has terminated any order.

Permittees are encouraged to reach private agreements with landowners to provide replacement water that complies with OAC 1501:13-9-04 (P). ORC 1513.162 affirms the right of any person to enforce or protect, under applicable law, his or her interest in water resources affected by a coal mining operation.

Replacement of a Water Supply:

Replacement of water supply means, with respect to protected water supplies contaminated, diminished, or interrupted by coal mining operations, provision of water supply on both a temporary and permanent basis equivalent to pre-mining quantity and quality. Replacement includes provision of an equivalent water delivery system and payment of operation and maintenance costs in excess of customary and reasonable delivery costs for the pre-mining water supply.

The replacement of a water supply applies to both surface and underground mining operations that affect water supplies. If replacement of a water supply is required under OAC 1501:13-9-04 (P), the permittee shall promptly replace the water supply of an owner of interest. The permittee will provide temporary and permanent water as follows:

For both surface and underground mining operations, the permittee will -

- Provide a temporary water supply within **48 hours** following conclusion of either an investigation by the permittee or notification by the Division;
- Provide a permanent water supply within **24 months** for water supplies affected by underground full-coal recovery operations following initial impact;
- Provide a permanent water supply within **24 months** for water supplies affected by underground room-and-pillar mining operations following initial impact; and,
- Provide a permanent water supply within **30 days** upon notification from the Chief that the water supply was affected by coal surface mining operations.

In instances where exceptional circumstances may exist or develop which prevent the permittee from meeting the above-mentioned time frames, the permittee will immediately contact the Division who will determine if an extension of time is warranted.

Temporary water supplies thus provided shall continue through any appeals process and/or until a permanent replacement supply has been provided or the water supply has recovered or been restored.

The Division will provide a hard copy of this Procedure Directive (PD) to those water supply owners when the outcome of a formal investigation and findings has determined that a water supply has been permanently impacted by mining operations.

Temporary replacement of water supplies:

Within two working days of receipt of a water supply complaint, the inspection staff will

check the field location of the complainant's water supply relative to the nearest mining operation. If the water supply is within 1000 feet of the affected limits, the inspection staff will immediately notify the Division's field hydrology manager. A field hydrologist will be assigned to conduct a site investigation of the complaint and develop an initial evaluation within five working days. Water supply complaints outside of the 1000 feet affected limits will be assigned to a field hydrologist and will be investigated in a timely manner.

If the investigating hydrologist concludes that a water supply was adversely affected by a mining operation, the hydrologist will provide all data and information supporting this decision to the appropriate inspection staff. The inspector will notify the permittee by telephone to provide a temporary water supply within 48 hours and will provide all documentation from the investigating hydrologist. If necessary, the inspector will follow up with issuance of a subsidence damage notice or an Order by the Chief requiring temporary and permanent replacement of the water supply. Reimbursement of all reasonable costs necessary to provide his/her own temporary water will be made in accordance with the reimbursement procedures outlined in this PD. If the permittee appeals a Chief's Order to replace a water supply, the permittee shall continue to provide the temporary water supply until a final non-appealable Order exists holding the permittee is not responsible for replacement of the water supply, unless temporary relief has been granted by the Reclamation Commission or appropriate Court of Appeals.

Temporary water supplies shall be of like-kind of the pre-existing supply in terms of quality and quantity to meet the reasonable needs of the landowner until a permanent water supply replacement has been achieved or until the existing water supply has recovered. Adversely impacted water supply uses shall include, but are not limited to: ordinary household purposes, including drinking, cooking, bathing, sanitation, and laundry, and drinking water for poultry, livestock and domestic animals. If the adversely affected water supply remains adequate in quality and quantity for most domestic uses (washing clothes, showering, etc.) but is not potable, then delivered potable bottled water shall be delivered in amounts to meet the needs of family members. In general the temporary potable (bottled) water shall be equal to at least one gallon per person per day, or five gallons per family per day, or may be more or less based on a case-by-case basis.

If the existing adversely affected water supply is lost or not adequate in quantity and quality for most domestic uses, then the temporary supply shall provide for at least 75 gallons per person per day of potable water plumbed into the existing water supply system, unless specific needs require higher amounts. This shall be accomplished in the form of a non-pressurized storage vessel made of steel, plastic or concrete materials, or other method provided by the permittee. All temporary water supplies shall meet all applicable state, county and local laws and regulations regarding transportation, storage and disinfection, including Ohio Department of Health rules for Private Water Systems (OAC Chapter 3701-28).

