WPT1 Activity1 Review of Current Practices, Baseline Audit, and Improvements to existing equipment, systems / processes

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Work Package: Evaluating current market and setting the basis for rolling out improvements

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Content

1 Introduction

This report gives an overview of the current practices of the partners in the Green WIN project. The report is a deliverable in work package 1 of the project. A brief overview of this work package is given in the next chapter.

The main part of the report (chapter 3) describes the current practices of the water management organisations among the partners. These are:

- Canal and River Trust
- Ministerie van Infrastructuur en Waterstaat-Rijkswaterstaat
- Waterways Ireland
- Voies Navigables de France
- Vlaamse Landmaatschappij

The description of the current practices consists of the following:

1. overview existing assets
    - number of pumping stations,
    - classification into three classes (small, medium, large),
    - example(s) per class with characteristic data.
2. Asset management / maintenance, operations
    - Organisation
    - maintenance strategy
    - Performance reports (like CRT examples)
    - Maintenance execution: internal or outsourcing
3. Construction projects
    - Procurement of (new) installations
    - Type of contracts; detailed specifications, design and construct, Design, construct, maintain and finance
4. Developments
    - R&D technical aspects
    - Energy reduction
    - installations
    - System approach integrated pump, water and energy management

Details are given in appendices (chapter 6).

Chapter 4 summarises the results and from these, conclusions are drawn relevant for the work to be performed in the Green WIN project to reach the goals of the project.

2 WP. T1 Description of Work Package

This chapter gives a brief summary of Work Package WP T1 “Improving existing systems and processes”. The Application Form (AF) describes this as following:

> *“Re-configurations of existing equipment systems and processes to look for the opportunities to improve operational / management techniques that deliver greener operations. Evidence gathered will 'prove' (or rule out) which solutions best will help achieve CO2 reductions and will be built in to the Best Practice Guidelines being developed in WPT2. These will be presented to other WMO's, regional/local authorities, manufacturers and environmental/inland waterways pressure groups, to support the case for wider adoption”.*

2.1 Contribution to objectives Green WIN

Work Package WP T1 contributes to the goals of green WIN as following (from the AF):

> *“Sub Objective 2. Demonstrating CO2 reductions & energy efficiency for existing solutions A series of trials, validated by SME’s, assessing how WMO’s can improve the energy efficiency of single components/products and optimise efficiency throughout an entire system by using a better combination of components, other or renewable energy sources, or by “Smarter Management".*

2.2 System approach

Improvement asks for more than assessment of the performance of individual pumps only. Pumps function in a system consisting of several hierarchical levels see figure below:

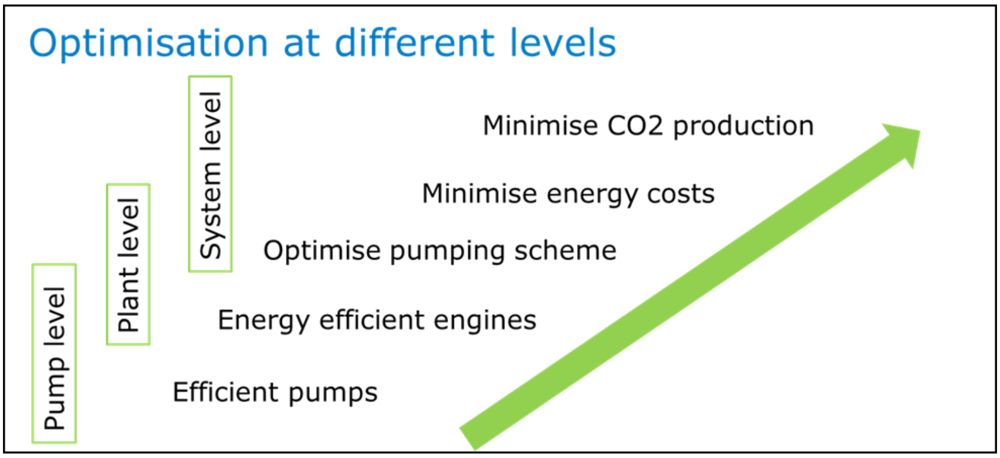

Figure 1 Optimisation at different levels

Bottom up schematized three hierarchical levels can be distinguished:

- Pump level
- Plant level/ pumping station
- System level (canal/water system)

Each level has his specific aspects for optimisation and improvement of their performance. Energy consumption and CO_2 production are the most important in a Green WIN context. The aspects for potential improvement are subsequently described at the three levels;

Pump level

At pump level, building from basic function, the displacement of water we have to take into account: pump (type, working range), drive (diesel, electric …) and energy supply (electricity, diesel).

At this level pumps can be optimized, taking into account pump types, their pump characteristics rated to the working range. Drives must be energy efficient. The energy source finally determines the CO_2 production.

Plant level/ pumping station

At plant level we are looking at systems that consists of (often) multiple pumps, connecting pipework, valves, debris gratings and such. System characteristics define and influence the operation of a pumping station. Installations for operating the pumps consist of hard and software. Sensors to feed the operation and control of the installations and connection with a control centre. All these installations can be placed in an building with climate control, access- and surveillance facilities. Facilities for maintenance and operations personal.

At this level a more complex set of aspects parameters comes into sight. Not limitative: cooperation of multiple pumps considering their working ranges. Energy consumption of building related installations like climate control are often important too.

System level (canal/water system)

At system level we see several pumping stations interacting with the water system. The water system is an open system with inflow and outflow; due to rainfall / evaporation, connecting water supplies and ground water.

At this level the volume of water pumped, how much and when is determined. Optimisation targets can be to pump as less water as possible whilst meeting the demands required and make optimal use of availability energy and where possible renewable energy.

3 Current practices partners

3.1 Canal and River Trust

The Canal & River Trust is a registered charity, constituted in 2012 to care for around 3,000 km of inland waterways and associated reservoirs and docks in England and Wales. The Trust's activities are focussed on the effective pursuit and promotion of 7 Charitable Objects; the operation, protection and promotion of inland waterways; their built and natural heritage; their history and culture; and their economic potential for public benefit. As statutory successor to British Waterways, the Trust also fulfils duties as a navigation authority, a harbour authority and various other statutory undertakings.

Overview existing assets

The Trust owns and maintains a wide range of pumping stations throughout the national canal network. The 76 Pumping Stations in the Trust's ownership either abstract water or transfer water (including back pumping) around the network. A small number are also used for flood water transfer. These pumping stations currently contain 122 individual pump sets.

Purpose of the Pumping Stations across the canal network

Purpose	No	Percentage
Abstraction	25	33
Transfer	48	63
Flood Transfer	3	4
Total	**76**	**100**

Principle pump types used throughout the network

Pump Design Type	Number	Percentage
Submersible	50	66
Axial Flow	9	12
Borehole	3	4
Spindle	5	7
Horizontal Split Case	8	10
Currently no equipment	1	1
Total	**76**	**100**

These pumps are selected from a range of manufactures including Flygt, Sulzer and KSB. The pumps range in motor size from 10kW to 250kW. Typical flow rates across all stations are between 0.06 m3/s to 1 m3/s

The number of individual pump units at a pumping station vary from a single pump to four pumps. To reduce the risk of navigation restrictions due to lack of water, pumping sites that are critical to water management have pumps in reserve i.e. on standby.

