

# RECLAMATION

*Managing Water in the West*

## Water Operation and Maintenance Bulletin

No. 221



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Design and Construction of Access Features  
for Toe Drains



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***Cover photograph***     *View looking downstream along a toe drain installation at the location of an inspection well under construction. The first riser and impervious fill (underground dam) are shown. Outer envelope sand filter is shown beyond the impervious fill. The rungs on the right side of the riser are temporary and used for access into the well during construction. They are later removed and replaced with a safety ladder.*

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# Design and Construction of Access Features for Toe Drains<sup>1</sup>

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## Introduction

Many existing embankment dam toe drains do not include adequate access features and, unfortunately, some new systems are still being designed without these features.

Modern best practice for the design of toe drains in embankment dams includes access for inspection and maintenance in order to assure the drain system and dam are functioning as intended. Inspection is typically achieved with video cameras, and maintenance can be performed by cleaning with jetting tools. In addition to inspection and maintenance, access to drain systems is also used to measure flow and trap sediment in the interest of monitoring performance over time.

Access to drain systems can be separated into two categories: inspection wells and clean outs. Inspection wells provide entry by personnel, contain flow measurement instrumentation, and allow inspection at the junction of several drains. Cleanouts provide indirect access to the drain system by remote video and jetting equipment and are much less expensive than inspection wells.

This paper presents specific design elements for inspection wells (IW), including precast concrete products for the risers, considerations for the base slab, and cylinder size. Interior design elements include doors, ladders, landings, lighting, and ventilation. Instrumentation design includes selection of weir or flume, energy dissipation, and sediment traps. Outside of the well, design of a barrier (underground dam) to force all water through the well is described.

Two types of cleanouts are described. The first is the “end cleanout” or “end access,” which consists of transition of the drain pipe to the ground surface using 22.5° fittings. The second, lateral cleanout, is located along drain lines utilizing a “Y” fitting and transition to the ground surface.

Example designs and case histories of several types of inspection wells and cleanouts are presented.

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<sup>1</sup> This paper was presented at the 2007 Association of State Dam Safety Officials Annual Conference (ASDSO), Austin, Texas, September 9–13, 2007.

## Purpose of Access Features

As part of a comprehensive dam safety inspection program, toe drains should be routinely examined. Uncertainty exists about seepage conditions and drain performance for many existing dams since the drains cannot be accessed or examined. An existing dam may exhibit poor performance in the form of artesian pressure, boils, sinkholes, etc. The engineer may wonder how the drain is performing. Is material being moved, has the pipe collapsed, is it broken, have the joints separated? Without access, these questions will go unanswered. If foundation soil is moving into a drain pipe, this can lead to further piping and potential failure of the dam.

For redundancy, pipe segments should be accessible from both ends. Due to limitations of video examination equipment and cleaning tools, access points should not be more than 1,000 feet apart for the best conditions. Less desirable conditions such as steep grades and numerous turns should have shorter access point spacing.

Access points can also be used for sediment traps and flow measurement points. Sediment traps are used to detect whether or not soil is moving into the drain. As described later, when sediment laden flow enters the trap, the flow velocity reduces, allowing the sediment to drop out of the flow. Flow measurements are used to discern whether the seepage performance of the dam is changing with time. These measurements should be taken and recorded on a regular basis as part of the dam monitoring program. Comparing data for equivalent loading (reservoir level) will indicate whether or not the performance is constant through time.

Location of access points is usually determined by foundation conditions, topography, outfall location, change in drain pipe size, constraints of existing infrastructure, and the length limits described above. Once the site has been categorized into geologic units, toe drain segments can be constructed in these units with the segments defined by the access points. An example is shown in figure 1. Since a larger amount of seepage would be expected through the alluvium than the till, the measurement points are arranged to monitor the flow from each respective unit. If a single measurement point were used for each abutment and flow readings changed with time, it would be unknown which portion of the drain was experiencing the change.

## Types of Access Features

Inspection wells provide all the features described above while joining two drain segments as illustrated in figure 1. They are the most costly of the ways to access a toe drain, with prices ranging from \$50,000 for a shallow, small diameter well to

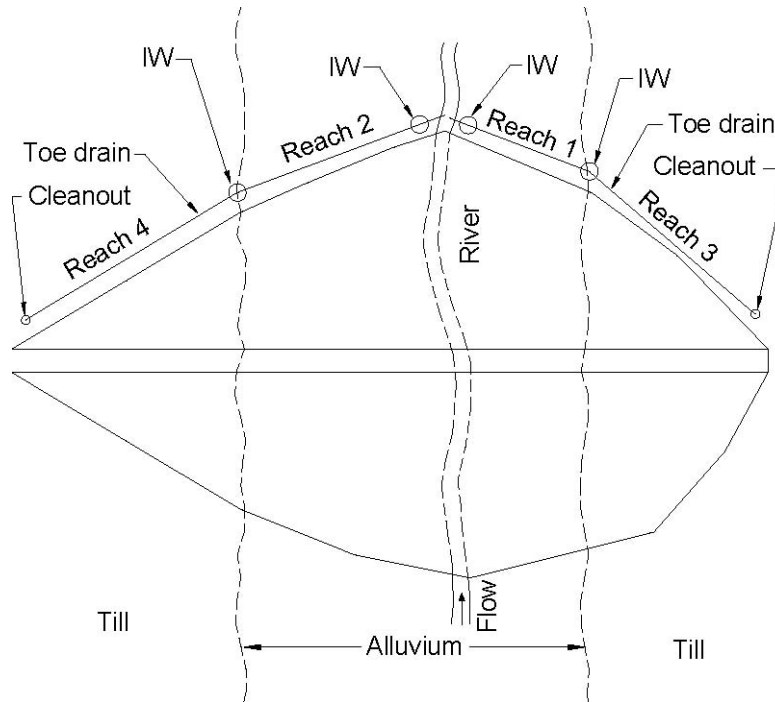


Figure 1.—Access layout plan for a simple dam.

