Technical Note 09 – Photobook of Damaged Underground Utilities

Contents

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1. Introduction

The Canterbury Earthquake Sequence (CES) caused widespread damage to buried utilities in the region. The investigation of such damage, undertaken in the subsequent weeks and months following the CES, included collection of several thousand photographs. This Photobook presents a selection of these photographs to help develop a greater understanding of the damage sustained to buried infrastructure in an earthquake.

The photographs come from many sources, including the Christchurch City Council, CityCare, Iplex Pipelines New Zealand Ltd, University of Canterbury and Opus International Consultants Ltd. The contributions of all sources is greatly appreciated. A full set of photographs can be made available upon request to Opus.

Damage and defects are presented in the following order:

- Pipes – Defects affecting the pipe barrel
- Joint – Defects affecting joints
- Fittings – Defects affecting fittings
- Existing – Failure at an existing defect or an existing problem identified because of the earthquake
- Other – Other defects, including combined failures.

Defect type has been used rather than material or system function, as this helps highlight which kind of problems affect all systems and which affect only some systems.

While all of the defects shown were identified following one or more earthquakes, not all the damage was caused by or during the earthquake for reasons including:

- Some defects were present beforehand and were only identified during post-event damage assessments;
- Some defects were present beforehand and were made worse during the seismic event(s);
- Some defects or deterioration would have caused failure in the future, but failure was brought forwards by the earthquake(s).

It is recognised that poor construction and installation practices can reduce the useful life of a system in normal service, and these practices also influence the seismic durability. Failure during an earthquake can occur because of poor construction and installation practices rather than because of an inherent weakness in the buried system.

As well as providing examples of observed damage, comments have also been included to describe possible repair options and (where known) methods to reduce the likelihood of similar damage in similar applications.

Image quality is limited in some cases. The main contributing factors for this include:

- The quality of available cell phone cameras;
- Poor ambient light, especially when working at night or in bad weather;
- Repair and restoration of service was more important than image quality;
- The repair crews were working under trying conditions.

The fact that any images were obtained under such difficult conditions is a tribute to the repair crews.

2. Pipe Damage

Reference: PI001

Material: Asbestos cement

Description: Circumferential crack.

Cause: Compression or bending.

Repair: Reconnect with repair clamp.

Comment: Relatively low beam stiffness of smaller diameter AC pipes can result in circumferential fracture even in normal service. These breaks can often be repaired by reconnecting the two halves.

Modern materials are more resistant to this kind of damage and good installation practice provides better support for all materials.

Reference: PI002

Material: Asbestos cement

Description: Break

Cause: Lateral shear or bending.

Repair: Replace collar and damaged pipe.

Comment: Fracture pattern indicates failure could be due to bending, compression or lateral shear. Modern materials have more tolerance to this kind of loading.

Reference: PI003

Material: Cast iron

Description: Circumferential crack.

Cause: Probably bending or lateral displacement.

Repair: Repair with flexible couplings.

Comment: The gibault joint can accommodate some displacement but the pipe has fractured when the joint ran out of travel.

Use modern materials and flexible joints to aoid failure.

Reference: PI004

Material: Copper

Description: Bending

Cause: Compression

Comment: Small diameter pipes are vulnerable to bending and the risks of bending increase when the pipe is near the surface. Most alternative materials would also bend but modern plastics are more likely to provide some (limited) service when damaged.

Reference: PI005

Material: Copper

Description: Crack

Cause: Probably compression.

Comment: The pipe appears to have split where buckled. It is likely it would have bent if not buried so deeply.

Reference: PI006

Material: Earthenware

Description: Break

Cause: Compression, shaking or bending.

Repair: Replace damaged pipes.

Comment: Earthenware pipes have poor tolerance to most seismic loads loading. Modern systems have better resistance to shaking and bending.

Reference: PI007

Material: Galvanized steel

Description: Bending

Cause: Compression of shallow buried pipe.

Repair: Replacement

Comment: Deeper burial will result in buckling rather than bending but failure will occur in both cases. Most alternative materials would also bend but modern plastics are more likely to provide some (limited) service when damaged.

Reference: PI008

Material: Galvanized steel

Description: Bending

Cause: Compression of shallow buried pipe.

Repair: Replacement

Comment: Deeper burial will result in buckling rather than bending but failure will occur in both cases. Most alternative materials would also bend but modern plastics are more likely to provide some (limited) service when damaged.

Reference: PI009

Material: Steel, probably lap welded.

Description: Pipe and/or joint failure.

Cause: Compression

Repair: Replace damaged section.

Comment: Compression of the line appears to have caused failure at welded joints, but there may also be buckling failure of the steel pipe. Buckling may still occur in modern welded steel, but some function is likely to remain due to improved strength and ductility of current welded joints.

