PVC-Free Pipe Purchasers' Report

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1) Introduction

This report provides a preliminary analysis of polyvinyl chloride (PVC) free pipe materials in construction. PVC reduction and elimination has become a priority for many government institutions, healthcare organizations, and design firms due to the serious environmental health impacts associated with the lifecycle of PVC. The pipe market represents about 50% of total PVC use in the United States. In the effort to provide leadership on pollution prevention and the protection of environmental health, the significance of modeling PVC free alternatives cannot be understated.

Based on the inventory of PVC pipe use provided, there are readily available PVC free alternatives for all pipe applications, many with a longer history on the market than PVC. Primary alternatives include ductile iron, copper, high density polyethylene (HDPE), cross liked polyethylene (PEX), concrete, and steel. Project specific design conditions may make these alternatives either less or more costly than the comparable PVC, but in general the alternative materials are cost competitive. Familiarity with a particular material is a large driver in material choice. [*]

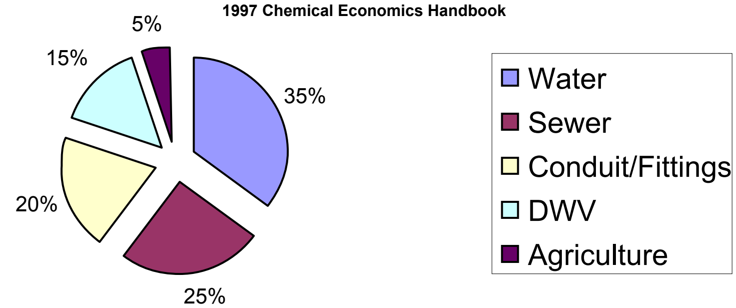
2) Summary of Pipe Sectors & Alternatives

The major pipe sectors are:

- **Water** – potable water delivery
- **Sewer** - sanitary (waste water transport outside of the building) and storm (site runoff transport)
- **Conduit /Ducting** – protection of electrical and communication wire, typically called conduit for above ground uses, and duct for below ground applications.
- **Drain/Waste/Vent** (DWV) - waste water transport within the building
- **Agriculture, Irrigation and Drainage** – water delivery for irrigation and ground drainage

Figure 1: 1996 PVC Pipe Sector Consumption (USA)

1997 Chemical Economics Handbook



[*] Note: Smaller thin walled piping, such as copper distribution, is often referred to as "tube" instead of pipe. The term "pipe" is used in this report to address both pipe and tube applications.

For each of the major piping sectors, there are a variety of alternative PVC free piping materials. This report will look at the primary alternatives (those alternative products with a large market share) in each sector using the premise that the marketplace has already determined which alternatives are most suitable and competitive to PVC.

The primary alternatives to PVC pipe in each sector are shown below in Table 1.

Table 1. Primary Alternatives to PVC by sector

Water	Ductile iron, HDPE, Concrete, Copper, PEX
Sewer	Concrete, HDPE
Conduit and Ducting	HDPE, Steel, Aluminum
Drain, Waste and Vent (DWV)	Cast Iron, Copper, ABS, PEX
Agriculture and Drainage	HDPE, Concrete

Adapted from Environment Canada report

ABS – Acrylonitrile butadiene styrene
HDPE – High Density Polyethylene
PEX – cross linked polyethylene

Acrylonitrile butadiene styrene (ABS) is not chlorinated, but like PVC has highly hazardous manufacturing intermediates, including carcinogens and is difficult to recycle. It is considered only marginally better than PVC environmentally.

High Density Polyethylene (HDPE) is available for all pipe applications. Being non-chlorinated, requiring fewer additives, and having a much higher recycling rate, it is considered a more benign plastic than PVC. PVC is more resistant to combustion, but smolders at a lower temperature than HDPE and releases toxic hydrochloric gases before combustion.

Cross linked polyethylene (PEX) is a polyethylene similar in many characteristics to HDPE but with molecules cross linked to improve its ability to handle higher temperatures.

Copper is highly recyclable but copper leaching into water supplies can be harmful to aquatic life. Copper also has significant life cycle problems in its mining and manufacture.

Concrete, iron and steel have significant embodied energy usage and their manufacture is not environmentally benign. However, all of them (with the exception of ABS) are generally considered environmentally superior to PVC. Aside from concrete, the primary PVC free alternatives are consistent with state government and professional association Environmentally Preferable Purchasing (EPP) guidelines (www.apwa.net/Documents/GovtAffairs/Policies/SolidWaste/solid-environpolicy.pdf). Steel, HDPE and copper pipe or conduit may all contain recycled content in the product. Quantities and post consumer content will vary with application and manufacturer.