The Trusts pumping stations are typically operated in three ways, dependent on the age of equipment, operational or environmental constraints and funding for upgrade.

Older pumping sets typically require manual operation to turn on and off which requires an operator to visit site which is likely to involve travelling time. An intermediate step is to make use of a timer clock to switch the pump on and off.

Fully automatic sites have a SCADA[1] system of control allowing pumps to operate on demand i.e. on predetermined water levels. This control function allows remote performance monitoring, diagnostics and the ability to adjust control parameters to match the resource requirements of a pumped system. Continued investment and development of the Trusts SCADA system over the last twenty years has seen the continued upgrade and inclusion of pumping stations onto the SCADA system.

The table below indicates the current pump control methods and telemetry (SCADA) systems which are utilised for the operation of The Trusts pumping stations.

Control	**Number**	**Percentage %**
Manual (Staff Operated)	14	18
Auto (Local Control)	5	6
Auto (SCADA local or remote level control)	56	73
No Equipment	1	1

Details of Trust pumping stations selected for this project are included in the appendix.

Asset management / maintenance, operations

Planned Preventative Maintenance on the Mechanical and Electrical Elements of a Pumping Station is completed by the Trusts MEICA[2] Framework contractor. This contract covers scheduled and reactive maintenance plus capital works to all the Trust's MEICA assets from 2017 to 2025. The contractor is programmed to complete one PPM maintenance visit per year with the option to complete extended scope servicing at every site with removable pumping equipment at the Trusts discretion.

[1] SCADA: Supervisory Control And Data Acquisition
[2] MEICA: Mechanical Electrical, Instrumentation, Control and Automation

The contract also provides provision for reactive repairs with a standard response time of four hours to the majority of our pumping stations.

The current scheduled maintenance costs for all pumping stations within The Trust under the MEICA contract framework are £ 67,650 (=€ 79,150) (total Annual Cost Contractor PPM 70 stations). This cost is based on one service per year per site and includes the optional cost to complete extended scope works including lifting a submersible pump from a wet well.

The MEICA maintenance contract is the principal point of M&E equipment condition monitoring and provides an inspection process and ability to measure individual site condition.

Reactive Repairs – The Trusts MEICA framework contractor provides national coverage for the reactive repairs to pumping stations with a typical response time of four hours. In the event of a failure the station (if connected to the SCADA system) will raise an alarm to an operational member of staff.

Typical failure types are shown below:

- Pump Overload – Causes include blockage due to vegetation debris, mechanical failure, electrical failure
- Pump Low or erratic flow – Causes include reduced or poor flow presentation due to blocked intake screens and or siltation build up
- Pump Thermal – Causes include pump overheating due to lack of water around pump body generally due to blocked intake screens
- Pump Seal Leakage – Cause include the mechanical failure of bearing seals allowing to water to leak from the pump volute to the motor
- Control Panel SCADA Communication – Causes include modem or router failure cutting communication to SCADA servers. Can prevent operation when remote water level instrumentation is utilised
- Control Panel Equipment – Causes include the failure of a component inhibiting or preventing operation of pumping equipment such as a call to run relay
- Field Equipment Instrumentation – Causes include failure of a water level transducer affecting the operation of the site either preventing pumping equipment being called when required or causing excessive pumping

The current re-active maintenance costs for 2019 are £46,500 (€ 54.405,00) and typically cover the cost of a one-time repair task or the replacement of minor components. Re-active costs vary year on year dependent on prevailing weather conditions and levels of traffic. The annual forecast for re-active costs directly related to pumping station for The Trust is £50,000 (€ 58.500,00) per annum.

Planned Repairs – Generally these either follow on works from planned preventative maintenance, reactive repairs or non-urgent small-scale repairs which are not significantly affecting the performance of the station and do not require a reactive response. Planned repairs generally are to wearing elements which would be expected to require an intervention during the life span of the equipment. Works are prioritised by the relevant MEICA Engineer and maybe grouped for economic efficiency or if felt to be significant in either scope or cost transferred for capital project investment prioritisation.

Typical Planned Repairs are shown below:

- Pump – Bottom end overhaul, replacing worn bearings and seals
- Pump – Motor electrical re-wind, stove and bake
- Pump – Worn impellor replacement
- Valves – Replacement of failed valves such as non-return or gate
- Pump Support – Replacement of failed or poor condition guide rails
- Control Panel – Replacement of failed or falling switch gear, indicators or displays
- Field Equipment – Replacement of failed transducers, stilling tubes, manhole covers

Typically, pumps should see an operational service life of between 15 and 25 years but in practice some pumps have limited life spans. The factors behind this are often unclear but can include poor selection / design, environmental conditions and external influences such as poor condition infrastructure. The current trend is for manufacturers not to repair but replace due to the reduction in capital costs for new equipment.

Of the 76 pumps used to maintain levels on Canal & River Trust navigations, The Trust logged flow data for 57 pumps in 2018, and energy data for 70 pumps

	2018 data
Total Electricity Consumed (kWh)	7,964,103 (70 pumps)
Total Electricity Cost (£)	£1,007,560 (=€ 1,178,845) (70 pumps)

The amount of electricity used to pump water in 2018 is equivalent to:

- 33.21% of the total electricity consumed by the Trust in a year
- 28.55% of the electricity spend of the Trust (£2,764,404 (=€ 3,234,350) electricity cost in 2016/17)
- 3,679 tonnes of CO_2 emitted (Carbon Trust Standard Rationale, 2016)
- 22% of the overall CO_2 footprint of The Trust (15/16 emissions of 15,323 t / CO_2)
- The energy use of 1,714 “average households” in a year (DECC, 2015)

New construction projects

Where works to M&E elements are beyond the scope of reactive or planned repairs, they are prioritised for capital investment as part of an annual program of projects to all water automation and monitoring equipment. Works typically fall into seven element categories as shown below and will be off three types of work either Repair, Replacement or Enhancement. All works are delivered by the MEICA framework contractor.

The table below indicates the intervention element project numbers and percentage for all M&E project works to pumping stations from 2012 to 2017. Where the project was a combination of work the most significant element is taken as the lead. Due the relative short life spans of M&E equipment compared to the civil elements investment is constant to maintain a steady state in terms of overall condition of the asset.

Element	**Number**	**Percentage %**
Pumps	38	50
Control System	14	18
Equipment	13	17
Pumps Ancillaries	8	10
Pump House	2	3
Delivery	1	1
Intake	1	1
Total	**77**	**100**

Below are typical repair or replacement works associated with each element:

Pumps

Replacement or repair of failed or life expired pump units. Average age of pump units replaced from 2012 to 2017 was 17 years. Pump life spans vary significantly dependent on a number factors including type, manufacturer, installation, utilisation, environment and station design. Pumps may be replaced on total failure were repair is uneconomic, or as their performance deteriorates as they reach end of life. Early intervention before complete failure often benefits customers by preventing un-planned failures leading to an operational impact. Of the 38 pump replacement projects completed 23 were to replace failed units. The Trust utilises several different pump types and manufacturers and a design review is carried out for each pump project to ensure the most suitable unit is utilised. This is generally based on past experience with performance and cost. In recent years the cost of overhaul of typical submersible pump units has increased with replacement costs reducing. The impact is that replacement is often chosen over repair as this provides the most cost-effective solution. Submersible pumps are typically straightforward removal from an auto coupling arrangement with limited site works required. Fixed pumps often require a degree of strip down on site to allow their removal or replacement. Replacement of fixed pumps may require modifications to the civils elements of the asset.