Reference: PI010

Material: PE

Description: Bending

Cause: Compression of shallow-buried pipeline.

Repair: Replace

Comment: Deeper burial will result in compressive buckling rather than bending. Most materials would also bend but modern plastics are more likely to provide some limited service when damaged.

Reference: PI011

Material: PE

Description: Bending

Cause: Probably compression, but possibly relative movement of pipe and a solid object.

Comment: Most alternative materials would also bend but modern plastics are more likely to provide some limited service when damaged.

Pipes have been observed to fail like this when compressed in laboratory tests.

Reference: PI012

Material: PE

Description: Buckling

Cause: Compression

Comment: The larger electrical ducts appear undamaged. Even if the ducts had deformed, the cables inside may not be damaged if there is sufficient clearance, even though it may affect future operations such as installation of new cables or removal of existing ones.

Reference: PI013

Material: PE

Description: Buckling and tear.

Cause: Compression

Comment: Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.

Reference: PI014

Material: PE

Description: Buckling and tear or third party damage.

Cause: Compression

Comment: The damage could have been caused by compressive buckling or by third party damage (struck by a tool or digger). Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.

Reference: PI015

Material: PE

Description: Buckling

Cause: Compression

Comment: Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.

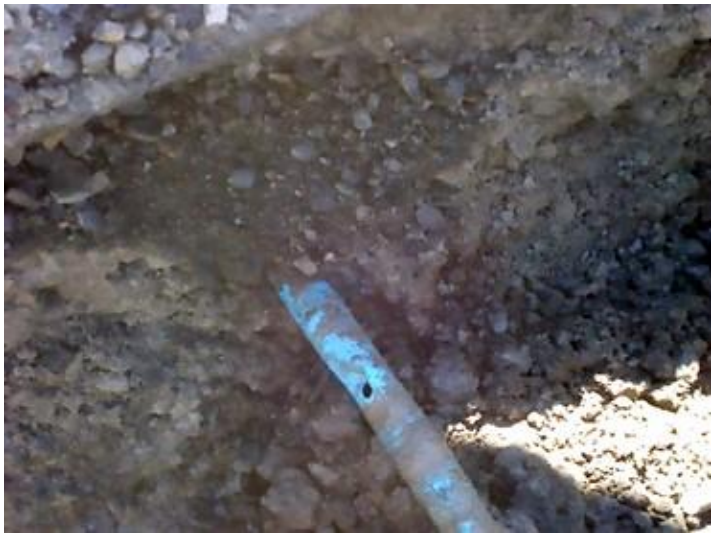
Reference: PI016

Material: PE

Description: Buckling

Cause: Compression

Comment: Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.



Reference: PI017

Material: PE

Description: Perforation

Cause: Probably compression.

Comment: The pipe appears to have buckled. Subsequent leakage then eroded away material around the leak, leaving the relatively round hole.

Reference: PI018

Material: PE

Description: Buckling and tear.

Cause: Compression.

Comment: The pipe has buckled and torn. Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.

Reference: PI019

Material: PE

Description: Buckling and tear.

Cause: Compression

Comment: The pipe has buckled and torn. Most alternative materials would also buckle and fail but modern plastics are more likely to provide some limited service when damaged.

Reference: PI020

Material: PE

Description: Buckling and tear.

Cause: Probably compression.

Comment: The pipe appears to have buckled, causing a tear in the pipe wall. Subsequent leakage then eroded away material around the leak leaving the relatively round hole.

Reference: PI021

Material: PE

Description: Buckling and tear.

Cause: Probably compression

Comment: The pipe appears to have split, most probably because of buckling that caused a local tear.

Reference: PI022

Material: PE

Description: Pipe failed.

Cause: Tension

Repair: Replace damaged pipe.

Comment: This type of failure only occurs when there has been severe tensile displacement. Snaking the pipe in the trench and using modern ductile pipeline systems will reduce the risk. While risks can be reduced by construction practices, it is not practical to eliminate all risks in service connections.

Reference: PI023

Material: PE100

Description: Pipe failed.

Cause: Tension

Repair: Replace damaged duct

Comment: This is a telecommunications cable duct. This type of failure only occurs when there has been severe tensile displacement. Snaking the pipe in the trench and using modern ductile pipeline systems will reduce the risk. While risks can be reduced by construction practices, it is not practical to eliminate all risks in service connections.

Source: Frank O'Callaghan, Iplex

Reference: PI024

Material: PE (probably older PE)

Description: Pipe failed.

Cause: Tension

Repair: Replace damaged pipe.

