

# INQUIP

ASSOCIATES, INC.

GEOTECHNICAL CONTRACTOR



**INQUIP ASSOCIATES, INC. is a geotechnical contractor performing work throughout the US, Canada and Latin America.**

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**A list of recently completed projects  
can be provided upon request  
and for specific information  
please contact us at [info@inquip.com](mailto:info@inquip.com)**



Terminal Island, CA

## INQUIP'S TIMELINE

### 1950

First slurry trench in the world:  
Terminal Island Project  
(by Inquip's predecessor)

### 1977

Inquip incorporates

### 1987

First cement-bentonite cutoff for  
the US Army Corps of Engineers

### 1991

First soil stabilization with large  
diameter auger on a Superfund site

### 1994

First industrial installation of  
reactive permeable barriers

### 1996

Installation of first impermeable  
reactive barrier

### 2002

Inquip remains a leader in  
geotechnical contracting

**I****NQUIP** Associates, Inc., a speciality geotechnical contractor, traces its roots to the beginning of slurry trench technology in 1950 on the Terminal Island Project. This was the first trench ever excavated under bentonite slurry for an industrial application. INQUIP was founded in 1977 to continue and further develop the activity of the groundwater control division of Industrial Engineering and Equipment Corporation, founded by Mr. Charles H. Toll, one of the pioneers in the development of the slurry trench method. Mr. Toll was instrumental in the promotion and construction of economical underground seepage barriers, including the Terminal Island Project.

**INQUIP's** main activity from its creation to the early eighties was related to the installation of soil-bentonite cutoff barriers and liners. In order to utilize the wide experience of its management team and to more efficiently satisfy the needs of its clients, INQUIP expanded its product line to other geotechnical techniques. This carefully controlled growth process is expected to continue in the future. Many of the speciality techniques offered by INQUIP have applications for the control and mitigation of pollution associated with landfills and waste management facilities.

**INQUIP** offers capabilities for the installation of:

- All types of underground seepage barriers
- Cast-in-place or precast slurry walls for support of excavations
- Deep soil mixing
- Leachate collection systems
- Liners
- Pressure and jet grouting
- Reactive Barriers

**INQUIP** has experience with federal and state regulations governing health and safety for remediation work on hazardous and toxic sites.

**INQUIP's** major goal is to provide excellent service to its clients and to maintain a high level of quality construction. Only qualified, technically capable field managers oversee site construction. The company management strongly believes that close understanding and cooperation with the Owner and it's Engineer are essential in resolving technical difficulties and achieving high performance. INQUIP looks forward to working closely with its clients for the successful completion of their projects.

If you have an immediate or future application for any of our specialty construction techniques, please contact us. If you need additional information please e-mail us at: [info@inquip.com](mailto:info@inquip.com), or call one of our offices listed on the back cover or toll free at 1-888-5INQUIP (546-7847).

# SLURRY TRENCH METHOD OF EXCAVATION

**BENTONITE SLURRY** has been used to stabilize trenches under excavation since 1950. This technique, referred to as the slurry trench method, has enabled excavation of deep, narrow, vertical trenches in soils which cannot otherwise stand unsupported without using shoring and/or dewatering, and particularly in soils beneath the groundwater table. During excavation, the vertical walls are supported by keeping the trench filled with bentonite slurry. The hydrostatic thrust of the slurry is the primary stabilizing force supporting the saturated soils. Recently, slurry fabricated with biodegradable polymers instead of bentonite has also been used to stabilize trenches for specific applications.

The slurry trench method of excavation is used for the following types of construction:

- Soil-bentonite (S-B) cutoff walls
- Soil-cement-bentonite (S-C-B) cutoff walls
- Cement-bentonite (C-B) cutoff walls
- Cast-in-place concrete slurry walls
- Precast concrete slurry walls
- Bio-Polymer (B-P) drainage or recharge trenches
- Reactive permeable and impermeable barriers

INQUIP specializes in construction using all the above techniques throughout the United States and Canada, and occasionally internationally, both as a contractor and subcontractor. In some cases INQUIP works directly with the general contractor, owner or engineer by providing expertise and specialized equipment.

INQUIP is available to discuss your project and to supply for your consideration specific application information and budget costs. Please contact any of our regional offices for more details.