Control Systems

Replacement of control systems is usually due to life expiry of the existing equipment. The Trust has undertaken a program of Dynamic Logic outstation replacement for Mitsubishi PLC units as the older DL units became un-reliable. This unreliability was affecting pump control, communication and diagnostics. Of the 14 control system projects 9 were for DL upgrade. Currently 4 pumping stations are operating with DL outstations and are awaiting upgrade to PLC

Equipment

Replacement of equipment can include items such as flow meters or variable speed drives. 2 flow projects have been completed in the last 5 years to replace failed equipment. Flow meter replacement can include excavation of existing equipment, rebuilding of chamber and modifications to existing pipework. See Enhancement for details of adding flow meters to existing systems.

Developments

Highlighting Inefficient Sites

The Annual Pumping Report produced by The Trust compares all Pumping Stations in terms of usage and power consumed. The power consumed per volume of water raised (kW/Ml/m) indicates the relative efficiency for each pumping system. This figure provides a tool to focus on poorly performing sites.

Pump System Efficiency

A programme of installing variable speed drives (VSD) has been underway since 2011. This enables variation in the speed of the pump motor and allows adjustment in power consumption to fine tune a pump to its best efficiency point (BEP). By optimising the pump to its duty point (flow) using a drive the minimum amount of power is utilised to achieve the duty flow. Not all pumps or systems are suitable for VSD equipment. Each pumping station enhancement is now considered for VSD installation.

Pumping SCADA Control & Set Points

The installation of SCADA telemetry and level instrumentation on a pumping station allows enhanced control options. The decision to install or upgrade SCADA instrumentation is considered as part of the prioritisation process. Each site has a Water Management Operational Procedure which documents the level reference or datum control point for the SCADA instrumentation. This Operational Procedure defines the optimum control parameters for the operation of the site with SCADA control. SCADA also enables pump use to be monitored, examined and analysed. Pump switch on-off points can be set to water levels or to a clock timer to provide the right pound level to meet water demand and with a bias towards off-peak electricity timing the set points can reduce overall pumping costs.

Overarching SCADA

A series of pumping stations operating independently occasionally create imbalances in individual canal pounds leading to a deficiency in pumping or excessive pumping leading to waste. A project of Overarching SCADA is underway which aims to design and implement a system which controls the chain of pumps as a whole. Pumping regimes will be developed to achieve either net transfer of water or lock recirculation as required in all conditions i.e. summer or winter, drought, normal or flood conditions, night time or daytime. Each pumping regime will be designed to be efficient so as to minimise the cost of pumping and eliminate any water that is pumped to waste. A further objective is to contribute to the reduction of CO^2 emissions as part of the Trust's carbon management plan.

Power Grid Demand Balancing

Working with energy providers, the Trust has linked suitable pumps to an energy management system which can under/over speed pumps or alternatively switches pumps on or off allowing the release of energy or absorb excessive energy back to the National Grid to even out its temporary peaks and troughs in demand. This reduces the demand in standby power stations and allows the greater use of green powers sources such as wind and solar. These short-term interventions generate revenue for the Trust and in turn helps to reduce carbon emissions.

Overview costs pumping stations CRT 2019		
Item	cost / year	
Works planned include pump replacement, control panel replacement, wet well clearance and valve replacement	£ 350,000	€ 409,500
On-going capital investment forecast based on asset strategy modelling on pumping stations over the next 10 years.	£ 350,000	€ 409,500
Total current annual average maintenance, running and investment costs pumping stations CRT	£ 1,425,000	€ 1.667,250
Average total operational costs per pumping station	£ 19,000	€ 22,230

3.2 Ministerie van Infrastructuur en Waterstaat-Rijkswaterstaat

Rijkswaterstaat manages the Dutch national waterways and water systems. The waterways and water system consist of approximately 3,400 km of waterways (canals and navigable rivers) and 68,000 km2 of surface water. Over 180 larger hydraulic structures are in operation to enable navigation and water management; 133 locks, 14 discharge sluices, 10 weirs, 6 storm surge barriers and 20 pumping stations.

Overview existing assets

The pumping stations have functions for water management (8), control level canals (10) and lock operations (2). Each station has between 1 – 6 pumps. Total number of pumps is 57. The stations for water management are the largest. Among these the two largest 250 m3/s (6 pumps) and 120 m3/s. (3 pumps). Most pumps function with relatively low head 1 to 2 meter. The pumping stations to control canal levels have the largest head (max 10 m). The capacity of these stations ranges from 10 to 20 m3/s. The smallest pumping stations deliver 2 m3/s or less.

The pump types are axial flow and centrifugal pumps. All pumping stations are remotely operated, most function fully automated. A few older pumps are driven by diesel engines. Nearly all are electric. The electricity used per year is estimated at 10,000 MWh. Not all pumping stations are individually metered. This figure is estimated from the measured electricity use in 2016. The use of diesel fuel is negligible on this amount.

As well as through direct energy use, CO_2 emissions are caused by maintenance and operations - and also, by construction of the facilities. Rijkswaterstaat has a calculation procedure (DUBOCALC) to determine the CO_2 emission from these operations. This procedure is used in the procurement procedure for new stations, but has not been applied to the existing stations

Asset management / maintenance, operations)

All operational maintenance activities are procured to commercial companies. Operational technical services and maintenance is combined with similar work for stretches of canals in larger contracts. New construction and renovation is procured in separate contracts.

The pumping stations are remotely operated from control centres manned with Rijkswaterstaat staff. Operation is combined with operation of locks and discharge sluices. Some of the control centres also manage the navigation traffic.

Nearly all pumps are designed for a long life. Because of the nature of our networks relatively a low number of working hours is needed. For canal level control only during dry periods and for water management during wet periods. Lifetimes up to 50 years or even longer are not exceptional. Components and electric engines have to be replaced during that time.

Regular maintenance is included in the larger contracts mentioned before. This is steered with rather global performance requirements (RAMS). Variable maintenance is planned within an asset management framework on system level: canal / water system including all facilities. A risk-based maintenance practice is used for structures, including pumps. Inspections feed asset management plans on object level (e.g. pumping station). This is done by the staff of Rijkswaterstaat regions. From these plans a network wide scheme for larger maintenance measures, as renovation and replacement of pumps, is drawn up by a central Rijkswaterstaat planning staff. The planned measures are outsourced, mostly in combined larger contracts. Some of the measures are commissioned to the maintenance contractor. Contract surveillance is done by a central unit (PPO, Programs, Projects and Maintenance). The distribution of costs over different assets and their breakdown to eg. pump level is not specified in these contracts.