Comment: Older PE has limited ductility and is less tolerant of tensile displacement than modern PE. There appears to be a smaller pipe inserted inside a larger pipe. Snaking the pipe in the trench and using modern ductile pipeline systems will reduce the risk. While risks can be reduced by construction practices, it is not practical to eliminate all risks in service connections.

Source: Frank O'Callaghan, Iplex

Reference: PI025

Material: PE

Description: Pipe failed.

Cause: Tension and lateral displacement.

Repair: Replace damaged pipe.

Comment: The pipe appears to have failed due to lateral spreading of several hundred millimetres. While risks can be reduced by construction practices and use of modern materials, it is not practical to eliminate all risks in service connections.

Reference: PI026

Material: PE

Description: Pipe failed.

Cause: Tension

Repair: Replace damaged pipe.

Comment: This type of failure only occurs when there has been severe tensile displacement. Snaking the pipe in the trench and using modern ductile pipeline systems will reduce the risk. While risks can be reduced by construction practices, it is not practical to eliminate all risks in service connections.

Reference: PI027

Material: PE

Description: Pipe failed.

Cause: Tension

Comment: This appears to be a failure in an older PE pipe with relatively low ductility. A modern PE may have been able to accommodate displacement by deforming rather than failing.

Reference: PI028

Material: PVC

Description: Bending

Cause: Compression of shallow-buried duct.

Repair: Replace.

Comment: Given the severity of bending, there is a strong likelihood of damage to the cable housed inside the duct. The orange colour indicates that t the duct probably houses an electrical cable. The smaller diameter black PE pipe to the left has been squeezed off to stop leakage.

Reference: PI029

Material: PVC

Description: Buckling

Cause: Permanent Ground Displacement. Pipe is driven into a fixed structure (most likely) or rigid structure is driven into pipe (less likely).

Repair: Replace damaged pipe length. May need to replace adjoining pipes if damaged.

Comment: Where possible locate pipelines away from similar structures where risk of lateral spreading is present and direction of movement likely to cause damage. Despite the damage, some limited service may be retained if the buckled pipe wall does not tear.

Reference: PI030

Material: PVC. May be PVC-M

Description: Buckling and tear.

Cause: Compression

Repair: Cut out damaged pipe and repair.

Comment: No practical solution. Some service may have been retained if compression had been slightly less as this may have avoided tearing.

Reference: PI031

Material: PVC-M

Description: Buckling.

Cause: PGD. Pipe is driven into a fixed structure (most likely) or rigid structure is driven into pipe (less likely).

Repair: Replace damaged pipe length. May need to replace adjoining pipes if damaged.

Comment: Where possible, locate pipelines away from similar structures where risk of lateral spreading is present and direction of movement likely to cause damage. Despite the damage, some service may be possible if the buckled pipe wall does not tear.

3. Joint Damage

Reference: J001

Material: Asbestos cement

Description: Leaking joint.
Cause: Bending or tension .

Repair: Replace the collar with a repair coupling if necessary or replace the affected pipes.

Comment: Many AC pipe sockets have short insertion depths so are potentially vulnerable to shaking as well as permanent displacement. Modern pipeline systems present a lower risk.

Reference: J002

Material: Asbestos cement

Description: Joint break.

Cause: Compression or bending causing socket to fracture.

Repair: Replace collar and damaged pipe.

Comment: Fracture pattern indicates failure could be due to bending, compression or lateral shear. Modern pipeline systems have more tolerance to this kind of loading.

Reference: J003

Material: Cast iron

Description: Leaking joint.

Cause: Bending or compression.

Repair: Cut out and replace, or attempt reassembling if not misaligned.

Comment: These joints have very low capacity to cope with displacement or deflection. Modern pipeline systems are more robust.

Reference: J004

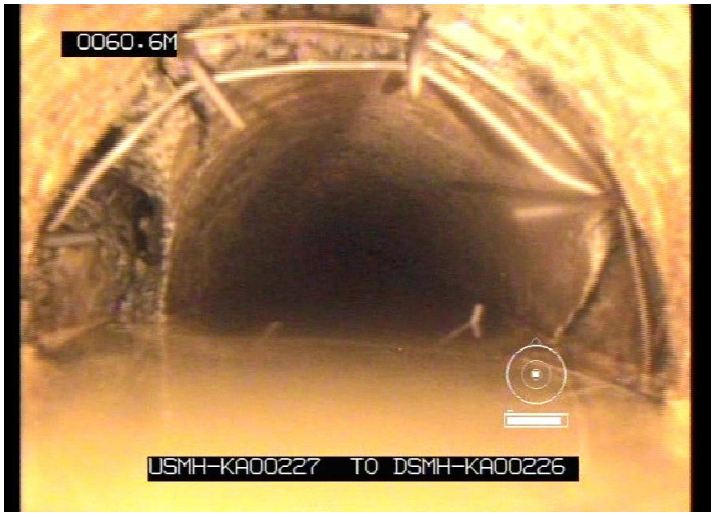
Material: Cast iron pipe and lead run joint.