3) Cost issues

A detailed cost analysis of the alternatives is beyond the scope of this report. It is important to note, however, that material costs for the pipe itself are frequently a relatively small fraction of the total project cost. While the pipe costs itself can vary considerably over time and geography due to market location and material/resin costs, there are a variety of other variable that can affect project cost. These include but are not limited to the experience and comfort level of the contractor with a particular pipe material, soil and other site conditions, installation method, and local labor costs which can have a dramatic impact on total pipe project costs. An analysis of PVC pipe alternatives by Environment Canada found that PVC alternatives are generally cost comparable. The costs of substituting for PVC pipe in the municipal pipe market represented 3% (high) and 1% (low) of total revenues from water and sewer rates. (http://www.on.ec.gc.ca/water/greatlakes/data/chlor-alkali/ A Technical and Socio-Economic Comparison of Options to Products Derived From the Chlor-alkali Industry).

Conversation with industry officials and literature review suggest that pipe material cost differences, to the extent that they do exist, are often not the determinant issue in pipe selection. In many instances in the pipe market, the choice of material has less to do with real cost differences and more to do with familiarity with one pipe type and a resistance to change. This is an important discussion in the context of value engineering. The fact that a wide range of PVC free materials have maintained significant market share in competition with PVC indicates that each of the alternatives already has broad market acceptance and demonstrated effectiveness.

4) Alternative materials comparison issues

The long-term durability of piping systems depends on many factors, including the soil environment, proper installation, material properties such as corrosion resistance, chemical resistance and strength and the performance of joints. (Env. Canada). Each of the primary PVC free materials have benefits that have kept them as significant market players.

A) Water

The water distribution piping market is typically divided into small diameter pipe (4" - 12") and large diameter pipe (14" - 36"). Smaller pipe and tubing (under 4") is used for distribution within buildings. Sewage pipe has been categorized into three size segments: small (4" - 15"), medium (18" - 36") and large sizes (over 36"). Small diameter pipe accounts for about 65% (by length) of total demand for pipe. See Table 2.

Systems are a tree-like pipe network consisting of:
Transmission lines - (water mains - typically 36" diameter or less)
Distribution lines - (lower diameter sizes: 6" - 12")
Service connections - (from street to building) 4" and less

Water mains typically operate at pressures from 100 to 150 lbs per sq. in. (psi), while distribution lines operate between 40 and 100 psi. Service connection lines are usually a diameter of 1" or less and can be made of various materials: polyethylene, PVC, iron or copper pipe. (Env. Canada)

Currently, PVC has a dominant share of the market for small diameter pipe in the water main (4" - 12"), sanitary sewer and storm sewer (4"-15") markets, while traditional materials (ductile iron and concrete) continue to have majority market share in the larger diameter pipe. (Env. Canada). According to the Plastics News (July 16, 2001) the demand for large diameter pipe plastic pipe has increased 8.3% between 1990 and 2000.

The smaller tube sizes used for in building distribution are primarily split between PVC, copper, and iron. There is limited data on the breakdown of market share.

Polyethylene is just beginning to penetrate the market for all sizes.

The use of galvanized steel and polybutylene has declined due to corrosion problems with galvanized and catastrophic failures with polybutylene.

One of the key design concerns for drinking water infrastructure design and installation is leakage. When one turns on the tap for potable water, there is a cost associated with the acquisition, treatment, and supply (pumping) of the waster. If a water distribution system leaks, the lost water can become an extremely high cost. In arid areas, such as the American Southwest, where costs to acquire water can be exorbitant, leaks can be an expensive proposition. In Charleston West Virginia, a 4 inch leak in their 24 inch diameter iron pipe resulted in the loss of 3 to 5 million gallons of water per day. In Washington D.C, there is about 66 million gallons of water unaccounted for. (Plastics Pipe Institute Fall 2002)

HDPE has a slight advantage in leak resistance over PVC. This is because it can be delivered in longer lengths, minimizing the quantity of joints. Furthermore, the butt or electro-fusion processes used to join HDPE provides stronger, tighter, more leak proof joints compared to the bell and spigot joints used in PVC pipe for mains or the solvent glue joints used for smaller distribution. The longer length of HDPE can require longer trenches to be open at a time, but its length and flexibility can allow for trenchless procedures, particularly in sewer replacement. HDPE's greater flexibility and resilience (particularly at lower temperatures) also make it less susceptible to surge and hammer shocks or to damage from digging. HDPE's flexibility and resilience has made it increasingly popular in earthquake territory or other areas where soils can shift. For larger diameters, the fusion technique requires a fusion machine, which might be problematic in cramped spaces. For smaller diameter pipes, a handheld device can be used to weld/melt the pipe lengths together. Mechanical couplings are available for HDPE, though some of these couplings may be made of PVC.

PEX is another form of polyethylene that retains HDPE's flexibility and chemical resistance while providing resistance to higher temperatures for which HDPE is not suitable. It is coupled with either fusion techniques or mechanical crimp couplings. Due to its higher temperature ratings it was initially used in radiant and district heating system applications, but is now also beginning to be used more widely in water supply and gas distribution systems.