For those water supplies utilized to meet agricultural needs, including springs, cisterns, ponds, and streams that are used for agricultural watering, the permittee shall provide a temporary water supply within 48 hours to provide the average consumption needs for livestock species. These instances will be handled on a case-by-case basis and the Division will rely on the recommendations of the local agricultural extension office to ensure that both quality and quantity

are acceptable for the amount and type of existing livestock species.

Quality of permanent replacement water supply:

The water quality of the replacement or restored water supply must meet or exceed the premining quality and must not restrict or limit the premining use. The quality of the replacement water supply will be evaluated based upon values of pH, alkalinity, acidity, iron, manganese, hardness, sulfate, suspended solids and specific conductance and/or total dissolved solids. In addition, domestic water supplies will need to be approved by the local health department. If other parameters that may affect the usability of the replacement supply are suspected or known (e.g. dissolved gases, elevated sodium or chloride, etc.) the evaluation will also consider such conditions in determining acceptability of the replacement water supply.

If premining water quality data are inadequate or nonexistent, the acceptability of the replacement supply will be judged in comparison to ambient water quality of water from the same or similar water-bearing zone (i.e., aquifer) in the surrounding area. Other considerations may include recommendations by the Ohio Environmental Protection Agency, Ohio Department of Health or other appropriate agency or entity for the appropriate use classification.

The long-term treatment of an existing water supply that has been contaminated by mining is not acceptable as a permanent replacement water supply unless 1) water treatment is agreed to by the landowner and permittee and the continued use and treatment of the water supply will not result in contamination of other aquifers or surface water, or 2) no other practical permanent water supply replacement option is available other than treatment of an existing water supply.

Where long-term treatment of an existing or a replaced water supply is approved by the Division, appropriate water treatment systems (e.g., softeners, chlorinators, filters, etc.) may be installed on a replacement supply to achieve the required quality, provided that such systems do not restrict or limit the premining use. However, wherever possible, the permittee will select and provide a replacement water supply that will minimize the type and extent of treatment necessary to achieve the required quality. Additional costs (operation and maintenance) may be associated with the addition of treatment equipment.

Quantity of permanent replacement water supply:

The quantity of the permanent replacement supply must meet or exceed the premining quantity available for use, and must not restrict or limit the premining use. Determining the quantity of an existing supply is more problematic than determining quality, therefore an accurate determination of quantity of water available from the existing supply prior to mining may be very important. If the quantity of a water supply has been impacted, it may be necessary to determine the quantity of the permanent replacement supply. There are several test methods that produce accurate and reproducible results that can be used to determine the quantity and/or yield of both the existing and replacement supply. These tests methods include: a step-drawdown test, a slug test, a specific capacity test, and the peak demand test (the peak demand test is utilized by many financial lending institutions). **Please refer to Appendix for an explanation of the various water supply quantity tests.**

If the premining quantity data is inadequate or nonexistent for a domestic supply, the replacement supply shall provide either 1) a minimum of 75 gallons per person per day, or 2) a sufficient amount to accommodate the size and amenities of the residence (e.g., number of bathrooms, bedrooms and water-using appliances) in accordance with guidelines in Midwest Private Water Systems Handbook (1979, Midwest Plan Service). Selection of the appropriate method to calculate minimum quantity will be based on the circumstances specific to each case.

For other legitimate uses, such as agricultural, where the premining quantity data is inadequate or nonexistent, the Chief will determine the minimum replacement quantities based on appropriate sources of technical information and comparable uses in the surrounding area.

Appropriate supplemental water storage systems may be installed to achieve the quantity requirements, provided that such systems comply with all applicable local, state and federal laws and regulations.

Duration of permanent replacement water supplies:

Assuming normal usage and routine maintenance performed by a landowner, the expected duration (i.e., life expectancy) of the permanent replacement water supply system must be of like-kind in terms of serviceability of the existing water supply system.