Description: Leaking joint.

Cause: Compression or bending.

Repair: If pipe undamaged, cut out joint and repair. For minor displacements, may be able to repack lead.

Comment: These joints have very low sealing capacity when deflected. Minor displacement results in leakage. In some cases, the joint can be resealed by repositioning the lead seal. Use modern pipeline systems to avoid failure.



Reference: J005

Material: Concrete, reinforced

Description: Joint failure.

Cause: Compression

Repair: If localised damage, may be able to use repair patch or line affected section. Otherwise, cut out and repair.

Comment: Some other materials can survive limited compression. Otherwise accept risk and plan for repair.

Reference: J006

Material: Concrete, reinforced

Description: Joint failure.

Cause: Compression

Repair: If localised damage, may be able to use repair patch or line affected section. Otherwise, cut out and repair.

Comment: Some other materials can survive limited compression. Otherwise accept risk and plan for repair.

Reference: J007

Material: Concrete, reinforced

Description: Joint failure.

Cause: Flotation

Repair: May be possible to reinstall undamaged pipes.

Comment: Where a flotation risk is identified, it may be better to re-route the pipeline into ground with a lower flotation risk or to review design and installation practices to minimise risk.

Reference: J008

Material: Concrete, reinforced

Description Joint failure.

Cause: Lateral shear or bending

Comment: Modern pipeline systems may be more tolerant.

Reference: J009

Material: Copper pipe with threaded joint

Description: Leaking joint.

Cause: Possibly bending.

Repair: May be able to remake joint otherwise replace damaged components.

Comment: More flexible modern pipelines have better tolerance to displacement and deflection.

Reference: J010

Material: Ductile Iron (DN150)

Description: Joint failure.

Cause: Lateral spread.

Repair: Replace damaged joints. It may be possible to reuse the pipes if the ends are undamaged, but the joint will probably need replacement.

Comment: The only practicable way to avoid this is avoid locating system where lateral spread is a hazard. Modern plastics may have remained intact though deformed.

Reference: J011

Material: PE

Description: Leaking joint.

Cause: Leaking PE or PP bodied compression fitting on PVC pipe.

Repair: May be able to re-make joint, but will usually need to replace connector and any damaged pipe.

Comment: Modern PE pipe and joints have better tolerance to displacement.

Reference: J012

Material: Galvanized steel

Description: Leaking threaded joint.

Repair; Replace joint .

Comment: Threaded joints have little tolerance to any form of displacement. It is probably worth replacing the galvanized steel pipe with modern PE.

4. Fittings Damage

Reference: FT001

Material: Cast iron

Description: Gibault failure.

Cause: Probably tension or bending, but possibly large amplitude shaking.

Repair: Reconnect pipes with replacement coupler if not badly damaged, otherwise replace damaged pipes and repair.

Comment: Modern pipeline systems are more tolerant of displacement.

Reference: FT002

Material: PE

Description: Compression fitting leaking.

Cause: Probably failed in tension, possibly bending.

Repair: Replace damaged fitting

Comments: The left hand cone appears to have been displaced. Use of an insert may have helped transfer displacement into the pipe barrel, preventing failure.

Reference: FT003

Material: PE

Description: Compression fitting leaking.

Cause: Tension or bending

Repair: Replace damaged fitting.

Comments: Use of an insert may have helped transfer displacement into the pipe barrel and prevented failure.

Reference: FT004

Material: PE

Description: Compression fitting leaking.

Cause: Tension or bending

Repair: Replace damaged fitting.

Comments: Use of an insert may have helped transfer displacement into the pipe barrel and prevented failure.

Reference: FT005

Material: PE

Description: Compression fitting leaking.

Cause: Tension or bending

Repair: Replace damaged fitting.

Comments: Use of an insert may have helped transfer displacement into the pipe barrel and prevented failure.

Reference: FT006

Material: PE

Description: Compression fitting failed

Cause: Ground movement

Repair: Replace damaged fitting.

Comment: Modern PE with inserts in mechanical joints is more tolerant of deformation and can transfer deformation away from fittings into the pipe barrel.

Reference: FT007

Material: PE

Description: Compression fitting failed.

Cause: Ground movement

Repair: Replace damaged fitting

Comment: Modern PE with inserts in mechanical joints is more tolerant of deformation and can transfer deformation away from fittings into the pipe barrel.

Reference: FT008

Material: PE

Description: Compression fitting failed.