Ductile Iron (DI) has significantly higher tensile strength, making it more capable of handling higher pressures, crushes and hammer than PVC. DI does not lose strength at high or low temperatures as PVC does. Ductile iron is impermeable to hydrocarbons and other groundwater contamination unlike PVC or other plastic pipe.

"There has been much debate over the durability and expected lifespan of each of these materials. The life of a pipe system depends not only on the material, but the installation and the surrounding environment. All these types of pipe have been on the market for over 30 years, and while there are examples of pipe failures for each of them, this study did not find conclusive evidence to suggest that one material has a significantly different lifespan from the other. When properly designed and installed, pipe systems of any of these materials can be sufficiently durable to withstand many decades of services." (Env. Canada)

B) Sewer

Prior to the 1960s most sewer systems were combined sewers, that is, carried both sanitary and storm water. The system had to be designed to carry large volumes of water during rain events, but otherwise the capacity was little used. In addition, when it did rain the flood of relatively fresh water often negatively impacted water treatment. Design changed so that by the mid 1960s sanitary and storm systems were designed and constructed separately. Storm sewers collect water from roof drains, parking lots and streets. Unlike sanitary sewers, storm wastewater is not typically treated and the flow is directly discharged into a receiving body of water.

Similar to water distribution use, PVC is dominant in the smaller size sewer pipe market with HDPE just beginning to seriously compete. These smaller lines are commonly used in the collection network of subdivisions. In this segment, the competing concrete pipe is non-reinforced concrete pipe in 8" and 10" sections. The smallest diameter reinforced concrete pipe is usually 12" pipe.

As in water main pipe, HDPE is a comparable alternative to PVC pipe in sewer systems. HDPE sewer pipes are also available in diameters ranging from 4 inches to 36 inches, although for storm sewer, much of the demand is for 10 to 15 inch, while for sanitary 8 to 12 inch are popular diameters. At larger diameters, the major market share is held by concrete, primarily due to cost.

C) Conduit and Ducting

Galvanized steel and aluminum are the traditional conduit materials. Over the last few decades PVC has been able to take a large share of this market. Over the last decade HDPE has seen the most growth in the conduit sector, and easily competes with PVC. There is limited data on the breakdown of market share. HDPE's extremely low coefficient of friction makes it easy to pull cable through; one reason for its increasing popularity. Fire code concerns have limited HDPE acceptance for indoor conduit applications making it the primary alternative to PVC for outdoor and underground applications. Steel and aluminum conduit are the primary alternatives to PVC for indoor applications. While PVC is fire resistant, it's tendency to smolder and emit hydrochloric gases before combustion is a particularly dangerous attribute in medium and high voltage conduit applications. HDPE comes in rolls of several hundred feet while PVC and metal conduits comes in rigid 20 foot sections. This makes HDPE easier to use for larger installations and metal easier for smaller installation. Some metal conduit products may be coated with PVC. It is important to specify those products that are PVC free.

D) Drain Waste and Vent (DWV)

Cast Iron and copper are the traditional DWV materials. PVC is widely used in residential construction because of the ease of joining with solvent glues. ABS and PEX have both become popular alternatives to PVC in more recent years. As previously noted, ABS has serious environmental problems of its own.

E) Agriculture, Irrigation & Drainage

A variety of alternatives to PVC are used both for water delivery and for drainage. Irrigation sprinkler, drip and drainage systems have long been available in HDPE and have significant advantages in resilience against compression, shovel attack and ground movement. Corrugated steel, concrete and HDPE are all competitive alternatives for drainage. HDPE drainage pipe is now available in formulations with high recycled content. Plastic pipe has carved a hunk of the huge market previously dominated by concrete and steel. Highway drainage is a fast growing market for HDPE. Recently, the Corrugated Polyethylene Pipe Association initiated a third party certification system which allows for increased acceptance of their product by the American Association of State Highway and Transportation Officials. Footing and underslab drains are all available in HDPE.

5) Obstacles to Change

Journal articles and reports have some consensus as to why PVC has made such strong inroads in the water and sewer markets, and why HDPE, a viable alternative resin, has had difficulty in the market place. Primarily it has to do with what was there first, and a resistance to change.

According to an Environment Canada report, "In the case of HDPE, one reason for the low market share is the different marketing strategies initially employed for PVC and HDPE. Though HDPE has always been a competing plastic, with a longer history of use in pipe than PVC, the initial target markets for HDPE pipe suppliers were industrial settings, such as the chemical process industries, and the mining sector. In contrast, PVC pipe suppliers, who also sold ductile iron pipe, targeted municipal infrastructure pipe markets. As a result, municipal design engineers and contractors are more familiar working with PVC pipe, and seldom specify or design HDPE systems." (Env. Canada)

A trade journal article reporting on the difficulty in breaking into the market reports, "Even though polyethylene pipe has gained AWWA acceptance, U.S. water utilities and the engineers who design water systems have been slow to consider it as an alternative to the products they know and have used for years. Why risk trying something that – to the potable water industry- is new? (Underground Construction, June 2000).