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**INQUIP** has considerable experience working on hazardous and toxic waste sites. These projects often involve the remediation or closure of the sites using one or more of our specialty geotechnical techniques. Slurry cutoff walls are often used to contain contaminated groundwater and prevent the horizontal migration of leachates. Collection/extraction trenches constructed by the Bio-Polymer technique are useful to extract leachate or prevent the infiltration of clean groundwater. Other INQUIP techniques such as grouting, HDPE curtain walls, stabilization and permeable reactive barriers have been successfully used to contain or eliminate pollution.

Proper planning and engineering are a requirement on all pollution containment projects. The chemistry of the leachate may effect the bentonite slurry and is normally tested prior to construction for compatibility and application rate. Groundwater flow may change after the installation of a slurry wall, so groundwater modeling is often used to evaluate groundwater control schemes. With proper planning, containment is often the most economical and lowest risk approach for pollution control.

Combinations of geotechnical techniques are commonly used to minimize costs and optimize the construction of a pollution containment. The combination of a slurry wall with groundwater wells or collection trenches, capped with a barrier membrane, is often the most acceptable and economical method for groundwater containment. When space is limited, groundwater barriers and extraction can be combined in a single trench fitted with a HDPE curtain wall, aggregate, and extraction wells or piping. On difficult sites, problem soils or sludges may be stabilized to reduce the generation of leachates, and then contained with a slurry wall and less extensive groundwater controls.

INQUIP specializes in creating innovative and cost-effective systems and combinations of techniques for pollution containment.

INQUIP is available to discuss your project and to provide for your consideration specific constructability information and budget costs. Please contact any of our regional offices for more information.



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**INQUIP ASSOCIATES, INC.** is committed to conducting all phases of its projects with a consistently high level of quality and reliability. Utilization of proven construction methods and attention to consistent and systematic quality control testing will allow Inquip to achieve these goals. INQUIP's Managers and Site Superintendents review all quality control data on a daily basis to ensure that the work is performed to the specified standards.

The following procedures for controlling activities related to inspection, testing, and noncompliance conditions are briefly outlined below.

**Inspection:** Preparatory, initial, and follow-up inspections are performed by the Site Superintendent or Quality Control Manager, to verify compliance with the plans and specifications. These inspections include visually examining the material, equipment, workmanship, and test records for all aspects of the project. Results of these inspections are noted on daily quality control sheets.

**Testing:** Tests are performed as specified in the approved Project Specifications and appropriate contract documents. The Site Superintendent, or one of his staff fully qualified by experience to perform tests, performs all field tests. Independent testing laboratories approved by the Engineer provide laboratory testing.

The Site Superintendent will verify that:

- the testing procedures comply with contract requirements
- the testing equipment is available and complies with testing standards
- the testing instruments are properly calibrated
- recording forms including all the test documentation requirements have been prepared

**Noncompliance:** The Site Superintendent will notify the Project Manager of any noncompliance with the contract requirements. The cause of the non-compliance will be determined, and corrective action in the system will be made to preclude recurrence of noncompliance.

**Reporting Procedures:** INQUIP uses a daily on-site reporting system which documents the quality control testing conducted and involves the Client's Engineer in all QC/QA observations. The Quality Control form is filled out each day by the Site Superintendent and reviewed with the Engineer and INQUIP's Project Manager for compliance. These forms are filled out in triplicate with one copy to the Engineer, one to the Project Manager, and one left on site at all times.



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# SOIL-BENTONITE CUTOFF WALL

**SOIL-BENTONITE (S-B)** cutoff walls are excavated in a continuous manner under bentonite slurry. The cutoff is keyed in most cases into an impervious stratum or bedrock. Impervious backfill is placed into the trench, displacing the slurry to form the completed cutoff. The backfill includes soils excavated from the trench and/or borrow materials. These materials are blended with slurry to yield a homogeneous mixture with a consistency corresponding to a 3 to 6 inch slump. The low permeability of the cutoff results primarily from the native clay in the backfill mixture. If not enough clay is present, dry bentonite, or borrow finer, are added to the mixture. Secondly, low permeability results, also from the development of a bentonite "filter cake" on each wall of the trench and from slurry entering the voids of the formation adjacent to the trench.

A key factor in selecting the S-B cutoff over other alternate systems is economics. In many cases this method offers substantial savings over conventional systems such as sheet piling, grouting, clay core trenches, well points or reservoir liners. Sometimes the S-B cutoff is combined with other systems to obtain optimum efficiency. S-B cutoffs are most economical where excavation depth is in the range of standard construction equipment, such as backhoes (including those modified to reach depths in excess of 80 feet), and when the excavated material can be used to backfill the trench. They have proven to be effective seepage barriers. Permeabilities can be achieved from  $1 \times 10^{-6}$  to less than  $1 \times 10^{-7}$  cm per sec.