\$75,000 for deeper, larger diameter wells with mechanical ventilation and lighting. Access at the upstream end (relative to flow in the pipe) of a toe drain can be achieved by an end access, which is less costly than an IW. These features are commonly referred to as cleanouts, end access points, or end sweeps. In a similar manner, lateral access points can be used for intermediate access between IWs and end access points for very long drain segments. Sedimentation traps and flow measurement are not possible with lateral sweeps.

## Inspection Wells

The first component of an inspection well is the square base slab as shown in figure 2. Reinforced concrete is used, which can be either cast in place or a pre-cast product. Slabs larger than 14 feet may be difficult to transport over the road, so cast in place construction would have to be used. The size of the base is dependent on the size of the risers described in the next section. The base should extend beyond the outside diameter of the riser by no less than 6 inches (e.g., a 10-foot-diameter riser would have an 11-foot-square base slab). Bearing capacity of the inspection well foundation is not an issue since the weight of the soil replaced by the volume of the IW results in a condition similar to a floating foundation.

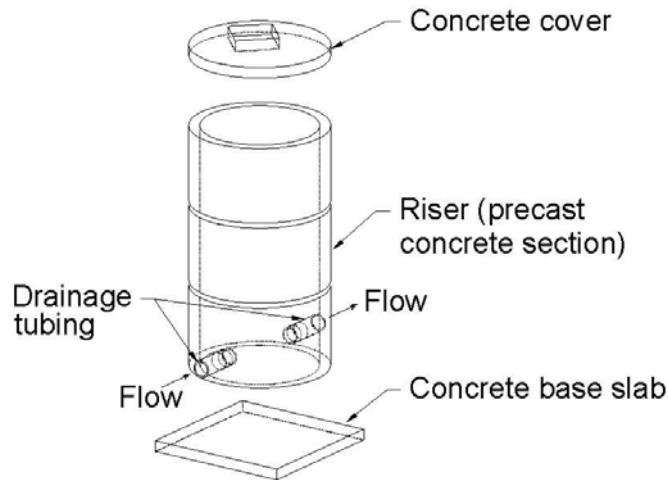


Figure 2.—Isometric view of inspection well basic components.

The next components of the IW are the risers as shown on figure 2. The risers are pre-cast concrete rings (sewer pipe), 8, 10, or 12 feet in diameter. The size (diameter) of the riser is dependent on the expected flow through the well. Larger flows require a larger structure in order to accommodate the sediment trap and flow measurement device. Smaller flows can be measured by a weir, while larger flows will require a flume which, itself, will require a larger diameter well. The height of the IW is dependent on the invert elevation of the drain and the final grade of the ground surface. The riser should be set no less than one foot above final grade. When the ground surface is sloping, the IW should be no less than 1 foot above the highest point on the slope/riser contact. Risers typically come in 4 to 8 foot lengths, and this determines the number of risers needed. Typically, the pre-cast manufacturer will determine the length of the individual segments given the total height required. Risers should be built in accordance with ASTM C 478. Interlocking joints should be used between risers, and these joints should be sealed for water tightness meeting the requirements of ASTM C 920 (Sikaflex or equivalent). The bottom face of the bottom riser and the top face of the top riser should have flat surfaces as butt joints are used against the base and lid. These surfaces should also be sealed. Finally, a precast concrete lid is placed on top of the IW. Lid thickness is determined by the precast manufacturer and dependent on the well diameter and prescribed loads. Typically, in dam applications, vehicle loading is not required, but if the IW is situated such that it is possible that a vehicle could pass over the IW, intentionally or not, HS-20 loading can be specified. An off-the-shelf flush mount door (sidewalk hatch) is cast into the lid at the time of fabrication (Bilco or equivalent). Doors are typically 5 to 8 feet square, pneumatically operated, and come in one and two leaf models. The doors should be lockable from the outside but escapable from the inside. A typical door is shown in figure 3.