One of the great barriers to changing the PVC water and sewer market is the resistance to change. Most engineers, contractors and public works officials have been working with the same materials for a long time, have become very familiar with their characteristics and are not anxious to take on a new material with different characteristics.

Appendix A – PVC Consumption Breakdowns

PVC Pipe Market

The figure below categorizes PVC consumption and demonstrates that construction consumes over three quarters of the PVC in the US and hence is the most significant end use of PVC (Figure 1).

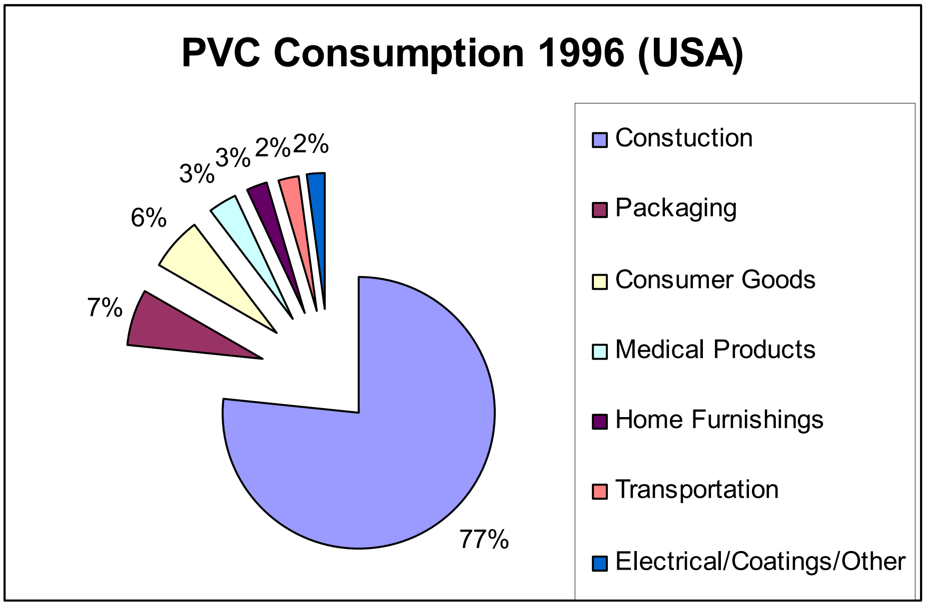


Figure 1.

Figure 2 depicts a sub-sector breakdown of PVC use in the construction sector and shows that the most significant segment is Pipes, tubing and fittings consuming about 2/3 of the total (Figure 2).

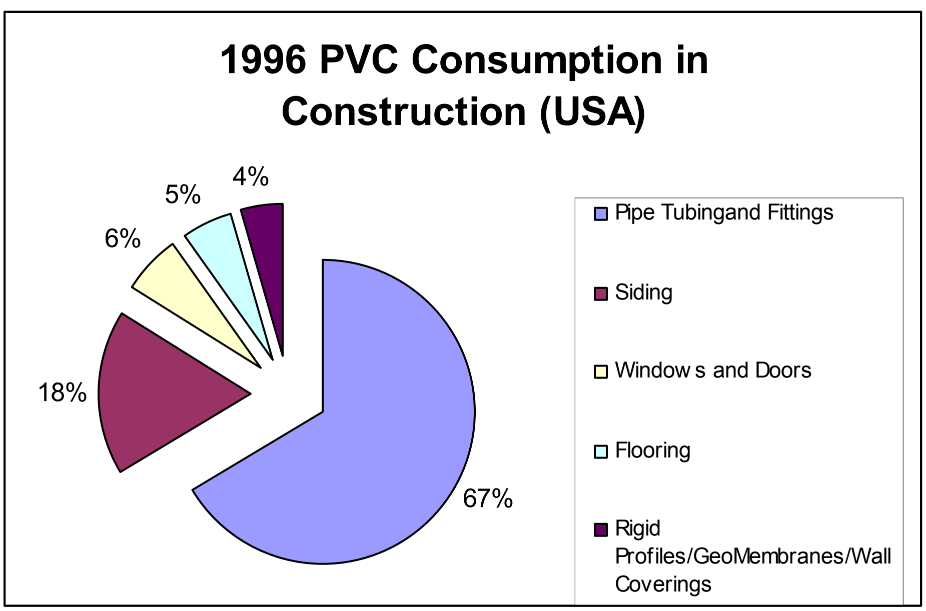


Figure 2.