New construction projects

New construction of infrastructure is planned on a national network level. The general policy for procurement is large multidisciplinary contracts, based on overall performance specifications. The preferable contract types are design, build and maintain, or design, build, maintain and finance. In past decades only a few smaller pumping stations have been built. This coming decade two very large pumping station projects are planned. A new station in the *"Afsluitdijk"* and extension of the *IJmuiden station*. Both are needed to discharge larger volumes of water because of climate change and sea level rise. Rijkswaterstaat staff is involved in the design of the pumping stations, because the unique functional demands and need for innovative technology.

Developments

Three developments are observed:

- Reduced use of energy, maximize use of green energy
- Predictive maintenance
- Energy production

Use of predictive models, water flow models combined with rainfall models, can reduce pumped volumes and energy use. Another development is to tune the pumping operations to the availability of renewable energy (wind, solar). To do this, the steering software has to be adapted and will be combined with an advanced water flow and rainfall model.

Process data from installations, combined with data from operation (SCADA) can monitor the installations and their deterioration. Available data is therefore extended with data from additional electricity use sensors. By analysing this data, maintenance needs can be predicted.

In one pumping station a hybrid pump has been installed. This works two ways, normal pumping and production of energy when water has to be discharged. This technique has potential application in more situations.

3.3 Waterways Ireland

Waterways Ireland is a cross-border navigational authority responsible for inland navigable waterway systems throughout the island of Ireland, principally for recreational purposes. The navigable waterways within Waterways Ireland's jurisdictional remit extend a linear length of approximately 1,000 km, of which 850 km is in Ireland and 150 km in Northern Ireland. The waterways under Waterways Ireland's remit include a number of River Navigations and Canals traversing three regional areas: the Eastern Region, the Western Region and the Northern Region.

Overview existing assets

Currently there are 33 freshwater back pumps operating throughout Waterways Ireland's network. These pumps are back pumping water from Rivers into canals and up through a number of canal levels to control canal water depth and lock operations. There are 8 pumps operating on the Grand Canal (6 at the Leinster Aquaduct and the adjoining Locks 16, 17 and 18 and 2 at Shannon Harbour) and 1 at Richmond Harbour on the Royal Canal in the Eastern Region; 4 operating on the Lough Allen Canal and 2 at Roosky dry dock in the Western Region; and 18 in the Northern Region on the Shannon Erne Waterway (2 pumps at each of Locks 8 to 16).

These pumps are a combination of KSB, ABS/Sulzer and ITT Flygt pumps. There are also a number of large 6" and 8" diameter portable water pumps which are used intermittently for operational projects and emergency water supply to the canals.

The flow rate for these pumps varies from 0.07 to 0.225 m^3/s with a nominal head of between 1m and 3 m. Estimated daily pumping requirements range from 500 m^3 to 21,000 m^3 at different sites. Some of these pumps are very old and require replacement with dual duty stand by systems and optimization of system controls.

Currently all the pumps are manually operated although there are existing controls to undertake limited remote operation at the Leinster Aquaduct and Locks 16, 17 and 18 on the Grand Canal which require modification and updating.

Most of these pumps are submersible and all are electric although not all pumping sites are individually metered. Previous data indicates an approximate energy consumption of 140,000 kWh at four trial sites with associated CO_2 emissions of 64,130 $kgCO_2$. This data requires verification and a more comprehensive of energy consumption and associated CO_2 emissions assessment is required for all Waterways Ireland pumps.

Asset management / maintenance, operations

All operational maintenance activities are dependent upon requirements at specific pumping stations. These are undertaken by the Mechanical and Operations sections of Waterways Ireland or procured from commercial engineering companies if required. All pumps are operated manually by the relevant regional Operations staff who combine this work with the management of navigation traffic, the operation of locks and the operation of discharge sluices. There is a lot of local knowledge on the ground by

Operational staff. In addition to managing water levels in dry flow conditions these staff have a significant role in managing water flow and discharging to receiving waters during flood conditions.

Several pumps are currently in use for a high number of hours to maintain canal levels. Water quality is generally good. Some pumps have been in place for over 40 years. There is a requirement to update and optimise system controls to facilitate remote control if required.

Maintenance of the pumps, due to accessibility and resources, tends to be more on the basis of fix/repair on failure.

Waterways Ireland are in the process of rolling out an asset management system and programme of inspections for all of its assets including pumping stations. This system will provide for major principal inspections and more routine annual inspections.

New construction projects

Procurement of new pumping installations occurs on an as-needs basis per site. Lock 34 at the Shannon Harbour trial site will constitute a new pumping installation. This will provide an original site for best practice pumping layout, pumping selection and procurement informed from the Green WIN laboratory and site trials.

Waterways Ireland is proposing to develop a new recreational water space, combined with a linear section of waterway as part of the restoration of the Ulster Canal. Works involve undertaking a hydrological investigation to locate a sustainable water supply to initially fill the proposed recreational water space and to replenish it as required; and to prepare a civil engineering design for the water supply system including pumping, recirculation and the delivery of water into the water space.

Developments

New legislation covering abstractions under the EU Water Framework is being prepared at a national level Ireland. Waterways Ireland is working with the Irish Environmental Protection Agency in providing abstraction data for their national Qube hydrological model. Canal water requirement data will be an important issue in determining the flow limits in the catchments from which canal supplies are derived. Consequently, the provision of accurate pumping data utilising flow meters etc. will be employed. The efficiency of pumps is becoming increasingly important at a national level.

Ultimately, EPA wishes to undertake a joint and comprehensive water balance measurement exercise over the course of several days. This will benefit both organisations in determining how much water is entering, leaking from and flowing out of the canals at various locations. It is of key importance to measure all elements either concurrently, or over a very short time span to ensure measurements are relevant to each other.

3.4 Voies Navigables de France

Voies Navigables de France (VNF) maintains, operates and develops the largest European network: 6,700km of rivers, canals and channelled rivers, 4,000 structures (locks, dams, canal-bridges) and 40,000 hectares of river public domain.

Through its missions, VNF meets three major societal expectations:

- Creating the conditions for the development of freight transport
- Contributing to the development of the territories and tourism related activities
- Ensuring the hydraulic management by guaranteeing the safety of the works and the different uses of the water, by fighting against the floods and the hydraulic stress, and by preserving the biodiversity.

Overview existing assets

VNF owns and maintains a wide range of pumping stations throughout the canal and river network. The purpose of the pumps are:

- Abstract water from river or groundwater sources to supply water to the receiving canal
- Recirculate or back pump water which has been displaced by boat traffic travelling through a lock or series of locks
- Transfer water to a higher canal pound to accommodate water loss through seepage, evaporation and transpiration or for onward transfer to another length of canal

VNF operates 85 pumping stations (84 in the NWE area) with one to six pumps for each pumping station. This represents more than 180 pumps in total Pumps are of different types: submersible, axial flow, borehole, etc. These pumps operate with a large scope of water flow capacity, from 0.3 m3/s to 7.5 m3/s. Most of the pump are remote operated, only few function fully automated.

The electricity used is estimated at 15,000 MWh per year. VNF uses an energy consumption supervision tool to manage energy efficiency. Only a few pumping stations are individually metered. Electricity is the only energy source used; in the framework of VNF energy supply contract, it is certified by providers to be green electricity.