Cause: Ground movement

Repair: replace damaged fitting

Comment: Modern PE with inserts in mechanical joints is more tolerant of deformation and can transfer deformation away from fittings into the pipe barrel.

Reference: FT009

Material: PE

Description: Compression fitting failed.

Cause: Ground movement

Repair: replace damaged fitting

Comment: Modern PE with inserts in mechanical joints is more tolerant of deformation and can transfer deformation away from fittings into the pipe barrel.

Reference: FT010

Material: PE

Description: Compression fitting failed.

Cause: Ground movement

Repair: replace damaged fitting

Comment: Modern PE with inserts in mechanical joints is more tolerant of deformation and can transfer deformation away from fittings into the pipe barrel.

Reference: FT011

Material: PE

Description: Threaded fitting failed.

Repair: Replace damaged fitting.

Cause: Tension or bending

Comments: Threaded fittings have low tolerance to displacement. If alternative stop taps and fittings cannot be used, may need to accept risk.

Reference: FT012

Material: PE

Description: Saddle leaking.

Cause: Unknown, could be shaking, compression or bending.

Repair: May be able to re-make joint. Otherwise cut out and replace.

Comment: Leaking saddle connection on PE service pipe. The second set of drips to the left may be associated with the saddle or an actual leak. Fused joints are more tolerant of displacement.

Reference: FT013

Material: PVC

Description: Junction failure.

Cause: Ground movement drives lateral into the barrel of the main pipe.

Repair: Cut out and replace.

Comments: No practical avoidance in reticulation systems. Accept risk and make plans for repair.

5. Existing Damage

Reference: EX001

Material: Asbestos cement

Description: Crack

Cause: Pressure related split.

Repair: Replace damaged pipe.

Comment: Requires degraded pipe wall, but triggered by ground movement or pressure surge.

Scalloped edges show continued flow of water after crack formed and show that the material was degraded at the time of failure.

Reference: EX002

Material: Cast iron

Description: Crack

Cause: Pressure related split.

Repair: Replace damaged pipe section.

Comment: Probably associated with deterioration of pipe wall and possibly aggravated by pressure surge.

Reference: EX003

Material: Cast iron

Description: Crack, holed

Cause: Pressure related split.

Repair: Replace damaged pipe

Comment: Requires degraded pipe wall, but triggered by ground movement or pressure surge.

Reference: EX004

Material: Copper

Description: Corroded pipe

Cause: Shaking and corrosion.

Repair: Replace damaged pipe.

Comment: The copper pipe had perforated, but the hole was blocked by a plug of corrosion product. Shaking probably displaced the plug causing the leak to open up.

Reference: EX005

Material: PE

Description: Break

Cause: Probably interference damage.

Comment: Appears to have been damaged by a drill or pole.

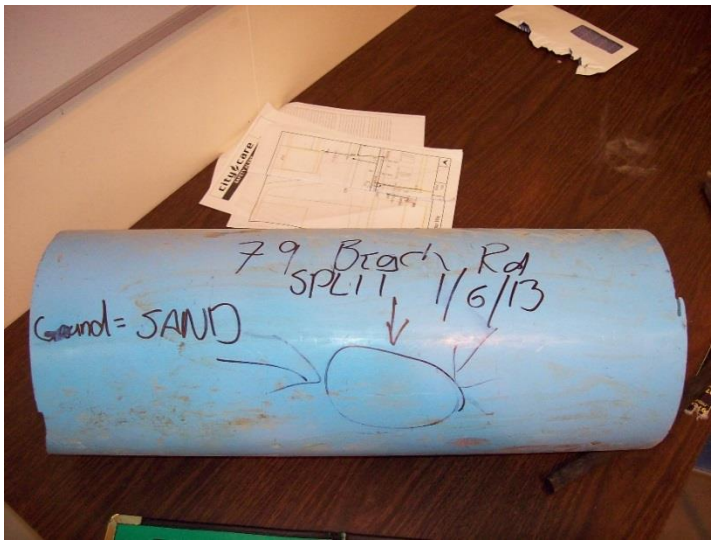
Reference: EX006

Material: PE

Description: Emergency seal

Cause: Pipe folded back to provide emergency seal.

Comment: Temporary repair method.



Reference: EX007

Material: PVC-U

Description: Crack

Cause: Installation practice.

Repair: Repair clamp or replace damaged pipe section.

Comment: Typically caused by local point load (eg from stone) leading to slow crack growth but actual failure could be triggered by additional stress during a surge or shaking from earthquake.

Reference: EX008

Material: PVC-U

Description: Crack

Cause: Installation practice.

Repair: Replace affected pipe.

Comment: Split due to slow crack caused by uneven bedding or point load (eg rock impingement). While the earthquake may have triggered failure continued crack growth would have caused failure in the future. The bifurcation to the right is a common feature in PVC pipe failures.