Breaking out Pipes, tubes and fittings from other construction uses we see that this sub sector represents almost half of the entire PVC consumption (figure 3)

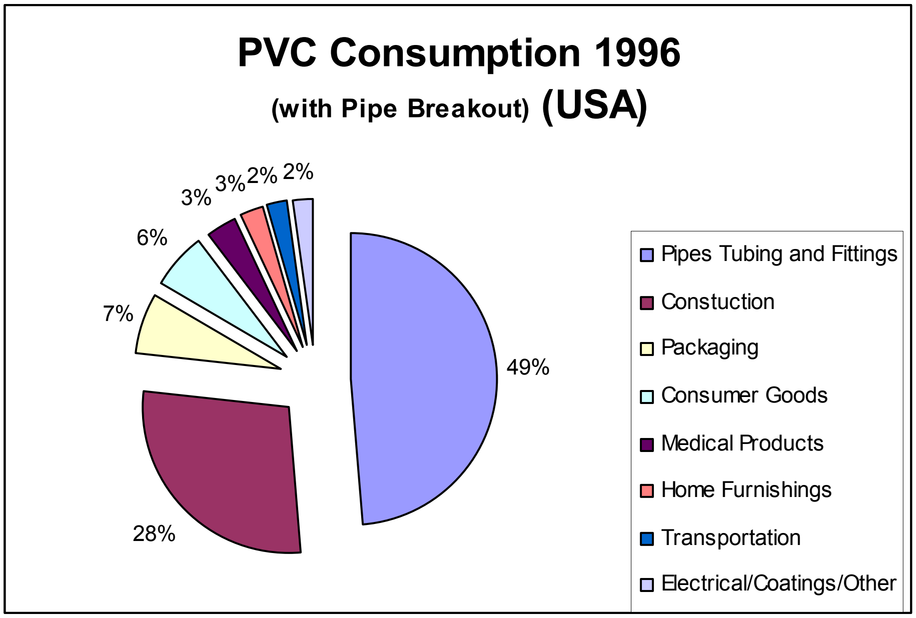


Figure 3.

The data suggests that even a small movement away from PVC pipes can significantly impact the size of the PVC market. Currently, for every 10% shift in the PVC pipe tubing fitting market, there is a corresponding 5% shift in the entire PVC market. Importantly, this does not necessarily mean other PVC sector targets should be abandoned. For example, market movement away from PVC medical devices, though smaller PVC use sector (3% of entire PVC consumption), may actually be a significant driver of the PVC pipe market, or other market sectors.

Appendix B - Sewer and Water Pipe Design Primer

The following primer is intended to provide the layperson with an introduction to pipe design, construction techniques, and associated vocabulary.

1) Engineering and Design

Water and Sewer Layout

Though it may not be obvious, pipelines are designed to follow the natural topographic variation and mimic natural drainage flow to take advantage of gravity. It is important that pipelines not be too deep to make excavation and installation prohibitively expensive, but also that the pipeline not be so shallow that it is difficult to service the building.

Pressure Pipe

In pipes, fluids are transported under two conditions; pressure or gravity flow. These two methods are important as they have implications on pipe material selection and layout. In pressure pipe, fluids are moved through the pipe by a pump, and as a result are put under pressure. Water pipes are usually pressure systems, as lakes, rivers, reservoirs, and other bodies from where water is obtained are typically located at elevations below where the water needs to be delivered. Because water does not flow against gravity, water delivery to apartment buildings, and upper floors of houses needs to be pumped, and hence is under pressure. Because the fluid is under pressure, joints for pressure systems must be rather "strong" or tight, otherwise as the pressure wave hits the joint, the pipe will fall apart, or create unacceptable leaks. Most codes for pressure pipe have what is called an allowable leakage rate. This means that the code allows for pipes to have a small degree of leakage. Pipes which are seamless, such as HDPE will have no leakage, even though it may be allowed by code. Though wastewater is typically designed for gravity flow, there are occasions where wastewater is also pumped. Usually this occurs where the topography is very flat, or where there is a hill along the pipe route.

Gravity Pipe

As implied, gravity flow uses gravity to transport the liquid. Wastewater is typically conveyed in a gravity system. A major concern with gravity systems is what is called Inflow and Infiltration (I & I) where water enters cracks or leaky joints. This is a concern for a variety of reasons. First, it can cause added expense to the wastewater plant because the plant is "forced" to treat excess water that does not require treatment. Associated with this excess dilute loading is poor wastewater treatment and unneeded treatment expense. Secondly, it can cause overflows at the wastewater plant or in the downstream conveyance system during rainstorms when pipe capacity is exceeded. This is one reason why during heavy rains wastewater plants may not function and that there are overflows. It is not necessarily because of poor system design but because breakdown of old pipe or poor construction have allowed for I&I. When a pipe collection system passes through an area of high water table, outside I&I can be problematic. The water table puts pressure on the gravity pipe, and it is continuously forced into the collection system. A US standard for sewage water infiltration allowance is 200 gallons per inch diameter per mile per day.

Corrosion
In metal water pipes, corrosion can occur because chemical reactions cause the pipe to act mildly electrically charged. This charge can cause it to release ions, causing it to lose strength. This can be remedied typically by supplying coatings such as tar or enamel.