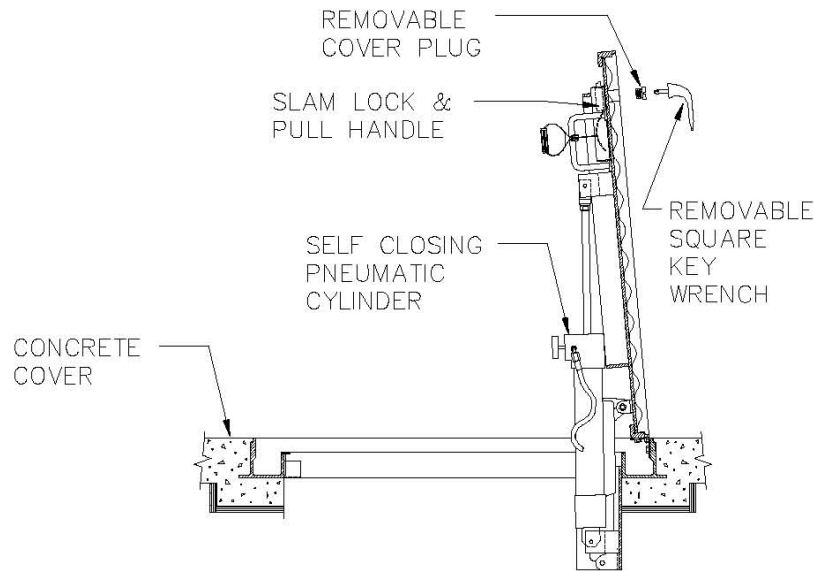


Figure 3.—Typical inspection well door.

The bottom of the inspection well is separated into several bays. Divider walls are used to make these bays. The number of bays depends on the number of inlet and outlet pipes and the required flow measurements. The walls should be constructed out of metal, which will offer flexibility if changes are required at a later date. The upstream bay serves as the sediment trap and will also act as a quieting pool prior to flow passing through the weir or flume. Depending on the amount of flow entering this bay, a baffle may be needed to aid in quieting the flow. The bottom of this bay should be painted white with water proof paint to aid in the detection of sediment in the bottom of the bay. The flow then passes through the measurement device consisting of a flume or weir. While weirs are more economical and require less space, they can be difficult to meet the approach requirements for quiet flow. Flumes typically are a better flow measurement scheme for inspection wells since they produce more consistent readings through a larger flow range. Downstream of the weir/flume is the discharge bay that has no special requirements. As mentioned previously, the number of inlet and outlet pipes is dependent on the overall drain system layout. The simplest arrangement is one pipe in and one pipe out. Figure 4 illustrates the basic components for the bottom of an IW.

In order for the measurement device to work, a head drop is required through the IW. The drop should be no less than one pipe diameter of the largest pipe penetrating the well. As an example, the invert of a 12-inch inlet pipe should be at least 12 inches higher than the invert of a 12-inch outlet pipe. The invert of the measurement device should be set above the spring line of the discharge pipe, assuming the discharge pipe is not expected to flow full. Note that this



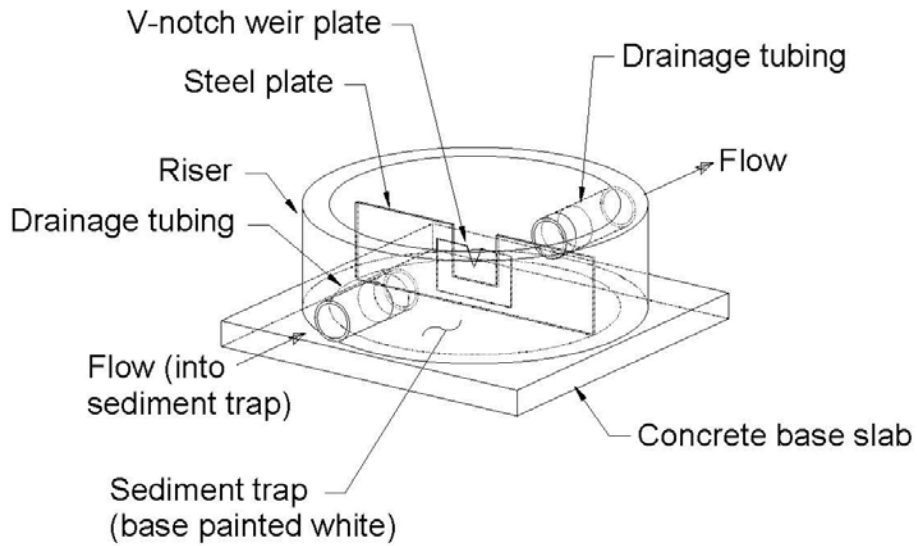


Figure 4.—Components in the bottom of a typical inspection well. Optional baffle at the end of the inlet pipe is not shown.

arrangement can lead to “flooding” of the inlet pipe (the device backs up flow into the inlet pipe). To avoid this condition, the inlet pipe would have to be set above the expected flow depth through the device. The designer should be aware that to meet the head drop requirements through the inspection well, the grade of the inlet and outlet drain segments may differ by more than a foot. That is, it is not possible to “insert” the IW into a constant grade invert from one segment to the next. Large changes in elevation through IWs can be problematic at sites with little topographic relief and flooding of the inlet or discharge pipe might not be avoidable at all times.

Access in and out of the IW is by ladder. To prevent fall-type injuries, a safety ladder (safety rail) or landings should be used. Landings are constructed from metal grating at intervals prescribed by the applicable safety standard. Note that adequate free space should be left at the landings so equipment in the bottom of the well can be removed and replaced. At the top of the ladder an extendable grab bar (Ladder Up or equivalent) is required to assist workers in passing through the door. Figure 5 illustrates a typical ladder and associated safety features.

Ventilation for the IW can be passive or active, with the passive system being less costly. Client or safety requirements will dictate which type of system to use. The passive system consists of a vent tube, typically 8-inch diameter from near the bottom of the well, through the lid, and terminated with a 180° bend. This arrangement is also known as a J-vent due to its shape. Note that when passive systems are used, air monitoring is required since IWs are considered confined space.