S-B cutoff walls have been used for many years as permanent cutoffs through and below dams and as temporary cutoffs to minimize the flow of groundwater into large excavations. They are also used for containment at hazardous and toxic waste sites to minimize the outward migration of leachate or the inflow of groundwater when leachate collection or extraction systems are provided as part of the remediation program.



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# CEMENT-BENTONITE CUT-OFF WALL

**CEMENT-BENTONITE** (C-B) slurry trench cutoff walls utilize a bentonite slurry containing cement during the excavation phase to stabilize the trench. After completion of the excavation, the cement causes the slurry to harden to a strength comparable to that of a stiff clay, thereby eliminating the need for trench backfilling. The cement bentonite slurry contains no aggregate other than some suspended soil particles from the excavation process. The bentonite provides the media to keep the cement suspension until initial set occurs.

Strength and plasticity of the hardened cement-bentonite slurry will vary, depending mostly on the cement/water ratio and the type of cement, with higher strengths having lower plasticity. Mixes can be designed to achieve unconfined strength from 50 psi to well over 20 psi at 28 days.

Additives, including setting retarders, can be incorporated in the mixture to achieve certain operating characteristics, or for economy. For example, flyash is sometimes used as a filler to increase the density of the slurry and to reduce the cement content. The permeability of C-B cutoff walls depends on the proportions of bentonite, cement and flyash used in the mix. The coefficient of permeability for such mixes is normally in the range of  $1 \times 10^{-6}$  cm/sec. INQUIP has developed some proprietary mixes with lower permeabilities if required.

Some of the primary reasons for selecting C-B cutoff walls instead of soil-bentonite cutoff walls are:

- Design requirement for strength of the backfill.

- Potential for trench instability due to soft and loose soil zones or adjacent surcharges. The panel method of excavation can be employed where these conditions are critical.
- Site conditions restricting the working area and preventing the preparation of the S-B backfill mixture alongside the trench.
- Unavailable or costly materials suitable for soil-bentonite backfill.

INQUIP has experience in the installation of C-B cutoff walls since 1977, and has access to advances in mix technology through license agreements, and research.



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**CONCRETE SLURRY WALLS** are slurry walls constructed to carry structural loading. These slurry walls are reinforced concrete structure, and used as retaining walls, basement walls, or as the walls of tunnels especially when groundwater presents a problem for construction. There are at least two kinds of structural walls: diaphragm (or cast-in-place) walls and precast walls. Concrete slurry walls are usually excavated under bentonite slurry in alternating panels. The length of the panel depends on site conditions and the length of the excavating tool, typically a slurry clam bucket. Special techniques are used to pursue the integrity and ----- of the joints between panels.

Diaphragm walls are the most common concrete slurry walls. After excavating a panel slurry, it must be "desanded" to remove excess sand that is suspended into the slurry filled panel. Next, prefabricated steel reinforcing or "rebar cages" are lowered to the panel. The rebar cages may also incorporate future structural or utility connections using "blockouts" that are pre-set in the wall. Next, the panel is filled with a high slump concrete through tremie pipes. After the primary panels are set, the secondary panels between the primary panels to complete the wall. Control of verticality and careful cleaning of the slurry is important to the quality of the seal between panels. Sometimes steel beams soldier piles) are used to better reinforce the connection between the primary and secondary panels. This is referred to as the "soldier pile tremie concrete" (SPTC) method. The appearance of the completed wall is a direct reflection of the soil excavation. In some cases, the surface of the wall can be covered with paint or shotcrete for a better visual effect.

Precast concrete slurry walls are built utilizing precast concrete panels, either reinforced or prestressed, which are inserted into slurry filled trenches. The precast elements are usually placed in a special C-B slurry to seal the joints. When settlement is critical, the bottom of the precast panel can be set into tremie concrete. The main advantage of the precast walls is the ability to have an architectural appearance of the completed wall.