In sewer pipes corrosion can occur because of chemical reactions caused by the biological production of sulfuric acid. In concrete pipes, the acid reacts with the lime to form calcium sulfate which lacks structural strength. The best protection is corrosion resistant pipe such as vitrified clay or plastic. Concrete pipe can be protected with coatings and or linings.

Flexible Pipe
Pipes with higher flexibility, such as PVC and HDPE (and larger diameter ductile iron) require proper pipe bedding and full sidefill support to resist deflection. The bedding, the sidefill and the walls of these "flexible" pipes must form a structural unit to resist the pipe deflection caused by overlying soil loads. In practice, this means that these pipes require increased labour and materials for backfilling and sidefilling.

Joints

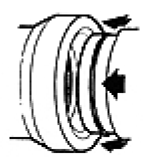
There are a variety of ways in which pipes are joined. These are:

- **Mechanical** – a joint where pipes are joined by bolting or threaded their ends together.

- **Solvent Cement** –Solvents are used to join PVC DWV pipe. The solvent is used to soften and “glue” two pipe sections together. Health concerns have been raised about these solvents.

- **Welded** – both metal and some plastic pipes can be welded. Plastic pipe uses a hot plate to melt the ends of the plates to be joined. The plate is removed and the ends are pushed together using joining machinery, creating a seamless joint.

- **Bell and Spigot** – Bell and spigot joints are often used in gravity lines. With bell and spigot joints, each pipe length has a bell (or larger diameter end piece) end and spigot (or normal diameter) end. The spigot is inserted into the bell via a compression fit. Much sewer work uses bell and spigot joints.



Bell and Spigot Joint
best fit gasket company http://www.bestfitt.com/instructions/prepjoin.htm

2) Construction

Traffic
Traffic can add significant changes to pipeline project. In a new subdivision, the entire pipeline length can be excavated and the pipe placed without disturbing circulation. In an urbanized area, because of traffic flow and associated safety concerns, it can be almost impossible to dig up an entire street to lay pipe. When pipe is place in urbanized areas, the street is typically dug up section by section. A section of pipe is laid,

the hole backfilled, the adjacent section of street excavated, the new piece of pipe joined, and the hole backfilled. In this way, the excavation site "moves" along the route of the new pipeline with little disruption of street level traffic. This type of construction requires the joining of pipe sections to form one contiguous pipeline versus the placement of one long section of pipe. One disadvantage to this form of pipeline placement are that there are many joints each with the potential for failure or leakage The advantage is that there is little disruption to above grade activities. Trenchless technologies which favor HDPE pipe are now becoming commonplace.

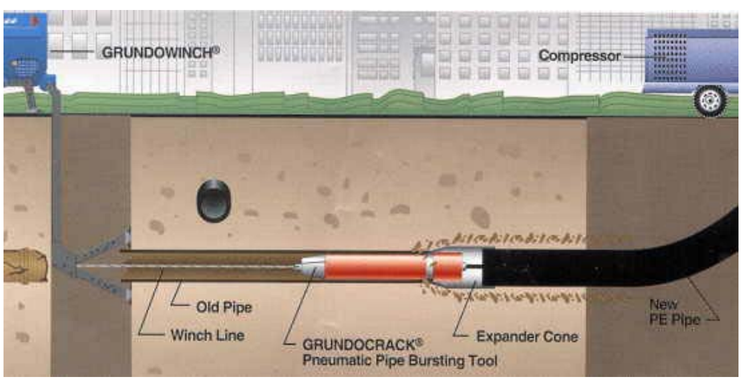
Trenchless Technologies

i) Sliplining

If an older pipe is to be replaced, sliplining is frequently used to minimize installation costs. Costs are minimized because no excavation is required. Sliplining involves the placement of newer pipe inside that of an older, usually failed pipe. As the inside diameter of the "new' pipe will be smaller than the old, the new smaller pipe diameter will be able to carry less flow so this method requires that there be excess capacity in the older larger pipe. The new pipe, in lengths of 1000m can either be pushed of pulled through the older pipe. (PM Construction)

ii) Pipe Bursting

This is a relatively new technique for pipe placement. It is the only trenchless technology that allows for the replacement pipe to have larger diameter than the original pipe. In this method, a pneumatic bursting machine is dragged through the existing pipe. Old pipe fragments are displaced into the surrounding soil and the new larger pipe, in lengths up to 500 meters, is pulled in behind as replacement.



Appendix C - Case Studies

The following case studies have been provided to show examples of where and how PVC alternatives are used. All these case studies illustrate the use of HDPE, not because it is the preferred alternative to PVC, but because the other alternatives (ductile iron, copper, concrete) have already proven themselves in the North American marketplace.