Responsibility for permanent water supply replacement:

When a permittee learns of the water problem or receives a subsidence damage report or an Order by the Chief requiring permanent replacement of a water supply, the permittee will adhere to the timetables as described on Page 2 of this directive for permanent water supply replacement and will bear all costs associated with installation of an appropriate replacement water supply and/or treatment system.

Generally, the Division does not become involved in enforcing the terms of private voluntary replacement agreements between the permittee and private water supply owner. However, for those water supplies that have been damaged or diminished in quality and quantity by subsidence of underground coal mining operations where the water owner of interest has been working directly with the permittee on the owner's water loss claim, the permittee will notify the Division in writing of said subsidence damage and of the existence of agreements for temporary and permanent replacement pursuant to provisions of the Division PD *Underground 90-2: Subsidence Damage*. If the permittee provides voluntary permanent replacement of a water supply the permittee shall submit a Private Water Supply Replacement Verification Form (attached to PD) along with all the required attachments to the Division immediately following completion that includes the location of the affected and replacement water supply and the new water supply development information. This form will become part of the permit file.

If the permanent replacement water supply involves connection to a public water supply system or the equivalent, the permittee's responsibilities will include, in addition to the above, payment of initial tap-in fees and installation of a water metering device, where required by the

public water authority.

In addition to the above, the permittee shall pay for any additional materials and labor necessary to connect the replacement supply to the existing plumbing system, the county permit to install, and bacterial testing of domestic water supply replacement by the county health department. The permittee shall be responsible for the purchase of a new pump if the existing pump is inadequately matched to the replacement or re-drilled well, or no pump existed (e.g., the original supply was a developed spring with no pumping system), or the existing pump was damaged by the contamination or diminution of the well. Cisterns may be considered as an option for water supply replacement in limited circumstances.

If the replacement of a domestic water supply involves deepening an existing well or drilling a new well, such drilling must comply with all applicable state and local regulations. Permit approvals obtained from other agencies must be submitted to the Division prior to any drilling.

If a water treatment system is necessary to meet premining water quality parameters, the permittee will arrange for, and bear all costs associated with the installation of an appropriate system capable of producing water that meets the quality and quantity requirements of this PD.

In the event that a permittee and a landowner desire a public water supply as a permanent *agricultural* use replacement, the Division will accept this option upon request by the landowner and the operator. Such a request must be accompanied by written confirmation by the landowner and supporting documentation that:

- The water resource(s) have recovered after disturbance to the extent that they are still available for future development on the property in acceptable quantities and qualities, and/or;
- Re-development of water resource(s) on the property is not technologically or economically feasible.

Absent an accepted private agreement between the permittee and the water supply owner, the permittee must provide documentation that a reasonable level of compensation for public water costs has been offered to the landowner.

Multiple Users and Ownership Control:

In those instances where a water supply may provide water to multiple landowners and users, the permanent replacement supply must be adequate in quality and quantity for the purpose served by the pre-mining supply. This would apply to multiple users of a particular water supply, including the landowner on whose property the water source is located, and also all users of the water source.

Operation and Maintenance Costs

The permittee is responsible for the operation and maintenance (O&M) costs of the

permanent replacement water supply system and water treatment system in excess of the customary and reasonable O&M costs of the premining water supply. The permittee should attempt to reach a private agreement with the water supply owner on the amount and payment of any increased O&M costs. Upon agreement by the permittee and the water supply owner, the obligation to pay such operation and maintenance costs may be satisfied by a one-time (lump sum) payment in an amount which covers the present worth of the increased annual operation and maintenance for a period of time agreed to by the permittee and the water supply owner.

The O&M costs should reflect a number of factors, including: a change in the O&M costs of water systems and water treatment, any change in reliability, a change in projected operation and maintenance schedules, or a change from the pre-mining water supply delivery system (e.g., private well to a public water supply system). The additional O&M costs will be considered on a case-by-case basis and any disputes over the reasonableness of these costs will be decided by the Chief.

After installation of the replacement water supply, O&M data should be collected by the permittee for a period of time not less than six months or more than twelve months to determine increased O&M costs. During this period of time, the permittee should consult with the water supply owner about any increased O&M costs of the replacement water supply over the pre-mining water supply.