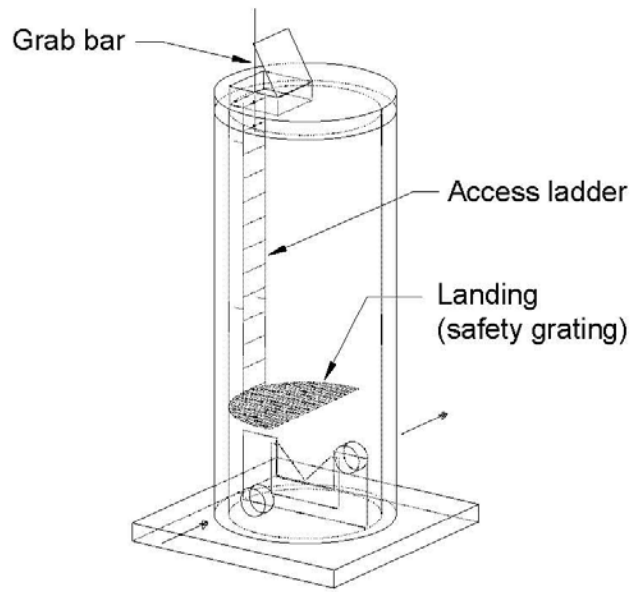


Figure 5.—Typical ladder and associated safety features.

The active type of ventilation has the same J-vent arrangement but with an inline fan added into the pipe near the bottom of the IW. Details of sizing the fan and on/off switching to the door are beyond the scope of this paper. A typical J-vent is shown in figure 6.

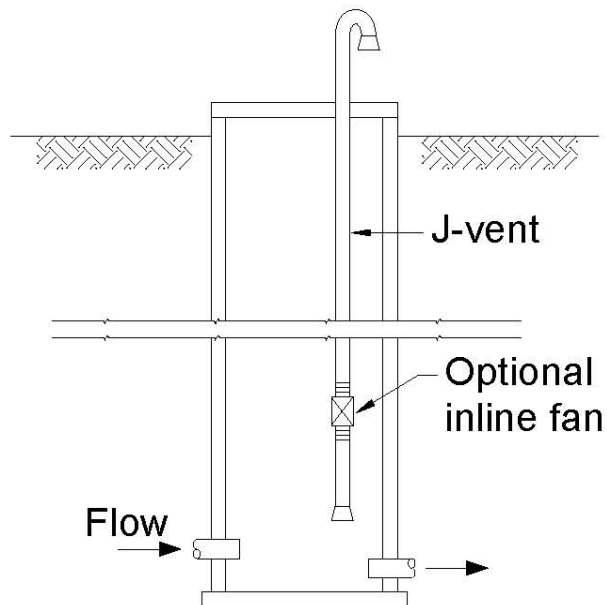


Figure 6.—Typical inspection well ventilation.

Electrical power is an optional feature for IWs. If active ventilation is needed, it will be required. When power is utilized, lighting can be added to the interior of the well as well as power outlets for power tools, etc.

Outside of the IW, special attention to the backfill is required. If the backfill arrangement around the toe drain (filter and gravel envelope) were duplicated around the IW, this would allow flow in the filter and drain (flow parallel to the toe drain alignment) to not enter the pipe and bypass the flow measurement device. For this reason, an “underground dam” is used to force water into the pipe and through the measurement device. The dam consists of finer grain material that encapsulates the IW. Nonperforated pipe is used through the dam backfill. Figure 7 illustrates this arrangement.

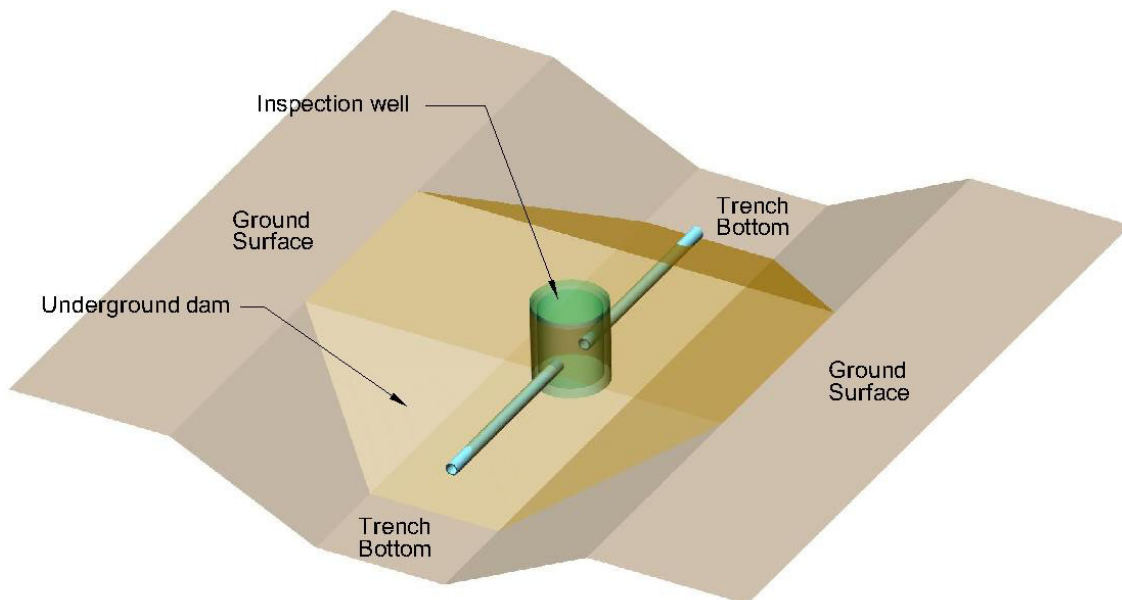


Figure 7.—Isometric view of an underground dam around an IW.