Concrete slurry walls are often used as the walls for a variety of deep excavations where the space is intended to be permanently useable. Sometimes concrete slurry walls are used to accelerate the construction of large buildings using the "top-down" construction approach where the basement and the upper floor are constructed simultaneously after a concrete slurry wall is installed to support the basic structure. Also, the "cover and cut" construction developed in Europe, has enabled construction of underground structures in congested areas in a more expedient and efficient manner. With this method, cast-in-place or precast slurry walls are placed as the perimeter finished walls of the underground structure. The top cover is then poured on grade, leaving access openings through which the mass excavation under the top cover and between the slurry walls is performed. This method can minimize the disturbance of traffic and other above ground activities. Such activities are restored while the remaining work takes place below the cover slab. Concrete slurry walls are also used to support bridge abutments and other structures which must carry vertical loadings and horizontal earth loads.



# BIO-POLYMER DRAIN & RECHARGE TRENCHES

**THE BIO-POLYMER** slurry trenching method has been used on numerous polluted sites to reduce the cost of remediation. B-P trenches have been used to install pump and treat systems, air sparging trenches, groundwater collection and reinjection galleries and groundwater barriers. B-P drains also have uses in civil engineering including applications as toe or chimney drains for earthen dams, groundwater diversion trenches, and dewatering for slope stabilization.

The construction of complex drainage trenches (with multiple liners, pipes, and aggregate) can be made cost-effective with the bio-polymer trench technique; however, there are a number of construction parameters which must be considered. Light structures placed in a B-P trench must be weighted to sink into place through the slurry. Standard manufacturer's recommendations are available for placing some types of pipe under water or slurry. Fabrics must be designed not to trap the polymer in its weave. In general, needle punch fabrics are not recommended, especially when woven fabrics are better suited and inexpensive. HDPE liners can be placed in the trench using special frames, rollers, and other construction aids. However, it is not possible to weld joints under the slurry. Often a complex design can be simplified by substituting wells for sumps for man-holes. INQUIP is available to advise you with our experience using proven materials and installation methods. The B-P method has been used on numerous polluted sites to eliminate the need to pump contaminated ground water during installation of the called in trenches.



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# REACTIVE BARRIERS

Reactive Barriers are in-ground or insitu treatment systems that use specially engineered media or bio-organisms to clean contaminated soil and groundwater. Reactive barriers can be permeable or impermeable and may use such media as iron filings, carbon, peat moss, and bacteria. Reactive barriers can be used to treat a variety of organic compounds and heavy metal contamination. The significant advantage of reactive barriers is that they are effective without pumping, and above ground treatment facilities or off-site disposal.

The installation of reactive materials can be subdivided into two categories:

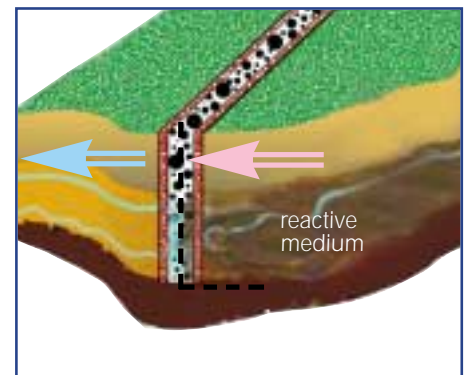
- one-time (buried) installations
- replaceable (cassette) installations.

The one-time installation is the case where the reactive media is simply buried in a trench. The primary design variable is the width of the reactive media required for the lifetime of the installation. Cassette installations require a permanent, underground structure such as a slotted tank, large diameter manhole, or similar receiving structure. The cassette system anticipates changing the reactive media or using a sequential treatment system. Piping, valves, and connections can be necessary with cassette systems so the installations are usually more complicated and costly.

The efficiency of reactive barrier installations can be significantly improved by controlling the flow of groundwater through the media. The funnel and gate installations often use slurry walls as wingwalls to funnel groundwater into a permeable reactive barrier or gate. Slurry walls can also be used to encircle contamination and permit a single vessel of permeable reactive media inside the containment to economically treat a controlled volume of groundwater. Special bacteria or high carbon flyash can be buried in a soil-bentonite slurry wall to create an impermeable reactive barrier.

The construction of reactive barriers can be made more economical using proven slurry trench and soil mixing methods. For permeable reactive barriers, the Bio-Polymer Drain Method can be used to install the media without the need for dewatering, sheeting or shoring. Injecting reactive media via soil mixing can treat soil contamination in one application without excavation or other invasive methods.

Inquip installed the first commercial permeable reactive barrier in 1994. This funnel and gate used cement-bentonite slurry walls to funnel groundwater through an iron filings gate on a congested industrial site in California. Inquip also installed the first commercial impermeable reactive barrier in 1996. A soil-bentonite slurry wall was installed with a high-carbon flyash additive in the backfill around a sludge landfill in Michigan.