O&M costs should be based on the predicted useful life of the pre-mining water supply delivery system. As an example, 20 years could be a reasonable amount of time to hold a permittee responsible for costs when the delivery system from a well or spring would likely have required repairs and/or replacement within the 20-year period even if the well or spring had not been impacted by mining. The permittee and water supply owner may also consider typical life expectancy of water supply systems used in the surrounding area. The suggested time period of 20 years is only an example and should not be considered a standard for addressing O&M costs or for the number of years that increases from a public water bill would need to be paid.

For complaints submitted and investigated by the Division, a copy of the O&M plan must be submitted to the Division explaining how the increased O&M costs will be paid. Once an agreement is reached with the water supply owner regarding O&M costs, a written acknowledgement should be signed by the water supply owner and permittee and submitted to the Division's investigating hydrologist who will be responsible for verification.

Reimbursement for temporary water supply costs:

Except for any period of time when the permittee provided a temporary water supply, the permittee shall reimburse the landowner for the reasonable costs of obtaining a water supply from the time of the contamination, diminution or interruption until permanent water supply replacement has been provided or the existing water supply has recovered.

Reimbursable temporary water supply costs are those reasonable and necessary expenditures that are beyond the costs that would have been incurred if the original water supply system was still in use. Examples include costs of: 1) ordinary bottled water, 2) hauled water, 3)

temporary storage tanks and associated plumbing, 4) laundromat costs for washing clothes (not to include detergent or automatic dryer costs), 5) transportation of hauled water, not to exceed the most current State of Ohio reimbursement rate (different cost than item 2 above), and 6) temporary connection to a neighboring water supply. The Chief will decide any disputes over the reasonableness of costs incurred for a temporary supply or over what, if anything, the permittee should reimburse.

The landowner must maintain and provide accurate records for reimbursement of temporary water supply costs including dated invoices, cash register receipts, etc. The landowner shall send a legible copy of all documents, invoices and receipts for reasonable costs to the permittee and to the Division's investigating hydrologist. The permittee shall reimburse the landowner within 45 days of receipt of bona fide documents, invoices and receipts for reasonable and necessary costs, and send a photocopy of all reimbursement checks to the Division's investigating hydrologist.

Reimbursement for landowner-initiated permanent water supply replacement costs:

If, by the time the Chief determines that a water supply has been adversely affected by a mining operation and the landowner has already obtained a permanent replacement supply on his/her own initiative, the Chief will order the permittee to reimburse the landowner for the reasonable and customary costs of obtaining the permanent water supply. The landowner will send a legible copy of all documents, invoices and receipts for reasonable and customary costs to the permittee and to the Division's investigating hydrologist. The permittee shall reimburse the landowner within 45 days of receipt of bona fide documents, invoices and receipts for reasonable and customary costs, and send a photocopy of all reimbursement checks to the Division's hydrologist. The Chief will decide any disputes over the reasonableness of costs incurred for a temporary water supply or over what, if anything, the permittee should reimburse.

Responsibility for abandonment of wells:

If the water supply from a well that has been contaminated or diminished by mining operations will no longer be used by the landowner for any legitimate use, the permittee shall plug and bear all costs associated with proper abandonment (i.e., plugging) of the well in accordance with Ohio Department of Health requirements, pursuant to OAC Chapter 3701-28. The operator shall submit a well sealing report to the ODNR, Division of Soil and Water Resources and a copy will be given to the Division's investigating hydrologist.

Reclamation of disturbed areas:

The permittee will grade, seed, fertilize, and mulch areas that have been disturbed during the construction and installation of temporary and permanent replacement water supplies in a manner consistent with the existing land use. The Division will consider maintenance of the reclaimed areas to be a private matter between the permittee and the landowner.

Termination of Order by the Chief:

In general, an Order by the Chief requiring replacement of a water supply will be terminated when the permanent replacement water supply is successfully completed and operating and the Chief finds that all quality, quantity, duration, reimbursement, abandonment and reclamation requirements have been achieved. In cases where treatment systems are necessary, the Chief must also find that the permittee and landowner have reached an agreement to cover the reasonable costs of operation and maintenance prior to termination of the Chief's Order.