## **End Access**

Access to the end of a drain system can be made by bringing the drainage pipe to the ground surface (also known as a sweep). This can be done by a series of off-the-shelf fittings. For a pipe exiting the ground at a 45° angle, two 22.5° fittings can be used. Angles greater than 22.5° should not be used due to difficulty in getting cameras and cleaning tools past these sharper bends. At the connection between the drain pipe and sweep, the pipe should transition from perforated to nonperforated since the sweep will be backfilled with finer grained material. This

material acts as a barrier to prevent surface water from entering the drain system along the sweep, similar to impervious caps that are placed over toe drains. Near the ground surface, the drainage pipe should be protected, typically with a CMP pipe. The drain pipe is centered inside the CMP pipe with granular backfill. This protective shroud is embedded in the ground about 10 feet and does not require concrete backfill. A lockable lid is fitted to the CMP pipe to protect access into the drain system. The components of these features are illustrated in figure 8.

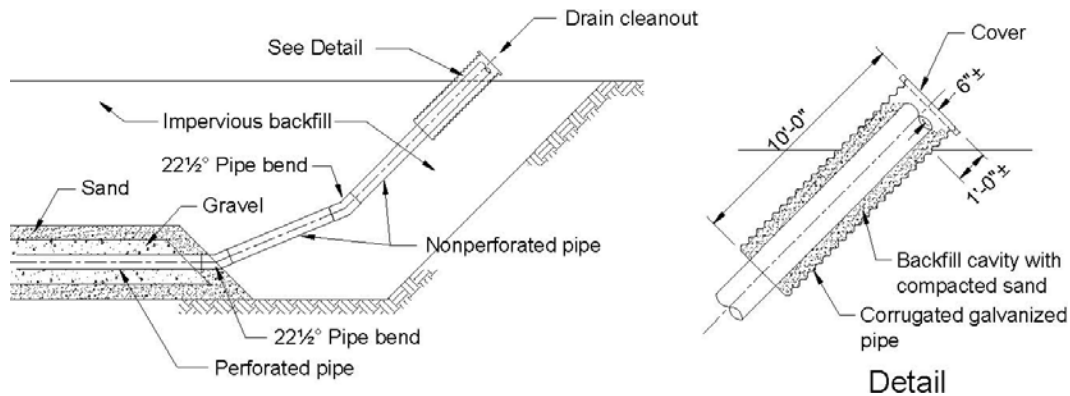


Figure 8.—Toe drain end access features.

## Lateral Access

Similar to the end access feature described above, access to long drain segments can be achieved by adding a lateral access. This type of access includes a “Y” fitting inserted into the main toe drain line that only allows one-way access. A short piece of nonperforated pipe is installed into the lateral portion of the “Y.” The “Y” fitting adjusts the alignment in the horizontal direction. Next, a pipe bend is added to adjust the alignment in the vertical direction. Another short nonperforated piece of pipe is added followed by another pipe bend. These two pipe bends will bring the pipe out of the ground in the vertical plane at a 45° angle. The access is then finished the same as the detail shown in figure 8. An isometric view of a typical lateral access and its components is shown in figure 9.

## Case History Installations

This section includes photographs of several toe drain installations that are typical of those described in this paper. Figure 10 shows the interior of a simple shallow

inspection well constructed at McKay Dam in 1994. Figure 11 shows a more elaborate inspection well at a greater depth constructed at Keechelus Dam in 2002. Figure 12 shows an inspection well being constructed along a toe drain alignment at Keechelus Dam. Figure 13 illustrates a completed IW at Ochoco Dam added during modification to the existing drain system in 1998. Figure 14 shows the entry features of a typical inspection well. Figure 15 shows a painted sediment trap in a typical inspection well. Figure 16 shows a completed IW with a number of additional features at Keechelus Dam. Figures 17 and 18 illustrate a number of access features associated with the right abutment drainage system at Ochoco Dam. Figure 19 is a close up view of a typical terminal cleanout installation. Additional details of the photographs are included in the captions of each photo.