Reference: EX009

Material: PVC-U

Description: Break

Cause: Impact during shaking or PGD.

Repair: Replace damaged pipe.

Comment: Good installation and construction practice will reduce the risk.

Multiple fractures and scalloped fracture face (seen near the pallet) usually indicate high-speed, high-energy impact. It is likely the pipe was struck by a displaced object or was displaced into an object during ground movement.

Good installation practice including placement of bedding materials and maintaining separation from rigid objects should minimise risks.

Reference: EX010

Material: Galvanized steel

Description: Crack

Cause: Bending or buckling.

Comment: Leaking steel pipe next to coupling.

Reference: EX011

Material: Steel

Description: Leaking pipe.

Cause: Corroded steel.

Repair. Cut out leak or possibly weld patch and remake joint.

Comment: Leaking steel pipe next to gibault. Similar failures are seen in normal service in bitumen coated steel pipes where the coating has been damaged when the fitting was installed.

Reference: EX012

Material: Riveted steel, with cement lining and bitumen coating.

Description: Perforation

Cause: Corrosion.

Repair: Replace joint and pipe. In principle, the damaged section could be cut away but the poor condition of the coating and age of the pipes means that complete pipe replacement is preferred.

Comment: Similar features are often associated with gibault joints damaging the external coating. Shaking or other ground movement can dislodge corrosion product plug leading to leakage.

6. Other Damage

Reference: OT001

Material: Asbestos cement pipe connected to concrete pump station

Description: Break and pump station flotation.

Cause: Liquefaction

Repair: Replace pipeline.

Comment: A combination of rigid pipe barrel and joints with limited capacity to accommodate deflection has resulted in widespread damage due to flotation. If the pump station was undamaged and retained some functionality or could be re-levelled, it may be possible to either make a temporary connection. Avoid similar problems in future by design to avoid flotation or locate away from liquefiable ground. A flexible modern pipeline system with end load resistant joints might have tolerated this displacement.

Reference: OT002

Material: Brass

Description: Fitting failed.

Cause: Probably tension due to ground movement.

Repair: Replace fitting

Comment: May have been corroded at time of failure but threaded fittings have low tolerance to displacement even when new.

Reference: OT003

Material: Bronze

Description: Bronze tapping saddle leaking.

Cause: Shaking or displacement.

Repair: Replace saddle connection.

Comment: May have been due to corrosion. Snaking the service pipe and taking it off at a slight angle may have reduced vulnerability.

Reference: OT004

Material: Cast iron encased in concrete

Description: Break

Cause: Bending.

Repair: Replace the entire pipe bridge length.

Comment: The concrete encasement failed in bending when compressed. The pipe then responded as reinforcement and failed in bending. Concrete encasement may have aggravated loading by providing rigid encasement, but cast iron has poor tolerance to deflection and bending.

Avoid installing rigid systems where compressive PGD expected. Use modern materials that can maintain service when deformed or and adjust design to allow for compressive displacement without causing buckling or bending.

Reference: OT005

Material: Cast iron

Description: Shattered coupler, sheared pipe barrel

Cause: Lateral shear, bending or tension.

Repair: Replace damaged sections.

Comment: Cast iron has limited ability to accommodate deflection, especially when deteriorated. Casting defects in bends and other fittings increase the risk of local weak points. Modern pipeline systems would be more tolerant.

Reference: OT006

Material: Concrete

Description: Biaxial separation

Cause: Lateral spread.

Repair: Expose several pipe lengths back and reconnect using flexible joints.

Comments: Rubber ring jointed pipes have minimal resistance to end loads. A flexible pipe barrel would also be needed to withstand the lateral displacement in this condition. Where possible, avoid ground at risk of lateral spread. A flexible modern pipeline system with end load resistant joints may have tolerated this displacement.

Reference: OT007

Material: Copper connected to galvanized steel

Description: Elbow failed.

Cause: Ground movement.

Repair: Replace damaged joint.

Comment: Galvanized pipes performed poorly in Christchurch and Kaiapoi. Replacement is probably better than repair. Modern service pipe materials with inserts in mechanical joints would perform better.

Reference: OT08

Material: Copper

Description: Copper pipe failed.

Cause: Unknown, possibly PGD

Repair: Replace damaged fittings

Comment: Modern service pipe materials with inserts in mechanical joints would perform better.

Reference: OT009

Material: PE

Description: Displaced joint.

Cause: Ground movement.

Repair: Remake joint.

Comment: While modern PE with inserts in mechanical joints is more tolerant of deformation, the short section of pipe between fittings does not allow room for substantial deformation.