Western Lake Superior Sanitary District commits to PVC free pipe The Western Lake Superior Sanitary District (WSLLD) is a regional wastewater treatment plant located in Duluth, Minnesota. It is the largest American point source discharge to Lake Superior. The WLSSD, has adopted a nationally recognized pollution prevention program which has as its basis a commitment to zero discharge of persistent toxic substances. This commitment reads:

> "The WLSSD as a discharger to Lake Superior is committed to the goal of zero discharge of persistent toxic substances and will establish programs to make continuous progress toward that goal. The District recognizes step-wise progress is only possible when pollution prevention strategies are adopted and rigorously pursued. These approaches will focus upon our discharge as well as indirect sources. WLSSD will work with its users to implement programs, practices, and policies which will support the goal.... WLSSD recognizes that airborne and other indirect sources beyond District control must be addressed in order for significant reductions to occur."

One component of their P2 program is a PVC free policy as a means towards dioxin reduction. As a wastewater treatment plant this policy has been applied to assist in the purchase of PVC-free pipe, an alternative PVC-free liner for their new anaerobic digestion facility, preference for PVC alternatives in their master plan development, PVC free electrical applications, and in the elimination of other uses of PVC such as office products. www.wlssd.duluth.mn.us

Bow, NH uses HDPE for roadway drainage. The community of 6,500 residents has 110 miles of roadway, and as old roads are upgraded and new roads built, the town includes storm drains made of HDPE. The corrugated polyethylene pipe was chosen for its ability to withstand frost action in the varied soil conditions beneath the town. "Metal pipe and cement pull apart from heat, and the freeze-and-contract movement in the winter. If there's a pocket of clay, water beneath the surface humps it up when it freezes, and that makes metal pipe come apart at the joints," comments Cleverly, the city engineer, noting that he hasn't seen any similar problems with corrugated polyethylene pipe. Additionally, Cleverly likes the safety factor HDPE pipe provides over metal pipe. He describes freshly-cut metal pipe ends as, "razor-sharp," compared to HDPE. "We try to be as safety-conscious as possible," he says. (CPPA website)

Atlanta Parks & Recreation uses 4" and 6" perforated polyethylene pipe to improve the hydraulic performance of a series of French drains running through the park and alongside a ball field. The Artis Group, Decatur, Ga., installed 1,000 linear feet of perforated pipe down the center of the drains to speed water flow. The smooth interior of the pipe provided greater hydraulic efficiency than ditches alone. (CPPA website)

HDPE pipe chosen for municipal sewer lines in Missoula, MT. City engineers evaluated all types of pipe and chose Hancor corrugated polyethylene. (Hancor Inc. website)

Appendix D – PVC Alternative comparisons

Technical Comparison of PVC and Ductile Iron Pipe

Technical Characteristics	PVC	Ductile Iron
Material Properties		
Corrosion Resistance	Resistant to acids	Can corrode; requires protection in some acidic soils and septic waters
Chemical Resistance	Can soften/degrade with organic solvents at high concentrations	Resistant to organic solvents; requires protection from acids
Impact Resistance	Moderate	High
Hydrostatic strength	Moderate	High
Tensile Strength	Moderate	High
Pipe Stiffness	Flexible; bends moderately	Flexible; bends slightly
Installation Factors		
Handling, weight	Light (~15 kg/m - 8" DR 18)	Heavy (32-36 kg/m - 8" Class 350)
Joining	Push on joints most common; mechanical and butt-fusion joints possible	Push-on joints most common; accommodates some deflection; mechanical joints possible
Bedding	generally requires more sidefill support to control deflection	more rigid at lower diameters; still requires careful bedding
Service		
Durability	High	High (with corrosion control as required)
Joint Integrity	Long term reliability	Long term reliability
Water Flow	Smooth walls; low friction factor	Slightly higher friction factor; larger internal diameter; higher flow
Temperature Range	Lower impact resistance with decreasing temperatures; lower tensile strength with increasing temperatures	Handles very high and low temperatures

Source: Env. Canada

Technical Comparison of PVC and HDPE Pipe

Characteristic	**PVC**	**HDPE**
Durability	Decades	Decades
Joining	bell and spigot push-on	butt-fusion above ground mostly, bolted flange for equipment connections
Joint integrity	tight seals; low leakage	butt-fusion results in tight seals
Weight	more dense than HDPE	less dense than PVC
Ductility	more stiff than HDPE	less stiff then PVC
Flexibility	rigid	flexible
Pressure rating	more susceptible to surge, hammer shocks	less susceptible to surge, hammer shocks
Tensile strength	PVC has better strength to volume ratio	HDPE has less strength to volume ratio
Internal wall smoothness	close to HDPE	close to PVC
Abrasion resistance	moderate	high
Chemical resistance	moderate	very good
Impact resistance	brittle at very low temperature, glass transition temperature higher than HDPE	better low temperature resistance, glass transition temperature lower than PVC
Fire resistance	will not sustain combustion	will sustain combustion
Tapping	mechanical taps	fusion or mechanical tapping