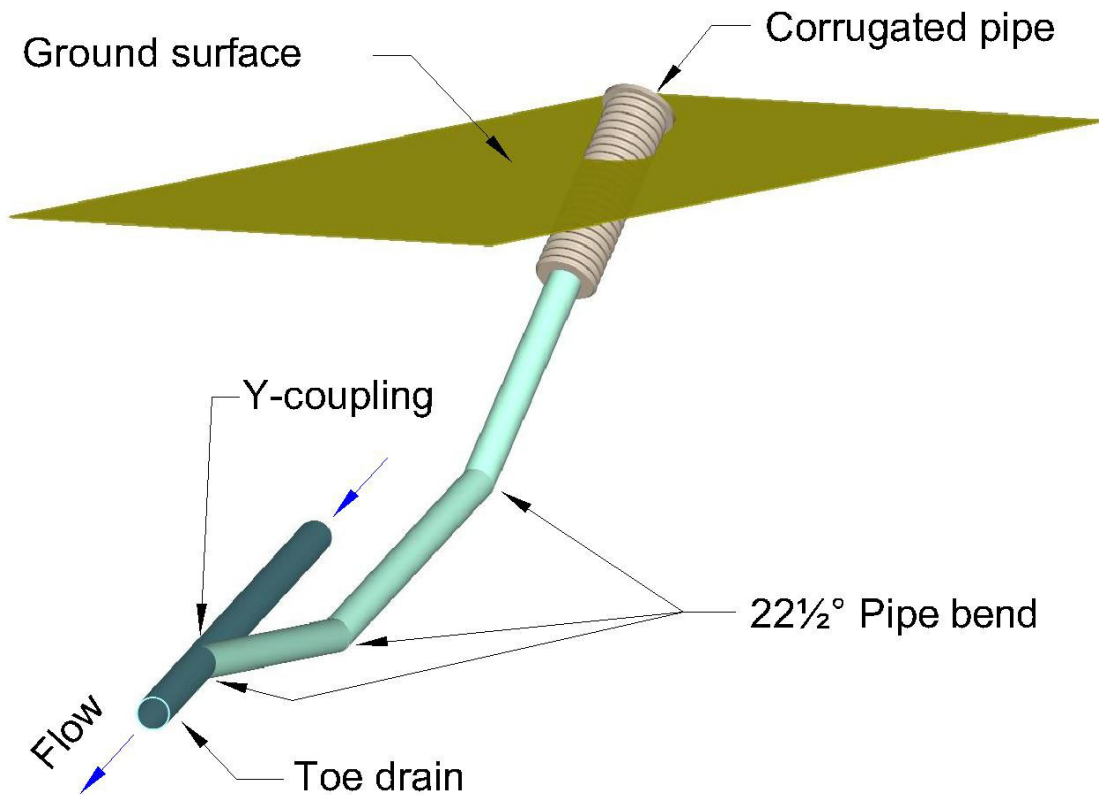


Figure 9.—Isometric view of a typical lateral access.

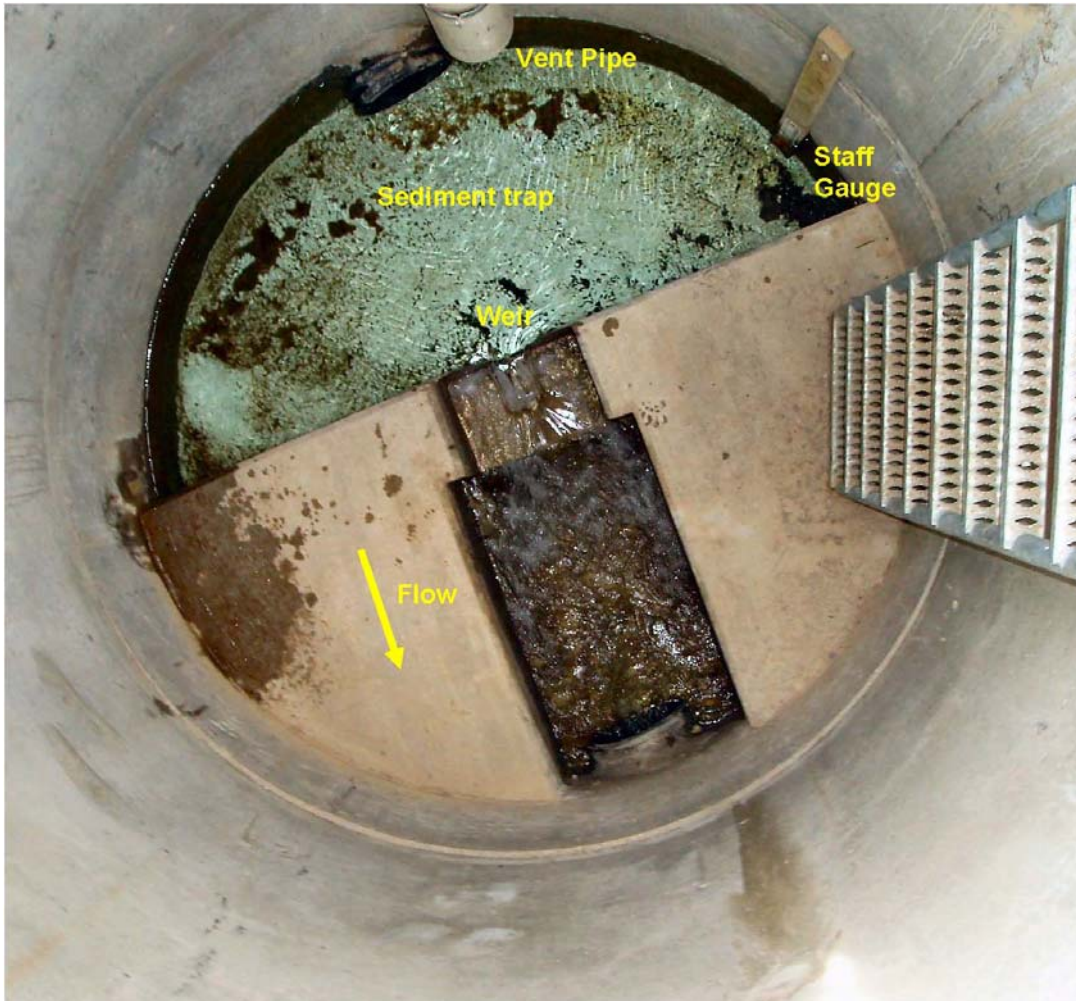


Figure 10.—View into a typical simple (no electrical or active ventilation) inspection well. Material in the sediment trap is algae, not sediment. This well utilized a concrete landing where the weir plate was mounted. Use of concrete backfill is no longer recommended due to the difficulty of changing out measurement devices at a later date.