Reference: OT010

Material: PE

Description: Fitting failed.

Cause: Probably tension.

Repair: Replace fitting with modern fitting with insert.

Comment: While modern PE with inserts in mechanical joints is more tolerant of deformation, the short section of pipe between fittings does not allow room for substantial deformation.

Reference: OT011

Material: PE

Description: Pipe strike.

Cause: Third party.

Repair; Replace damaged pipe.

Comment: Good installation practice including warning tapes and detection wires will reduce the risk.

Reference: OT012

Material: PE

Description: Pipe strike.

Cause: Third party.

Repair: Replace damaged pipe

Comment: Good installation practice including warning tapes and detection wires will reduce the risk.

Reference: OT013

Material: PE

Description: Leaking

Cause: Traffic damage to above-ground line.

Repair: Replace damaged pipe

Comment: Difficult to avoid where above ground pipes cross access routes. Risk may be reduced for smaller lines by installing a duct protector.

Reference: OT014

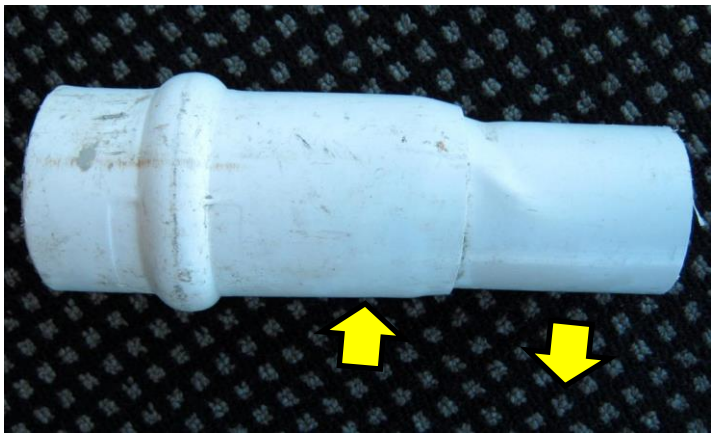
Material: PVC-U

Description: Break

Cause: Crushed by compression.

Repair: Cut out damaged section and repair.

Comment: Smaller PVC pipes may have sufficient ductility to accommodate compressive buckling, but larger and thicker walled pipes do not. There is no practical solution to minimising risk. This large pipe is too rigid to cope with buckling deformation. Butt welded steel may have remained partly serviceable under these loads, but unlikely.



Reference: OT015

Material: PVC-U

Description: Ductile deformation.

Cause: Lateral shear or possibly compression.

Repair: Cut out affected pipe and replace. May need to cut out adjacent pipes and sockets if damaged.

Comment: This is a form of subcritical damage. It is probably caused by a shearing movement as marked but could result from compressive buckling that has started to cause bending of the wall.

No practical method of avoiding. Minimise occurrence and impact by using modern materials.

Reference: OT016

Material: PVC-U

Description: Over-insertion (also known as telescoping or super socketing).

Cause: Compression.

Repair: Cut out defective area and repair.

Comment: Where the socket does not fracture, this may result in sub-critical damage or delayed failure. Effectively limited to thinner walled high-toughness PVC. With thicker walled pipes or older less, ductile materials the socket will shatter.

Reference: OT017

Material: PVC-U

Description: Reinsertion failure.

Cause: High amplitude shaking causes pipe to pull out of socket and then reinsert into the socket

Repair: Cut out and repair

Comment: A relatively rare phenomenon requiring ductile socketed materials and high amplitude shaking with magnitude greater than socket insertion depth. Where high amplitude shaking is expected, longer-socketed pipes or (more reliably) alternative materials such as fused PE could be used. Otherwise accept risk and prepare for repairs.