When, in response to an Order by the Chief, a new well is drilled or an existing well is deepened or otherwise modified, the permittee will notify the Division's investigating hydrologist as soon as the permanent replacement water supply system is completed and operating, and will submit to the same hydrologist copies of the following documents:

- 1) County permit for private/domestic water system;
- 2) Well log/drilling report required by ODNR Division of Soil and Water Resources, with results of the pumping test included on the document;
- 3) Bacterial sample report required by Ohio Department of Health, indicating a "safe" bacterial condition (*private/domestic water supply system only*);
- 4) Results of EPA certified laboratory testing for organic and/or inorganic parameters as directed by the investigating hydrologist (*The Division will be responsible for collection and laboratory processing.*);
- 5) If a new well was drilled, permittee must provide a copy of the *Well Sealing Report*, as required by ORC 1521.05, prepared and signed by the registered well driller, verifying that the old well was properly abandoned (plugged) in accordance with ODNR and Ohio Department of Health requirements, or evidence that the landowner plans to use the old well as a source of water for a specific use; and
- 6) All checks issued to the landowner as reimbursement for temporary water supply costs (*if there were any costs*).

When, in response to an Order by the Chief, connection to a public water supply is made, the permittee will notify the Division's hydrologist in writing, as soon as the connection is completed and operating, and shall submit to the same hydrologist copies of the following documents:

- 1) Written verification from the public water authority, indicating that the connection has been completed and is acceptable;
- 2) If the public supply replaces a well, permittee must provide a copy of the *Well Sealing Report*, as required by ORC 1521.05, prepared and signed by the registered well driller, verifying that the old well was properly abandoned (plugged) in accordance with ODNR and Ohio Department of Health requirements, or evidence that the landowner plans to use the well as a source of water for a specific use; and
- 3) All checks issued to the landowner as reimbursement for temporary water supply and operation and maintenance costs (*if there were any costs*).

The investigating hydrologist will be responsible for inspecting the permanent replacement water supply system, obtaining a water sample for analysis, reviewing copies of all required documents submitted by the permittee, completing the attached form, "PRIVATE WATER SUPPLY REPLACEMENT VERIFICATION," and determining when the Order by the Chief may be terminated. The hydrologist will also notify the assigned inspector and landowner when the Division intends to terminate the replacement order, and document any concerns or comments offered by the landowner.

Any questions should be initially directed to the Division's Field Hydrology Manager at 330-339-2207 or to the regional Coal Program Manager at the appropriate district office.



Lanny E. Erdos

Chief

ODNR, Division of Mineral Resources Management

**OHIO DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINERAL RESOURCES MANAGEMENT**

PRIVATE WATER SUPPLY REPLACEMENT VERIFICATION

WATER SUPPLY OWNER: _____

PERMITTEE: _____ PERMIT NO.: _____

BRIEF DESCRIPTION OF WATER SUPPLY AND/OR TREATMENT SYSTEM(S) FURNISHED BY PERMITTEE:

The following, where applicable, have been reviewed (check):

- County permit for private/domestic water system.
- Well log/drilling report (ODNR Division of Soil and Water Resources).
- Bacterial sample report (Ohio Department of Health) (*private/domestic systems only*)
- Water sample analyses (ODNR DMRM).
- Verification of proper well abandonment – *Well Sealing Report* (from well driller)
- Copies of reimbursement checks for temporary water supply and operation and maintenance costs, if any.
- Reclamation of areas disturbed during construction and installation.
- Other (describe):

VERIFICATION STATEMENT:

Based on the above review, the permittee has complied with the water quality, water quantity, duration, reimbursement, abandonment and reclamation requirements of Procedure Directive "Regulatory 2013 -- 01."

Division Hydrologist's signature: _____

Date: _____

Appendix

Recommended Water Quantity Tests

Accurate determination of water supply "yield" is important for a variety of reasons. If a water supply is alleged to have been adversely affected by mining and a replacement supply is proposed it may be necessary to determine the adequacy of yield of the replacement supply. In addition, a pump or yield test may have been performed prior to mining (during the permitting process) where a comparison pump or yield test may be needed to determine impact, and if it is determined that there has been an impact to determine whether the replacement water supply quantity is comparable to pre-mining.

This appendix discusses a number of acceptable methods for determining the quantity of private water supplies as defined in Pennsylvania Department of Environmental Protection (PADEP) *Doc#563-2112-605 "Water Supply Replacement and Permitting", 1998* and *Doc#562-4000-101 "Water Supply Replacement and Compliance", 1999*.