Figure 11.—View into a more sophisticated inspection well showing a landing for personnel and a flume. This well utilized aluminum brackets and a divider wall so the flume can be changed out.

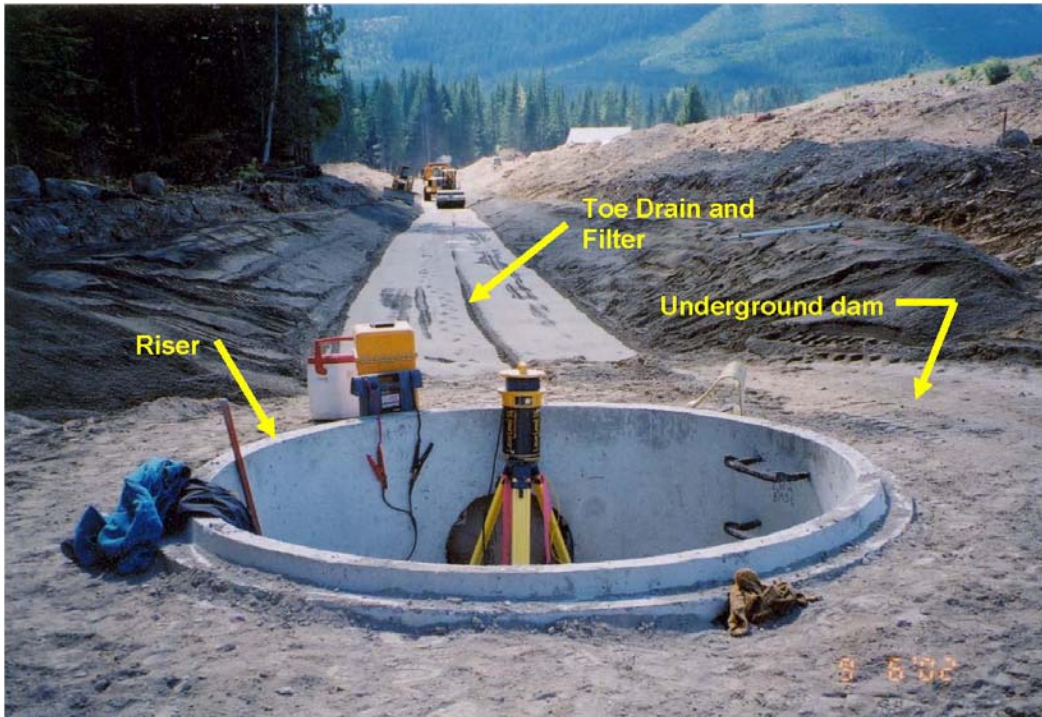


Figure 12.—View looking downstream along a toe drain installation at the location of an inspection well under construction. The first riser and impervious fill (underground dam) are shown. Outer envelope sand filter is shown beyond the impervious fill. The rungs on the right side of the riser are temporary and used for access into the well during construction; they are later removed and replaced with a safety ladder.





Figure 13.—Completed inspection well in the downstream face of a dam. Note that the upstream side of the inspection well is several feet higher than the slope. Also shown is a single leaf door for access. The individual to the right of the door is outfitted with a safety harness that connects to the safety rail on the ladder. This well installation utilized a safety rail along the ladder instead of intermittent landings along the ladder. This well is about 30 feet deep due to the overlying embankment fill.



Figure 14.—Typical inspection well door, ladder, and grab bar. Also shown (right corner of door frame) is a switch that automatically turns on the ventilation when the door is opened. The grab bar is in the “up” position and is lowered in order to close the door. Also note the name of the well is on the inside of the door for protection. Nameplates posted on the exterior of the well are subject to vandalism.



Figure 15.—View of a sediment trap in a typical inspection well. The bottom of the sediment trap is painted white so sediment is more easily detected. The photo shows a minor amount of sediment that discharged from the inlet pipe as well as material that fell out of the vent pipe shown in the upper left hand corner.



Figure 16.—View of the exterior of an inspection well. This well has a number of special features due to the local site conditions. The well was finished 10 feet above the ground surface due to the large amount of snow at this site. A ladder is provided on the outside of the well for access when snow is not present. A chain railing is provided on top of the well to prevent falls from the top of the structure. Three hazard markers were placed above the chain rail so snowmobiles would not hit the rail covered by snow. The well is also stained a dark gray to aid snowmelt on and around the structure. This well also has electrical power, active ventilation, and automated instrumentation.