Reference: OT018

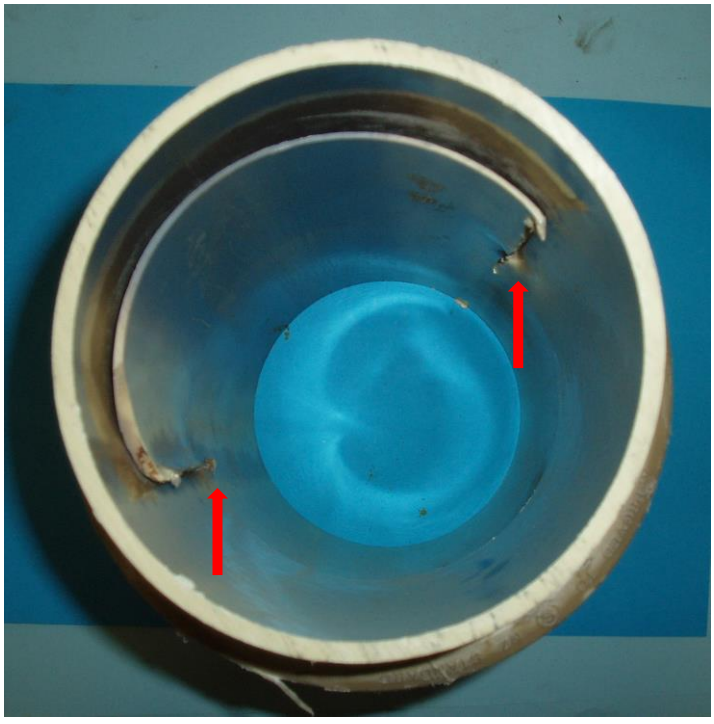
Material: PVC-U

Description: Reinsertion failure.

Cause: High amplitude shaking causes pipe to pull out of socket and then reinsert into the socket

Repair: Cut out and repair.

Comment: A relatively rare phenomenon requiring ductile socketed materials and high amplitude shaking with magnitude greater than socket insertion depth. Where high amplitude shaking is expected, longer-socketed pipes or (more reliably) alternative materials such as fused PE could be used. Otherwise accept risk and prepare for repairs.

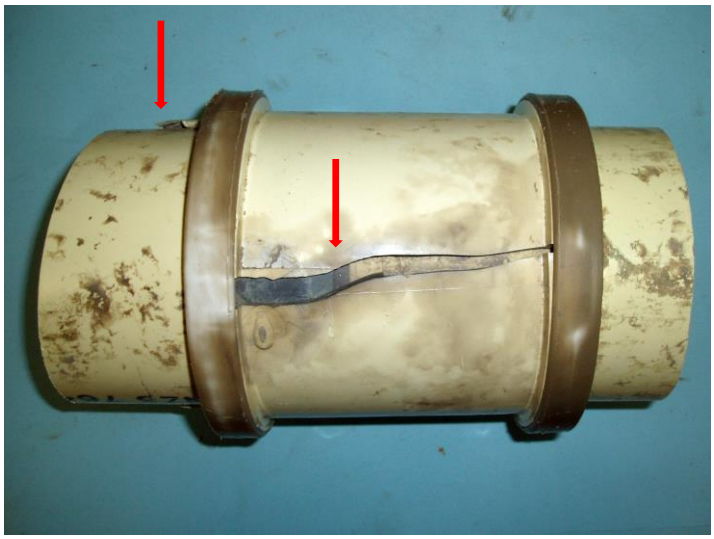


Reference: OT019

Material: PVC

Description: Reinsertion failure.

Comments: End on view of the PVC socket shown above. The red arrows mark where the pipe walls have cut through each other.



Reference: OT020

Material: PVC

Description: Pipe insertion causing surrounding coupling to fracture.

Cause: Compression

Repair: Cut out damage and repair.

Comment: The red arrows mark the position of the pipe ends. The pipe walls have cut through each other, and the increased diameter has cracked the surrounding socket. This type of failure can only occur in a collar or sleeve joint.

Reference: OT021

Material: PVC

Description: Split elbow.

Cause: Shaking

Repair: Replace failed elbow.

Comment: Solvent cemented PVC is not widely used as service pipes. Although cracking may have initiated in service with final failure being triggered by shaking, other fittings failed in the same event. Replacement with PE service lines may be advisable.

Reference: OT022

Material: PVC

Description: Pipe failed at tapping saddle.

Cause: Shaking or permanent ground displacement

Repair: Replace damaged pipe and re-make connection.

Comment: It is possible that there was a crack present which failed through shaking. Fused PE has better tolerance.

Reference: OT023

Material: Steel

Description: Pipe insertion causing surrounding cast iron coupling to fracture.

Cause: Compression

Repair: Cut out damage and repair.

Comment: This type of failure can only occur in a collar or sleeve joint. Modern welded steel pipelines are likely to buckle in compression but may retain some functionality.

Reference: OT024

Material: Steel, concrete lined

Description: Loss of concrete lining.

Cause: Most probably due to compression.

Repair: This is a sub critical failure that increases the risk of future leakage from corrosion of the unprotected steel. Replace damaged pipe sections as and when detected.

Comment: Not expected to cause problems in the short term, so will only be detected after an event if the joint or the pipe is damaged. Because of this, the scale of the problem is unknown and likely to remain until perforations start to cause detectable leakage issues. More flexible polymer linings would probably avoid this problem, there is no evidence that damage to concrete linings is a major issue.

Reference: OT025

Material: Galvanized steel or copper

Description: Joint break.

Cause: Ground movement

Repair: Replace damaged tee.

Comment: Modern service pipe systems with inserts at mechanical joints are more robust.