Asset management / maintenance, operations

All maintenance and management operations are operated at a local level and procured to commercial companies. Most common corrective maintenance is done. Pumping stations are operated by VNF staff. The working hours depend on the pump use: some are used mainly during dry periods, other mainly for water management during wet periods.

Most pumps are very old: life time go up to 50 years or even longer for many of them.

New construction projects

From 2027-2028, VNF should start operating the new Seine Nord Europe (SNE) canal, increasing significantly the number of operated pumps and total energy consumption (SNE energy consumption could be more than 3 times VNF total energy consumption).

The Seine Nord Europe project will also engage some other locks modernisation. For instance, the locks on the Dunkerque-Cuinchy itinerary (Holques Watten lock, Flandres lock and Cuinchy lock) will require to be significantly modified and modernised to allow bigger boats to navigate. This also includes the modernisation of the pumping process and equipment. VNF is aiming at a neutral energy and carbon impact operation.

Developments

In the context of climate change and water resource changes, VNF has launched a programme to modernise the water management of VNF inland waterways network and optimise the water resource. A new SCADA system is under development (AGHYRE tool) and will allow a much better supervision and information on water levels and volumes at local, regional and national levels. The development of monitoring systems to better monitor water uses is also part of the program.

To modernise the network and make it safer and more efficient, VNF works on the automation of the works and equipment operated on the inland waterways network: dams, locks, and also pumping stations.

VNF is developing renewable energy production. In partnership with renewable energy developers and operators, VNF plans to develop new hydropower plants on the French inland waterways network.

In the framework of the public private partnership to rebuild dams on the Aisne and Meuse rivers, VNF has developed with its partner 4 new hydroelectric micro-power plants for a total power capacity of 8.3 MW.

3 other projects were recently developed in partnerships with industrials to develop 3 other hydropower plants for a total of 18.3 MW capacity. 73 other hydropower plants are operated by industrials on VNF inland waterways network. Only one site is operated by VNF: the Bourg et Comin hydroelectric power plants.

VNF is working to achieve better preventive maintenance. The aim is to reduce operating costs and to facilitate a better water and energy efficiency of the equipment.

3.5 Vlaamse Landmaatschappij

VLM is not a water management organisation and does not own, operate or maintain any pumps. However, in the course of the design, planning and realisation of their nature and land development plans VLM does often interact with water management organisations and the final nature- or land developments plans can include actions or measures with (possible) repercussions on pumping installations.

This is definitely the case for the land development plan "*Mijn Mangelbeek*" with which VLM participates in Green WIN. These pumping stations have been installed to deal with the negative effects of mining subsidence due to former coal mine activities nearby.

Overview existing assets

There are five pumping stations located within the project area, each with a different set up. Two pumping stations consist of two Flygt pumps each which pump excess surface water into the Mangelbeek. Three other pumping stations consist of one "depth pump" which manages groundwater levels in the vicinity. All installations pump water from the subsided to the Mangelbeek (or one of its contributing canals or small ditches), the main river in the project-area

Pumping station	Pump	Capacity KW	Capacity (m^3/h)
Station Ganzestraat	P1 Flygt	5.9	252
	P2 Flygt	13.5	387
Station Waterstraat	P1 Flygt	5.9	253
	P2 Flygt	5.9	253
Station Bieststraat	Melotte	2.2	24
Station 't Wiek	Melotte	11	75
Station Kerkebosstraat	Melotte	1.5	10

All pumps are electrically powered, (exact power consumption is not clear yet) and are fully automated, depending on (ground) water level.

Asset management / maintenance, operations

All pumps in the project area are property of LRM (Limburgse Reconversie Maatschappij), an investment company that originated from former mining companies that were active in the region. Mining operations were stopped in the 1980-1990s.

As a result of mining activities that have started in the beginning of the 20th century, soil subsidence occurred and consequently, Belgian legislation stated that the mining companies have the everlasting obligation to protect the public and the environment from any (further) damage caused by the mining activities, including the prevention of effects due to soil subsidence (e.g. elevated groundwater levels, …) on public and private properties. At present, LRM is legally responsible to fulfil these obligations and as such, one of their branches, the “*Mijnschade en Bemaling Limburgs Mijngebied*” (MBLM), manage and maintain all pumping stations in the former mining region in Limburg.

From last year LRM began to upgrade the pumping stations with real-time monitoring. Before the upgrade the monitoring consisted of a monthly manual read out of the working hours of each pump and subsequent calculation of the pumped volumes.
In case of emergencies (broken pumps etc…) LRM has a team that can be deployed on short notice to minimize the consequences in the field.

The pumping stations in the project area were built between 1993 and 2001. Some pumps have been completely revised or replaced to ensure their continuous operation.

New construction projects

There are no new construction projects planned as the focus lies solely on the protection of inhabitants and environment from flooding.

Developments

As mentioned before, LRM is gradually upgrading its pumping stations with real-time flow monitoring and remote control. Some pumps have already been replaced by more energy efficient one. New pumps are slow start pumps and/or Concertor pumps in which flow is depending on the water level in the underground reservoirs.

LRM is also interested in the results of the Green WIN project. They look to reduce energy consumption and thus costs and the ecological impact of the pumps. The yearly energy consumption cost varies between 140.000 and 160.000 € depending on the yearly precipitation.

Another point of interest is to investigate the possibilities for the re-use of the pumped water (which is actually a combination of ground and surface water) as an alternative for the direct discharge in the Mangelbeek. One of the possible examples is the use of these pumped water volumes as a source to irrigate agricultural lands in dry periods.

Solutions like this depend on the water quality, availability and cost of extra investments to make these alternatives feasible.

4 Summary and conclusions

This report intends to set the baseline for improvement of the existing practices in pumping stations in waterways and water systems. To achieve Green WIN's main goal CO_2 reduction, we need to know what the CO_2 production is in current practice and how this can be reduced.

Chapter 2 describes a system approach that can serve as a framework to study energy consumption of pumping stations in waterway networks. The main part of this report, chapter 3 describes the current practices of the water management organisations among the partners: "Canal River and Trust, Waterways Ireland, Voies Navigables de France, Vlaamse Landmaatschappij and Rijkswaterstaat".

Each partner has given an overview of the following regarding pumping stations:

- Description of existing assets
- (with their main pumps of focus and interest included in the appendix)
- maintenance operations
- new construction projects
- new developments

The available information of the partners shows different levels of detail. CRT presented the most detailed set of information on the role of the pumps in the system, maintenance need and costs, use of energy and costs. This information was aggregated from central available data. Rijkswaterstaat, Waterways Ireland and VNF were not able to produce these specified data. With them these data are stored in local documents and local data systems. They are only accessible by the local staff. VLM has a different role than other partners. She does not operate and manage the pump stations. Therefore, only more general data was available for this report. The CRT experience is useful to other partners, as it can serve as an example for meaningful reports on performance and energy use of the pumping operations.