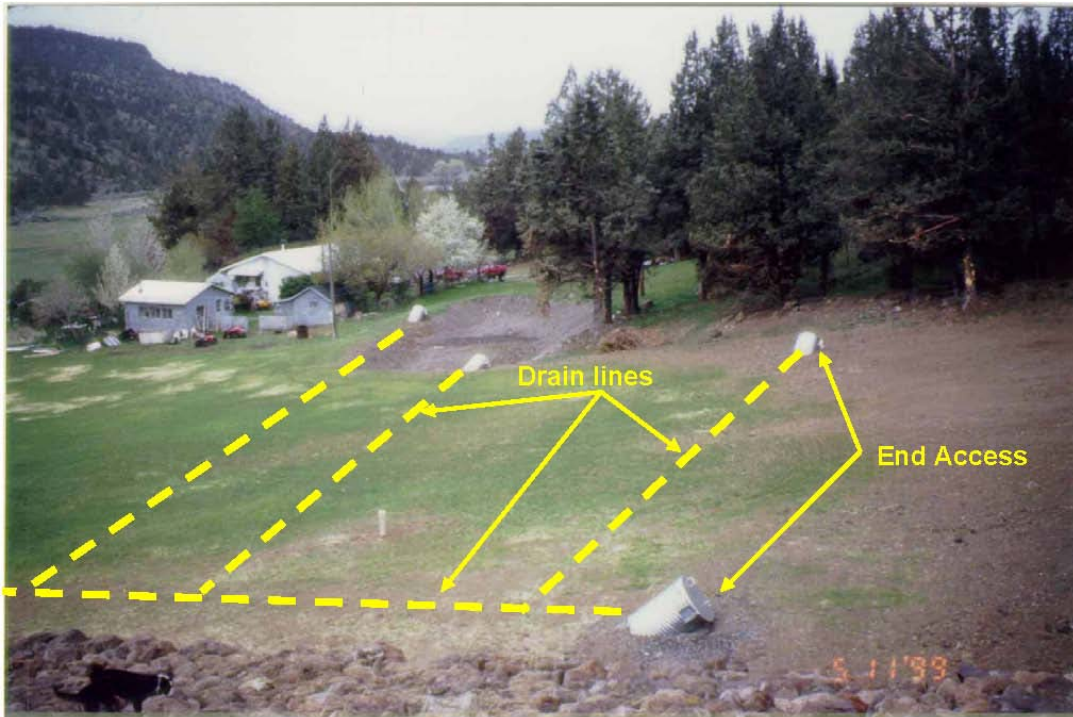


Figure 17.—View looking downstream from the right abutment toe of Ochoco Dam of typical end access features. These four access features are at the end of a network of four drain segments. The PVC riser in the lower left quadrant of the photograph is a piezometer installation that monitors this drain field. Also see figure 18.

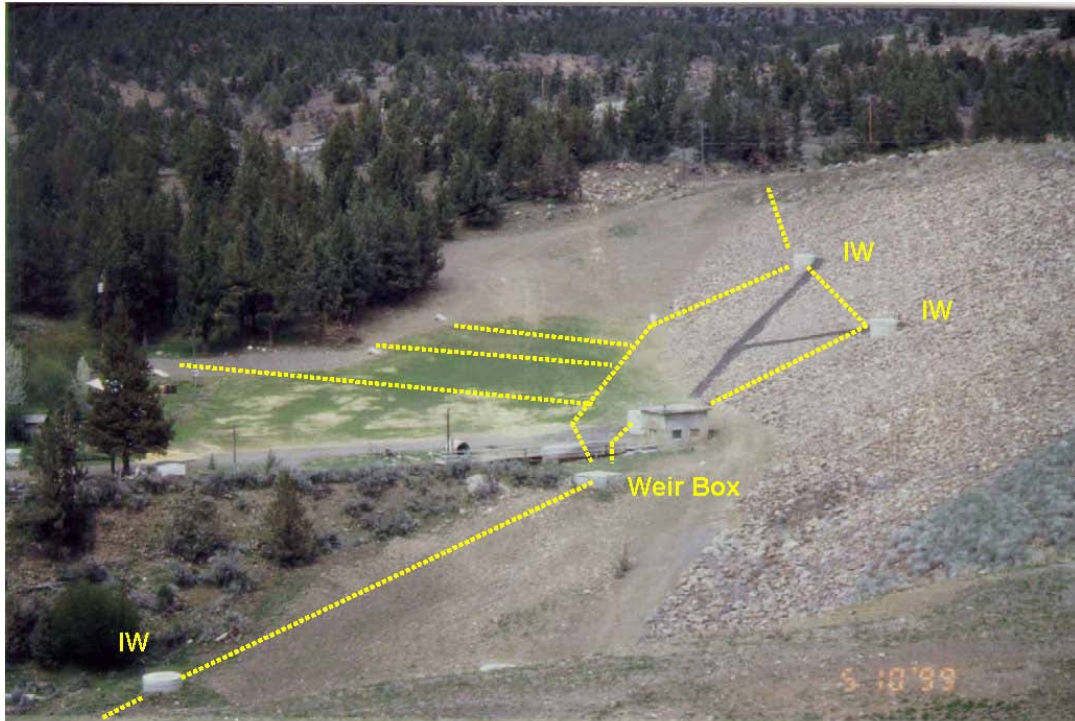


Figure 18.—View looking at toe drain access features on the downstream side of the right abutment of Ochoco Dam. The Y-shaped features on the face of the dam are footpaths to the inspection wells.



Figure 19.—Typical access point showing protective CMP pipe, lid, and lock.

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## Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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