Quantity Test for Wells –

Well yield is defined as the maximum pumping rate that can be sustained by a well without lowering the water level in the well below the pump intake. There are a number of pump tests that determine yield for wells that include: specific capacity test, peak demand test, and a step-drawdown test. When selecting a test procedure it is important to keep in mind that the results should be reproducible, simple to follow with standard equipment, produce results for pre- and post- mining comparisons, accurately simulate conditions of use, and limit any inconveniences to the landowner while performing the tests.

Before beginning any pump test it is best if the well has fully recovered from any prior use (drawdown). For wells that are accessible, it is important to collect and record pumping data, specific capacity, and recovery data. This would include changes in the SWL (static water level) throughout the test. For wells that are inaccessible, collecting and reporting the pumping rate, volume pumped, and duration of test(s) is vital.

Since the construction of an existing water supply and a replacement water supply may differ in the terms of depth or diameter of well, depth to the aquifer, casing depth, pump size, etc., caution should be used when comparing the data.

Specific Capacity

The "specific capacity" of a well is the number of gallons of water produced per minute for each foot of well drawdown and can be determined following a step-drawdown test.

Well yield can be calculated by multiplying the available drawdown in the well (the distance between the static water level and the normal pump setting in feet) with the specific capacity (units in gallons per minute per feet of drawdown), the result having the units of gallons per minute (gpm). This calculated yield takes into consideration both the storage capacity of the well and the aquifer

performance under the limited conditions of the specific capacity test. Since the pumping rate and the test duration both affect the specific capacity, they need to be nearly the same to compare results of two tests either between different wells or on the same well at different times. Seasonal variations of a well's recharge can influence yield.

The duration of a specific capacity test is often dictated by practical considerations such as how long the well users are willing to tolerate an interruption in their supply, or how quickly the well goes dry. The test duration of a domestic water supply should be developed to simulate the typical usage stresses. A typical test duration of 1 to 3 hours at a pumping rate of 5 gpm should suffice to simulate most household conditions. The test duration may be limited by some of the characteristics of the well that are mentioned above. When using the existing, in-place water supply pump, a discharge rate of 5 gpm may not be obtainable. Well plumbing fixtures, such as the pressure shut-off switch, sediment filter, and pressure tank may need to be by-passed or disconnected to maintain a stable, steady pumping rate. The test should be terminated when the water level drops within 5 feet of the pump, so the pump is not damaged by running it dry.

Well storage becomes overemphasized in short-duration specific capacity tests. Unlike a long-duration test of a high-performance industrial well, a short-duration test of a low-yielding well, especially a deep well, may result in borehole storage water representing most of the water discharged during the test. A borehole storage problem becomes significant if the specific capacity is then multiplied by the available drawdown to calculate a yield. A poor-performing, unreliable well can appear to have a relatively good yield when an inappropriate test method is used. There are two ways to avoid this problem. First, compare specific capacities (without borehole storage) and do not calculate a yield. This approach completely eliminates consideration of borehole storage. The second approach allows well storage to be considered but not overemphasized by subtracting the volume of borehole storage from the amount of water discharged prior to calculating specific capacity, then calculating the well yield. This second approach gives credit for borehole storage, but does not count it twice. If the individual conducting the yield test does not take into consideration the water removed from storage before calculating a yield, a long-duration pump test (an approximate 72-hour test) will be needed at a pumping rate that is high enough that borehole storage would become insignificant.

SC=R/D where:

SC = specific capacity (gpm/ft)

R = adjusted discharge rate (gpm) = $(Vt - Vs) / t$ where:

Vt = total volume of water discharged during test (gallons)

Vs = volume of water discharged from borehole storage (gallons) = $23.5Dr^2$

t = duration of the test (minutes)

D = total drawdown (feet)

r = well radius in feet. For a standard 6-1/2 inch diameter well, **Vs** = 1.72 gal/ft X **D**)

Safe Yield (gpm) = AD x SC x (safety factor), where **AD** (available drawdown in feet) = depth to pump intake minus static water level minus 5 feet.