From the information provided and accumulated from different partners several findings relevant for the Green WIN project can be given:

- ***Many stations, large variety in make and use:*** Each partner has a large amount of pumping stations installed, which are typically used for water management. The specific use of pump stations depends on their function in the waterways and water systems and the configuration of these stations. These vary a lot from each partner. Many stations are automated, mostly with simple algorithms, using water levels as triggers. A large portion of the pumping stations is aged, often 50 years and older. The coming decades renewal is expected to be needed.
- ***Top energy consumers:*** The power consumption of these pumping stations is high and is the top, or one of the top, energy consumer(s) of each partner. The

energy use is not known accurately for most stations, because they are not individually metered. Neither is the contribution of the different elements of the stations to energy use known.

- ***Total energy use:*** Three Green WIN partners, CRT, Rijkswaterstaat and VNF have an estimate of their total annual energy consumption. The other two partners do not have this specified for the pumping station assets.

WMO	MWh	remark
CRT	8,020	2017 70 pumps
Rijkswaterstaat	10,000	estimated based on use 2016
Waterways Ireland	Not specified	
VNF	15,000	Estimated annual average
VLM	Not specified	

- ***Maintenance practise often low tech:*** Maintenance philosophy differs from partner to partner. Mainly as long pumping stations function, little maintenance is performed. Corrective maintenance seems to be the most common practice.
- ***Higher demands in near future:*** Partners observe a need to be more "in control" in water management due to several developments; more stringent requirements for water extraction and discharges, often combined with environmental and water quality demands. Climate change leads to pressure on water management in more frequent extreme wet and dry periods. Both VNF and Rijkswaterstaat, plan future large-scale extensions of pumping capacity.

The findings listed above give a strong motivation for the goals set in Green WIN;

- Improvement of the current maintenance practice will lead to better performance and more efficient use of natural resources including energy. The costs of maintenance may increase and a balance between costs and benefits has to be developed. This asks for more knowledge.

- More advanced techniques for water management can make pumping operations more efficient and reduce energy use. For example by using predictive algorithms.

- Renewal of existing stations and expansion of pumping capacity ask for large investments the coming decades, based on smart and green decision making huge reductions in energy use may be achieved.

5 Appendices: lists of representative pumping stations

(Vlaamse Landmaatschappij: table included in paragraph 3.5)

5.1 Canal and River Trust

Partner	Pump usage	Pump type	Pump manu-facturer	Pump model	Nominal flow rate	Nominal rotational speed	Nominal Power	Nominal head	Minimum suction head	minimum flow rate	head at minimum flow rate	maximum flow rate	head at maximum flow rate	Pump assembly with motor	Vertical / horizontal rotational axis	Pump total height	Pump total width
					(m3/s)	RPM	kW	m	m	m3/s	m	m3/s	m	(yes/no)		mm	mm
CRT-Calcutt Pumping Station	Transfer	Submersible	KSB	KRTK 200/330/414UG	TBC	1450,00	41,00	5,5	10,50	TBC	TBC	0,25	14,00	yes	Vertical	1500,00	700,00
CRT-Caen Hill Pumping Station	Transfer	Immersible	Flygt	CT3240.805	TBC	1490,00	215,00	73,50	10,20	TBC	TBC	0,12	82,20	yes	Vertical	1800,00	600,00
CRT-Seend Pumping Station	Transfer	Submersible	Flygt	NP3301.180 MT (TBC)	TBC	985,00	55,00	12,60	10,50	TBC	TBC	0,24	17 (TBC)	yes	Vertical	1410,00	755,00
CRT-Tinsley Pumping Station	Abstraction	Submersible	Flygt	NP3301.180 HT ex hire	TBC	1475,00	55,00	TBC	TBC	TBC	TBC	0,13	TBC	yes	Vertical	1410,00	755,00

TBC To be confirmed by additional measurement or research

5.2 Ministerie van Infrastructuur en Waterstaat- Rijkswaterstaat

Partner	Pump Station	Annual energy consumption [KWh]	Pump type	Pump manufacturer	Pump model	Nominal flow rate	Nominal rotational speed	Nominal Power	Nominal head	Minimum suction head	minimum flow rate	head at minimum flow rate	maximum flow rate	head at maximum flow rate	Pump assembly with motor	Vertical / horizontal rotational axis	Pump total height	Pump total width
						(m3/s)	RPM	kW	m	m	m3/s	m	m3/s	m	(yes/no)		mm	mm
RWS	Station Born	23638				3												
RWS	Station Maasbracht	187657	Centrifugal pump		Centrifugal pump	3										horizontal		
RWS	Station Heumen	94544	Centrifugal pump		Centrifugal pump	3										horizontal		
RWS	Station Panheel	349325				3												
RWS	Station Oosterhout	36160	Centrifugal pump		Centrifugal pump	1		75										
RWS	Station IJmuiden	5781373	axial flow pump	Design: RWS Fabrication: Stork/Nijhuis	axial flow pump	40 and 50		1000	1,2							horizontal		
RWS	New Station at lock gate Eefde	1872689 (total for Eefde)	Centrifugal pump		Centrifugal pump	6,5												
RWS	Station at lock gate Hengelo	unknown	Centrifugal pump		Centrifugal pump	2			9,1									
RWS	Station at lock gate Delden	1151058				4,9												
RWS	Old station at lock gate Eefde	1872689 (total for Eefde)				3,4												
RWS	Station Zedemuden	80652	axial flow pump	Design: RWS Fabrication: Stork	axial flow pump	37,5			1						yes	horizontal		3,6m
RWS	Station Waaier					7,5												
RWS	Station Ravenswaaij (Marijkesluis)		axial flow pump	RWS	axial flow pump	5 and 7												
RWS	Station Merwedecanal		Archimedes' screw		Archimedes' screw	12			1							under slope		
RWS	Station at Vleutense Wetering		Centrifugal pump		Centrifugal pump													
RWS	Station for useage Kreekraksluizen	2605395				9												
RWS	Station at Jachtensluizen		axial flow pump		axial flow pump													
RWS	Station at duwvaartsluizen		axial flow pump		axial flow pump													
RWS	Station Reitsgraaf																	
RWS	Station Leemans		Centrifugal pump	RWS	Centrifugal pump	4,2		630	5,5							vertical		