Env. Canada

Technical Comparison of PVC and Concrete Sewer Pipe

Technical Characteristics	**PVC**	**Concrete**
Material Properties		
Corrosion Resistance	Resistant	resistant
Chemical Resistance	susceptible to some hydrocarbon solvents	susceptible to acids (i.e. sulphuric acid); solvents may cause dissolution
Impact Resistance	moderate; reduced at very low temperatures	moderate
Abrasion Resistance	High	high; moderate under acidic conditions
Tensile Strength	moderate; flexible	high; rigid sections; flexibility in system due to shorter lengths
Soil Stress Resistance	flexible; withstands stress with sidefill support	withstands high soil loads
Installation Factors		
Handling, weight	light (13 kg/m); long (6.1m) sections (8" basis)	heavy (72 kg/m); short (1.2 m) sections (8" basis)
Joining	push on joint	push-on joint; more joints
Bedding	180° bed tamping required	lower half support may be necessary
Service		
Durability	high; long life span expected, not proven beyond 30 years	high; long lifespan
Joint Integrity	long-term reliability with proper installation	long-term reliability with proper installation
Water Flow	smooth walls; low friction	smooth walls; low friction
Temperature Range	lower impact resistance with decreasing temperatures; flexibility increases with increasing temperatures	wide range application

Env. Canada

Technical Comparison of PVC and HDPE Sewer Pipe

Characteristic	PVC	HDPE
Durability	decades	decades
Joining	bell and spigot push-on	bell and spigot push-on, butt-fusion, clam shell connections
Joint integrity	tight seals; low infiltration	tight seals; low infiltration (higher for clam shell enclosures)
Weight	more dense than HDPE	less dense than PVC
Ductility	less ductile than HDPE	more ductile than PVC
Flexibility	flexible	flexible
Tensile strength	better strength/volume ratio	lower strength to volume ratio
Internal wall smoothness	close to HDPE	close to PVC
Abrasion resistance	moderate	high
Chemical resistance	softens with solvents at high concentrations	very good
Impact resistance	decreases at very low temps., glass transition temp. higher than HDPE	better low temp. resistance, glass transition temp. lower than PVC
Fire resistance	resistant to combustion	will sustain combustion

Env. Canada

Water and Sewer Pipe Market Share, 1993
(% of length) (what about <4"?)

Type of Pipe	Water main		Sanitary and Sewer Pipe		
	4"-12" (Small)	14"-36" (Large)	4"-15" (Small)	18"-36" (Medium)	36"+ (Large)
PVC	88%	25%	85%	34%	0%
HDPE	0%	10%	5%	2%	0%
Ductile iron	12%	35%	0%	0%	15%
Concrete	0%	30%	10%	64%	85%
Total	100%	100%	100%	100%	100%

Table 2. Environment Canada

APPENDIX E: Manufacturers and suppliers of HDPE piping

Agents Private International (HDPE duct and conduit)
Richmond Hill, Ontario, Canada
416-281-6902
http://www.agtprint.com

Arnco (HDPE conduit and duct)
Elyria, OH
800-321-7914
www.arncocorp.com

Chevron Phillips Chemical Company LP (HDPE pipe & conduit)
The Woodlands, TX
(800) 231-1212
http://www.cpchem.com

Endot Industries, Inc. (HDPE pipe and conduit)
Rockaway, NJ
1-800-44-ENDOT(443-6368)
http://www.endot.com/market/

Hancor (recycled HDPE drainage drain)
Findley, OH
1-888-FOR PIPE
www.hancor.com

ISCO Industries, LLC (HDPE pipe)
Louisville, KY
1-800-345-ISCO
www.isco-pipe.com

Lamson & Sessions (HDPE conduit)
Cleveland, Ohio
Phone: (800) 321-1970
http://www.lamson-sessions.com/news_hdpeconduit.htm

Vanguard Piping Systems (HDPE and PEX piping)
McPherson, Kansas
1-800-775-5039
www.vanguardpipe.com

Wis. Plastic Drain Tile (HDPE drain tile and piping, 100% recycled)
Jefferson, WI
800-362-6642
http://www.draintile.com/

Blackburn Nursery's Home & Garden Showplace (HDPE irrigation)
4100 SW 40th St.
Topeka, KS, 66611
(785)-272-2707
http://www.blackburnnursery.com/sprinklers/irrigation_pipe.shtml

Local Sources (California Bay Area)

AllBay Plumbing Supply Inc
2815 E 10th St, Oakland, Ca 94601
Phone:510-533-5060 Fax: 510-533-3590
Vanguard Products

Maskel-Robbins
3135 Diablo Avenue
Hayward, CA 94545
800-638-4373
Don Wescott, rep 510-612-5844 (cell)

P&F Distributing
511 Tunnel Ave.
Brisbane, CA 94005
415.467.4630
Ask for Navy Nesbit.

Cagwin & Dorward (HDPE irrigation installation)
Novato, CA
707-545-3134
Bob Giordano

Wyatt and Ewing Supply carry irrigation HDPE pipe.
They may also have the larger sizes to use for main lines and high pressure supply lines