A **safety factor** is employed in the safe yield formula as compensation for short-duration specific capacity tests which do not consider the extent to which yield will decrease if the well is pumped for periods longer than the test period and for the effect of seasonal or regional water-level fluctuations which deviate from that which existed at the time of the test. Safety factors of 0.9 and 0.75 are utilized for tests conducted between July through November and December through June, respectively.

Peak Demand Test

The PDT (Peak Demand Test) is commonly used by lending institutions to verify that a property being sold has a water supply of adequate yield. The test is used to simulate well usage during peak demands, and does not provide an actual yield value. It only tests a delivery system's ability to provide water to the user. The test is performed by running the water at a set rate for 15 minutes and then allowing the well to recover for 15 minutes. The on/off pumping cycles are repeated for 4 hours or until the well fails, whichever comes first. For the purpose of this test, a well is said to fail when the pump intake breaks suction and the discharge rate drops noticeably. The time when the well fails is recorded and this time can then be used to compare the performance of different wells and the same well at different times. The discharge rate must be recorded frequently during the test and should be measured at least every 5 minutes (three times per pumping cycle).

The parameters of the PDT must be carefully recorded, and when two tests are being used for comparative purposes, they must duplicate one another as nearly as possible. For example, if the test is going to be used to compare the performance of two wells, then the discharge rates for the two wells must be nearly identical during the test. If not, the wells have not undergone the same stress and the results cannot be compared in a meaningful way. Maintaining a constant discharge rate can be difficult to achieve, an in-place water delivery system for a home can be difficult to control, and the discharge rate may decline as the test advances.

If the PDT is being used to establish background conditions on one well, rather than for comparative purposes, the discharge rate used should be as close to 5 gpm (gallons per minute) as possible to adequately stress the well. The water supply system in place may limit the maximum, obtainable discharge rate. Also, the discharge rate cannot vary significantly during the test. PDTs conducted at low or variable discharge rates are not acceptable for establishing the background quantity of a supply, because a meaningful comparison to a replacement supply cannot be made.

Because the PDT does not require entry to the well bore, liability concerns from well damage are less. The test also provides a means of testing water supplies not physically accessible for water-level measurements. A disadvantage of the test is that the PDT takes longer to perform than a short-duration specific capacity test. Because of the on-and-off-cycles, the PDT will not adequately test the well if its duration is shortened to less than 4 hours. The PDT should only be allowed where borehole access requires an extraordinary effort.

Step-Drawdown

As part of a step-drawdown test, the well is pumped at several successively higher pumping rates and the drawdown for each rate, or "step", is recorded. The entire test is usually conducted during one day. To simplify calculations, it is recommended that the pumping rates used for each step are the same and that the pumped down water level be allowed to recover to the static level between each step test. Ideally, four or five pumping steps (including recovery) are conducted, each lasting one to two hours.

A step-drawdown test can be used to determine the specific capacity of the well at various discharge rates. This information is then used to determine optimum discharge rates of the well. The step-drawdown test provides three types of useful information: the relationship between discharge and drawdown for a particular well; the transmissivity of the aquifer at the well location; and, at times, whether or not the well was properly designed and developed.

The basic formula in the step-drawdown test is:

$s = BQ + CQ^P$ where:

s = drawdown in well

B = head loss coefficient due to laminar flow, usually assumed to be caused by the aquifer

C = head loss coefficient for turbulent flow, usually caused by flow into the bore hole and, if applicable, screen

P = exponent which indicates the severity of the turbulence, usually ranges from 1.5 to 3.5, with 2 being widely accepted

Q = discharge of the well

Quantity Tests for Springs –

The quantity of an undeveloped spring can be easily determined by measuring the discharge flow rate by some reliable method such as a calibrated container with a stop watch or a narrow notched weir.

Determining the quantity of water available from a developed spring can be more difficult. Measuring the overflow discharge of a developed spring is generally not an accurate measure of spring quantity. Frequently, springs are developed in such a way that water can both leave and enter the spring box through the bottom and sides, so that even very reliable springs may have little or no overflow from a reservoir. The quantity of a developed spring can be reliably measured directly from the overflow pipe, only if the spring is developed so that the entire flow of a spring is captured and piped into a watertight reservoir, such as a steel or concrete tank, and all flow to and from the tank is measured. Peak demand tests and specific capacity tests can sometimes be modified to test springs as long as the specific design components of the construction and spring containment structure is well known.