5.3 Waterways Ireland

Partner	Pump usage	No of pumps	Pump type	Pump manu-facturer	Pump model	Nominal flow rate	Nominal rotational speed	Nominal Power	Nominal head	Minimum suction head	Minimum flow rate	Head at minimum flow rate	Maximum flow rate	Head at maximum flow rate	Pump assembly with motor	Vertical / horizontal rotational axis	Pump total height	Pump total width
						(m3/s)	RPM	kW	m	m	m3/s	m	m3/s	m	(yes/no)		mm	mm
Richmond Harbour	ater level Trans	1	Submersible Propeller	KSB	PLZ 300	0,225	960	10,5	1,1	n/a	Old Insulation/ no data	Old Insulation/ no data	Old Insulation/ no data	Old Insulation/ no data	No	Vertical	Old Insulation/ no data	Old Insulation/ no data
Drumshanbo Lock	Lake Water Transfer to Canal	1	Submersible Propeller	ABS	HUP 302	0,31	960	17	3	n/a	0,18	6,5	0,375	2,5	Yes	Horizontal	968	1058
Shannon Harbour L35	Water level Transfer	1	Submersible Propeller	ABS	AFP 1521 M150/4	0,07	1470	14	2	n/a	0,11	4	0,115	3	Yes	Horizontal	1297	493
Shannon Harbour L36	Water level Transfer	1	Submersible Propeller	ABS	AFP 1521 M150/4	0,07	1470	14	2	n/a	0,11	4	0,115	3	Yes	Horizontal	1297	493
Grand Canal L16	Water level Transfer	1	Submersible Propeller	KSB	Amarex KRT D250-400/206	0,18	960	16,5	2,2	n/a	0,165	3,7	0,25	3,2	Yes	Horizontal	1100	825
Grand Canal L17	Water level Transfer	1	Submersible Propeller	KSB	Amarex KRT D250-400/206	0,18	960	16,5	2,2	n/a	0,165	3,7	0,25	3,2	Yes	Horizontal	1100	825
Grand Canal L18	Water level Transfer	1	Submersible Propeller	KSB	Amarex KRT D250-400/206	0,18	960	16,5	2,2	n/a	0,165	3,7	0,25	3,2	Yes	Horizontal	1100	825
Leinster Aquaduct	Water level Transfer	3	Submersible Propeller	KSB	Amarex KRT D250-400/266	0,121	960	22,5	2	n/a	0,165	3	0,19	3,8	Yes	Horizontal	100	640
Shannon Erne Lock 8	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 9	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 10	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 11	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 12	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 13	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 14	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 15	Water level Transfer	2		Flygt	ITT pump													
Shannon Erne Lock 16	Water level Transfer	2		Flygt	ITT pump													
Drumleague		1		ABS / Sulzer														
Battlebridge		2		ABS / Sulzer														
Rooskey Dry dock		2		Flygt	ITT pump													

5.4 Voies Navigables de France

Part 1 Detailed information from selected stations VNF

Partner Partenaire	Pump usage Utilisation de la pompe	Pump type Type de pompe	Pump manufacturer Constructeur de la pompe	Pump model Modèle de la pompe	Nominal flow rate Débit nominal	Nominal rotational speed Vitesse nominale de rotation	Nominal Power Puissance nominale	Nominal head Pression d'eau nominale	Minimum suction head Section minimale de la pression d'eau	minimum flow rate Débit minimal	head at minimum flow rate Pression d'eau au débit minimal	maximum flow rate Débit maximal	head at maximum flow rate Pression d'eau au débit maximal	Pump assembly with motor Pompe assemblée avec le moteur	Vertical / horizontal rotational axis Axe vertical ou horizontal	Pump total height Taille totale de la pompe	Pump total width Largeur totale de la pompe
					(m3/s)	RPM	kW	m	m	m3/s	m	m3/s	m	(yes/no)		mm	mm
VNF- Stock	Water transfer	Centrifigal pump with horizontal axis	Rateau	EPB41 model	0.6 (per pump)	970 tours per minute for motors n° 3 and 4 975 tours per minute for motors 1 and 2	103 kWfor pumps n°3 and 4 110 KW for pumps n° 1 and 2	When Stock water basin is full, it is 7,2 m the Vosges canal	aspiration diamètre nominal 0,5 m	0,0028 m3/s for pump 1 (data from bench test)	22,9 m for pump 1 (data from bench test)	0,5866 m3/s for pump 1 (data from bench test)	1,9 m for pump 1 (data from bench test)	no (machines reliées par des accouplements homocinétiques)	horizontal	1550,00	1280,00
VNF- Briare	Water transfer	Monoblock – centrifugal ; submersible pump	Flygt	CP3231 735/745	0.2 (per pump)	1480 rpm	6*170	0,20	0,44	0,24	43,00	0,29	37,00	yes	vertical	2345,00	1710,00
VNF- Crissey lock	Lock water transfer	Monoblock – centrifugal ; submersible pump	Flygt	CP 3400/735 3~830	0,60	735 rpm	125,00	0,40	0,50	0,60	10,76	0,90	4,79	yes	vertical	2200,00	2500,00
CRT-Tinsley Pumping Station	Abstraction	Submersible	Flygt	NP3301.180 HT ex hire	TBC	1475,00	55,00	TBC	TBC	TBC	TBC	0,13	TBC	yes	Vertical	1410,00	755,00

TBC To be confirmed by additional measurement or research

Pumping station site	Inland waterway	City	Power (kW)	Pump number
Station de pompage d'Aingeray	Moselle canalisée	AINGERAY	352 kW	4
Station de pompage de Neuves-Maisons	Moselle canalisée	PONT-SAINT-VINCENT	130-205kW	2
Station de pompage à Landrecies	Canal de la Sambre à l'Oise	LANDRECIES	0,00	2
Station de pompage à Pont Malin	Escaut canalisé	BOUCHAIN	0,00	5
Station de pompage à Denain	Escaut canalisé	DENAIN	0,00	5
Station de pompage n°12 de Cléry sur Somme	Canal du Nord	ALLAINES	630	3
Station de pompage n°18 de Noyon	Canal du Nord	NOYON	630	3
Station de pompage n°17 de Sermaize-Haudival	Canal du Nord	BEAURAINS-LES-NOYON	630	3
Station de pompage n°16 de Campagne	Canal du Nord	CATIGNY	630	3
Station de pompage n°11 de Allaines-Feuillaucourt	Canal du Nord	ALLAINES	630	3
Station de pompage n°10 d'Allaines	Canal du Nord	ALLAINES	630	3
Station de pompage n°9 de Moislains	Canal du Nord	ALLAINES	630	3
Station de pompage n°8 de Moislains	Canal du Nord	MOISLAINS	630	3
Station de pompage de Brax	Garonne	SERIGNAC-SUR-GARONNE	630 Kw A	3
Station de pompage de Gondrexange	Canal de la Marne au Rhin. branche Est	RECHICOURT-LE-CHATEAU	400 kVA	3
Station de pompage de Condé-sur-Marne	Canal de l'Aisne à la Marne	CONDE-SUR-MARNE	760 KW	3
Station de pompage de Réchicourt	Canal de la Marne au Rhin. branche Est	RECHICOURT-LE-CHATEAU	260	2
Station de pompage n°19 de Pont-l'Evêque	Canal du Nord	NOYON	315	3
Station de pompage n°15 de Languevoisin	Canal du Nord	LANGUEVOISIN-QUIQUERY	630	2
Station de pompage de l'écluse n°1 de Palluel	Canal du Nord	PALLUEL	92KVA	2
Station de pompage de l'écluse n°12 de Lagarde	Canal de la Marne au Rhin. branche Est	LAGARDE	60 kW	2
Station de pompage de l'écluse n°7 de Réchicourt-le-Château	Canal de la Marne au Rhin. branche Est	RECHICOURT-LE-CHATEAU	60 kW	2
Station de pompage de l'écluse n°10 de Maizières-lès-Vic	Canal de la Marne au Rhin. branche Est	MAIZIERES-LES-VIC	60 kW	2
Station de pompage de l'écluse n°15 de Mouacourt	Canal de la Marne au Rhin. branche Est	MOUACOURT	60 kW	2
Station de pompage de l'écluse n°8 de Réchicourt-le-Château	Canal de la Marne au Rhin. branche Est	RECHICOURT-LE-CHATEAU	60 kW	2
Station de pompage de l'écluse n°9 de Moussey	Canal de la Marne au Rhin. branche Est	MAIZIERES-LES-VIC	60 kW	2
Station de pompage de l'écluse n°11 de Maizières-lès-Vic	Canal de la Marne au Rhin. branche Est	BOURDONNAY	60 kW	2
Station de pompage de l'écluse n°13 de Lagarde	Canal de la Marne au Rhin. branche Est	LAGARDE	60 kW	2
Station de pompage de l'écluse n°14 de Xures	Canal de la Marne au Rhin. branche Est	XURES	60 kW	2
Station de pompage de l'écluse n°16 d'Hénaménil	Canal de la Marne au Rhin. branche Est	HENAMENIL	60 kW	2
Station de pompage de l'écluse n°17 de Bauzemont	Canal de la Marne au Rhin. branche Est	BAUZEMONT	0,00	2
Station de pompage de l'écluse n°18 d'Einville	Canal de la Marne au Rhin. branche Est	EINVILLE-AU-JARD	60 kW	2
Station de pompage de l'écluse n°19 de Maixe	Canal de la Marne au Rhin. branche Est	MAIXE	60 kW	2
Station de pompage de l'écluse n°20 de Crevic	Canal de la Marne au Rhin. branche Est	CREVIC	0,00	2
Station de pompage de l'écluse n°21 de Sommervillers	Canal de la Marne au Rhin. branche Est	DOMBASLE-SUR-MEURTHE	60 kW	2
Station de pompage de l'écluse n°22 de Dombasle-sur-Meurthe	Canal de la Marne au Rhin. branche Est	DOMBASLE-SUR-MEURTHE	60 kW	2
Station de pompage de Diane-Capelle	Canal des Houillères de la Sarre	DIANE-CAPELLE	630 kVA	4
Station de pompage d'Ancy sur Moselle	Moselle canalisée	ARS-SUR-MOSELLE	24 kw	2
Station de pompage n°1 et n°3 de Malmy	Canal des Ardennes	CHEMERY-SUR-BAR	138	2
Usine élévatoire de Messein	Canal des Vosges (ex Canal de l'est. branche Sud)	MEREVILLE		4
Station de pompage de Pont-à-Bar	Canal des Ardennes	DOM-LE-MESNIL	102 kW	1