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**INSITU SOIL MIXING** is a geotechnical technique that has numerous cost-effective applications for civil/infrastructure projects and environmental remediation. Typically, large mixing augers (3 to 12 ft diameter or more) or modified excavator tools are used to mix soil or sludge with a cement grout or other reagents to improve their properties or treat buried contamination. In situ soil mixing has the significant advantage of soil treatment without excavation, dewatering, or shoring. Soil mixing has the capability to go to depths greater than 100 ft. In situ soil stabilization has been used to build retaining walls, waterproof cutoff walls, and other foundation systems. In situ soil treatments can be used to volatilize or oxidize contaminants, stabilize sludges, mix and inject biological or reactive media, and to implement a wide variety of other in situ treatments.

The design of an in situ soil mixing project requires a comprehensive understanding of the site conditions and the goals of the construction. Usually, a pre-construction laboratory testing program is enacted to establish performance criteria, material requirements and budget costs. The testing may be used to determine workability, volume increase, strength, permeability, leachate chemistry or biological characteristics of the treated soils. A pilot program, or field test, can also be implemented, if required, to better determine the specifics of the project. A well-designed laboratory program and/or pilot program will usually provide an accurate prediction of project performance. INQUIP was one of the first contractors to use modified caisson-type equipment (12 ft diameter auger) for soil stabilization. INQUIP has also used modified excavators to stabilize slurries, soft soils and wastes. This line of work has been a natural extension of our normal slurry trench work mixing soils and grouts. Our staff has been involved in many large and innovative soil mixing projects including combinations of soil mixing with soil vapor extraction, zero valent metals, and biological agents. New concepts in soil mixing include the use of special soil mixing patterns, combinations of soil mixing with slurry walls and special mixing patterns to create a composite soil structure for creating retaining walls and foundations. Soil mixing is an extremely flexible geotechnical technique which has a variety of applications for contaminated soil treatment, as well as for soil improvement. In situ soil mixing continues to evolve and suggest new methods for soil improvement and treatments.



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Soil-Cement-Bentonite (S-C-B) cutoff walls are a more recent development in slurry trenching technology. S-C-B walls attempt to combine the low permeability of S-B walls in a material with a moderate strength. This technique may be advantageous on some sites since the trench spoil may be reused in the backfill, thus minimizing disposal volume. S-C-B walls may be divided into at least three types: S-C-B walls, Plastic concrete walls and walls constructed by insitu soil mixing which incorporate bentonite and cement. S-C-B walls are generally shallow (less than 50 ft deep) and constructed nearly identical to S-B walls but add cement as well as bentonite to the soils. Often the cement is added as a grout to aid in hydration and mixing. The amount of cement in S-C-B must be carefully controlled and limited to minimize the potential for creating cold joints on the long backfill slope. The most critical ingredient in S-C-B performance is the soil. With a clayey soil, a backfill with a permeability less than  $10^{-7}$  cm/sec may be created, but usually, native soils are mixed into the backfill and a more typical permeability is  $10^{-6}$  cm/sec. S-C-B walls usually have an unconfined compressive strength (UCS) of 5 to 250 psi.



When deeper trenches are required, plastic concrete may be the optimum choice for the slurry wall backfill. Plastic concrete is a weak concrete (UCS =500 to 1500 psi) with a small amount of bentonite, and may use sand and fly ash instead of soil for the base ingredient in the backfill. In deeper trenches, a more controllable and better engineered material is required to prevent the accumulation of sediments on the bottom of the trench and potentially windows at cold joints. Plastic concrete is often the material of choice in very deep cutoff walls or in cases where some consolidation of the adjacent soils is expected after the cutoff wall installation. Plastic concrete walls are usually constructed in alternating panels so the joints can be excavated between panels to create a strong seal. Plastic concrete ingredients are usually mixed in a ready mix plant or other similar equipment that can carefully control proportions.



Deep soil mixed (DSM) walls typically use a mixture of cement and bentonite as admixtures. DSM walls have similar strength and permeability to S-C-B slurry walls. With DSM walls all ingredients must be added as a fluid, so workability of the S-C-B grout is critical. The amount of admixture in DSM wall is also limited because of workability limitations of the grout. In DSM walls the grout also serves as the drilling fluid and therefore, soil resistance and spoil generation are also related to workability.