Pumping station site	Inland waterway	City	Power (kW)	Pump number
Station de pompage de Saint-Aignan	Canal des Ardennes	SAPOGNE-ET-FEUCHERES	144 kW	1
Station de pompage n°2 de Malmy	Canal des Ardennes	OMICOURT	120 kW	1
Station de pompage de l'écluse n°2 de Marquion	Canal du Nord	BARALLE	400KVA	2
Station de pompage de l'écluse n°3 de Sains-les-Marquion	Canal du Nord	MARQUION	400KVA	2
Station de pompage de l'écluse n°4 de Sains-les-Marquion	Canal du Nord	INCHY-EN-ARTOIS	400 KVA	2
Station de pompage de l'écluse n°5 de Moeuvres	Canal du Nord	MOEUVRES	400KVA	2
Station de pompage de l'écluse n°7 de Graincourt-les-Havrincourt	Canal du Nord	GRAINCOURT-LES-HAVRINCOURT	400KVA	2
Station de pompage de Cassine	Canal des Ardennes	VENDRESSE	36 kW	1
Station de pompage de Troussey	Canal de la Marne au Rhin. branche Ouest	TROUSSEY	250 kW	1
Station de pompage de Sauville	Canal des Ardennes	SAUVILLE	36 kW	1
Station de pompage de l'écluse de Clévant	Moselle canalisée. embranchement du port de Frouard	FROUARD	250 kW	3
Station de pompage de Wittring	Sarre	WITTRING	75	1
Station de pompage de l'écluse n°6 de Graincourt-les-Havrincourt	Canal du Nord	MOEUVRES	400KVA	2
Usine élévatoire de Briare	Canal latéral à la Loire	BRIARE	450Kw	6
Station de pompage à Etoquies	Sambre canalisée	LANDRECIES	18	1
Station de pompage de Bois l'Abbaye	Canal de la Sambre à l'Oise	CATILLON-SUR-SAMBRE	0,00	1
Station de pompage d'Estrees dite du site de Goeulzin	Scarpe inférieure	FLINES-LEZ-RACHES	0,00	1
Station de pompage de Thiennes	Lys	THIENNES		1
Station de pompage à Hachette	Sambre canalisée	MAROILLES	18	1
Station de pompage à Ors	Canal de la Sambre à l'Oise	LANDRECIES	0,00	1
Station de pompage de Lesdins	Canal de Saint-Quentin	LESDINS		2
Station de pompage de l'écluse n°6 de Réchicourt-le-Château	Canal de la Marne au Rhin. branche Est	RECHICOURT-LE-CHATEAU		2
Station de pompage de Bourg-et-Comin	Canal de l'Oise à l'Aisne	BOURG-ET-COMIN		2
Station de pompage de Pascal	Canal de Saint-Quentin	LESDINS		2
Station de pompage d'Omissy	Canal de Saint-Quentin	LESDINS		2
Station de pompage du Moulin-Brûlé	Canal de Saint-Quentin	MORCOURT		2
Station de pompage de Saint-Quentin	Canal de Saint-Quentin	DALLON		2
Station de pompage de Fontaines-les-Clercs	Canal de Saint-Quentin	FONTAINE-LES-CLERCS		2
Station de pompage de Seraucourt-le-Grand	Canal de Saint-Quentin	HAPPENCOURT		2
Station de pompage de Pont-Tugny	Canal de Saint-Quentin	SAINT-SIMON		2
Station de pompage Jussy	Canal de Saint-Quentin	JUSSY		2
Station de pompage Mennessis	Canal de Saint-Quentin	MENNESSIS		2
Station de pompage Voyaux	Canal de Saint-Quentin	MENNESSIS		2
Station de pompage Fargniers I	Canal de Saint-Quentin	TERGNIER		2
Station de pompage Fargniers II	Canal de Saint-Quentin	TERGNIER		2
Station de pompage Fargniers III	Canal de Saint-Quentin	TERGNIER		2
Station de pompage de Lauterbourg	Rhin à courant libre	LAUTERBOURG	350kW	3
Station de pompage de Niffer	Canal du Rhône au Rhin. branche Sud. embranchement à grand gabarit de Niffer-Mulhouse	KEMBS		2
Station de pompage de Sassegnies	Sambre canalisée	SASSEGNIES	18	1
Station de pompage de Wambrechies	Canal de la Deûle	QUESNOY-SUR-DEULE	18kw	1
Station de pompage de Dom le Mesnil	Canal des Ardennes	DOM-LE-MESNIL		1
Station de pompage du Jeu de Mail	Canal de Bourbourg	DUNKERQUE		1
Station de pompage d'Hennuin	Canal de Calais	SAINTE-MARIE-KERQUE		2
Station de pompage de Crissey	Canal du centre	CRISSEY	162,00	2
			Total	**181**

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VLAAMSE LAND MAATSCHAPPIJ